GROWTH RATES OF THE SARDINES, *SARDINELLA ALBELLA* (VAL.) AND *S. GIBBOSA* (BLEEK.), IN THE MANDAPAM AREA*

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ABSTRACT

The monthly mean lengths of the O-year-classes of *S. albella* and *S. gibbosa* were estimated for the Palk Bay seasons of 1952-56. They indicated that, for the greater part of the Palk Bay season, the length of each species increased at a decreasing rate. But towards the end of the season it appeared to increase at an increasing rate. The von Bertalanffy equation was fitted to the former part, the growth curve so obtained was extrapolated to the latter part of the season also, and the observed and expected mean lengths were compared. It was seen that the differences in the rate of change of the monthly mean lengths between years were statistically non-significant.

The asymptotic maximum lengths of the two sardines, estimated on the basis of the growth data of the first 6-7 months of life are considerably less than the modal sizes attained by them at the end of the first year of life, indicating that a change in growth rate has to take place if these modal sizes are to be attained. This expectation is supported by the observation that the mean lengths towards the end of the Palk Bay season are larger than those expected on the basis of the growth data of the earlier months and indicate the start of an exponential phase of growth. Hence there appears to be a periodicity in the growth of these young fishes, comparable to what is observed in temperate water fishes. The environmental data also indicate that a change in the growth rate towards the end of the Palk Bay season is possible.

The estimated monthly growth coefficients of the two species compare very well with each other and also with that of the Japanese sardine.

INTRODUCTION

From a study in 1952-54 of monthly (standard) length frequency distribution of the catches in the Mandapam area, it was seen that *S. albella* attained a modal size of about 107 mm and *S. gibbosa* 107-122 mm, at the end of the first year of life (Sekharan, 1955). The largest modes recorded in the Mandapam area were 117 mm for *S. albella* and 127 mm for *S. gibbosa*, the largest sizes being 129 mm and 139 mm

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respectively. The values of the maximum lengths observed at Mandapam were nearly equal to those recorded by other workers. Thus, in regard to *S. albella*, the maximum size recorded by Munro (1955) from Ceylon was 140 mm, and Venkataraman (1960) did not observe fish more than 160 mm in total length (about 130 mm in standard length) at Calicut. In regard to *S. gibbosa*, Ganapati and Rao (1957) did not record a length of more than 140 mm off Waltair. Therefore, taking into account the modal sizes attained at the end of the first year of life, it would appear that these are short-lived species having a life span of less than 2 years, although there is the possibility that they move away from the present fishing grounds. Holt (1960) also states that the maximum recorded age of these two species is 2 years.

In the Mandapam area, where the sardine fishery is important on the Palk Bay coast, the catches are supported mainly by the O-year-class (Sekharan, 1955, 1959). Therefore, a study of the growth rate of the sardines during the first 6-8 months of their life (i.e., during the Palk Bay fishing season) is of interest from the fisheries point of view and is attempted here.

Material and Methods

The present study is based on the monthly length frequency distribution of the catches from 1952 to 56 at Thedai-Pullamadam, the main centre selected for collection of material for all biological work during this investigation. This centre was ideally suited for the purpose, since the catches here consisted exclusively of the O-year-class (Sekharan, 1959). On each sampling day samples, usually of 25-100 fish each, were collected and the weight of each sample noted. Since there was no significant difference between samples in regard to length frequency distributions, they were pooled for each sampling day. Only night samples from shore seines were collected.

Since the object of length frequency studies is to estimate the size composition of the catchable part of the population, appropriate procedures were adopted to relate sample values to catches. Gulland (1955, 1966) has discussed this problem in detail.

Estimation of catches—Catch data were collected directly from the fishermen, who offered all cooperation during this study. Each boat owner in the Thedai-Pullamadam area was given a proforma in which he was requested to make entries of the data of each haul and the catch by weight (in kg)[2]. These entries compared well with those of the author, which were independently made. Figures of catch were summed up at monthly intervals. As in the Pacific sardine fishery (Clark, 1939, 1956) the catches were very poor on the full moon day and some days prior to and following that day. Hence all estimates were made for the lunar month (from full moon to full moon).

