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BIOLOGICAL NOTES ON KING MACKEREL, SCOMBEROMORUS CAVALLA (CUVIER), FROM NORTHEASTERN BRAZIL

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The main species of fish of commercial importance in northeastern Brazil is the king mackerel, *Scomberomorus cavalla* (Cuvier). It is found in the western Atlantic, from Maine to Brazil (Robins, 1958).

Some biological notes on the king mackerel are given in this paper, concerning its condition factor, age and growth in terms of fork length and weight.

MATERIAL AND METHODS

For condition factor study, the data analysed comprised 1,504 specimens of unknown sex, ranging from 36 to 120 cm in fork length, caught by trolling line in front of Fortaleza County, from January to December 1966. Fork lengths were taken in millimeters and later on grouped into classes of 1 cm interval, and the weights were taken in grams.

For age and growth studies, the data analysed comprised 328 specimens, being 103 males (ranging from 48 to 107 cm in fork length) and 225 females (ranging from 47 to 120 cm in fork length), caught by trolling line in front of Aquiraz County (Ceará — Brazil), from January to December 1966. Fork lengths were taken in millimeters, and then the otoliths (sagitae) from each specimen were extracted. They were washed with water and kept dry in envelopes. Due to lack of a balance, the weights were not taken. At the laboratory the otoliths were placed in a black dish containing xylol and the translucent rings on it were viewed under a binocular microscope by direct light.

Distances between otolith focus and the several translucent rings were taken in millimeters, as shown in figure 1.

CONDITION FACTOR

The well-known equation $K = \frac{W \cdot 10^3}{L^3}$

where W is the weight in grams; L is the fork length in centimeters, multiplyed by 10^3 to facilitate handling of data, was used.

Table I shows the mean values of K (condition factor) distributed by 1 cm fork length class interval, comprising the period from January to December 1966 (N = 1,504; fork lengths between 36 and 120 cm). Grand mean found was K = 8.07; minimum individual value was K = 4.35, and maximum was K = 11.31; minimum monthly mean was observed in July (K = 7.52) and maximum in September (K = 8.62). No data on variations of K according to sex and gonadal development are available. By looking at table I it can be seen that mean K per fork length classes tends to decrease as the size increases, fact already observed by Nomura (1967) for a fish of the same genus, the Spanish mackerel, *Scomberomorus maculatus* (Mitchill).

AGE AND GROWTH

Prior to the use of otoliths for age determination, modes of length frequency distribution of known data (Costa & Paiva, 1963, 1964, 1965, 1966) were decomposed by the Petersen method (1893). The modes found were not much evident, probably due to the

