AGE AND GROWTH STUDIES ON *SARDINELLA MADERENSIS* LOWE AND *SARDINELLA AURITA* CUV. and VAL. FROM THE MEDITERRANEAN SEA AT ALEXANDRIA (U.A.R.)

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INTRODUCTION

The Sardine was among the most important fishes contributing to the Egyptian Mediterranean fisheries. Prior to 1966, huge quantities of Nile flood water was annually discharged to the sea through Rosetta and Damietta mouths of the Nile during the period from August to November. The fertilizing effect of the Nile flood water initiated the developmeot of luxuriant phytoplankton, blooming off the Nile delta during autumn months.

The Sardine fish used to be attracted in big shoals to this region to feed, thus becoming vulnerable to the fishermen's gill-nets. The landings of this fish during the autumn season varied between 6000 and 8000 tons, or approximately 40–50 percent of the total catch from the Mediterranean fisheries of Egypt.

Since 1966, this condition no longer exists as a result of the construction of the Aswan High Dam and the storage of all the flood water infront of the dam.

The two species contributing to those catches, namely *Sardinela maderensis* Lowe and *Sardinella aurita* Cuv. & Val., are however fished in small quantities throughout the year by the shore - seines, particularly in summer. The summer catches consist of maturing fish whose gonads are ripening in preparation for spawning. As a matter of fact, a clear contrast in the condition of the fish existed between the fatty well-fed fish of autumn and the emaciated fish of summer.

This paper embraces the results of a study on the age and rate of growth of the two species. The study of age was based on reading winter annuli and growth zones on the scales and expressing them in terms of fish length.

Such a study was previously carried out, but not in detail, by El-Maghraby (1960) and Nassif (1961). The present wotk could be considered as the first comprehensive study on this subject on these two species in Egypt.

A study of the growth history of fish as recorded on their scales has been long aplied by fishery biologists, Hoffbauer (1899); Walter (1901); Dahl (1907), 1909 and 1910–; Lea (1910); Taylor (1916); Van Oosten (1929); Graham (1929) and others.

Lea (1910) was however the first to modify the basis of age determination and to introduce a new approach in his growth studies on the Clupeid fish *Clupea harengus* (herring)' Since then, his procedure has been widely adopted in fishery biology investigations.

The growth studis of the two species of *Sardinella* were attempted on Mediterranean samples by Fage (1920); Navarro (1952); Dieuzeide (1950); Ananaides (1951); Dieuzeide and Roland (1957); Ben-Tuvia (1960); El-Maghraby (1960) and Nassif (1961).

Growth studies on the two species were also done in West Africa by Postel (1955) and 1960) and Rossignol (1955).

MATERIAL AND METHODS

Random samples were obtained from the commercial catch from Anfoushy Abu-Kir, El-Meadia fish markets from September 1964 to August 1965. Samples were available most of the year round, except that *S. maderensis* was very scarce in December 1964 and March 1965. The frequency of samples examined each month varied from once to thres times.

The sample was taken as soon as possible to the laboratory. The total length and total weight of each fish in the sample were taken to respectively the nearest 0.5 cm. and gram. A number of scales was then taken from just behind the pectoral fin below the lateral line.

Age determination was based on scales taken during the period of investigation from 432 fish, *S. maderensis,* and 393 fish, *S. aurita.* Five to six scales were picked from a position just posterior to the pectoral fin below the lateral line of each fish, were cleaned in 10% hydrogen peroxide for 15 minutes, then mounted dry between two slides. Examination of these scales was carried out by projecting them on the screen of a microfilm-reader (magnification x 17).

The magnified distances from the focus of each scale to the successive annuli, as well as the total radius of the scale (on a diagonal line between the focus and the margin) were determined.

RESULTS

A.—The body-scale relationship of *S. maderensis and S. aurita :*

The use of scales in age determination is lased on finding the nature of the relation between the fish body length and a particular dimension of the scale. This dimension is represented by a radius passing from the scale focus to its outer margin.

It is a know fact that the length of the scale is directly proportional to the body length. The relation between this is practically constant over a wide range of fish length provided that the scales are taken from the appropriate body region, (Lea, 1910). Other workers applying this postulation to various fishes established a linear relationship between these two dimensions according to either of the following equations :

$$L = b' S$$

or

$$L = a + b. S$$

where, L = total length of fiish,

S = linear dimension of scale (scale radius),

a, b. = are constants.

From respectively 432 and 393 fish of *S. maderensis* and *S. aurita*, the data concerning total fish length, the whole scale dimensions and the scale dimension at each winter ring were taken.

The average observed scale radii (x 17) of *S. maderensis* of lengths between 75–170 mm. are given at each 5 mm. length interval in Table (1). Both the males and females were considered separately, but as no significant differences exist between the two sexes, the scale radius of both were treated together. The calculated scale radii and the body-scale ratio were then derived for the combined sexes.

Similarly the corresponding values for *S. auriia* are given in Table (2) for the length range 80 to 230 mm. at 5 mm. length range.

It is clear from these tables that the values of the ratio L/S showed constancy all along the length range studied. The direct proportionality formula representing the body - scale relation viz. L/S = b was used and the value of b for each species was calculated as an average of the ratio L/S for the whole length range. The value of b was found to be as follows :

S. maderensis 2.703

S. aurita 3.170

The relationship between total fish length and the scale radius of the two species is graphically represented in Figures (1) and (2). The straight line represents scale radius values as calculated from the above mentioned formula. In the same figures the average emperical values of the scale radius are also given. The fitness of the line to represent the body scale relation is indicated from the close equality of the calculated and observed values.

To derive the fish length at each year of life as indicated on the scale by different winter rings, the following simple proportionality formula was used for back-calculation :

$$l_n = \frac{S_n}{S} . L$$

where, l_n = length of fish at the end of n year,

S_n = length of fish-scale at the end of n year,

S = total scale-radius and

L = observed total length of the fish.

TABLE 1.—BODY-SCALE RELATIONSHIP OF *S. maderensis.*

Total length (mm)	Male		Female		Undetermined sex		Combined sexes		Calculated scale radius (×17)	L/S
	No.	scale radius (×17)	No.	scale radius (×17)	No.	scale radius (×17)	No.	scale radius (×17)		
75	—	—	—	—	1	25.50	1	25.50	27.75	2.94
100	8	38.42	5	35.80	1	44.00	14	37.88	37.00	2.64
105	12	38.86	7	39.26	3	40.00	22	39.69	38.85	2.65
110	16	40.69	19	40.48	2	41.00	37	40.60	40.70	2.71
115	10	41.13	11	41.97	5	45.30	26	42.29	42.55	2.72
120	15	43.26	14	43.64	3	48.67	32	43.93	44.40	2.73
125	7	44.64	2	46.92	7	48.14	16	46.46	46.25	2.69
130	21	46.65	8	46.13	16	53.06	45	48.84	48.09	2.66
135	22	50.05	10	48.77	59	53.97	91	52.43	49.94	2.57
140	25	51.72	20	51.03	26	59.58	71	54.40	51.79	2.57
145	18	52.98	8	52.58	12	61.13	38	55.43	53.64	2.62
150	7	53.14	12	51.88	7	62.29	26	55.02	55.49	2.72
155	—	—	4	56.62	—	—	4	56.62	57.34	2.74
160	5	58.30	1	56.00	—	—	6	57.92	59.19	2.76
170	—	—	3	60.39	—	—	3	60.39	62.89	2.82
	166		124		142		432			

TABLE 2.—BODY SCALE RELATIONSHIP OF *S. aurita*

Total Length (mm)	Male		Female		Undetermined sex		Combined sexes		L/S	Calculated scale radius (× 17)
	No.	scale radius (×17)	No.	scale radius (×17)	No.	scale radius (×17)	No.	scale radius (×17)		
80	—	—	—	—	4	23.6	4	23.6	3.39	25.24
85	—	—	—	—	2	24.5	2	24.5	3.47	26.81
90	—	—	—	—	6	26.7	6	26.7	3.37	28.39
95	—	—	—	—	2	30.2	2	30.2	3.15	29.97
125	—	—	—	—	1	38.0	1	38.0	3.29	39.43
135	—	—	—	—	1	45.7	1	45.7	2.95	42.59
140	1	48.3	8	47.8	16	47.4	25	47.6	2.94	44.16
145	1	50.0	10	48.1	23	48.5	34	48.4	3.00	45.74
150	2	47.2	10	49.0	18	49.8	30	49.3	3.04	47.32
155	2	50.7	5	50.8	19	51.1	26	51.0	3.04	48.90
160	5	49.0	4	50.1	24	51.7	33	51.1	3.13	50.47
165	3	52.6	2	51.9	11	54.8	16	54.0	3.06	52.05
170	4	52.3	7	50.8	11	55.3	22	53.3	3.19	53.63
175	9	54.2	6	54.0	7	57.2	22	55.1	3.18	55.21
180	10	57.3	11	56.3	4	58.1	25	57.0	3.16	56.78
185	7	60.1	23	58.7	2	59.4	32	59.0	3.14	58.36
190	15	61.1	13	59.9	1	55.0	29	60.4	3.15	59.94
195	7	61.7	16	61.7	5	61.8	28	61.7	3.16	61.51
200	10	63.9	14	62.8	1	64.3	25	63.3	3.16	63.09
205	4	64.0	10	64.1	—	—	14	64.1	3.20	64.67
210	1	69.0	10	66.4	1	64.0	12	66.4	3.16	66.25
215	—	—	2	68.0	1	65.0	3	67.0	3.21	67.82
230	1	70.0	—	—	—	—	1	70.0	3.29	72.56
Total .	82		151		160		393			