2. Actually, the fishermen gave the catch data in *pothies* (=approx. 864 lb. of fresh fish), which are their measures of the weight of catch. These were converted into kg by the author.

Both *S. albella* and *S. gibbosa* occur together in the same hauls. It was found that the information given by the fishermen on their relative abundance was not sufficiently satisfactory. Hence the species-wise estimates of catch were made by the author. The method adopted for *S. albella* is given below. (The same method was adopted for *S. gibbosa* also).

Let c_i = the total weight of catch (of both species) on the i—th sampling day at the fishing centre.

C_m = the total weight of catch (of both species) at the centre for a lunar month.

s_i = the weight of the sample (consisting of both species) collected on the i—th day from the centre.

a_i = the weight of *S. albella* in the sample.

Then, the catch (in weight) of *S. albella* on the i-th day of sampling (y_i) is

$$y_i = \frac{a_i}{s_i} c_i \qquad (1)$$

The weight of catch of *S. albella* on monthly basis (Y_m) then is

$$Ym = Cm \frac{\sum_i y_i}{\sum_i c_i} \qquad (2)$$

Length frequency and mean length— The standard length data were grouped into 5 mm size classes. The method of raising the sample values to the catch was the same as that described earlier for oil sardine (Sekharan, 1962). Estimates were made of the number of fish landed in each length-group on each sampling day and during the lunar month. From the monthly data (of size composition of the total catch), a monthly mean length was calculated by multiplying the mid-point of each size-group by the frequency, summing up the values and dividing the latter by the total frequency.

Growth formula— The von Bertalanffy equation (Beverton, 1954; Beverton and Holt, 1957) is adopted, which, as expressed for length, is

$$L_t = L_\alpha (1 - e^{-K(t - t_o)})$$

where L_t = length at time t, L_α = the upper asymptotic size, t_o = the time at which L_t = O, and K = a constant related to the coefficient of catabolism = the relative rate of approach to the asymptotic size. From this, Beverton (1954) gets the following expression for the relation between length at age t+1 ($= L_{t+1}$) and the length at age t ($= L_t$):

$$L_{t+1} = L_\alpha (1 - e^{-K}) + L_t \, e^{-K}$$

which is a straight line relation of the form $y = a + bx$. The constants can be evaluated by the method of least squares and the curve fitted, as described by Beverton (1954) and Beverton and Holt (1957). Ford (1933) and Walford (1946) have also shown that a plot of L_{t+1} against L_t can give a straight line relation. It may be mentioned here that this equation for growth in length can be used only for the part of the curve above the inflection point, whatever be the unit of time involved (year, month, hour, etc.).

For fitting the curve, the monthly means were used. The mode also could have been used, but since the fish belonged to a single year-class, the mean was more satisfactory. Other workers who have used this equation also employed the estimated means for different age-groups (Beverton, 1954; Beverton and Holt, 1957; Southward and Chapman, 1965).

GROWTH OF *S. ALBELLA* DURING THE SEASONS 1952-56

The monthly mean lengths are given in Table I. In 1953 (a very poor season), data for a continuous series of months were not available and hence the growth pattern during that year could not be studied. A preliminary plot of the monthly means of the other years showed that for the greater part of the Palk Bay season of each year, length increased at a decreasing rate. But, interestingly enough, towards the end of the Palk Bay season of each year, it appeared to increase at an increasing rate. The von Bertalanffy equation was fitted to the former part, the curve so obtained was extrapolated to the latter part (by estimating the monthly means on the assumption that the same growth equation is applicable to the latter part of the season also) and the observed and expected mean lengths were compared.