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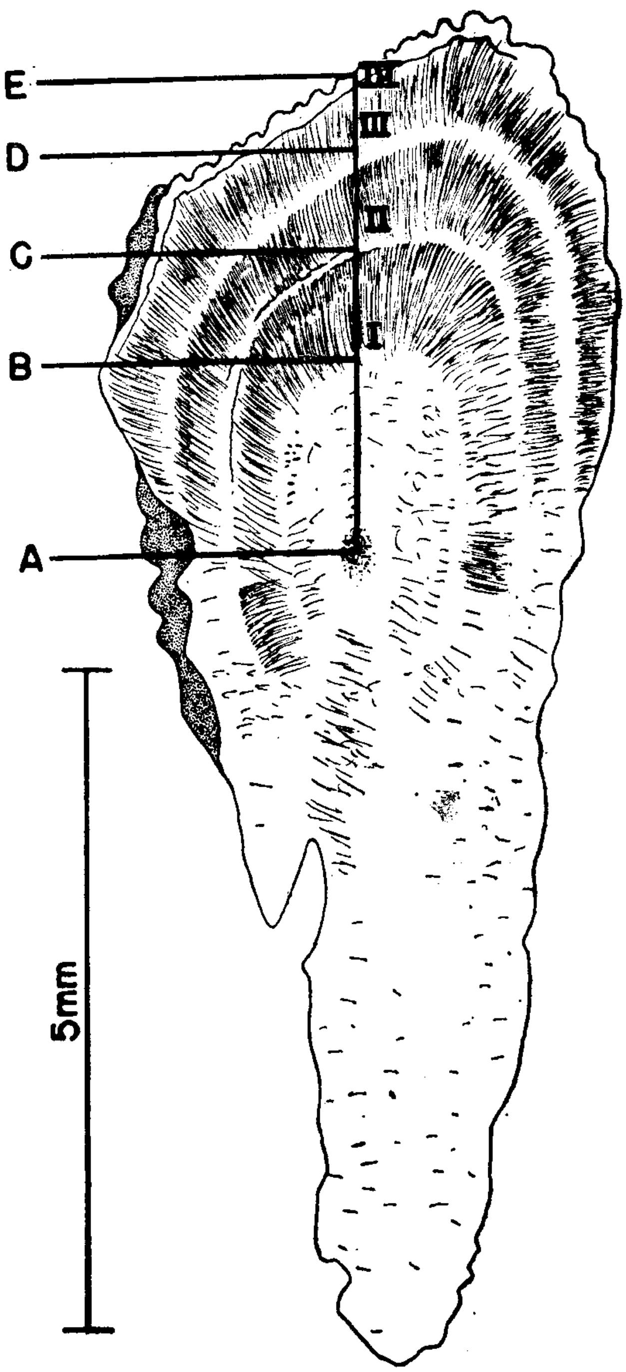

Figure 1 — Drawing of an otolith of king mackerel, *Scomberomorus cavalla* (Cuvier), belonging to a female with 630 mm fork length, showing four translucent rings and the radius A-E of the major axis used for measuring the distances between the focus and the I (B), II (C), III (D) and IV (E) rings.

method of fishing (trolling line), that causes selectivity in the catches. Also no data on young king mackerel are available, and so the Petersen method was abandoned.

The otoliths examined showed translucent rings around the focus, very similar to the ones seen by Nomura (1967) in Spanish mackerel otoliths.

In order to find out the periodicity of translucent rings formation observed on the otoliths, trimonthly females fork length data (just as an example) were plotted in figure 2. It can be seen that there is an abrupt change of one ring group to another between the first and the second trimester. Probably the rings are formed between April and June, and they may be considered as an annual formation.

With the purpose of finding out whether there is or not proportionality between fish and otolith growth, data on fork length and otolith size (measured as shown in figure 1), referring to 232 specimens (males and females grouped), were plotted in figure 3, which shows a linear relationship, expressed by the regression equation

$$Y = 1.35 + 0.0038\,X \quad (r = 0.81)$$

where X is the fork length and Y is the radius of the major otolith axis, both in millimeters. Due to that linearity, the size of a fish at the formation of each translucent ring can be determined through the back-calculation formula

$$L' = \frac{S' \cdot L}{S}$$

where L' is the fork length when a certain translucent ring was formed; S' is the length from the otolith focus to that certain translucent ring; S is the length from the otolith focus to its outer edge; and L is the fork length of the fish examined.

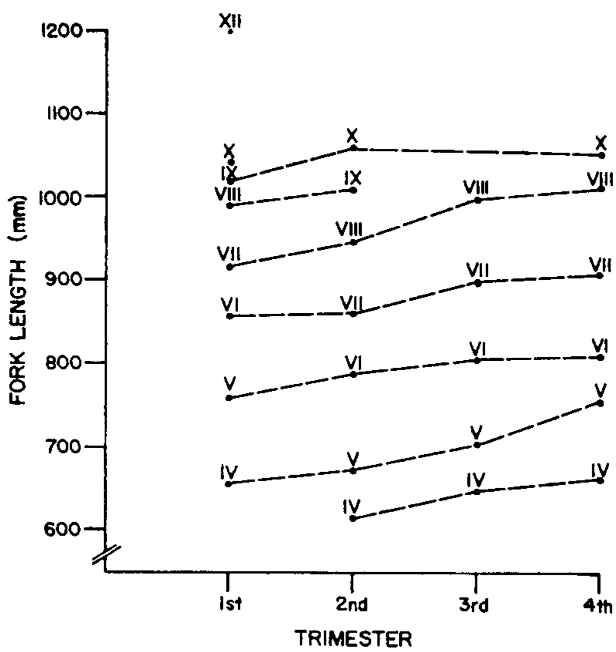

Figure 2 — Mean trimonthly fork length (mm) of the king mackerel, *Scomberomorus cavalla* (Cuvier), by age group.

