LENGTH-WEIGHT RELATIONSHIP AND COEFFICIENT OF CONDITION FOR *SARDINELLA MADERENSIS* LOWE AND *SARDINELLA AURITA* CUV. & VAL. FROM THE MEDITERRANEAN SEA AT ALEXANDRIA (U.A.R.)

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INTRODUCTION

The importance of the Sardine fish to the Egyptian fisheries was attributed to the relatively large catches landed annually during the autumn months. Numerous big, shoals of this fish used to aggregate during that period in the coastal waters off the Nile Delta to feed actively on the rich phytoplankton organisms. The autumn blooming of phytoplankton in this area was a regular annual phenomenon, before the construction of the Aswan High Dam. It occured as a result of the fertilizing effect of the Nile flood water flowing out to the sea.

The standing crop of phytoplankton in the surface waters used to increase for instance from a few thousand cells per litre in early August, just before the flood, to as much as about 10 million cells per litre in September and October. The sardine fish during that period stored in its tissues a high fat reserve which consequently increased its dietetic value.

As a matter of fact the variation in the concentration of plankton food in the waters infront of the delta in the different seasons of the year clearly affects the well-being of these fishes. The weight variations noticed within the same length group in the different seasons can be attributed to cyclic changes in the quantity of fat stored in the fish associated with or following feeding and breeding activities (El-Saby, 1937; El-Maghraby, 1960 and 1969).

The present work is a study of the length-weight relationship and the variation in the coefficient of condition of *Sardinella maderensis* and *Sardinella aurita* in the period from September 1964 to October 1965.

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 three times.

The sample was taken as soon as possible to the laboratory. The total length and total weight of each fish in the sample are 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.

Length-weight relationship was calculated for 805 fish, *S. maderensis*, ranging in total length between 50 and 270 mm., and for 883 fish, *S. aurita*, ranging in total length between 60 and 230 mm.

The condition factor (= coefficient of condition = pondral index) was calculated for each of 570 fish, *S. maderensis*, ranging between 50 and 270 mm, and 628 fish, *S. aurita*, ranging in length between 60 and 230 mm.

RESULTS AND DISCUSSION

The analysis of length-weight data has usually been directed towards two rather different objects.

1.—Towards establishing a mathematical equation to express the relationship between length and weight, so that one may be converted into the other.

2.—To measure the variation of fish condition from the observed weight in relation to length of the individual fish or relevant groups of individuals. These variations are mostly related to changes in the fat content of the fish, its robustness or general "Well being" and gonad development, etc.

Since the length of a fish is often more rapidly and accurately measured than the weight (especially in the field), it is thus very convenient to find a relationship by which weight could be determined if the length is only known.

The length-weight relationship of fish has sometimes been described by the "cube law" *i.e.* $W = c\ L^3$ (where W = weight, L = length and c = constant). This law, however, can be applied only if the form and specific gravity of fish remain constant throughout life. The cube relationship serves however best in the study of "condition", to obtain the value of (K) the "condition factor" or "pondral index" as an idication of the degree of well-being of the fish regardless of the actual length-weight relationship.

It has been found that the length-weight relationship of most fish can be better described by the general parabola :

$$W = c\ L^n$$

where, W = weight, L = length and c and n are constants which can be determined emperically.

For an ideal fish which maintains the same shape throughout life, the expoent equals 3 (Allen, 1938). But in the vast majority of instances where the length-weight relationships have been calculated, it has been found that the cube law is not obeyed and the exponent is not equal to 3. According to Hile (1936) this general equation ordinarily gives a better result in the expressions of the length-weight relatioship than does the cube parabola : $W = c\ L^3$.

The exponent "n" in all fish species studied for their length-weight relationship was howevr found to range between 2.5 and 4.0 (Hile, 1936 and Martin, 1949).