The estimated values of the constants— The mean lengths to which the von Bertalanffy equation was fitted are mentioned in the section below dealing with the fitting of the curve. In Fig. 1 is plotted L_{t+1} against L_t for the 1952 season. The calculated regression fitted the observed values well. The fit for the other seasons was equally good and hence is not shown by figures. The values of a, b, K and L_α for the various seasons are given below:

	1952	1954	1955	1956
a	24.00	21.39	17.36	20.20
b	0.7053	0.6902	0.7817	0.7414
K	0.35	0.37	0.25	0.30
L_α	81.36	69.00	78.91	78.65

TABLE 1. *Mean lengths (mm) of* S. gibbosa *and* S. albella *at Thedai—Pullamadam during 1952—56*

1952			1953			1954			1955			1956		
Lunar month	*S. albella*	*S. gibbosa*	Lunar month	*S. albella*	*S. gibbosa*	Lunar month	*S. albella*	*S. gibbosa*	Lunar month	*S. albella*	*S. gibbosa*	Lunar month	*S. albella*	*S. gibbosa*
10/4-8/5	36.84	36.66	30/3-28/4	N.S.	N.S.	19/3-17/4	N.S.	N.S.	8/3-6/4	—	N.S.	28/2-25/3	N.C.	N.C.
9/5-7/6	50.09	52.70	29/4-27/5	N.S.	N.S.	18/4-16/5	29.93	26.02	7/4-5/5	44.15	57.27	26/3-24/4	N.S.	N.S.
8/6-6/7	57.90	62.03	28/5-26/6	55.23	61.90	17/5-15/6	42.05	44.92	6/5-4/6	48.57	62.90	25/4-23/5	40.95	43.01
7/7-4/8	66.25	74.20	27/6-25/7	65.96	68.43	16/6-15/7	48.50	60.89	5/6-4/7	60.27	84.43	24/5-22/6	48.42	64.13
5/8-3/9	71.63	79.80	26/7-23/8	N.S.	74.20	16/7-13/8	57.53	69.67	5/7-2/8	63.76	61.02	23/6-21/7	53.60	69.06
4/9-2/10	73.39	83.25	24/8-22/9	80.09	78.22	14/8-11/9	60.09	77.47	3/8-1/9	66.29	N.C.	22/7-20/8	63.11	73.10
3/10-31/10	102.11	89.87	23/9-21/10	—	91.57	12/9-11/10	64.79	87.38	2/9-30/9	74.64	86.74	21/8-19/9	68.20	N.S.
						12/10-9/11	75.83	94.33	1/10-30/10	78.00	81.20	20/9-18/10	74.60	81.80
												19/10-17/11	88.27	98.60

N.S.—No sample; N.C.—No catch.

It may be seen that the regression coefficient (b) was different for different years. The significance of these differences was tested by the method of analysis of covariance. The details of the variance analysis are given below:

Source of variation	Sum of squares	Degrees of freedom	Mean square
Deviation from average total regression	145.57	12	
Deviation from individual regressions within samples	144.04	9	16.00
Difference	1.53	3	0.51

There seems to be no significant difference between regressions. Therefore, the differences in the value of K between the O-year-classes during the Palk Bay season are most probably not significant.

Fitting the curve— The remaining item required for fitting the curve was t_0 (the estimated time when the fish was born). The curve can of course be fitted by giving an arbitrary value to t_0 . But such a procedure was not adopted here, since from the data on biology an estimate of the spawning time could be obtained. Mathematically, the absolute value of t_0 depends on the age allotted to the monthly means.

From data on maturity, it was seen that March-April was the period of maximum occurrence of mature fish (Sekharan, 1955). The first week of March or some time prior to or after it could, therefore, be regarded as peak spawning time for mathematical purposes, the age (t, in months) of the first mean length of each season counted from that time, and of the other mean lengths by adding the value of 1 successively. These estimates are given in Table 2. For each monthly mean, a separate value of t_0 was obtained and an average t_0 for each season found. This was used in fitting the curve.

It will be seen from Fig. 1 b-e that the calculated curves fit the data for the months on which they are based. On the other hand, the observed monthly means towards the end of the season lie clearly above the points expected on the basis of the growth data of the earlier months, thereby indicating the start of another growth cycle.