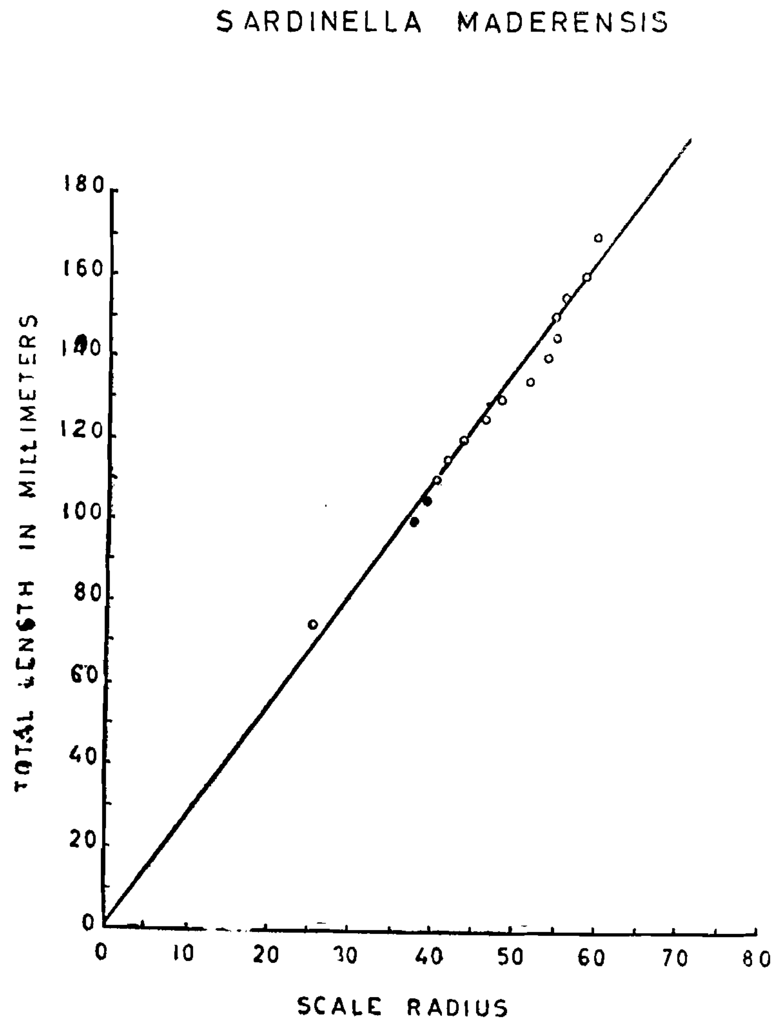

FIG. 1.—The relation between total length and scale radius of *S. maderensis*.

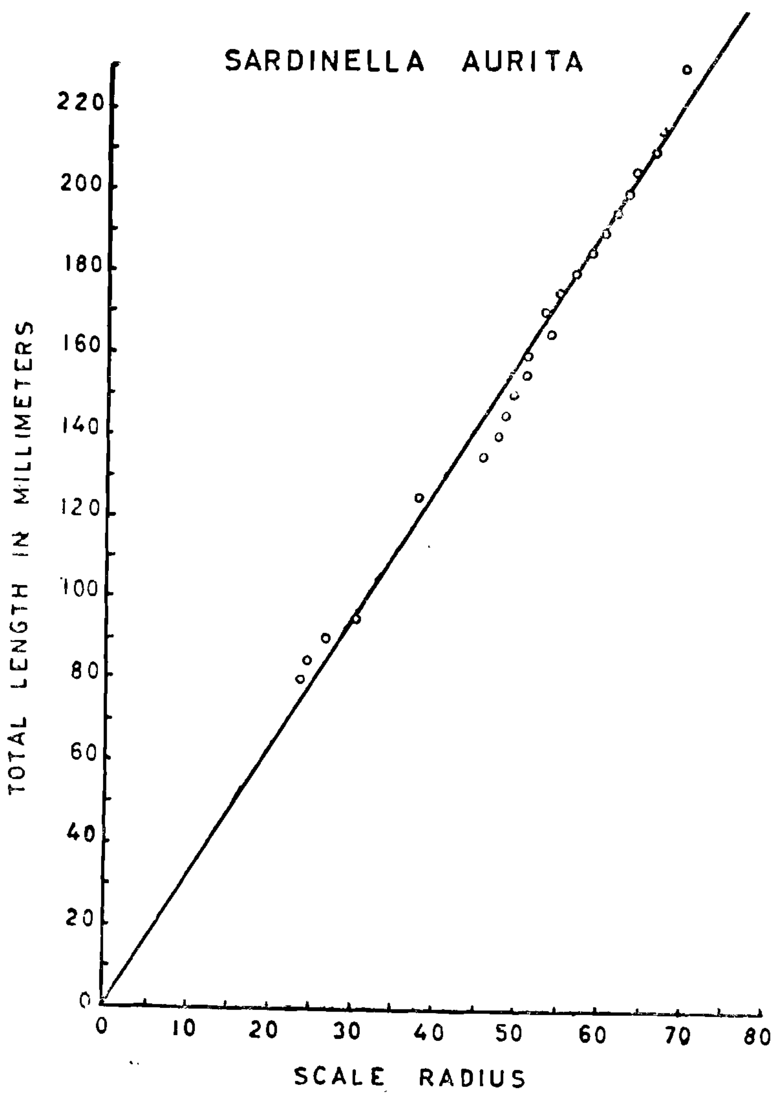

FIG. 2.—The relation between total length and scale radius of *S. aurita*.

B.—Time of annulus formation :

Assumping that the annulus (winter ring) is laid down annually on the scale at a particular time each year (Van Oosten 1929), the procedure adopted to know the time of annulus formation is as follows :

1.—The increment added to the scales after the last formed annulus is measured'

2.—This is then transformed to length increment by the use of scale proportionality formula.

In Tables (3) and (4) the length increment values of respectively *S. maderensis* and *S. aurita* for different age groups are recorded monthly. As data for separate sexes were not available throughout the year, the monthly tracing of the increments for each sex was not possible. The monthly increment was therefore traced from the data of both sexes combined (including fishes of undetermined sex).

It is observed from Table (3) that the annulus shows itself in *S. maderensis* almost at the edge of the scale in the few fishes examined in March. An extra growth is indicated in April by an increment on the scale. This was found to equal (in terms of fish length) 11.2 mm for age-group I and 4.7 mm for age-group II.

The new growth was observed on the scale of *S. aurita* earlier in March and it was found to be equivalent to 8.4 mm of fish length for age-group I and 4.3mm for age-group II. Unfortunately data on the scales of this species was lacking in February; but it is most probable that the annulus appears in some individuals in this month. February and March could thus be taken as the earliest months in the year when the annulus could be shown on the scales of the two species In few individuals it has a later appearance in May or even in June.

C.—Length distribution of age groups :

In order to show the length distribution of age-groups, fishes that have completed the full season's growth were only considered.

The numbers and percentages of different age groups recorded in *S. maderensis* and *S. aurita* at 5 mm length interval are given in Tables (5) and (6). The percentages are graphically represented in Figures (3) and (4).

It was not easy to detect the true annuli from the false ones in the scales of *S. maderensis* for lengths larger than 170 mm. In the large fish the annuli become confused with each other. It is obvious from tables (5) and (6) that the large range considered in *S. maderensis* (100–170 mm) covered only 3 age groups namely: I, II and III. In *S. aurita* on the other hand 4 age groups are represented within the length range 135–230 mm. Fishes of 0 group are presumably represented by individuals smaller than 100 mm (*S. maderensis*) and 135 mm (*S. aurita*).