Representing the relationship between a fish length and weight graphically always give a curvilinear shape. The general parabola, $W = c\ L^n$, can be expressed in the logarithmic form, thus turned into a straight line ;

The relation is thus expressed as:

$$\log W = \log c + n \log L$$

n equals the slope and log c equals the intercept which are easily determined by fitting a line to the logaritbms of L and W. The value of log c and n are computed from the followig formula which are simply solutions of the normal equations:

$$\log c = \frac{\Sigma \log W \cdot \Sigma (\log L)^2 - \Sigma \log L \cdot \Sigma (\log L \cdot \log W)}{N \cdot \Sigma ((\log L)^2 - (\Sigma \text{ Log } L)^2}$$

and:

$$n = \frac{\Sigma \log W - N \cdot \log c}{\Sigma \log L}$$

Variations in the relation between length and weight of the fish considered from the weight and length of eah individual fish are usually considered to be more indicative to the fish condition than the length-weight relation formula. This has been frequently studied under the general name " condition ". The changes in condition has usually been analysed by means of a *"condition factor"* or *"coefficient of condition"* or *"pondral index"*.

In this case, assuming that the cube law is obeyed, the condition factor is obtained by the equation:

$$K = \frac{100\ W}{L^3} \text{ (Hile, 1936)}$$

where W= weight in grams and L = length in centimeters.

The length-weight relationship of S. maderensis:

In the analysis of length-weight relationship for *S. maderensis*, 805 fish were used with total length ranging between 50–270 mm. The average observed weights for the different length groups are calculated for separate sexes. As there is no apparent difference between males and females the average observed weights for both sexes combined were calculated. These results are given in Table (1). To express the length-weight relation in terms of the parabola; $W = c\ L^n$, where W = weight in gram and L = length in millimeters. The values of c and n were calculated from the above mentioned equations (*see* p. 5).

The calculated length-weight formula was found to be:

$$\log W = -4.8932 + 2.9176 \log L$$

or

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

In Figure (1) the weight in grams of *S. maderensis* is plotted against the total length in mm. The smooth line is drawn using the weight values calculated from the formula. In Table (1) the empirical and calculated weights are also included at each centimeter length interval. The close proximity of the empirical and calculated values indicates the fitness of the formula. The vertical dots represent the extent of the variation in the observed body weights for each length group.