Growth of *S. gibbosa* During the Seasons 1952-56

The montly mean lengths are given in Table 1. In 1955 and 1956, sufficient data for a continuous series of months were not available and hence the growth pattern during these seasons could not be studied. A plot of the monthly means of the other years showed that, as in *S. albella*, length increased at a decreasing rate towards the greater part of the Palk Bay season of each year and that towards the end of the season it probably increased at an increasing rate. The von Bertalanffy equation was fitted

TABLE 2. *Estimated values of t_o of* S. albella

	1952 Lunar months	t	1954 Lunar months	t	1955 Lunar months	t	1956 Lunar months	t
1	10/4 to 8/5	1.5	19/3 to 17/4	—	8/3 to 6/4	—	28/2 to 25/3	—
2	9/5 to 7/6	2.5	18/4 to 16/5	1.5	7/4 to 5/5	2.5	26/3 to 24/4	—
3	8/6 to 6/7	3.5	17/5 to 15/6	2.5	6/5 to 4/6	3.5	25/4 to 23/5	2.5
4	7/7 to 4/8	4.5	16/6 to 15/7	3.5	5/6 to 4/7	4.5	24/5 to 22/6	3.5
5	5/8 to 3/9	5.5	16/7 to 13/8	4.5	5/7 to 2/8	5.5	23/6 to 21/7	4.5
6	4/9 to 2/10	6.5	14/8 to 11/9	5.5	3/8 to 1/9	6.5	22/7 to 20/8	5.5
7							21/8 to 19/9	6.5
Average t_o		—0.23		—0.02		—0.86		—0.16

to the former part, the growth curve so obtained was extended to the latter part of the season as in the case of *S. albella* and the expected and observed monthly mean lengths were compared.

The estimated values of the constants— The monthly mean lengths to which the von Bertalanffy equation was fitted are mentioned in the section below dealing with the fitting of the curve. In Fig. 2 a is plotted L_{t+1} against L_t for the 1952 season. That the calculated regression closely fits the observed values will be seen from the figure. The fit for the other seasons was equally good and hence is not shown by figures. The estimated vlaues of the parameters are given below.

	1952	1953	1954
a	25.81	19.87	26.98
b	0.7325	0.7882	0.7249
K	0.31	0.24	0.32
L_∞	95.59	93.81	96.36

The details of the test for heterogeneity of regressions are given below:

Source of variation	Degrees of freedom	Sum of squares	Mean square
Deviation from average total regression	8	23.41	
Deviation from individual regressions within samples	6	23.03	3.84
Difference	2	0.38	0.19

