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Growth Characteristics of the Chub Mackerel (*Scomber japonicus* Houttuyn, 1782) in Izmir Bay (Aegean Sea, Turkiye)

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Abstract: Age and growth of chub mackerel, *Scomber japonicus,* were studied in the Izmir Bay (Aegean Sea). A total of 520 specimens were collected during the period November 1997 to October 1998 from purse-seine boats operating in the Izmir Bay. Fork lengths ranged between 12.5 and 27.2 cm. Overall female: Male ratio was 1:1.13. Age distribution of the samples ranged from I to IV years (otolith readings). Chub mackerel grew positive allometrically (b = 3.40±0.05 at 95% confidence level). Growth parameters of the population were: L_∞ = 27.15 cm, K = 0.20 $year^{-1}$, t_0 = -0.48 years for females; L_8 = 29.64 cm, K = 0.23 $year^{-1}$, t_0 = -0.39 years for males and L_8 = 29.87 cm, K = 0.20 $year^{-1}$, t_0 = -0.36 years for both sexes. Growth index (Φ') was calculated as 2.29, 2.31 and 2.25, respectively for females, males and sexes combined.

Key words: *Scomber japonicus*, age, growth, Aegean Sea, Izmir Bay

INTRODUCTION

Chub mackerel (*Scomber japonicus* Houttuyn, 1782) is a cosmopolitan middle-sized pelagic species with a very wide distribution over the continental shelf of the tropical and subtropical regions of the Atlantic, Indian and Pacific Oceans as well as the adjacent seas. It is a primarily coastal species, found from the surface down to 300 m depth (Collette and Nauen, 1983). *Scomber japonicus* is of worldwide commercial importance, being one of the target species in purse seine fisheries. A major proportion of the *S. japonicus* catch in the Mediterranean and Black Seas is taken by the Turkish fishery (Sever *et al*., 2006).

Because of the worldwide importance of the chub mackerel fishery, several studies have been made that were mainly related to its biology (Kramer, 1969; Angelescu, 1979; Schaefer, 1980; Rodrigues-Roda, 1982; Collette and Nauen, 1983; Moreno and Castro, 1995; Hernández and Ortega, 2000; Kiparissis *et al*., 2000; Cabral *et al*., 2002) age and growth (Fitch, 1951; Knaggs and Parrish, 1973; Baird, 1977; Baird, 1978; Aguayo and Steffens, 1986; Ostapenko, 1986; Perrotta, 1992; Perrotta, 1993; Lorenzo *et al*., 1995; Lorenzo and Pajuelo, 1996; Gluyas-Millán and Quiñonez-Velázquez, 1997) and length-weight relationships (Rafail, 1972; Gasim *et al*., 1992; Petrakis and Stergiou, 1995; Gonçalves *et al*., 1997; Cucalón-Zenck, 1999; Stergiou and Moutopoulos, 2001; Moutopoulos and Stergiou, 2002; Santos *et al*., 2002; Stergiou *et al*., 2004).

However, similar to other pelagic species in Turkish seas, scarce information is available on chub mackerel from the regional water. Concerning the Turkish coasts only, Tuggac (1956) and Atli (1959) studied the biology of *S. japonicus* inhabiting the Sea of Marmara. In addition, Sever *et al.* (2006) studied the diet composition of juvenile chub mackerel in the Izmir Bay (Aegean Sea).

The aim of the present study was therefore to determine sex composition, age structure, length-weight relationship, and growth characteristics of chub mackerel occuring within the Izmir Bay (Aegean Sea) fishery so that data are available for comparison with other studies from nearby or distant areas.

MATERIALS AND METHODS

A total of 520 *S. japonicus* specimens were sampled monthly during the period November 1997 to October 1998 from commercial purse seine boats operating in Izmir Bay. Izmir Bay is situated at the western coast of the Anatolian peninsula, and is connected to the Aegean Sea. The bay is roughly L shaped. The leg of the L is about 20 km wide and 40 km long and the base of the L is about 5-7 km wide and 24 km long (Fig. 1). Izmir Bay has been divided into three areas according to their physical characteristics. These areas are the Outer, Middle and Inner Bay. The Outer Bay is about 70 m deep. Depth decreases significantly towards the Inner Bay to about 10 m depth (Sayın, 2003). All the fisheries activeties are prohibited in the Inner Bay which is heavily polluted by domestic and industrial waste.