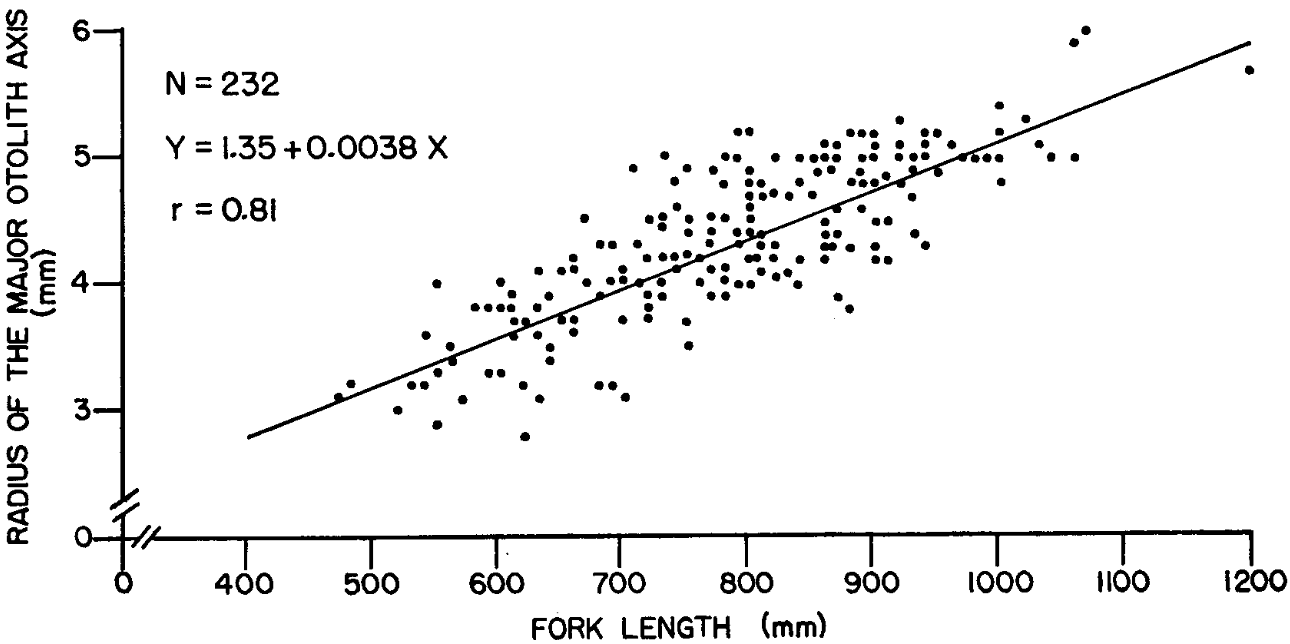

Figure 3 — Regression of the radius of the major axis (mm) of the otolith of the king mackerel, *Scomberomorus cavalla* (Cuvier), on its fork length (mm).

Translucent rings found in male otoliths, observed by direct method, varied in number from III to IX and, in females, from III to XII, with no data on the first two rings for both sexes, and XI ring for female. Back-calculation method was used to find out at which size the fish attains I and II rings, and also for III rings, because originally this age group was represented by few specimens. Results obtained by the two methods are shown in table II.