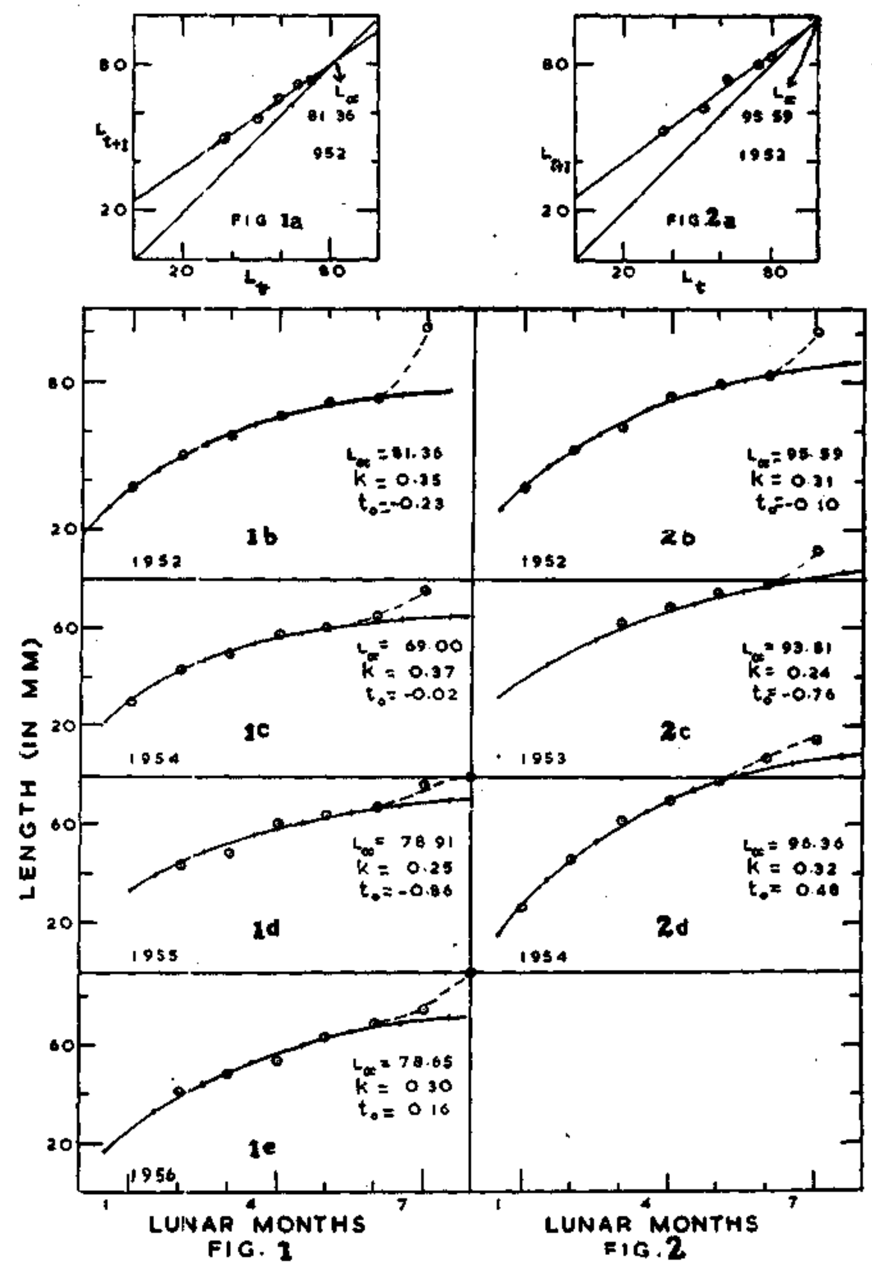

FIG. 1. a-e. Monthly growth of *S. albella* during the Palk Bay seasons.

FIG. 2. a-d. Monthly growth of *S. gibbosa* during the Palk Bay seasons.

(The continuous line represents the calculated growth curve; the broken line indicates the change in growth rate).

As in *S. albella*, the mean square between regressions was less than the mean square due to individual regressions. It would, therefore, appear that the differences in the relative rate of approach to the upper asymptote between the O-year-classes during the Palk Bay season are most probably not significant.

Fitting the curve— The value of t_0 was estimated from the age allotted to each monthly mean on the same considerations as in *S. albella*. Maturity studies (Sekharan, 1955) showed that March-April is the peak period of occurrence of mature fish. From the mathematical point of view, the first week of March or some time prior to or after it could be regarded as the peak spawning time and the age (t, in months) of the first mean length of each season counted from that period, as stated in regard to *S. albella*. The age (t, in months) allotted to the monthly means and the average t_0 for each season are given in Table 3.

The calculated curves (Fig. 2b - d) fit the data closely. But as in *S. albella*, the monthly means observed towards the end of the season lie above the points expected on the basis of the data of earlier months.

TABLE 3. *Estimated values of t_0 of* S. gibbosa

	1952		1953		1954	
	Lunar months	t	Lunar months	t	Lunar months	t
1	10/4 to 8/5	1.5	30/3 to 28/4	—	19/3 to 17/4	—
2	9/5 to 7/6	2.5	29/4 to 27/5	—	18/4 to 16/5	1.5
3	8/6 to 6/7	3.5	28/5 to 26/6	3.5	17/5 to 15/6	2.5
4	7/7 to 4/8	4.5	27/6 to 25/7	4.5	16/6 to 15/7	3.5
5	5/8 to 3/9	5.5	26/7 to 23/8	5.5	16/7 to 13/8	4.5
6	4/9 to 2/10	6.5	24/8 to 22/9	6.5	14/8 to 11/9	5.5
Average t_0		—0.10		—0.76		—0.48

DISCUSSION

The results of this study indicate that:

1. the monthly growth rate of the O-year-classes of the two species of sardines can be expected to change towards the end of the Palk Bay season;
2. most probably such a change takes place;
3. the trend of pattern of growth was the same between years considered here (i.e., the growth curves of the different years had the same shape), and
4. the differences in the relative rate of approach to the upper asymptote between years were not significant (i.e., during the period considered here).