Sixty purse seine vessels are present in the harbours of Aegean Region and 53 of them operating in the Izmir Bay. While the leading fish species caught by these vessels are pilchard, chub mackerel and anchovy; other

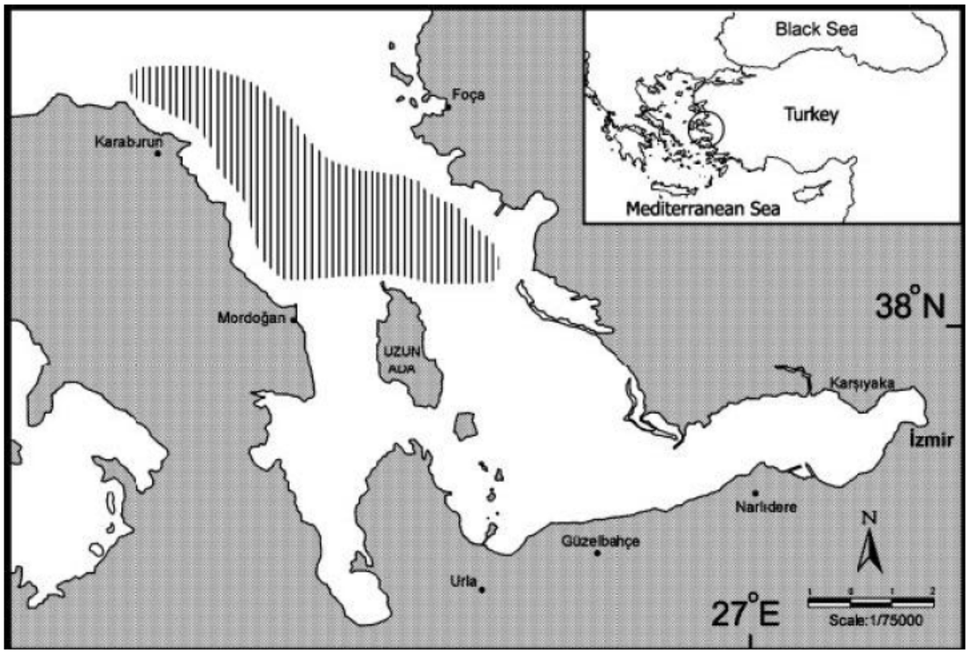

Fig. 1: Map of fish sampling area (Shaded area shows the chub mackerel fishery grounds in Izmir Bay, Aegean Sea)

species such as bogue, mackerel, grey mullet and horse mackerel are also important. The vessels are of three types and can be classified by the type of nets used: Pilchard-anchovy purse seine nets, grey mullet purse seine nets, and tuna purse seine nets. Fourty one out of the 53 vessels mentioned above execute pilchard-anchovy fishing. The length and the height of the nets used in the pilchard-anchovy fishing in the region ranges between 255-550 and 50-140 m, respectively. The size of the vessels varies between 17-22 m with motor capacities of 240-400 HP. The mesh size of the main part of this type of purse seine nets is 13-14 mm (Hossucu *et al.*, 1994).

Data aquisition: Fork Length (FL) of the fish was measured to the closest 1 mm. Total body Weight (W) was determined to the closest 0.01 g. Sex was macroscopically identified in the samples. Sex ratios were compared to the 1:1 proportion by using the chi-square (χ^2) test (Zar, 1999).

Length-weight relationship was described using the logarithmic form of the formula: $W = a \times FL^b$ (Ricker, 1979); and was calculated for each sex separately. Length-weight regressions were tested for differences in slopes and intercepts between sexes using analysis of covariance (Zar, 1999).

The Condition Factor (CF) was estimated for all specimens used in the present study, according to the equations: $CF = W \times 100/L^3$ (Bagenal, 1978).