TABLE 3.—MONTHLY INCREMENTS (mm) OF *S. mederensis*

(NUMBER OF FISHES STUDIED IN PARENTHESES)

Date	Sexes unknown			Male			Female			Sexes combined		
	0	I	II	0	I	II	0	I	II	0	I	II
September, 1964	115 (1)	29.5 (6)	—	—	—	—	—	—	—	115 (1)	29.5 (6)	—
October	—	31.4 (16)	14 (1)	—	—	—	—	—	—	—	31.4 (16)	14 (1)
November	115 (1)	28.0 (155)	10.4 (7)	—	—	—	—	—	—	115 (1)	28.0 (155)	10.4 (7)
December	—	29.6 (34)	9.7 (17)	—	—	—	—	—	—	—	29.6 (34)	9.7 (17)
January, 1965	—	—	—	—	—	—	—	—	—	—	—	—
February	112.5 (12)	27.5 (12)	—	—	25 (1)	10 (1)	112 (8)	27.7 (14)	7.7 (3)	112.6 (20)	27.6 (27)	8.3 (4)
March	—	—	0 (4)	—	—	—	—	—	—	—	—	0 (4)
April	—	—	5 (1)	—	30.6 (39)	11.3 (6)	—	24.3 (3)	10.0 (1)	—	30.1 (42)	11.1 (7)
					11.9 (8)	4.6 (7)		6 (1)			16.2 (9)	4.7 (8)
May	—	—	—	117 (5)	26.8 (3)	12 (1)	112.5 (4)	27.3 (13)	9.5 (2)	115.0 (9)	27.2 (16)	10.3 (3)
						4.5 (2)		3 (2)	4.0 (1)		8.2 (12)	4.3 (3)
					9.2 (10)	5.6 (7)	—	6.6 (5)	8.5 (4)	—	6.4 (15)	8.5 (4)
June	—	—	—	—	6.3 (10)	8.0 (1)			5.6 (5)			5.6 (12)
						6.0 (2)		14.7 (3)	—	—	15.6 (9)	8.0 (1)
July	—	—	—	—	16 (6)	9.0 (1)						6.0 (2)
						6.0 (2)	—	10.1 (38)	11.0 (6)	75 (1)	9.6 (82)	10.7 (7)
August	75 (1)	—	—	—	9.2 (44)				5.8 (5)			5.9 (7)
	(15)	(223)	(30)	(5)	(121)	(30)	(12)	(79)	(27)	(32)	(423)	(87)

TABLE 4.—MONTHLY INCREMENTS (mm) OF *S. aurita*

Date	Undetermined sex			Male			
	0	I	II	0	I	II	III
September, 1964. .	—	41.7 (32)	17.5 (2)	—	—	—	—
October	—	43.9 (9)	19.7 (3)	—	—	—	—
November.	148.6 (62)	42.6 (24)	—	—	—	—	—
December	—	—	—	—	—	—	—
January, 1965. . .	—	—	—	—	—	—	—
February	—	—	—	—	—	—	—
March	170 (1)	57 (7)	35.1 (1)	160 (1)	61.4 (20)	32 (3)	—
			3 (1)		10 (5)	3 (1)	
April	—	—	—	—	63.3 (9)	22.5 (2)	30 (1)
					11.6 (6)		
May	—	—	—	—	7.3 (3)	7.8 (6)	15 (3)
June	—	—	—	—	60.7 (7)	8.5 (4)	—
July	—	—	—	145 (1)	22.5 (2)	—	23 (1)
August	87.1 (14)	—	—	—	43.6 (5)	13 (1)	10 (1)
	(77)	(72)	(7)	(2)	(57)	(17)	(6)

(NUMBER OF FISHES STUDIED IN PARENTHESES)

Female				Combined sexed			
0	I	II	III	0	I	II	III
—	—	—	—	—	41.7 (32)	17.5 (2)	—
—	—	—	—	—	43.9 (9)	19.7 (3)	—
—	—	—	—	148.6 (62)	42.6 (24)	—	—
—	59.7 (10)	25.3 (4)	—	—	59.7 (10)	25.3 (4)	—
—	59.2 (24)	19 (2)	—	—	59.2 (24)	19.0 (2)	—
—	—	—	—	—	—	—	—
170 (1)	62.3 (14)	31.7 (3)	—	166.7 (3)	60.9 (41)	32.3 (7)	—
	5.7 (3)	5.5 (2)			8.4 (8)	4.3 (4)	
150 (1)	45.7 (7)	—	—	150 (1)	55.6 (16)	22.5 (2)	30 (1)
	10.4 (8)				10.9 (14)		
—	59.8 (4)	20 (4)	17 (1)	—	59.8 (4)	20.0 (4)	15.5 (4)
	8.5 (10)	6.4 (13)			8.2 (13)	6.8 (19)	
—	54 (6)	8 (2)	21 (3)	—	57.6 (13)	8.3 (6)	21.5 (4)
—	50 (1)	—	—	145 (1)	50 (1)	—	—
	7.4 (16)				9.1 (18)		
—	51 (4)	7.3 (6)	—	87.1 (14)	46.9 (9)	8.1 (7)	10 (1)
(2)	(107)	(36)	(4)	(81)	(236)	(60)	(10)

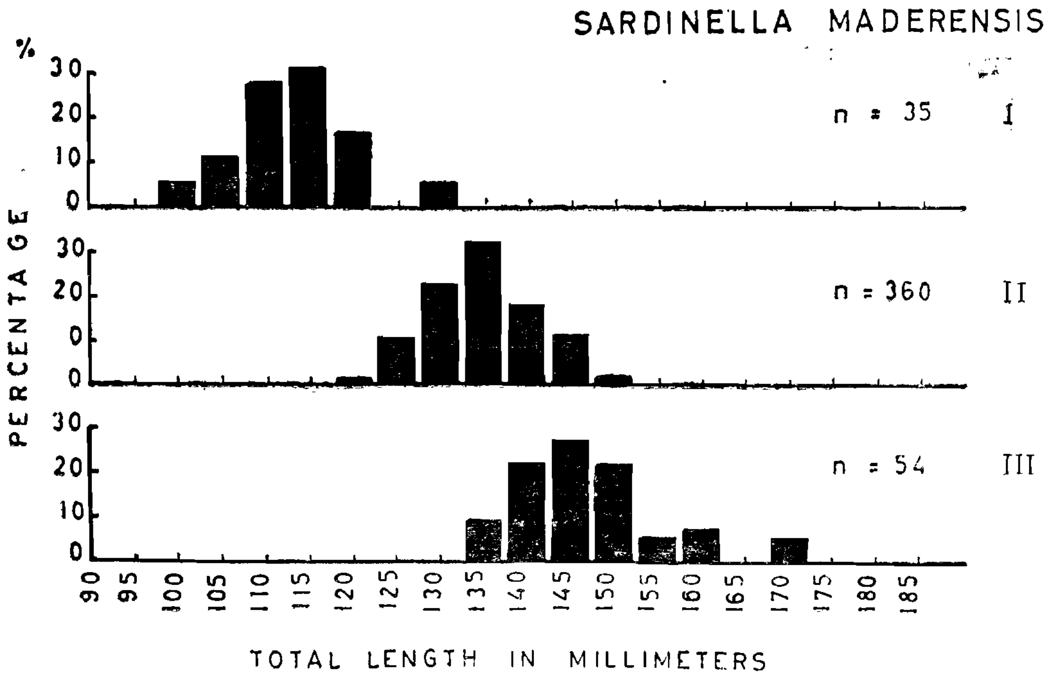

FIG. 3.—The age distribution at different lengths for *S. maderensis*.

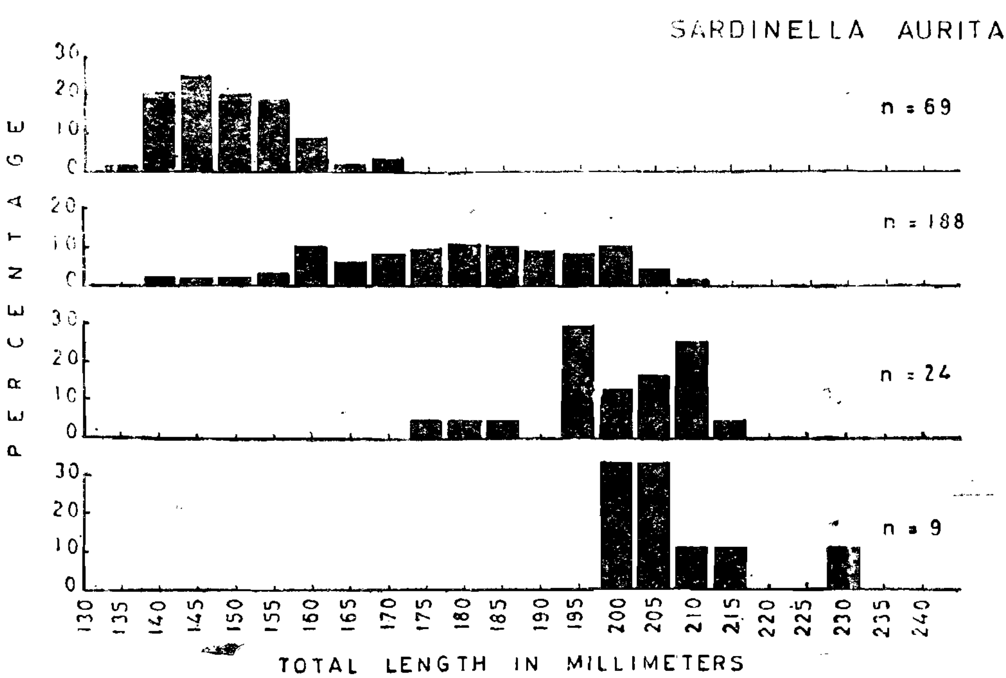

FIG. 4.—The age distribution at different lengths for *S. aurita*.