Growth curves relating size to age were fitted through the mathematical expression of von Bertalanffy, adjusted by Ford-Walford method (Beverton & Holt, 1957):

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

where L_t is the fork length (cm) relative to a certain age; L_∞ is the assymptotic fork length (cm) which L assumes when the age increases indefinitely; t is a certain age; t_0 is the initial age; K is the growth coefficient; and *e* is the base of Naeperian logarithms. Male age group IX is not well represented; so, only age from I to VIII were used; as to females, age group XI has no representation, and XII is poorly represented; so, only age from I to X were used, resulting in the following equations (figure 4):

$$\text{males: } L_t = 116.00 [1 - e^{-0.18(t + 0.22)}]$$

$$\text{females: } L_t = 137.00 [1 - e^{-0.15(t + 0.13)}]$$

$$\text{males and females: } L_t = 141.23 [1 - e^{-0.14(t + 0.14)}]$$

As no studies of this kind are known for the species, comparisions can not be made. However, comparing with the results obtained by Nomura (1967) with its relative, the Spanish mackerel, it can be seen that king mackerel grows faster than that species.

Growth in terms of fork length (cm) by age group is shown in table III.

No data on length and weight by sex are available, but only grouped. The same data used for calculating condition factor K were used for calculating the length-weight relationship by least squares of logarithms, resulting in the equation:

$$\log W = -2.048 + 2.960 \log L$$

where W is the weight in grams and L is the fork length in centimeters. A length-weight equation was obtained by Nomura & Costa (1966), using data from June to September 1965.

T A B L E I

Mean values of condition factor K for the king mackerel, *Scomberomorus cavalla* (Cuvier), from northeastern Brazil, of unknown sex, distributed into classes of 1 cm fork length interval, comprising the period from January to December 1966.