The age of fishes was assigned by otolith reading. Estimates of theoretical growth in length were obtained by fitting the von Bertallanffy growth function to the mean length at age data. Growth model was determined by $Lt = L_\infty [1-\exp^{-K(t-t0)}]$ (Sparre and Venema, 1992). Overall growth performance of a species can be interpreted by the growth index $\Phi' = \log(K) + 2\log(L_\infty)$, which can also be used for comparing growth rates among species (Munro and Pauly, 1983).

RESULTS

Sex composition and age: The relative sex composition for the 520 chub mackerel specimens sampled was 46.92% females and 53.08% males. Overall sex ratio between females and males was 1: 1.13. No significant differences between sexes ($\chi^2 = 8.196$, $p = 0.316$) were observed. By determining the fish age, it was observed that 31.3% of the females samples belonged to age group I and 29.4% of males sampled belonged to age group III (Table 1).

The age distribution of individuals belonging to the chub mackerel samples was I to IV. Maximum FL observed was 27.20 cm, but this single specimen was not included for growth parameter estimation. Maximum FL observed were 25.20, 26.40 cm for, females and males, respectively, corresponding to a 4 year-old fish. Between the mean fork lengths that were estimated for females and males, only the age group III presented a statistically significant difference (t-test 2.53, $p<0.05$) (Table 2).

Table 1: Age-sex composition of *Scomber japonicus* (n = number of fishes) in Izmir Bay

Age	Female (n)	Male (n)	Total (n)	(%)	Female:Male
I	76	72	148	28.46	1 : 0.95
II	55	61	116	22.31	1 : 1.11
III	82	86	168	32.31	1 : 1.05
IV	31	57	88	16.92	1 : 1.84
Total	244	276	520	100.00	1 : 1.13

Table 2: Length-age key for females and males of chub mackerel in Izmir Bay (FL = Fork Length, n = Number of fishes, SD = Standard Deviation)

	Age-classes							
	Females				Males			
FL (cm)	I	II	III	IV	I	II	III	IV
12.0-12.9	1				2			
13.0-13.9	8				5			
14.0-14.9	11				10			
15.0-15.9	13				16	3		
16.0-16.9	11	3			6	5		
17.0-17.9	22	11	1		27	7	2	
18.0-18.9	6	13	5		6	20	11	
19.0-19.9	3	18	11	9		9	13	5
20.0-20.9	1	6	13	4		10	22	10
21.0-21.9		3	18	8		4	14	9
22.0-22.9		1	6	10		3	13	7
23.0-23.9			3	15			5	13
24.0-24.9			1	4			1	12
25.0-25.9				4				3
26.0-26.9								3
27.0-27.9								
Mean FL	16.12	18.74	20.47*	22.13	16.32	19.00	21.38*	23.00
SD	4.95	4.10	6.44	5.59	4.24	5.02	4.54	4.81
n	76	55	58	54	72	61	81	62
%	31.28	22.63	23.87	22.22	26.09	22.10	29.35	22.46

*(t test, $t < t_{0.05} = 2.53$)