It could thus be concluded that:

In *S. maderensis*:

Fishes of Age-group I vary in total length between 100 and 130 mm with a mode at 115 mm.

Fishes of Age-group II vary between 120 and 160 mm with a mode at 135 mm.

Fishes of Age-group III vary between 135 and 170 mm with a mode at 145 mm.

TABLE 5.—THE NUMBER AND PERCENTAGE FREQUENCY OF AGE-GROUPS AT DIFFERENT LENGTH INTERALS OF *S. maderensis*

Age group	I		II		III	
Total length (mm)	No.	%	No.	%	No.	%
75	—	—	—	—	—	—
80	—	—	—	—	—	—
100	2	5.71	—	—	—	—
105	4	11.43	—	—	—	—
110	10	28.57	—	—	—	—
115	11	31.43	—	—	—	—
120	6	17.14	5	1.63	—	—
125	—	—	33	10.78	—	—
130	2	5.71	70	22.88	—	—
135	—	—	100	32.68	5	9.26
140	—	—	55	17.97	12	22.22
145	—	—	34	11.11	15	27.78
150	—	—	7	2.29	12	22.22
155	—	—	1	0.33	3	5.56
160	—	—	1	0.33	4	7.41
165	—	—	—	—	—	—
170	—	—	—	—	3	5.56
Total number . .	35		306		54	

TABLE 6.—The number and percentage frequency of age-groups at different length intervals of *S. aurita*

Age group	I		II		III		IV	
Total length (mm)	No.	%	No.	%	No.	%	No.	%
135	1	1.45	—	—	—	—	—	—
140	14	20.29	4	2.13	—	—	—	—
145	18	26.09	4	2.13	—	—	—	—
150	14	20.29	5	2.66	—	—	—	—
155	13	18.84	7	3.72	—	—	—	—
160	6	8.70	20	10.64	—	—	—	—
165	1	1.45	11	5.85	—	—	—	—
170	2	2.90	15	7.98	—	—	—	—
175	—	—	18	9.57	1	4.17	—	—
180	—	—	20	10.64	1	4.17	—	—
185	—	—	20	10.64	1	4.17	—	—
190	—	—	17	9.04	—	—	—	—
195	—	—	16	8.51	7	29.17	—	—
200	—	—	19	10.11	3	12.50	3	33.33
205	—	—	8	4.26	4	16.67	3	33.33
210	—	—	3	1.60	6	25.00	1	11.11
215	—	—	1	0.53	1	4.17	1	11.11
220	—	—	—	—	—	—	—	—
225	—	—	—	—	—	—	—	—
230	—	—	—	—	—	—	1	11.11
Total Number . .	69		188		24		9	

In *S. aurita* **:**

Fishes of age-group I vary in total length between 135 and 170 mm with a mode at 145 mm ; those of age-group II vary between 140 and 215 mm with no distinct mode ; those of age-group III vary between 175 and 215 mm with a mode at 195 mm. and those of age-group IV vary between 200 and 230 mm with a mode at 205 mm'

D.—Growth rates :

For the construction of the growth curves to represent the growth rate of the two species of *Sardinella*, only fishes that completed the seasons's growth were considered. Mean values of length at time of formation of each annulus were back-calculated for separate age-groups. The general growth curve was based on the summation of the average annual length increments. This procedure was adopted by Hile and Jobes (1941), Hile and Jobes (1942) and Jobes (1952).

Sardinella maderensis :

The lengths calculated for *S. maderensis* at the end of different years of life are represented in Table (7). The lengths at the first, second and third annulus were found to be respectively 107.2, 135.6 and 146.4 mm.

TABLE 7.—CALCULATED LENGTH AT THE END OF DIFFERENT YEARS OF LIFE OF *S. maderensis* (Increments in Parentheses)

Age-group	No. of fish	Calculated length (mm) at end of year		
		1	2	3
I	35	113.1	—	—
II	306	106.6	135.2 (28.6)	—
III	54	106.8	133.9 (27.1)	144.7 (10.8)
Grand Average Increments of length .	395	107.2	28.4	10.8
Sum of Average Increment	—	107.2	135.6	146.4

TABLE 8.—CALCULATED TOTAL LENGTH, LENGTH INCREMENTS, CALCULATED WEIGHTS AND WEIGHT INCREMENTS OF *S. maderensis* AT DIFFERANT YEARS OF LIFE

Years of Life	Calculated length (mm)	Increment	% increase	Calculated weight (gm)	Increment	% Increase
1	107.2	107.2	73.22	10.72	10.72	40.64
2	135.6	28.4	19.40	21.17	10.45	39.61
3	146.4	10.8	7.38	26.38	5.21	17.75

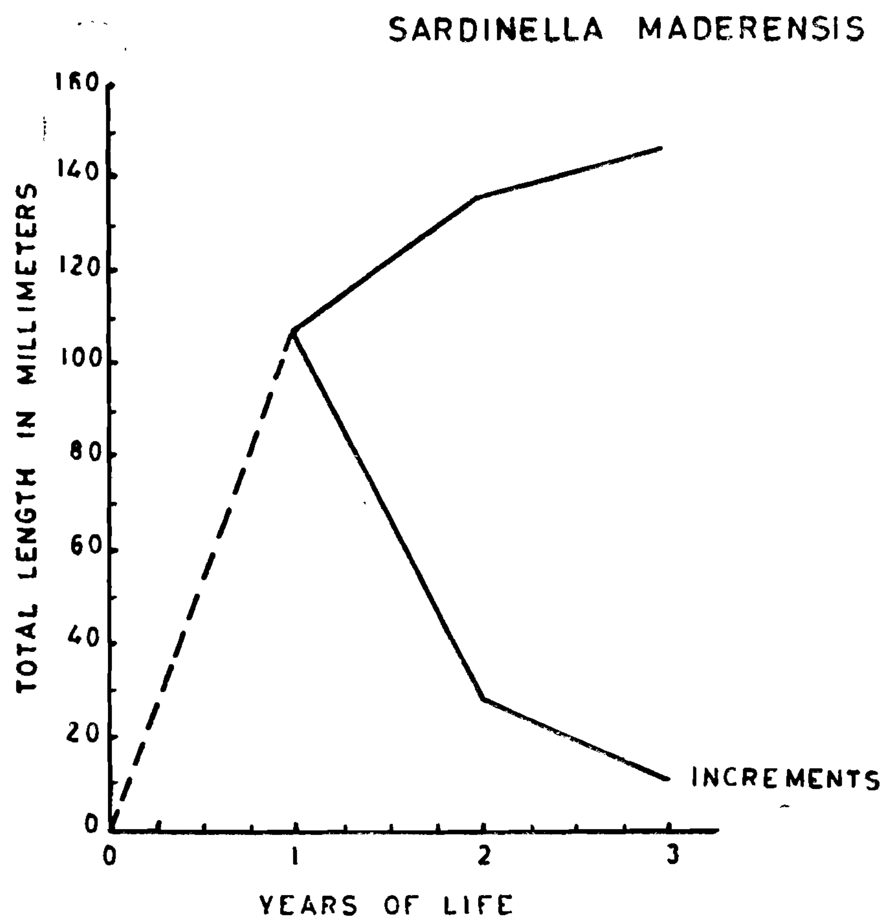

FIG. 5.—Growth in length with age for *S. maderensis*.