Fork length (cm)	January		February		March		April		May		June		July		August		September		October		November		December		Total	
	n	K	n	K	n	K	n	K	n	K	n	K	n	K	n	K	n	K	n	K	n	K	n	K	n	K
36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.50	1	7.29	...	...	...	...	...	...	2	7.39
40	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.34	...	...	...	...	...	...	...	...	1	7.34
41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.69	...	...	...	...	...	...	1	7.69
42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	7.52	...	...	...	...	...	...	4	7.52
45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.02	7	7.03	1	8.23	...	...	...	...	9	7.16
46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	7.47	...	...	...	...	...	...	6	7.47
47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.22	5	7.05	1	7.42	...	...	...	...	7	7.13
48	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	7.55	5	7.12	...	...	1	6.69	...	...	8	7.18
49	...	...	1	6.63	...	...	...	...	...	...	...	...	...	...	5	7.00	8	7.15	3	7.31	2	7.05	...	...	19	7.10
50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	6.68	7	7.10	3	7.26	1	7.20	1	7.68	17	7.05
51	...	...	1	7.54	...	...	...	...	...	...	...	...	...	...	...	...	7	7.14	...	...	5	7.01	...	...	13	7.12
52	...	...	...	...	1	7.11	1	7.54	1	11.31	...	...	...	...	2	6.54	7	7.07	4	7.15	6	7.77	3	7.40	25	7.44
53	4	7.25	2	6.95	...	...	1	8.33	...	...	...	...	...	...	2	7.42	5	7.23	2	7.22	9	7.19	3	7.43	28	7.27
54	1	7.49	...	...	...	...	3	7.94	...	...	...	...	2	6.32	2	7.02	3	7.02	1	7.18	14	7.24	3	7.13	29	7.21
55	2	7.69	...	...	...	...	1	7.99	1	7.81	...	...	1	7.63	3	7.21	4	6.76	1	7.51	5	7.09	4	7.29	22	7.98
56	2	7.57	1	7.06	1	7.17	5	7.39	...	...	...	...	2	7.17	3	7.29	1	7.00	...	...	12	7.17	2	7.40	29	7.25
57	...	...	...	...	3	7.76	1	8.37	2	7.15	...	...	3	7.29	5	7.03	2	7.05	...	...	3	7.50	6	7.35	25	7.35
58	1	6.87	1	6.41	2	7.05	5	8.13	1	7.02	...	...	2	6.76	2	6.66	8	6.40	1	7.33	6	7.35	7	7.55	36	7.15
59	1	7.79	1	7.64	8	7.33	...	...	2	7.96	...	...	3	7.11	5	7.26	1	7.21	2	7.33	7	7.50	3	7.06	33	7.37
60	1	7.50	1	7.87	5	7.52	9	7.63	2	7.66	...	...	5	7.92	2	6.92	1	6.48	4	6.73	12	7.19	2	7.31	44	7.38
61	1	6.87	...	...	3	7.24	5	7.66	2	7.73	...	...	7	6.98	3	6.99	3	7.24	1	6.48	3	8.80	2	7.31	30	7.25
62	...	...	1	7.13	4	7.57	1	7.64	3	7.76	...	...	7	7.57	4	7.31	...	...	5	7.78	2	6.99	...	...	27	7.53
63	1	8.12	1	6.87	5	7.34	8	7.97	6	7.68	...	...	12	7.32	4	6.91	1	6.92	...	...	7	7.17	3	7.23	48	7.38
64	...	...	...	...	2	7.48	4	8.36	2	7.30	...	...	5	7.59	7	7.06	3	7.20	1	6.94	6	7.43	...	...	30	7.45
65	1	6.88	1	7.06	2	7.25	3	8.09	7	7.57	...	...	8	7.22	8	7.29	1	7.65	6	7.18	6	7.47	5	7.52	48	7.40
66	1	7.41	1	7.37	1	7.76	4	7.15	1	7.48	1	7.20	4	4.35	7	7.05	5	7.11	4	7.51	3	7.48	1	7.72	33	7.19
67	1	7.85	1	8.05	2	7.46	...	...	3	7.09	...	...	6	7.25	15	7.08	3	7.50	2	7.23	3	7.54	1	6.98	37	7.25
68	1	7.31	1	7.57	1	7.31	1	6.70	...	...	...	...	6	7.14	14	7.10	13	6.89	3	7.46	5	7.43	3	7.30	48	7.14
69	...	...	...	...	1	7.37	2	7.61	3	7.38	...	...	1	7.46	19	7.21	6	7.31	6	7.58	8	7.77	6	7.12	52	7 36
70	1	8.07	...	...	...	...	...	...	3	7.31	...	...	3	7.48	12	7.11	5	6.98	4	7.21	8	7.44	2	7.94	38	7.29
71	5	7.51	...	...	6	7.34	...	...	...	...	...	...	2	6.94	11	7.23	8	7.02	9	7.41	7	7.43	10	7.50	58	7.33
72	3	7.10	1	7.45	1	6.56	2	7.56	3	7.72	...	...	...	...	8	7.27	4	7.14	11	7.34	8	7.62	6	7.50	47	7.39
73	1	6.89	2	7.72	3	7.77	2	7.62	...	...	...	...	...	...	12	7.04	5	7.12	4	6.86	11	7.20	11	7.01	51	7.15
74	1	7.28	3	7.04	2	7.39	3	6.93	...	...	...	...	1	7.40	9	7.29	7	7.16	5	7.38	9	7.64	10	7.22	50	7.30
75	6	7.38	2	7.89	1	6.66	1	8.77	...	...	...	...	1	6.87	6	7.31	9	7.09	6	7.26	9	7.27	6	7.36	47	7.30
76	3	7.56	1	8.15	2	7.11	1	7.43	...	...	...	...	...	...	5	7.63	2	6.90	9	7.42	8	7.50	2	6.74	33	7.41
77	3	7.39	5	7.48	8	7.11	1	8.39	4	5.68	1	7.21	1	7.67	5	6.99	3	7.08	3	7.05	6	7.41	12	7.40	52	7.17
78	3	7.30	6	7.48	6	6.53	5	7.34	1	7.16	...	...	1	8.18	4	7.03	2	7.26	4	7.33	7	7.29	4	7.12	43	7 22
79	2	7.15	3	7.19	2	7.66	1	9.90	...	...	...	...	2	6.15	9	7.07	3	7.02	2	7.57	5	7.36	3	7.62	32	7.28
80	1	7.42	3	7.47	2	6.84	1	7.34	1	7.54	...	...	1	8.20	4	7.77	6	7.58	2	7.10	6	7.45	3	7.07	30	7.44
81	...	...	2	7.34	2	7.39	3	7.01	1	7.39	...	...	...	...	1	7.34	2	6.58	3	7.44	4	7.13	5	7.49	23	7.25
82	2	7.44	2	7.90	3	7.08	1	7.31	...	...	...	...	...	...	5	7.79	3	7.72	3	7.83	3	7.36	2	7.52	24	7.58
83	5	7.19	1	7.22	3	7.22	1	7.34	...	...	...	...	1	7.69	4	7.23	2	7.39	1	8.11	2	7.33	3	8.67	23	7.49
84	1	7.29	...	...	3	7.49	2	6.95	1	7.17	...	...	...	...	6	7.53	1	7.24	...	...	3	7.27	4	6.64	21	7.22
85	3	6.89	1	7.20	2	6.82	...	...	2	7.02	...	...	...	...	5	7.76	3	7.15	1	7.59	3	8.02	4	7.20	24	7.34
86	2	7.46	3	7.38	2	6.78	...	...	...	...	...	...	1	8.06	2	6.99	2	7.47	3	7.20	1	7.04	2	7.24	18	7.26