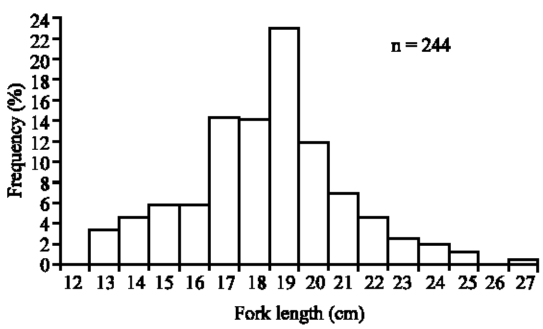

Fig. 2: Length distributions of females chub mackerel caught in Izmir Bay

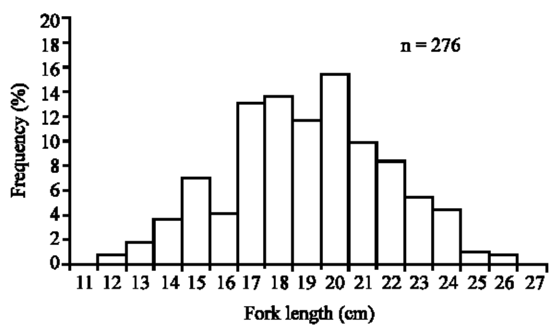

Fig. 3: Length distributions of males chub mackerel caught in Izmir Bay

Length frequency: Fork length of all specimens ranged from 12.50 to 27.20 cm; specimens between 17.00 and 20.00 cm were abundant for both sexes. Minimum and maximum fork length values of females and males fish were 13.00 and 27.20 cm, 12.50 and 26.40 cm, respectively (Fig. 2 and 3).

Length-weight relationship: Relationships between fork length and weight for females (Fig. 4), males (Fig. 5) and all individuals combined (Fig. 6) are described by the equations: $W = 0.003\ L^{3.415}$ ($r^2 = 0.974$; b = 3.415±0.072, 95% CI; n = 244), $W = 0.003\ L^{3.399}$ ($r^2 = 0.968$; b = 3.399±0.076, 95% CI, n = 276) and $W = 0.003\ L^{3.403}$ ($r^2 = 0.985$; b = 3.403±0.052, 95% CI; n = 520). The estimated length-weight relationship for the entire sample yielded a significant correlation coefficient (r).

Age-length relationship: The von Bertalanffy growth parameters were estimated as: L_∞ = 27.15 cm, K= 0.26 $year^{-1}$, t_0 = -0.48 years for females L_8 = 29.64 cm, K = 0.23 $year^{-1}$, t_0 = -0.39 years for males and L_8 = 29.87 cm, K = 0.20 $year^{-1}$, t_0 = -0.36 years for sexes combined.

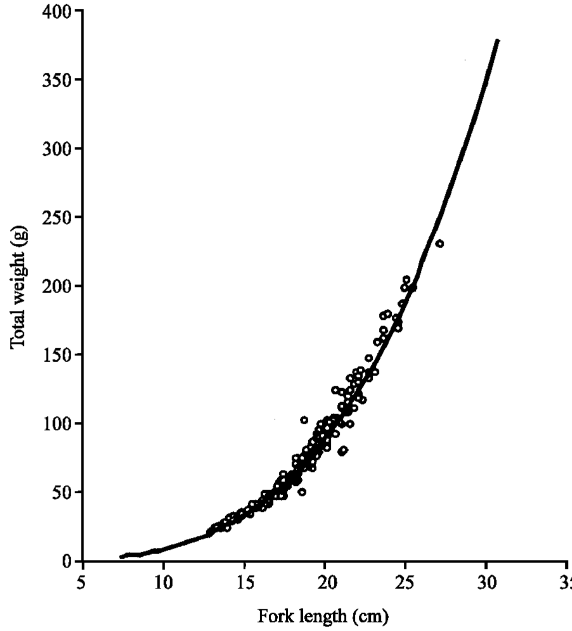

Fig. 4: Relationship between fork length and total weight of female chub mackerel (n = 244) from Izmir Bay

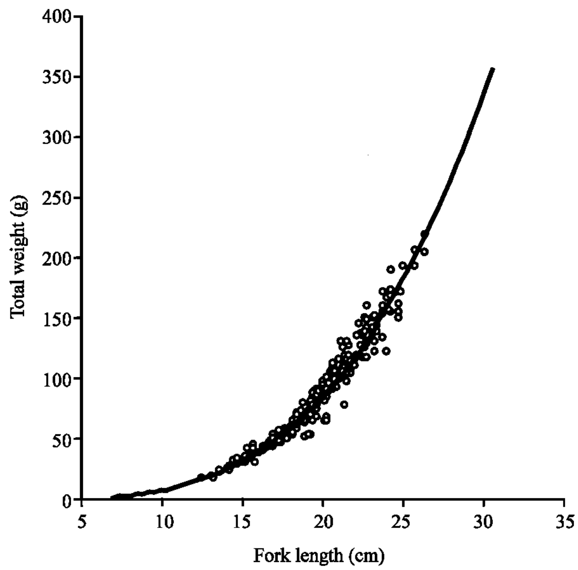

Fig. 5: Relationship between fork length and total weight of male chub mackerel (n = 276) from Izmir Bay

Considering the L_8 and K values, Φ' (growth index) was calculated as: 2.29, 2.31 and, 2.25 for females, males and the combined sexes, respectively.