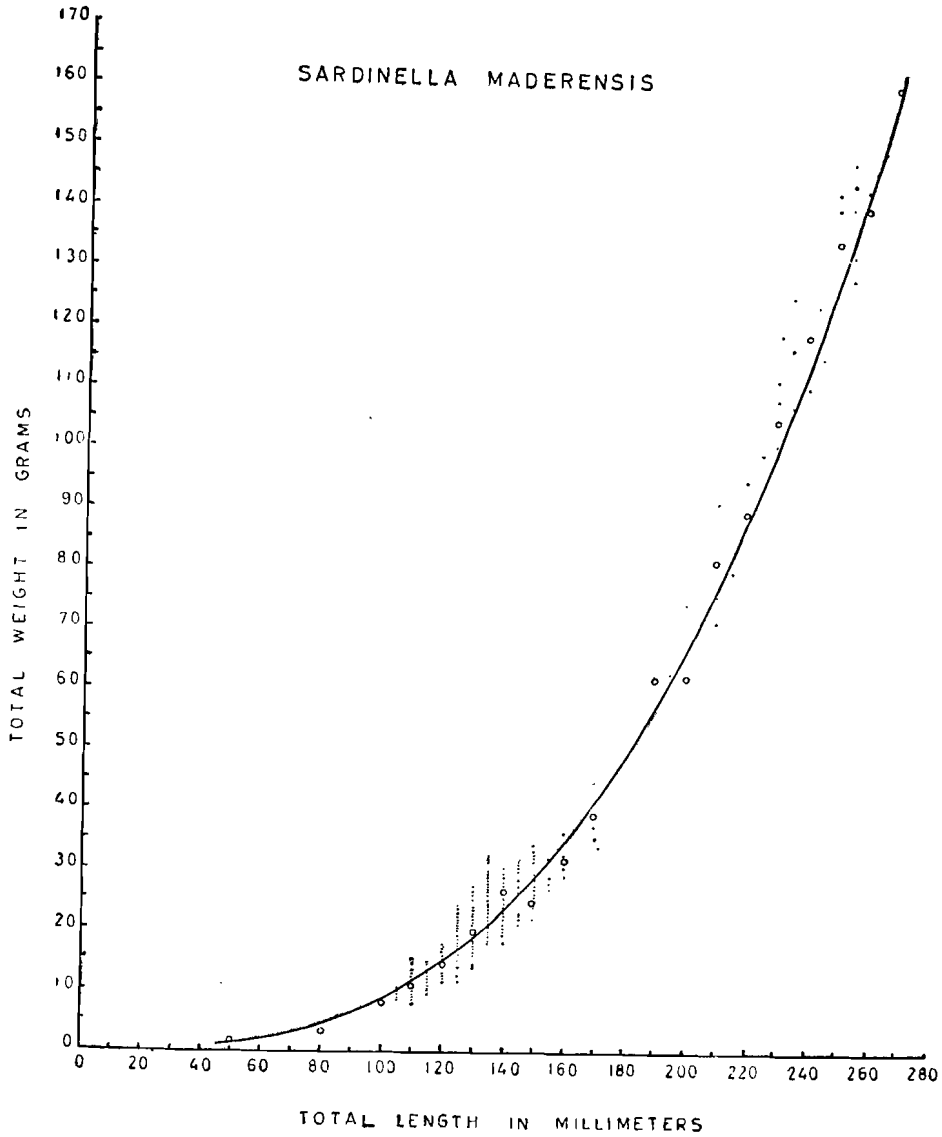


FIG. 1.—The relation between the length and weight of *S. maderensis*.

The length range for the majority of the fishes examined (94 %) lies between 100–160 mm. This is the prevailing length range of the character for the catch of *S. maderensis* population fished from Alexandria from year to year. Excluding thus the less frequent length groups (*i.e.* smaller than 100 mm and longer than 160 mm, the formula that best fit the prevailing length range was found to be :

$$\log W = -4.8237 + 2.879 \log L$$

or

$$W = 1.501 \times 10^{-5} L^{2.879}$$

TABLE 1.—LENGTH-WEIGHT RELATIONSHIP OF *S. maderensis*

Total length (mm)	Male		Female		Combined dexes		Calculated weight (gm) combined sexes
	No.	av, wt. (gm)	No.	av. wt. (gm)	No.	av. wt. (gm)	
50	—	—	—	—	1	1.5	1.16
80	—	—	—	—	1	3.5	4.57
100	8	8.6	5	8.2	14	8.4	8.77
110	30	10.1	27	10.5	70	10.6	11.58
120	27	13.7	26	13.2	104	14.7	14.93
130	28	17.6	12	17.7	213	19.9	18.86
140	52	21.3	32	22.2	255	26.5	23.41
150	25	25.3	23	25.6	88	24.7	28.64
160	5	31.9	5	29.1	15	31.6	34.56
170	—	—	3	39.2	3	39.2	41.23
190	—	—	2	61.5	2	61.5	57.9
200	—	—	1	62.0	1	62.0	66.27
210	2	76.0	3	86.7	6	81.3	76.42
220	—	—	4	89.3	4	89.3	87.52
230	—	—	3	103.5	4	104.6	99.63
240	2	122.5	3	116.2	5	118.7	112.80
250	6	131.5	3	135.0	9	133.7	127.10
260	4	142.5	3	139.5	8	139.9	142.60
270	—	—	2	159.5	2	159.5	159.20
	189		157		805		