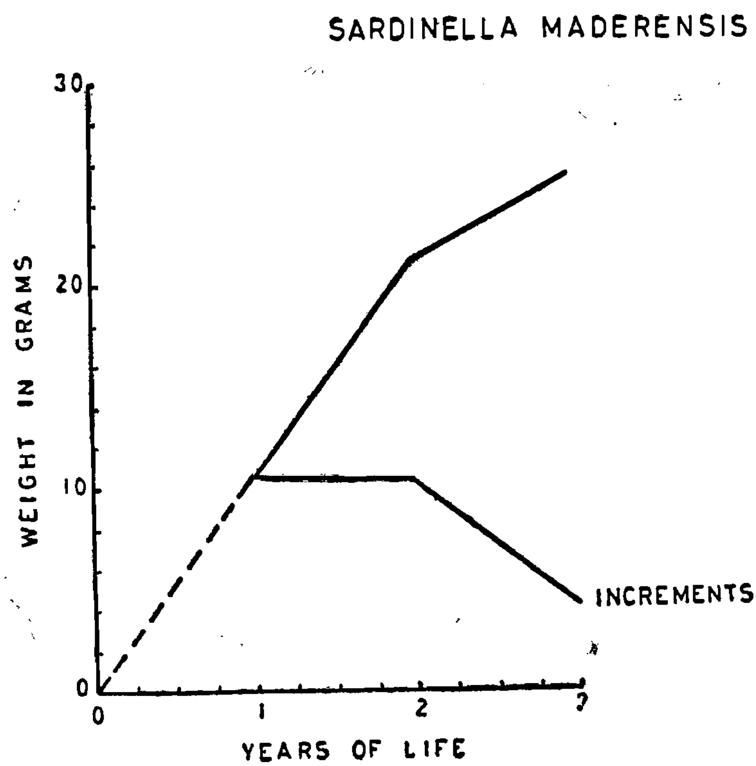

FIG. 6.—Growth in weight with age for *S. maaderensis*.

Table (8) is derived from Table (7) to demonstrate the percentage in the length increments in the different years of life relative to the length value at the end of the third year. These data were used to trace the growth in length curve represented in Figure (5).

Applying the length-weight formula of *S. maderensis*:

$$W = 1.2780 \times 10^{-5} \; . \; L^{2.9176}$$

The respective weight values for the lengths at the first, second and third year of life were found to be 10.72, 21.17 and 26.38 grams. A growth in weight curve based on the sums of the average increments in weight included in Table (9) was similarly constructed and graphically represented in figure (6). The percentage in weight increments in different years of life relative to the weight value calculated for the third year are likewise included in Table (8).

TABLE 9.—Calculated weights at the end of different years of life of *S. maderensis* (Increments in Parentheses)

Age-group	No. of fish	Calculated weights (grams) at end of year		
		1	2	3
I	35	12.53	—	—
II	306	10.54	21.08 (10.54)	—
III	54	10.60	20.51 (9.91)	25.72 (5.21)
Grand Av. Increments of weight.	395	10.72	10.45	5.21
Sum of Av. Increments	—	10.72	21.17	26.38

The growth curves of length and weight do not represent the complete picture of growth in *S. maderensis*. Fishes older than age-group. III were excluded because their age determination was practically impossible. As previously stated, the annuli in large fish are confused together as shown in the scale photographs (Fig. 7 "a-e")

FIG. 7. —Scale of *S. aurita* of length 200 mm showing [illegible] + years.

FIG. 7 *b*.—Scale of *S. aurita* of length 200 mm showing 3 + years.

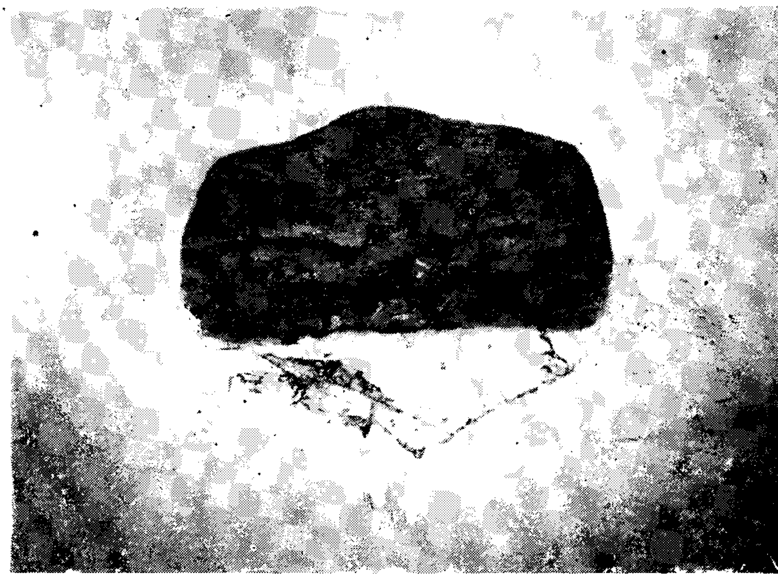

FIG. 7 *c*.—Scale of *S. aurita* of length 145 mm showing 1 years.

FIG. 7 *d*.—Scale of *S. maderensis* of length 125 mm showing 1^{+} years.

FIG. *c*.—Scale of *S. maderensis* of length 135 mm showing 2^+ years.

Sardinella aurita :

A similar procedure was followed in *S. aurita* to obtain the calculated lengths and weights of different years of life. The results are given in Tables (10) and (11). In is evident from Table (10) that the lengths 132.3, 182.4, 208.0 and 227.8 mm are calculated for this species at the end of respectively the first, second, third and fourth years of its life.

The fish weight for the calculated lengths at each year of life could be derived by applying the length-weight formula of this species, viz : $W = 4.314 \times 10^{-6} L^{3.12}$.

The weight values at each year of life were found to be respectively 17.97, 46.89, 68.49 and 87.87 grams. The increments of length and weight at each year of life and their percentages relative to their values at the end of the fourth year of life are given in Table 12.

The growth rate in length and weight of *S. maderensis* and *S. aurita* could be easily compared from Tables (7), (9), (10) and (11). To facilitate the comparison, the growth in length and weight of both species are graphically represented in figures (8) and (9).

TABLE 10.—CALCULATED TOTAL LENGTH AT THE END OF DIFFERENT YEARS OF LIFE OF *S. aurita* (Increments in Parentheses)

Age-groups	No. of fish	Calculated length (mm) at end of year			
		1	2	3	4
I	69	149.1	—	—	—
II	188	126.8	178.4 (51.6)	—	—
III	24	133.2	175.7 (42.5)	200 (24.3)	—
IV	9	118.2	157.4 (39.2)	186.3 (28.9)	206.1 (19.8)
Grand Av. Increment of length. .	290	132.3	50.1	25.6	19.8
Sum of Av. Increment	—	132.3	182.4	208.0	227.8

TABLE 11.—CALCULATED WEIGHTS AT THE END OF DIFFERENT YEARS OF LIFE OF *S. aurita* (Increments in Parentheses)

Age-groups	No. of fish	Calculated weights (gram) at end of year			
		1	2	3	4
I	69	26.08	—	—	—
II	188	15.74	45.65(29.91)	—	—
III	24	18.34	43.51(25.17)	65.19(21.68)	—
IV	9	12.65	30.88(18.23)	52.25(21.37)	71.63(19.38)
Grand Av. Acreent and weight . . .	290	17.97	28.92	21.60	19.38
Sum of Av. Increment	—	17.97	46.89	68.49	87.87

TABLE 12.—CALCULATED TOTAL LENGTH, LENGTH INCREMENTS, CALCULATED WEIGHTS AND WEIGHT INCREMENTS OF *S. aurita*, AT DIFFERENT YEARS OF LIFE

Yers of Life	Calcul. Length (mm)	Increment	°/₀ Incease	Calcul. wt. (gm)	Increment	°/₀ Increase
1	132.3	132.5	58.08	17.97	17.97	20.45
2	182.4	50.1	21.99	46.89	28.92	32.91
3	208.0	25.6	11.24	68.49	21.60	24.58
4	227.8	19.8	8.69	87.87	19.38	22.06