Condition factor: The condition factors were estimated monthly for females and males over the entire observation period. Minimum and maximum values were calculated as: 0.85 (June) and 1.20 (January) for females, and 0.76 (June)

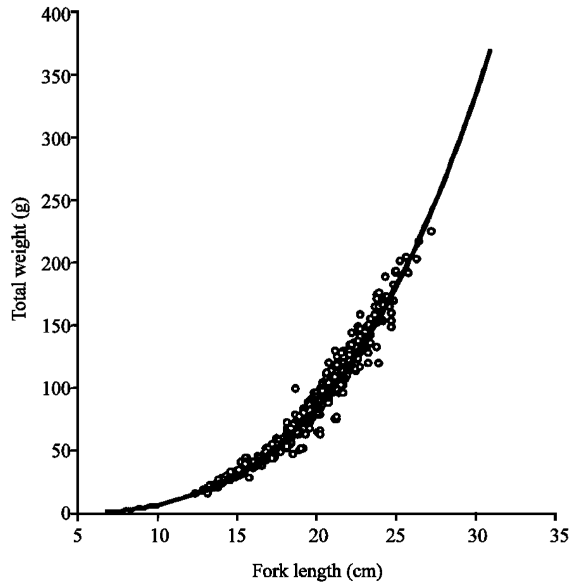

Fig. 6: Relationship between fork length and total weight of all chub mackerel (n = 520) from Izmir Bay

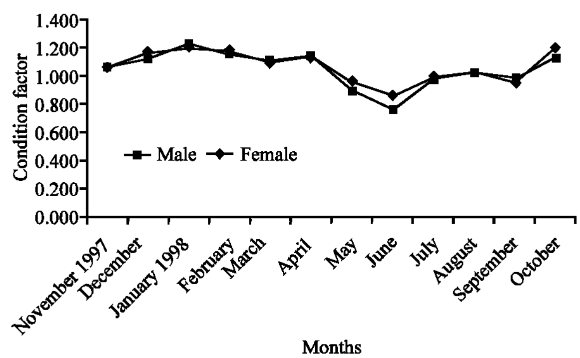

Fig. 7: Monthly condition factor distribution of females and males chub mackerel from Izmir Bay

and 1.22 (January) for males, respectively. Variation of the condition factor showed an increase in growth rates during autumn months and a decrease during early summer months (Fig. 7).

DISCUSSION

The number of chub mackerel specimens obtained in this study is relatively few, despite the species is known to be rather common in the Aegean Sea. The three major reason for a limited monthly sample size in this study performed in the Izmir Bay can be listed as follows: a large part of the Izmir Bay was banned for commercial fishing activities during the study period and only a restricted *S. japonicus* fishery grounds at the outer bay exist (Fig. 1)

Table 3: Females:Males ratio of *Scomber japonicus* by geographic areas

Area	n	Females:Males	Author(s)
Turkiye (Marmara Sea)	1475	1:1.08	Tuggac, 1956
Turkiye (Marmara Sea)	2687	1:0.94	Atlı, 1959
California (Northeast Pacific)	-	1:1.00	Kramer, 1969
South Africa	6718	1:0.88	Baird, 1978
Argentina	767	1:0.66	Angelescu, 1979
Canary Islands	749	1:1.08	Lorenzo and Pajuelo, 1993
Gulf of California	2554	1:1.03	Gluyas-Millán and Quiñonez-Velázquez, 1997
Hellenic Seas (Northern Aegean)	840	1:1.10	Kiparissis *et al.*, 2000
Turkiye (Aegean Sea)	520	1:1.13	This study

Table 4: Length-weight parameters estimates of *Scomber japonicus* by geographic areas