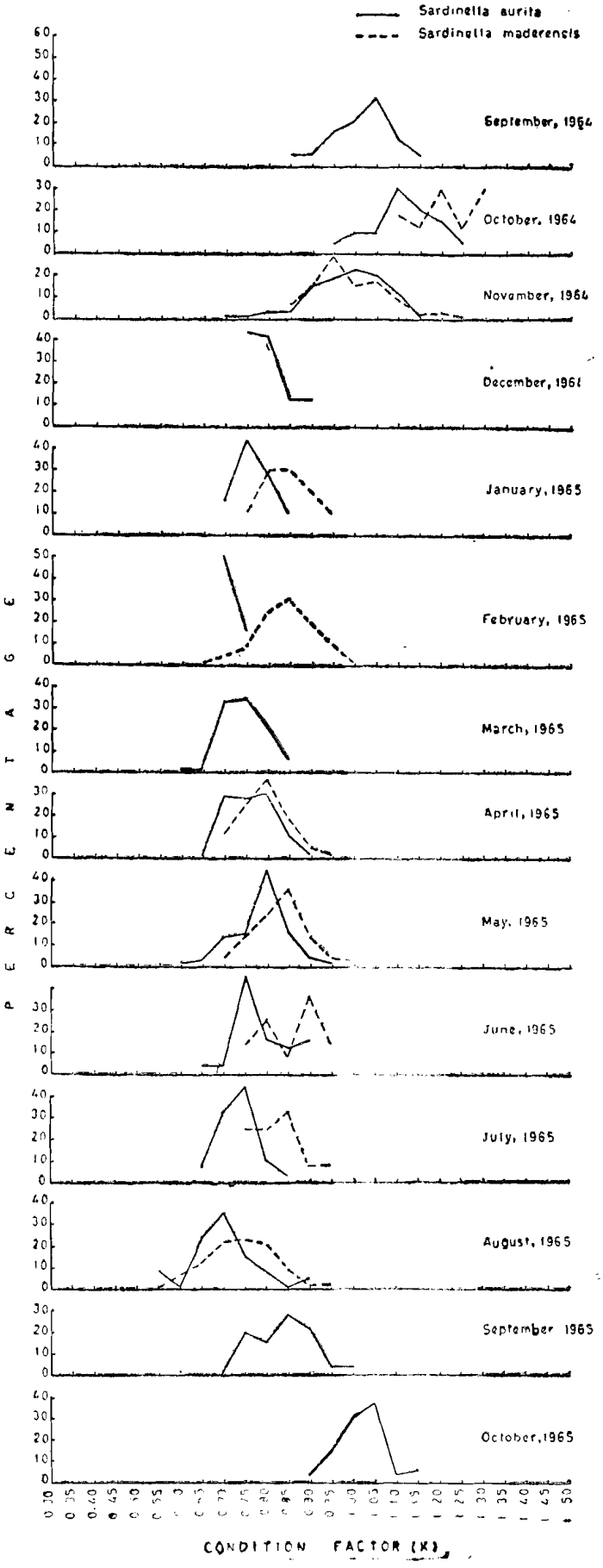


FIG. 2.—The variation of the percentage of condition factor intervals in different months for both species of *Sardinella*.