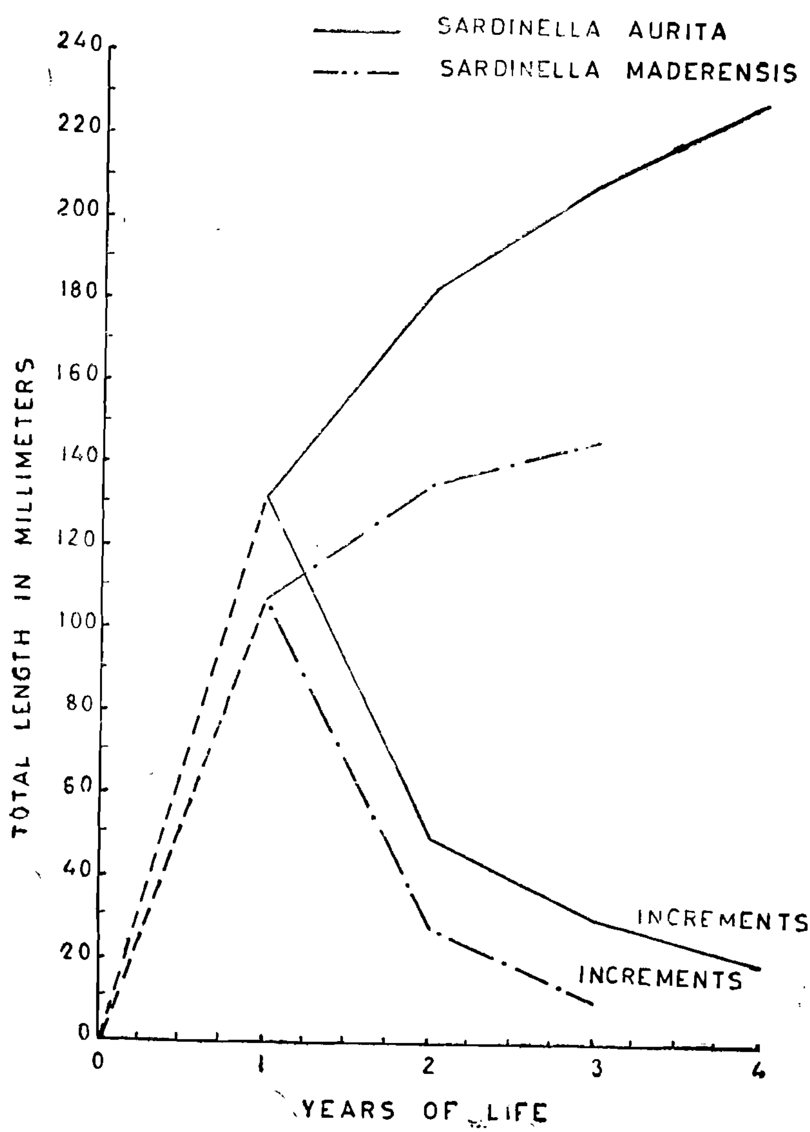

FIG. 8.—Growth in length with age for both species of *Sardinella*.

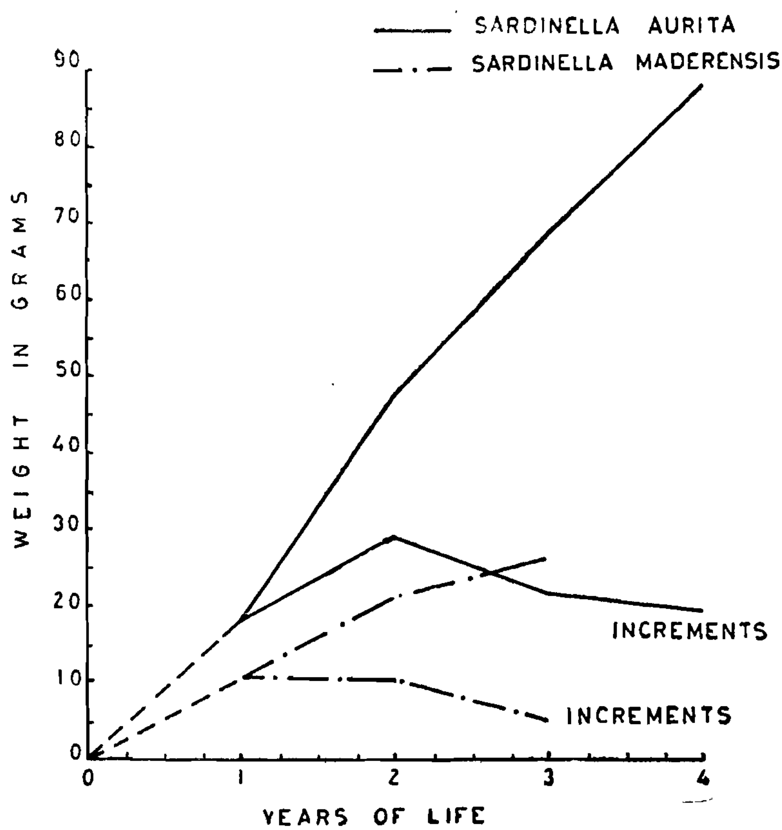

FIG. 9.—Growth in weight with age for both species of Sardinella.

E.—The theoretical growth rate of S. aurita :

It was possible to find the theoretical rate of growth of *S. aurita* because four year-groups were represented in the samples. The presence of at least 4 years age-groups are necessary for adopting the procedure stated below.

Unfortunately, it was not possible to carry this theoretical treatment in *S. maderensis* owing to the absence of data on fishes older than 3 years.

In order to determine theoretically the maximum length attained by the fish, the following procedure was followed.

Ford-Walford's transformation curve (Walford, 1946) was applied to the data. In constructing this curve the total body lengths at ages (t) = 1, 2 and 3 years are plotted along the X-axis against the lengths at ages (t+1)=2, 3 and 4 years along the Y-axis. The points fall along the straight line which is considered by Walford as a transformation of the growh curve. This is graphically represented in (Fig. (10).

As the exponent value in the length-weight relationship for *S. aurita* is equal to 3.12, hence it can be stated that the growth of these fishes conforms to Von Bertalanffy's growth equation which is as follows:

$$l_t = L\infty \; [1 - e^{-k\,(t - t_o)}]$$

where, l_t = total length at (t) years,

$L\infty$ = asymptotic (maximum) body length,

k = coefficient of growth.

t = years of life,

t_o = a parameter indicating the hypotheical time in which the fish would has been at zero size.

The values of $L\infty$ and k can be deduced from Walford's transformation curve. The ultimate length, *i.e.* $L\infty$ can be located graphically at the point where the length at age (t) equials the length at age (t + 1). This point is located where the straight line intersects a bisector drawn at 45° thrrough the zero point.

The slope of the straight line in Ford-Walford's transformation curve (Figure10) equals to e^{-k} from which k can be deduced.

Knowing $L\infty$ and k, we can arrive at t_o from the following equation :

$$\log_e \left(\frac{L\infty - l_t}{L\infty} \right) = kt - kt_o$$

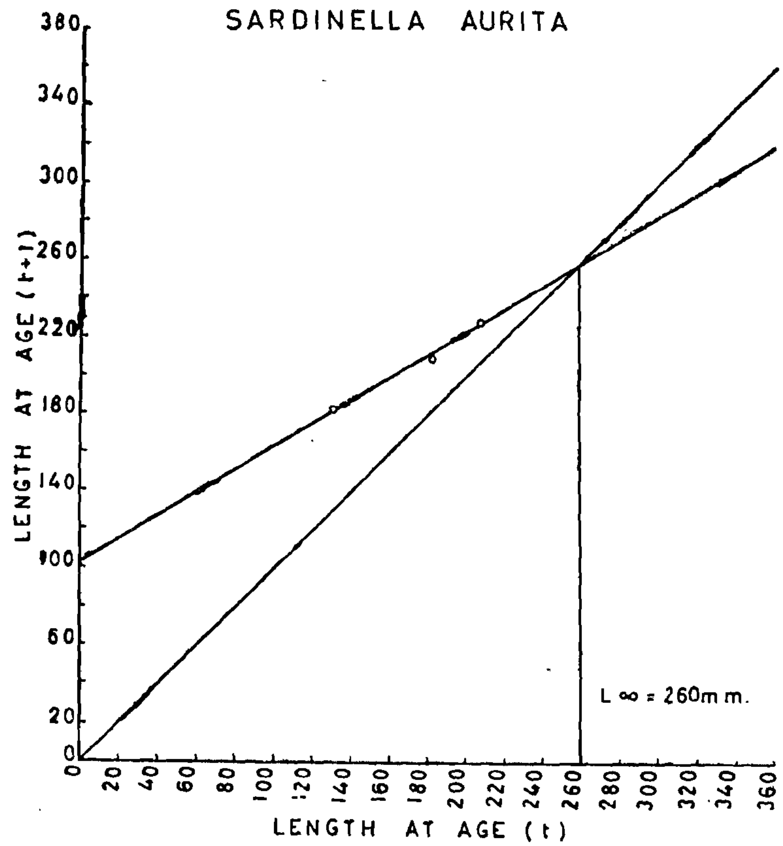

FIG. 10.—Ford-Walford's transformation growth curve for *S. aurita*.