The asymptotic maximum size estimated on the basis of the growth rate during the first 6 - 7 months of life does not exceed 82 mm in the case of *S. albella* and 96 mm in the case of *S. gibbosa*. But the modal sizes at the end of the first year of life itself exceed these values considerably (Sekharan, 1955) which indicates that a change in the growth rate has to take place if these modal sizes are to be attained. This theoretical expectation is supported by the observation that the means of the last two months of the Palk Bay season lie above the points of the curve calculated on the basis of the growth data of earlier months. The means towards the end of the season, in fact, indicate an acceleration in growth rate, that is, the beginning of an exponential growth phase, corresponding to the early part of the sigmoid curve. Lack of data for more months from the Palk Bay precluded the possibility of analysing this part of the growth curve mathematically. Needless to say, both mathematically and biologically, it would have been an invalid procedure to try to fit the von Bertalanffy equation to this part of the growth curve also.

Since older age-groups of *S. albella* and *S. gibbosa* were scarce in the Mandapam area, as already reported (Sekharan, 1955, 1959), their monthly growth pattern could not be investigated. The present results in regard to the O-year-classes, however, indicate that the growth pattern here is probably analogous to what is observed in temperate water fishes, which have a period of rapid growth (e.g., summer) and another of little or no growth (e.g., winter) during each year. Studies of this nature extended to other age-groups and other fishes in future would be of help in determining whether periodicity in growth is a general phenomenon in fishes in the tropical areas.

It is beyond the scope of this study to enquire into the factors responsible for the observed changes in the growth rate of the sardines towards the end of the Palk Bay season, since both internal rhythm and environmental parameters may be involved. But certain changes that occur in the environment at this time may be referred to. Jayaraman (1954) has shown that by about October (i.e., about the beginning of the new growth cycle) significant changes occur in the hydrological conditions of Palk Bay (phosphates, salinity etc.). This is also the period of a peak in plankton production as observed by Prasad (1956) and by the present author during the study of the food of these fishes (Sekharan, unpublished). Furthermore, the north-east monsoon commences about this time and certain changes in the atmospheric and surface temperatures are known to take place (Prasad, 1957). The peaks in stomach fullness and zooplankton items in stomach occur some time before. Apart from the effect of the quality and quantity of food and other gross environmental parameters, other less obvious factors responsible for increase in organic production in plankton at this time might themselves contribute to an increase in the production of organic tissue in fishes. Rae (1958) has drawn pointed attention to the fact that 'the organic content of sea water or *biological factor*" may partly be responsible for the variations in growth and abundance of marine populations in space and time.

The similarity of the shape of the growth curves of the young fishes of the different years is partly explained by the fact that variations in salinity, temperature and other environmental conditions have had the same general trend between years in the Palk Bay, as shown by Prasad's (1957, 1958) observations for 1950-55 and by the unpublished data for later years maintained at the Central Marine Fisheries Research Institute, Mandapam Camp. The minor variations in the values of environmental parameters for corresponding periods of different years might have influenced the growth rate of the young sardines of different years. On the other hand, as seen from the present investigation, the differences in the rate of change of the monthly mean lengths (and in the values of K) between years were statistically not significant.

Another point of interest may be referred to here. The estimated monthly growth coefficients (K) for the Palk Bay season varied from 0.25 to 0.37 in the case of *S. albella* and from 0.24 to 0.32 in the case of *S. gibbosa*, bringing out one more parallel feature in the biology of these fishes. (They show other parallel features in taxonomy, food, length-weight relationship and fecundity). These values compare well with the value (0.35) found for the Japanese sardine by Hayashi (1957). From the point of view of establishing a common biological characteristic, it would be interesting, in future, to estimate the monthly growth coefficients of the other sardines also for comparable growth phases. Mention may here be made of the fact that Holt (1960) made preliminary estimates of the annual growth coefficients of *Sardinella*, *Sardina* and *Sardinops*, but found them to vary widely (0.2-1.6).

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