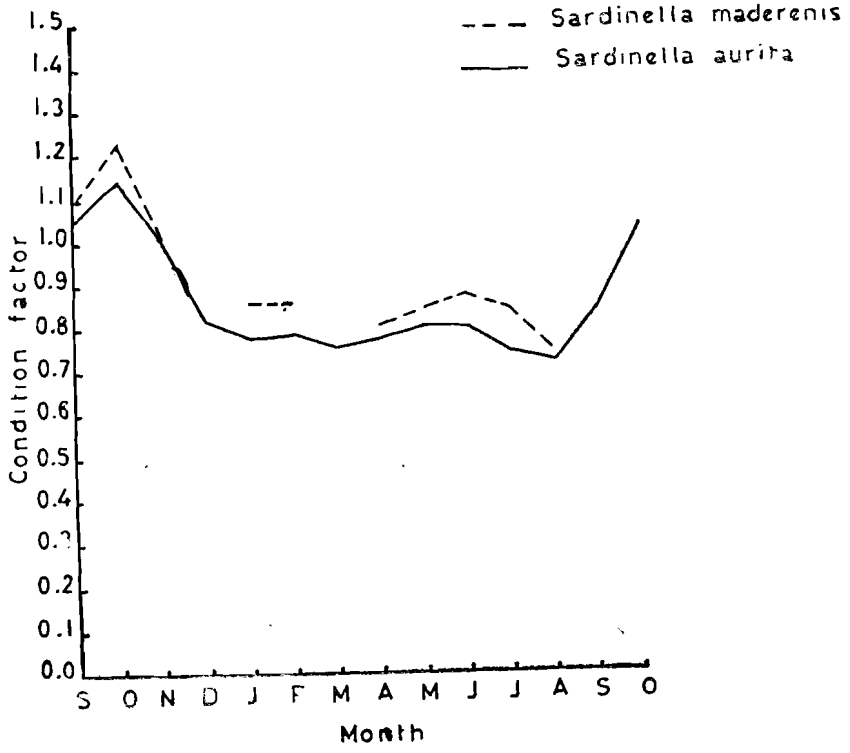


FIG. 3.—The variation of the averages of condition factor in different months for both species of *Sardinella*.

TABLE 2.—THE PERCENTAGE DISTRIBUTION OF THE DIFFERENT LEVELS OF

Condition Factor levels	Sept. 1964		Oct. 1964		Nov. 1964		Jan. 1965	
	No.	%	No.	%	No.	%	No,	%
0.55	—	—	—	—	—	—	—	—
0.60	—	—	—	—	—	—	—	—
0.65	—	—	—	—	—	—	—	—
0.70	—	—	—	—	—	—	—	—
0.75	—	—	—	—	1	0.60	1	10.00
0.80	—	—	—	—	—	—	3	30.00
0.85	—	—	—	—	11	6.63	3	30.00
0.90	—	—	—	—	25	15.06	2	20.00
0.95	1	14.29	—	—	48	28.92	1	10.00
1.00	—	—	—	—	26	15.66	—	—
1.05	4	57.14	—	—	29	17.47	—	—
1.10	—	—	3	17.65	15	9.04	—	—
1.15	2	28.57	2	11.77	4	2.41	—	—
1.20	—	—	5	29.41	5	3.01	—	—
1.25	—	—	2	11.77	2	1.20	—	—
1.30	—	—	5	29.41	—	—	—	—
	7		17		166		10	

CONDITION FACTOR FOR *S. maderensis* IN THE DIFFERENT MONTHS OF THE YEAR

Feb. 1965		April 1965		May 1965		June 1965		July 1965		August 1965	
No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
—	—	—	—	—	—	—	—	—	—	1	0.96
—	—	—	—	—	—	—	—	—	—	7	6.73
1	1.61	—	—	—	—	—	—	—	—	13	12.50
3	4.84	8	11.43	3	3.49	—	—	—	—	23	22.12
5	8.07	18	25.71	13	15.12	5	13.89	3	25.00	24	23.08
15	24.19	26	37.14	21	24.42	9	25.00	3	25.00	22	21.15
19	30.65	13	18.57	31	36.05	3	8.33	4	33.33	10	9.62
12	19.36	4	5.71	12	13.95	13	36.11	1	8.33	2	1.92
6	9.68	1	1.43	4	4.65	5	13.89	1	8.33	2	1.92
1	1.61	—	—	2	2.33	—	—	—	—	—	—
—	—	—	—	—	—	1	2.78	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
62		70		86		36		12		104	

The Condition factor of S. maderensis :

The condition factor (K) was calculated for 570 fish ranging in length from 50 to 270 mm. using the following formula :

$$K = \frac{100{,}000\ W}{L^3}$$

where, W = weight in grms, L = total lenght in millimeters.

The condition factor values recorded monthly for the individual fish in each sample are grouped at 0.05 interval range. The condition factor values are found to vary in *S. maderensis* in the course of the year between 0.55 and 1.30. The condition value range for each month and the percentage of its frequency is given for the period September 1964 to August 1965 in Table (2). In figure (2) these percentages are plotted against the condition factor intervals for each month (data representing December 1964 and March 1965 are lacking).

The average condition value for every month is given in Table (3) and the monthly Variation in this average is graphically represented in Figure (3).