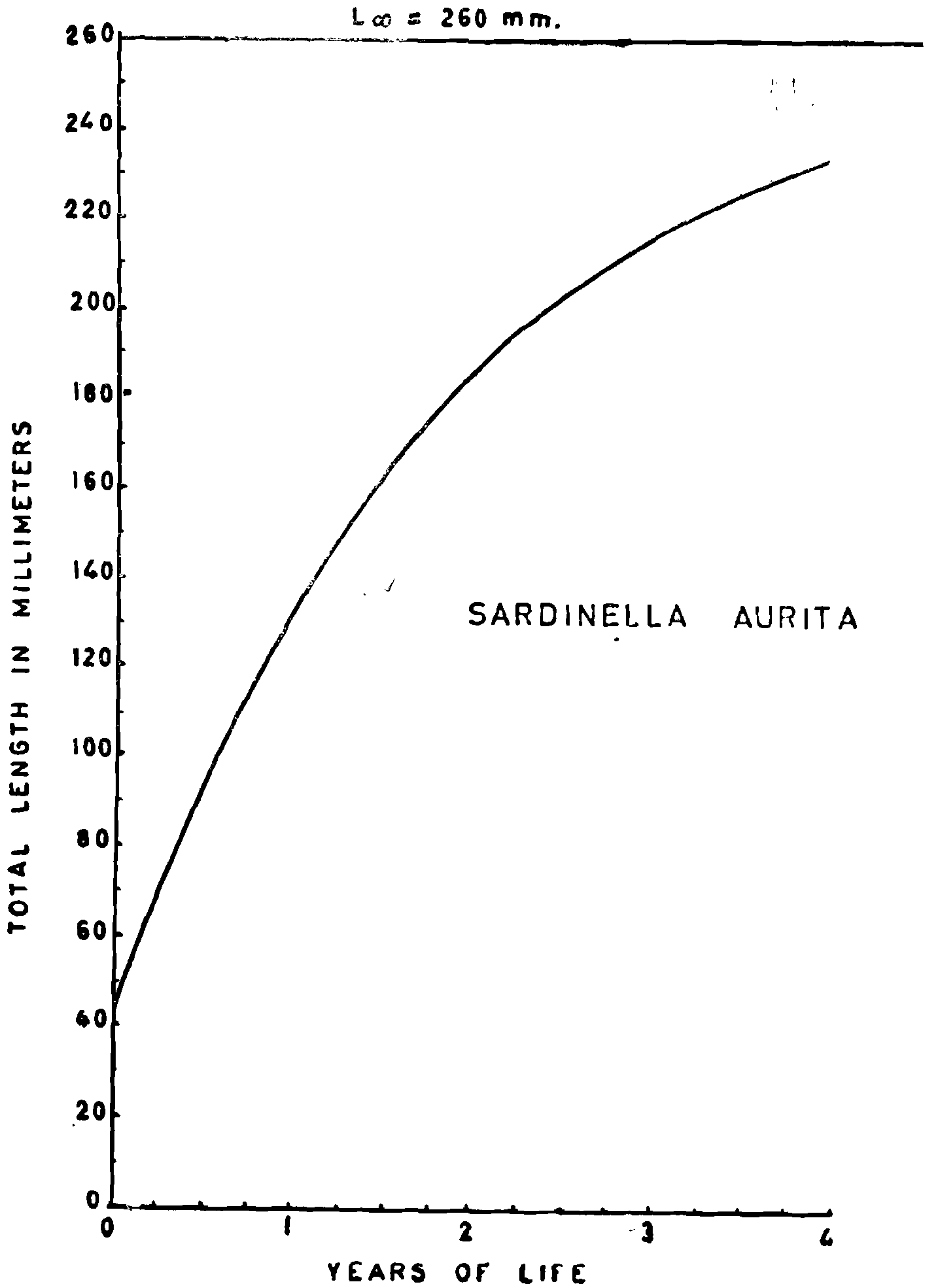

FIG. 11.—Theoretical growth in length for *S. aurita*.

The parameters of the Von Bertalanffy's equation in *S. aurita* have been calculatd as :

$L\infty = 260.0$ mm

$k = 0.531$

$t_o = 0.3395$

These parameters are used in the Von Bertalanffy's equation to get the theoretical length values at 0, 1, 2, 3 and 4 years of life. These lengths were calculated to be as follows :

Years of life	: 0	1	2	3	4
calculated theoretical length	: 43	132.5	185	216	234

The theoretical length values at 0, 1, 2, 3 and 4 years are used to get the, hypothetical length-growth curve Figure (11).

The theoretical weights of *S. aurita* at each year of life is likewise obtained from the length-weight formula of this fish, *i.e.*

$$W = 4.315 \times 10^{-6} . L^{3.12}$$

By substituting $L\infty^{3.12}$ for $L^{3.12}$, the equation becomes

$$W\infty \text{ (asypptotic weight) } = 4.315 \times 10^{-6} . L\infty^{3.12}$$

$$W\infty = 147.8 \text{ grams.}$$

The hypothetical weight values at 0, 1, 2 3, and 4 years of life are found to be as follows :

Years of life	:	0	1	2	3	4
Calculated theoretical weight	:	—	18	51	83	106.5

These values are used for the graphical representation of the hypotheticl growth in weight shown in Figure (12).

The theoretical length and weight values of the different years of life are compared with the corresponding ones obtined from scale readings in (Table 13). The latter values are expresse by the sums of average increments (*see* Tables 10 and 11).

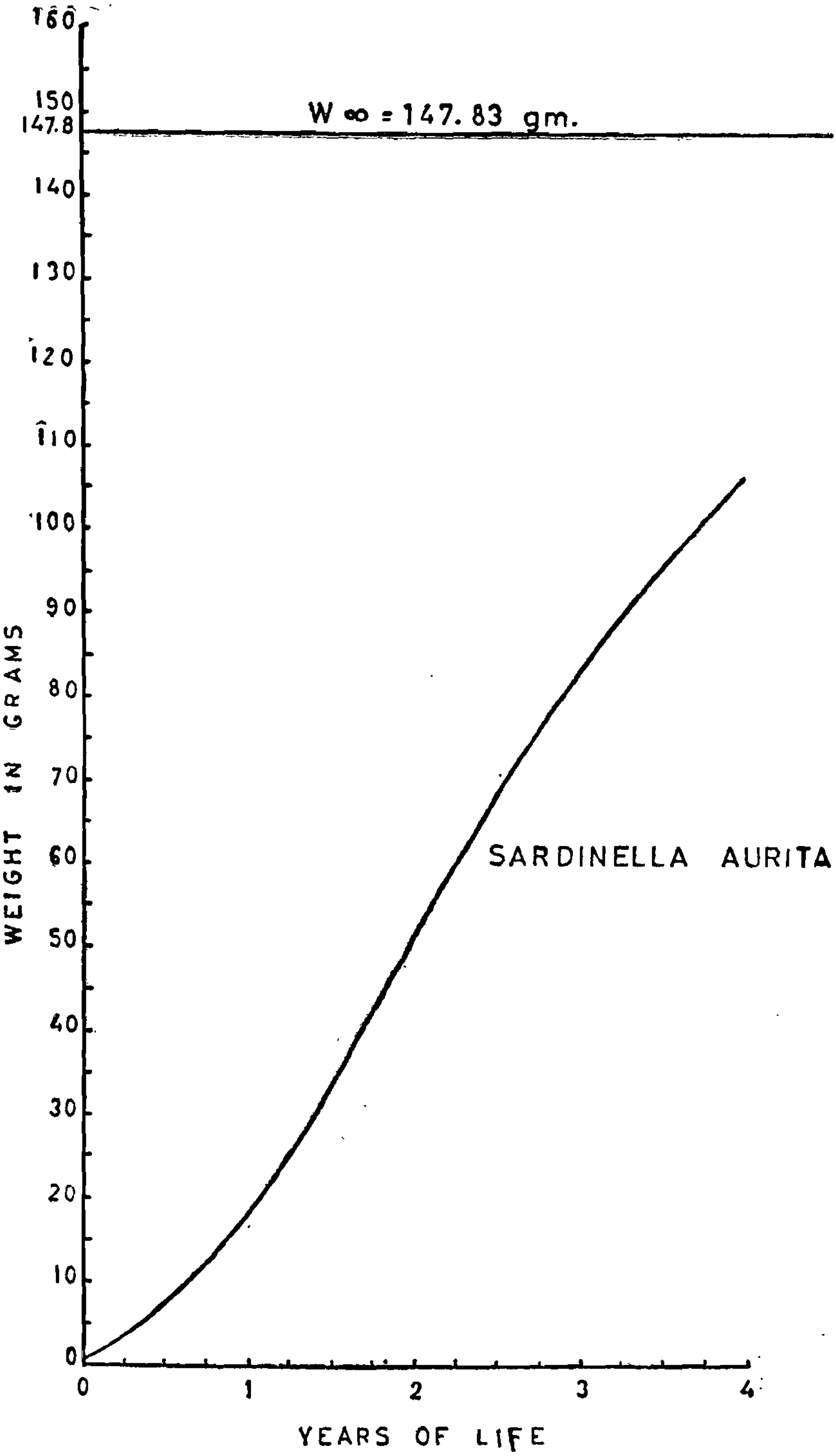

Fig. 12.—Theoretical growth in weight for *S. aurita*.