87	1	7.77	1	7.99	1	6.83	1	7.23	...	...	1	7.59	...	...	7	7.54	3	8.76	1	7.38	5	7.59	1	8.56	22	7.51
88	3	8.03	3	7.59	...	...	...	...	1	8.00	...	...	...	...	4	7.56	...	...	2	6.95	2	7.37	1	6.72	16	7.53
89	...	...	1	6.99	3	7.17	...	...	...	...	...	...	1	7.19	5	7.45	1	7.43	2	8.23	...	...	4	7.85	17	7.54
90	1	8.41	1	7.20	1	6.72	2	7.66	...	...	...	...	...	...	3	7.70	1	8.23	...	...	3	7.27	2	7.02	14	7.49
91	1	6.74	...	...	4	7.31	2	7.30	...	...	...	...	...	...	1	5.65	3	7.65	1	8.16	1	6.32	1	7.16	14	7.20
92	...	...	...	...	1	6.42	1	7.99	1	6.82	...	...	...	...	2	7.58	2	7.78	4	7.46	3	8.31	2	7.21	16	7.57
93	...	...	1	6.66	2	6.94	...	...	...	...	...	...	...	...	2	6.51	1	7.79	...	...	...	...	1	7.35	7	6.96
94	2	7.24	1	8.22	...	...	1	7.13	...	...	...	...	...	...	5	7.24	1	7.01	...	...	1	6.71	1	7.93	12	7.30
95	1	8.06	...	...	2	6.76	...	...	2	7.26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	7.26
96	...	...	2	7.19	...	...	...	...	...	...	...	...	...	...	3	6.78	...	...	...	...	2	7.95	...	...	7	7.23
97	1	5.94	2	7.52	1	7.22	...	...	...	...	...	...	...	...	1	6.97	1	7.41	...	...	...	...	...	...	6	7.09
98	...	...	...	...	1	6.82	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.88	2	7.35
99	...	...	1	6.32	...	...	...	...	...	...	...	...	...	...	1	6.44	...	...	3	7.40	...	...	...	...	5	6.99
101	...	...	...	...	1	6.11	...	...	...	...	...	...	...	...	...	...	...	...	1	6.24	...	...	...	...	2	6.18
102	...	...	...	...	...	...	...	...	1	6.52	...	...	...	...	...	...	...	...	...	...	3	7.55	...	...	4	7.29
103	...	...	...	...	...	...	1	7.14	1	8.78	...	...	...	...	1	6.59	...	...	...	...	1	6.89	...	...	4	7.35
104	1	7.04	1	6.76	...	...	2	6.74	...	...	...	...	...	...	1	8.00	...	...	...	...	1	7.16	...	...	6	7.07
105	...	...	...	...	...	...	1	7.86	...	...	...	...	...	...	...	...	...	...	1	6.61	1	7.40	...	...	3	7.29
106	...	...	...	...	...	...	1	6.83	1	6.61	...	...	...	...	...	...	...	...	...	...	1	6.90	...	...	3	6.78
108	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.54	1	7.54
110	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.22	...	...	...	...	...	...	...	...	1	7.22
111	...	...	...	...	...	...	...	...	1	7.42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.42
112	...	...	...	...	...	...	1	6.32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	6.32
113	...	...	1	4.81	1	6.62	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	6.62	3	6.02
115	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	6.72	...	...	...	...	...	...	...	...	2	6.72
116	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	6.38	...	...	...	...	...	...	1	6.38
118	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.46	...	...	1	7.46
119	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	5.96	...	...	...	...	...	...	...	...	1	5.96
120	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	7.57	1	7.19	...	...	...	...	...	...	2	7.38
Total (n)	71	—	64	—	107	—	91	—	60	—	3	—	89	—	272	—	200	—	136	—	251	—	160	—	1,504	—
Grand K	—	7.59	—	7.86	—	7.72	—	8.41	—	8.12	—	7.66	—	7.52	—	7.94	—	8.62	—	7.96	—	8.21	—	7.92	—	8.07