TABLE 3.—THE AVERAGE VALUES OF CONDITION FACTORS OF *S. maderensis* AND *S. aurita* IN DIFFERENT MONTHS

Month	S. maderensis		S. aurita	
	No.	average condition factor	No.	average condition factor
September,–1964	97	1.09	38	1.05
October	17	1.23	20	1.14
November	166	1.01	90	1.00
December	—	—	16	0.82
January,–1965	10	0.86	32	0.78
February	62	0.86	341	0.79
March	—	—	74	0.76
April	70	0.81	73	0.78
May	86	0.85	67	0.81
June	36	0.88	24	0.81
July	12	0.85	27	0.75
August	104	0.76	81	0.73
September	—	—	45	0.85
October	—	—	45	1.04

It is obvious from Figures (2) and (3) that the average condition values varied from 0.76 in August to 1.23 in October. The value increased in September and attained its highest level in October. Another minor peak was recorded in June. The autumn peak was also recorded by El-Maghraby (1960).

The autumn peak in the condition factor of the fish could be attributed to the storage of excess fat in that time as a result of its feeding on the phytoplankton bloom which took place in autumn in years previous to 1966 El-Saby (1937) found that more than 1/4 of the fish weight during autumn consist of fat.

As to the early summer minor peak, it most probably resulted from an increase in the feeding activity of the fish after the winter dormant phase.

The pattern of change in the condition factor value corresponds with the the changes in the fat content of this species as found by El-Saby (1937). He found that the fat content is at its maximum during autumn and at its minimum in July and August.

The length-weight relationship of S. aurita :

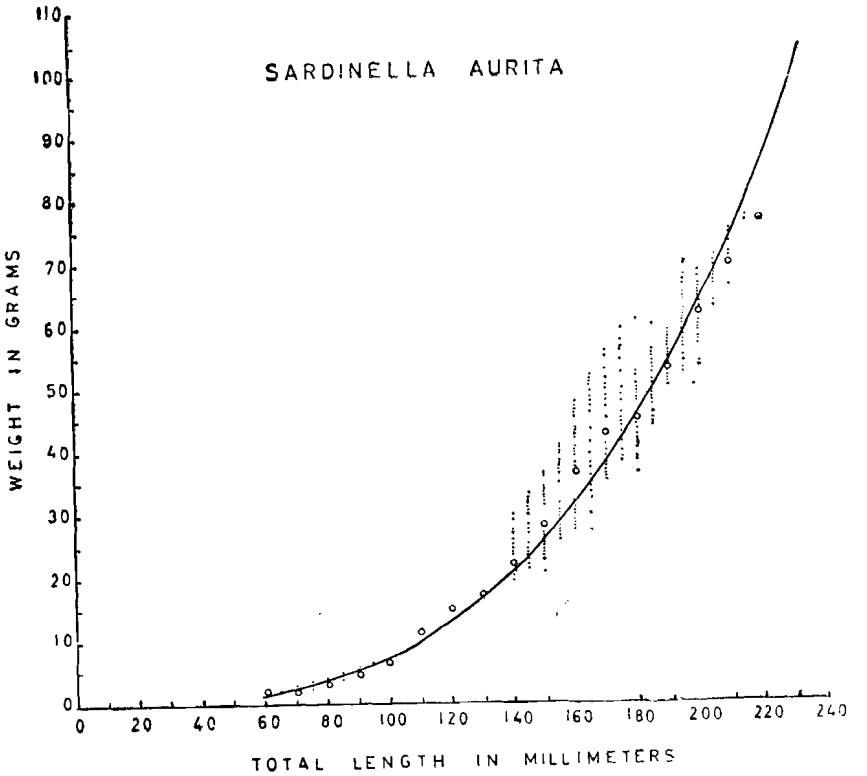
For the calculation of the length-weight relationship of *S. aurita*, 883 fish ranging in length from 60–230 mm. were used. The same method used in the calculation of *S. maderensis* is applied to *S. aurita*, the logarithmic equation was as follows :

$$\log W = -5.3649 + 3.12 \log L$$

or

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

Figure (4) represents the length-weight relationship of *S. aurita* together with the average observd weights and the extent of the variation in the body weights for the different length groups.



— FIG. 4.—The relation between the length and weight of *S. aurita*.