TABLE 13.—LENGTHS ANE WEIGHTS OF *S. aurita* CALCULATED FROM SUM OF INCREMENTS AND FROM BERTALANFFY'S EQUATION

Years of Life	Length (mm)		Weight (gm)	
	Calculated from sum of increments	Calculated from Bertalanffy's equation	Calculated from sum of increments	Calculated from Bertalanffy's equation
1	132.3	132.30	17.97	17.96
2	182.4	184.91	46.89	51.00
3	208.0	215.85	68.49	82.72
4	227.8	234.04	87.87	106.36

DISCUSSION

The straight lines representing the relation between body and scale of *S. maderensis* and *S. aurita* (Fig. 1, 2), are best to fit this relationship. This is proved by the close fitness of the average emperical values of scale radius to these lines. It is clear from the graphs, taht this linear relation passed in both species through the origin of the two axis. The direct proportionality formula for back culalation is thus applied.

The time of annulus formation in both specis was deduced from tracing the growth increments on the scales throughout the year. It takes place in *S. maderensis* in early spring (*i.e.* in March) and a month later (*i.e.* in April) a small extra growth was indicated on the scale marking the beginning of a new growth period.

The corresponding time of annulus formation seems to come earlier in *S. aurita*. A small extra growth zone was indicated for this species in March and it is most probable that the annulus is laid in February.

In both species, the time of annulus formation is, however, not the same in all fishes. It appears in some individuals in early spring while in others it does not show until early summer.

Heald and Griffiths (1967) found that the formation of annulus on the scales of *Sardinella anchovia* Val. (*S. aurita*) takes place in February and March in the three years old fish. They found that fishes of age group I form their first annulus in early April.

The analysis of age-groups in both species has revealed that there is a distinct overlapping between successive age-groups (*see* Table 5 , 6, and Figs. 3 , 4). That is to say, a fish of a particular length could belong to 2 or 3 age-groups. For instance, fishes of *S. maderensis* and *S. aurita* of respectively 135 and 175 mm total length could belong to age-groups II and III. This phenomenon is clearly illustrated in the scales photographs in figure (7 *a-e*).

The discrepancies in the calculated lengths attained at the end of different years of life are obvious from one age-group to the next (*see* Tables 7 and 10). This is particularly so in *S. aurita* and it might be attributed to the pressure exerted by the new growth zone on the early annuli. The apparent trend of the calculated length values is generally to decrease with the increase in age. This conforms with Lee's phenomenon (1920) of apparent decrease in growth rate.

The percentage increase in length in the different years of life (*see* Table 8) demonstrates that *S. maderensis* achieves its maximum increase in length at the end of its first year, 73.22%. Growth sharply decrease to 19.40% and 7.38% in the second and third year of life respectively.

As to the growth in weight, the highest percentage increase is accomplished during the first two years of life. The percentage weight increase (relative to the calculated weight attained at the third year of life) is nearly equal at the first and second years of life (about 40%).

The growth in length of *S. aurita* has a similar trend as in *S. maderensis*. That is to say, the fish attains its largest percentage increase in length at the end of its first year of life (58%), it successively decreases during the second, third and fourth years of life to respectively 22%, 11% and 9%.

The percentage increase in weight in *S. aurita* (relative to the weight attained at the fourth year of life) are the highest at the second year of life. In this respect, it is different from *S. maderensis* which has a high and nearly equal growth increase in the first and second years of life (*see* Table 12).

On the whole, it is clear from figures (8 and 9) that the growth rate in both length and weight relative to age are higher in *S. aurita* than in *S. maderensis*.

The values of length and weight of *S. aurita* at different years of life as calculted from the sums of average increments and from applying the Von Bertalanffy's equation are given in (Table 13). Comparing the values obtained from the two method, it is obvious that a pronounced difference exist at the third and fourth year of life.

If the necessary data on fish growth from scale reading are available, Von Bertalanffy's euqation is preferred to calculate the growth rate. This is because, the equation is based on several parameters in its construction namely, L_∞ k and t_0. Moreover, the equation can also give the asymptotic length and weight of fish throughout its life.

The growth rate in each of the two species of *Sardinella* at different localities inside the Mediterranean Sea as well as at West Africa are given in Tables (14) and (15).

TABLE 14.—THE LENGTHS (mm) OF *S. maderensis* ATTAINED AT DIFFERENT AGE-GROUPS FROM ALEXANDRIA COMPARED WITH THOSE OF OTHER LOCALITIES

Country	Author	Age groups						
		I	II	III	IV	V	VI	VII
Egypt	Fage, 1920	110–115	120 125	135	140–150	—	—	—
Algeria	Dieuzeide, 1950	—	—	—	175	180–220	230·255	—
Alexandria	El-Maghraby, 1960	111	127	139	163	—	—	—
Palestine	Ben-Tuvia, 1960	115	145	175	195	220	—	275
Alexandria	Present work	113	135	145	—	—	—	—

TABLE 15.—THE LENGTHS (mm) OF *S. aurita* ATTAINED AT DIFFERENT AGE-GROUPS FROM ALEXANDRIA COMPARED WITH THOSE OF OTHER LOCALITIES

Country	Author	Age groups					
		0	I	II	III	IV	V
Balearic	Navarro, 1932	130	182	218	238	—	—
Canary	Navarro, 1932	137	189	236	268	285	—
Aegean Sea	Ananiades, 1951	—	120	170	210	240	260
Senegal	Postel, 1955	—	150	210–220	250–260	290–300	330–340
Middle Congo	Rossignol, 1955	—	150	230	270	290	—
Palestine	Ben-Tuvia, 1956	112	158	192	217	234	257
Algeria	Dieuzeide & Roland, 1957	60–120	130–160	170–200	210–260	—	—
Gulf du Lion	Lee, 1961	105	169	214	234	—	—
Alexandria	Present work	—	149	178	200	206	—

A close agreement is observed, in *S. maderensis*, between the average length at different years of life recorded in this investigation and those of Fage (1920), El-Maghraby (1960) and that of Ben-Tuvia (1960). In Algeria, Dieuzeide (1950) gave only lengths attained by fishes at age groups IV to VI, which were not easy to determine in our sample.

As for *S. aurita*, close ageement is likewise observed between our data and those of Ben-Tuvia (1956) in Palestine ; Dieuzeide and Roland (1957) in Algerian waters. On the other hand, those of Navarro (1920) in Balearic and Canaries ; Ananiades (1951) in Aegean Sea ; Lee (1961) in the Gulf of Lion ; Postel (1955) in Senegal and of Rossignol (1955) in Gabon (Middle Congo) show somewhat higher rate of growth for this species in these areas.

SUMMARY

The present study is aimed to give information on the age and growth for the two most important species of Egyptian Sardine, namely *Sardinella maderensis* Lowe and *Sardinella aurita* Cuv. and Val. The results of this study could be summarised as follows :

1.—The relation between the body length and scale radius of both species was found to be linear and the equation calculated to represent this relationship is given. Annulus formation on the scales of *S. maderensis* takes place in March. In April, an extra growth shows itself as small incremet outside the newly formed annulus. Annulus formation takes place in February in *S. aurita*. The time of annulus formation in both species could be in some individuals as late as June.

2.—There is a distinct overlaping in the lengths of the successive age-groups, *i.e.* a fish of a particular length might belong to two or three age-goups. Discrepancies in the calculted lengths attained at the end of different years of life are obvious from one age-group to the next in *S. aurita*. This might partly be attributed to a pressure exerted on the inner annuli by the newly formed growth zones. As far as the rate of growth in length, it was found that both species attain their highest increase in length at the end of the first year of life, the rate then gradually decreases in successive years. On the whole, the decrease in growth from one year to the next conforms with Lee's phenomenon.

3.—As to the growth in weight, the highest increase in case of *S. maderensis* is shared between the first and second years of life In case of *S. aurita*, on he other hand, the fish attains its maximum increase at the end of its second year of life.

4.—Using the Von Bertalanffy's equation in *S. aurita*, the maximum values of length and weight attained by this species during its life were found to be, 260.0 mm. and 47.8 grams respectively. It appears that along the first three successive years of life, *S. aurita* requires more length and weight than *S. maderensis*.

5.—In *S. maderensis* and *S. aurita*, close agreement is observed between their rates of growth calculated in this study and those from certain localities, the gowth rates of *S. aurita* in other localities are slightly higher.

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