TABLE II

Mean fork lengths (cm) obtained for the king mackerel, *Scomberomorus cavalla* (Cuvier), from northeastern Brazil, by age group, sexes separated and grouped. The number of fishes examined is in brackets.

Age (years)	Males	Females	Both sexes
I	21.8 * (85)	21.6 * (147)	21.7 * (232)
II	38.9 * (82)	38.3 * (147)	38.6 * (229)
III	52.2 * (81)	52.3 * (147)	52.2 * (228)
IV	59.8 (14)	63.9 (26)	62.5 (40)
V	71.0 (19)	72.9 (52)	71.7 (71)
VI	77.7 (29)	81.1 (55)	79.9 (84)
VII	84.6 (21)	88.8 (50)	87.5 (71)
VIII	90.8 (15)	97.1 (12)	93.6 (27)
IX	102.4 (2)	101.6 (8)	101.8 (10)
X	—	107.7 (4)	107.7 (4)
XI	—	...	...
XII	—	120.0 (1)	120.0 (1)

* Back-calculated.

TABLE III

Growth of the king mackerel, *Scomberomorus cavalla* (Cuvier), from northeastern Brazil, in terms of fork length (cm) by age group, sexes separated and grouped.

Age (years)	Males	Females	Both sexes
I	21.8	21.6	21.7
II	17.1	16.7	16.9
III	13.3	14.0	13.6
IV	7.6	11.6	10.3
V	11.2 (?)	9.0	9.2
VI	6.7	8.2	8.2
VII	6.9	7.7	7.6
VIII	6.2	8.3	6.1
IX	11.6 (?)	4.5	8.2 (?)
X	...	6.1	5.9
XI	...	...	...
XII	...	...	...

TABLE IV

Calculated weights (g) by fork length and by age group, using length-weight relationships and condition factor (K) by fork length class and grand K, together with the observed mean weight (g) of king mackerel, *Scomberomorus cavalla* (Cuvier), from northeastern Brazil.

Age (years)	Fork length (cm)	Calculated weights (g)				Mean observed weight (g)
		Length-weight relationship		Condition factor		
		Nomura & Costa (1)	Nomura & Rodrigues (2)	K by class	Grand K	
I	21.7	73.8	80.7	...	82.4	...
II	38.6	430.6	443.7	...	464.1	...
III	52.2	1,055.0	1,089.0	1,058.2	1,147.8	1,046.0
IV	62.5	1,816.0	1,854.0	1,838.4	1,970.2	1,795.0
V	71.7	2,736.0	2,774.0	2,724.0	2,974.6	2,757.0
VI	79.9	3,794.0	3,820.0	3,795.0	4,116.4	3,811.0
VII	87.5	5,012.0	5,012.0	5,031.1	5,406.2	4,946.0
VIII	93.6	6,124.0	6,252.0	5,986.2	6,617.6	6,068.0
IX	101.8	7,925.0	7,871.0	7,690.8	8,513.9	7,738.0
X	107.7	9,376.0	9,269.0	9,419.4	10,081.4	9,500.0
XI	...	...	...	...	...	...
XII	120.0	13,010.0	12,770.0	12,752.6	13,945.0	12,755.0