Length range (cm)	Length type	a	b	Area	Author(s)
-	FL	0.002	3.40	USA (California)	Knaggs and Parrish, 1973
17.50-44.20	TL	0.028	2.81	Arjentina	Perrotta, 1992
-	TL	-	3.20	Libya	Gasim *et al.*, 1992
18.70-29.60	FL	0.012	2.97	Greece	Petrakis and Stergiou, 1995
15.80-39.50	TL	0.004	3.23	Portugal	Gonçalves *et al.*, 1997
14.50-31.20	SL	$1.17*10^{-6}$	3.48	Gulf of California	Gluyas-Millán and Quiñonez-Velázquez, 1997
12.50-37.40	FL	0.005	3.35	Ecuador	Cucalón-Zenck, 1999
9.10-31.00	TL	$9.65*10^{-7}$	3.50	Hellenic Seas	Kiparissis *et al.*, 2000
18.70-29.60	FL	0.012	2.97	Greece	Stergiou and Moutopoulos, 2001
22.90-33.00	TL	0.001	3.70	Greece	Moutopoulos and Stergiou, 2002
21.30-33.80	TL	-	-	Naxos Island (Greece)	Stergiou *et al.*, 2004
12.50-27.20	FL	0.003	3.41	Izmir Bay	This study

chub mackerel is not caught commonly in Izmir Bay, when compared to the Black Sea and Sea of Marmara and the most important pelagic species of Izmir Bay is pilchard (*Sardina pilchardus*) and a special chub mackerel-directed fishing is not conducted, chub mackerel is hunted by purse seine vessels and their monthly efforts are extremely variable. Especially during the study period and particularly out of the fishing seasons, it was a real challenge for us to obtain sufficient number of specimens, however, as our data show, the results are consistent and reliable.

In this study the sex ratio was calculated as 1:1.13 (Female: Male). When the ratios from other areas are considered, it can be seen that the females and males of this species are approximately presented in equal amounts in the various populations (Table 3).

Fork length of specimens in this study ranged from 12.50 to 27.20 cm. However, when compared in detail with worldwide data for this species (excluding the coasts of Turkiye) results are quite variable as can be seen in Table 4. From these comparisons one may realize that chub mackerel reaches its maximum length particularly along the Southwest Atlantic coasts (Argentina) where rich upwelling regions are present along the coasts, providing optimum feeding regimes.

As a consequence of otolith readings in female and male specimens, a maximum of 4 years was determined in the age structure of the cohorts in this study. Mean lengths of age groups obtained here are compared to findings by other authors and are presented in Table 5. As seen in Table 5, there exist significant differences between the age groups of our study and those of other author (s) in various regions of the world. For example: a maximum age of 8 years was found in South Africa, Argentina, California, Japan, Equator and Chile. The major factors responsible for the differences of the result are considered to be related to the ecosystem functions in the zones (in which) these fishes were caught as these are generally upwelling zones with cold nutrient rich water masses allowing a high productivity with rich plankton populations.

If we compare our findings of chub mackerel on its growth parameters with other results found in various publications reporting data from different regions of the world, the highest L_∞ values were encountered along the coast of South Africa (L_∞ = 68.01) (Opstapenko, 1986). In spite of these result, the lowest L_∞ values were found in Egypt (L_∞= 27.90) (Rafail, 1972). Our result regarding the K value representing the annual growth rate show some differences when compared to results of other authors. For example, annual growth rate in this study was K = 0.20 whereas it was K = 0.49 in the Egyptian study (Rafail, 1972). However, similar findings of growth rates like those of our study were obtained in other regions such as Argentina (K = 0.26) (Perrotta, 1992) (Table 6). However, some of the data should be taken caution because of different sample size, sampling season and study methodology which all may have contributed to the variability.