In Table (4) are included the fequency, average observed weights for separate sexes, and for both sexes combined and the calculated weights for both sexes at 10 mm length interval.

TABLE 4.—LENGTH-WEIGHT RELATIONSHIP OF *Sardinella aurita.*

Total length (mm)	Male		Female		Combined sexes		Calculated weight (gm) combined sexes
	No.	av. wt. (gm)	No.	av. wt. (gm)	No.	av. wt. (gm)	
60	—	—	—	—	7	1.71	1.50
70	—	—	—	—	12	2.17	2.43
80	—	—	—	—	21	3.38	3.68
90	—	—	—	—	18	5.03	5.31
100	—	—	—	—	2	6.50	7.38
110	—	—	—	—	1	11.50	9.92
120	—	—	—	—	76	15.01	13.02
130	—	—	—	—	213	17.31	16.69
140	1	22.50	11	31.32	72	21.95	21.03
150	11	24.86	31	24.16	91	28.06	26.08
160	16	29.91	14	28.61	80	36.50	31.84
170	17	35.62	11	37.50	56	42.59	38.50
180	23	43.43	20	44.60	54	46.18	46.03
190	28	52.79	44	52.78	75	53.29	54.48
200	24	62.54	39	61.13	69	61.82	63.87
210	6	67.75	24	69.88	31	69.57	74.35
220	—	—	3	78.83	4	76.88	85.94
230	1	82.50	—	—	1	82.50	98.72
	127		197		883		

The close proximity between the observed and calculated weights for different length groups indicates the fitness of the length-weight equation computed for expressing this relation.

The condition factor of S. aurita:

The condition factor (K) was calculated for 628 fish ranging in length from 60 to 250 mm. using the following formula:

$$K = \frac{1000{,}000 \quad W}{L^3}$$

where: W = weight in grams, L = total length in millimeters.

In Table (5) and Figure (2), the distribution of different range value for condition factor of *S. aurita* is given for the interval of time from September 1964 to October 1965. The variation in the average value of this factor for this time interval is given in Table (3) and graphically represented in Figure (3).

It is obvious from the table and graph that the maximum condition value for this species occurred in autumn (and was repeated again in the autumn of 1965). It thus occured, as in *S. maderenis*, during the active feeding period of the fish. El-Saby (1937)) has also estimated the fat reserve deposited in the body of this species during autumn to exceed 25% of the fish weight.

El-Maghraby (1969) gave a detailed study of the length-weight relation of *S. maderensis* and *S. aurita*. The length-weight equations given by him for the autumn actively feeding individuals of these two species indicate their well-being and fatness. This is in contrast to the summer ripe, ready to spawn fish whose length-weight equations indicate the lean and emaciated condition of them.

El-Maghraby (1960 and 1969) has linked the seasonal change in fish weight with that of the fat stored in the fish body. He attributed these changes to the biological cycle of the fish namely, a quiescent phase in winter, a maturity phase in summer and an active feeding phase in autumn.

When comparing the condition factor of the two species, it is obvious that its value for *S. maderensis* is generally slightly higher than for *S. aurita* all along the different seasons of the year.

In Table (6) the calculated weights and the condition factor value of the different length groups of *S. maderensis* and *S. aurita* are compared. The higher weight and condition values of the first species is obvious at every length group. This is attributed to the deeper body of the first species which consequently acquires more weight.