(1) $\log W = -2.169 + 3.022 \log L$ $(r = 1.00)$
(2) $\log W = -2.048 + 2.960 \log L$ $(r = 1.00)$

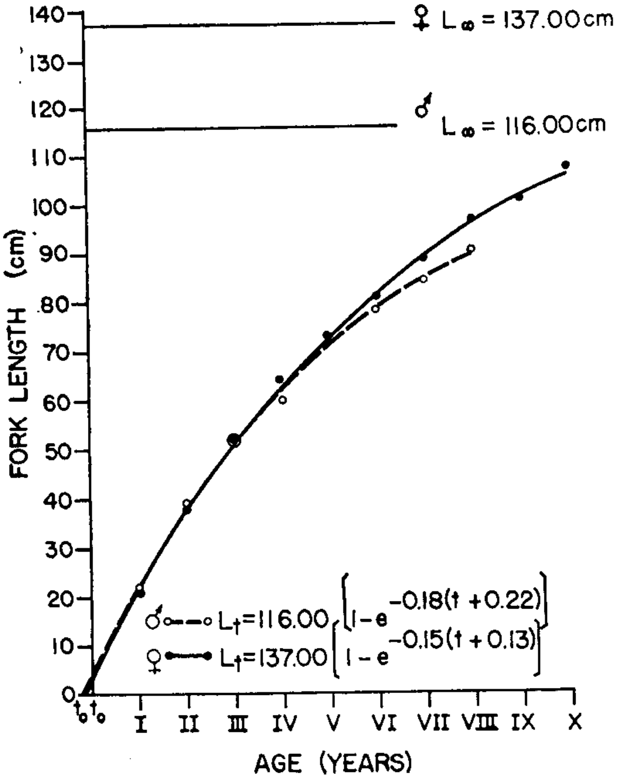

Figure 4 — Growth curves for male and female king mackerel, *Scomberomorus cavalla* (Cuvier), from northeastern Brazil.

Using both length-weight equations, the condition factor K obtained by fork length class and grand K, mean weights by age group were calculated, as shown in table IV, together with the mean observed weight (g). As expected, the mean calculated weights based on the condition factor K obtained by fork length class are closer to the mean observed weights, the same occuring with both length-weight equations. However, with the grand K there is a significant difference, because the values of K obtained by fork length classes are very variable, influencing the grand mean.

CONCLUSÕES

Dos dados analisados podem ser extraídas as seguintes conclusões:

1 — As médias de K (fator de condição) por classe de comprimento zoológico tendem a diminuir à medida que o tamanho aumenta, fato também observado para a serra, espécie pertencente ao mesmo gênero da cavala.

2 — Os anéis translúcidos existentes nos otolitos formam-se anualmente, provàvelmente entre abril e junho.

3 — Há relação linear entre o crescimento dos peixes e o dos otolitos, podendo-se assim determinar o comprimento de um peixe quando da formação de cada anel, utilizando-se a fórmula do retro-cálculo.

4 — As curvas de crescimento foram matemàticamente determinadas, resultando nas equações:

$$\text{machos: } L_t = 116{,}00\ [1 - e^{-0{,}18\ (t + 0{,}22)}]$$

$$\text{fêmeas: } L_t = 137{,}00\ [1 - e^{-0{,}15\ (t + 0{,}13)}]$$

$$\text{machos e fêmeas: } L_t = 141{,}23\ [1 - e^{-0{,}14\ (t + 0{,}14)}]$$

5 — A relação pêso-comprimento obtida foi a seguinte:

$$\log W = -\ 2{,}048 + 2{,}960 \log L$$

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