Values for the condition factor ranged from 0.85 to 1.20 for females and from 0.76 to 1.28 for males. Our values are quite similar to those given for the Northeast Pacific

Table 5: Age-length relationships of *Scomber japonicus* by geographic areas (age determined from otolith)

Age groups									
I	II	III	IV	V	VI	VII	VIII	Area	Author(s)
26.80	30.40	33.00	35.30	37.00	38.10	39.30	39.80	California	Fitch, 1951
14.80	18.10	20.50	22.20	22.60	26.30	32.60	-	Turkiye (Marmara Sea)	Tuggac, 1956
14.40	21.09	26.54	30.81	33.43	35.83	38.09	39.76	Japan	Yonemori and Aikawa, 1956*
14.90	18.90	21.20	23.30	25.10	25.80	27.50	-	Turkiye (Marmara Sea)	Atli, 1959
20.40	25.00	29.75	34.00	-	-	-	-	Senegal	Viskrebenzev, 1963*
15.10	23.60	29.00	32.50	34.80	36.30	37.30	-	Northwest Africa	Domanevsky, 1970*
23.16	31.48	38.26	43.73	48.98	52.05	56.63	59.27	South Africa	Baird, 1977
27.30	30.83	33.61	35.78	37.48	38.81	39.85	40.67	USA (California)	Knaggs and Parrish, 1973
26.80	31.19	33.86	36.06	38.00	39.74	41.27	42.63	Argentina	Angelescu, 1979
-	-	42.34	44.16	45.91	49.00	50.00	-	Namibia	Morales and Sánchez, 1980*
22.40	26.42	-	-	-	-	-	-	Spain	Rodriguez-Roda, 1982
14.15	23.00	28.89	32.81	35.41	37.14	38.29	-	Peru	Mendo, 1984*
21.50	27.53	31.67	34.78	37.52	39.64	42.75	-	Portugal	Martins and Serrano-Gordo, 1984*
18.00	25.70	29.10	29.90	31.30	33.00	34.70	31.20	Ecuador	Dawson, 1986*
15.30	19.55	23.30	26.49	29.21	31.52	33.48	35.15	Chile	Aguayo and Steffens, 1986
23.10	24.80	-	-	-	-	-	-	Cataluna, Canarias Islands and South America	Perrotta, 1993
16.50	18.30	20.10	21.20	24.00	24.90	26.50	-	Gulf of California	Gluyas-Millán and Quiñonez-Velázquez, 1997
16.21	18.88	20.35	22.42	-	-	-	-	Turkiye (Aegean Sea)	This study

* From Hernández and Ortega, (2000) (The correctness of the data could not be absolutely validated and have to be taken with caution)

Table 6: Growth parameters of *Scomber japonicus* by geographic area

L_∞	K	t_0	Φ'	Area	Author(s)
27.90	0.49	-	2.58	Egypt	Rafail, 1972
43.61	0.24	-3.02	2.65	USA (California)	Knaggs and Parrish, 1973
44.60	0.26	-2.59	2.71	Arjentina	Costello and Cousseau, 1976*
71.60	0.16	1.89	2.91	Namibia	Baird, 1977
33.00	0.47	-	2.71	Turkiye (Marmara Sea)	Pauly, 1978
53.83	0.17	-2.03	2.70	Portugal	Martins *et al.*, 1983*
40.60	0.41	-0.05	2.83	Peru	Mendo, 1984*
40.50	0.21	-2.07	2.54	Ecuador	Dawson, 1986*
44.37	0.16	-1.54	2.50	Chile	Aguayo and Steffens, 1986
68.01	0.21	-0.98	2.96	South-East Atlantic	Ostapenko, 1988
29.80	0.61	-0.27	2.73	Mexico	Nevárez-Martinez *et al.*, 1994*
47.60	0.15	-2.18	-	Hellenic Seas	Kiparissis *et al.*, 2000
55.40	-	-	-	Naxos Island (Greece)	Stergiou *et al.*, 2004
29.87	0.20	-0.36	2.25	Turkiye (Aegean Sea)	This study

* From Hernández and Ortega, (2000) (The correctness of the data could not be absolutely validated and have to be taken with caution)

(0.83-1.26) by Kramer (1969) for Argentine continental shelf (0.54) by Angelescu (1979) and for Gulf of Guayaquil (Ecuador) (0.38-0.51) by Cucalón-Zenck (1999).

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