TABLE 5.—THE PERCENTAGE DISTRIBUTION OF THE DIFFERENT LEVELS OF

Condition factor levels	Sept. 1964		Oct. 1964		Nov. 1964		Dec. 1964		Jan. 1965		Feb. 1965	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0.55	—	—	—	—	—	—	—	—	—	—	—	—
0.60	—	—	—	—	—	—	—	—	1	3.13	—	—
0.65	—	—	—	—	—	—	—	—	—	—	—	—
0.70	—	—	—	—	1	1.11	—	—	5	15.63	3	50.00
0.75	—	—	—	—	1	1.11	7	43.75	14	43.75	1	16.67
0.80	—	—	—	—	3	3.33	5	31.25	9	28.13	—	—
0.85	2	5.26	—	—	3	3.33	2	12.50	3	9.38	2	33.33
0.90	2	5.26	—	—	14	15.56	2	12.50	—	—	—	—
0.95	6	15.79	1	5.00	17	18.89	—	—	—	—	—	—
1.00	8	21.05	2	10.00	21	23.33	—	—	—	—	—	—
1.05	12	31.58	2	10.00	18	20.00	—	—	—	—	—	—
1.10	5	13.16	6	30.00	11	12.22	—	—	—	—	—	—
1.15	2	5.26	4	20.00	1	1.11	—	—	—	—	—	—
1.20	—	—	3	15.00	—	—	—	—	—	—	—	—
1.25	—	—	1	5.00	—	—	—	—	—	—	—	—
1.30	—	—	—	—	—	—	—	—	—	—	—	—
1.35	—	—	1	5.00	—	—	—	—	—	—	—	—
1.40	1	2.63	—	—	—	—	—	—	—	—	—	—
	38		20		90		16		32		6	

CONDIT ON FACTOR OF *S. aurita* IN THE DIFFERENT MONTHS OF THE YEAR

March 1965		April 1965		May 1965		June 1965		July 1965		Aug. 1965		Sept. 1965		Oct. 1965	
No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
—	—	—	—	—	—	—	—	—	—	7	8.64	—	—	—	—
1	1.35	—	—	1	1.49	—	—	—	—	1	1.23	1	2.22	—	—
1	1.35	1	1.37	2	2.99	1	4.17	2	7.41	19	23.46	—	—	—	—
25	23.78	21	28.77	9	13.43	1	4.17	9	33.33	29	35.80	1	2.22	—	—
26	25.14	20	27.40	10	14.93	11	45.83	12	44.44	13	16.05	9	20.00	—	—
16	21.62	22	30.14	30	44.78	4	16.67	3	11.11	7	8.64	7	15.56	—	—
5	6.76	8	10.96	11	16.42	3	12.50	1	3.70	1	1.23	13	28.89	—	—
—	—	1	1.37	3	4.48	4	16.67	—	—	4	4.94	10	22.22	2	4.44
—	—	—	—	1	1.49	—	—	—	—	—	—	4	8.89	7	15.56
—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	31.11
—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	37.78
—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	4.44
—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	6.67
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
74		73		67		24		27		81		45		45	

TABLE 6.—COMPARISON BETWEEN THE CALCULATED WEIGHTS OF *S. maderensis* AND *S. Aurita*

Total length in (mm)	S. maderensis		S. aurita	
	calculated weight	Condition K	calculated weight	Condition K
100	8.77	0.877	7.38	0.738
110	11.58	0.870	9.92	0.745
120	14.93	0.864	13.02	0.753
130	18.86	0.858	16.69	0.760
140	23.41	0.853	21.03	0.766
150	28.64	0.849	26.08	0.773
160	34.56	0.846	31.84	0.777
170	41.23	0.839	38.50	0.784
180	57.09	0.979	46.03	0.789
190	66.27	0.966	54.48	0.794
200	76.42	0.955	63.87	0.798
210	87.52	0.945	74.35	0.803
220	99.63	0.936	85.94	0.807
230	112.80	0.927	98.72	0.811

SUMMARY

The present study is aimed to give information on the length weight relationship and coefficient of condition for the two most important species of Egyptian Mediterranean Sardine, namely *Sardinella maderensis* Lowe and *Sardinella aurita* Cuv. and Val.

The results of this study could be summarised as follows:

The parabola expressing the relationship between length and weight for the two species of *Sardinella* were as follows:

S. maderensis : $W = 1.278 \times 10^{-5}. \ L^{2.9176}$

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

The condition factor which represents the well-being of the fish for each of the two species studied show two peaks a high one during the autumn months (September, October and December) and another one of lower extent during the spring (April, May and June). The large peak of autumn coincided with the maximum in the fat content of these two species.

Comparing the calculated weights of the different length groups of both species shows that *Sardinella maderensis* is generally heavier or more robust than *Sardinella aurita*.

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