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Age, Growth, Mortality and Reproduction of the Chub Mackerel (*Scomber japonicus* Houttuyn, 1782) from Saros Bay (Northern Aegean Sea, Turkey)

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Abstract

Age, growth, mortality and reproduction of the chub mackerel (*Scomber japonicus* Houttuyn, 1782) were determined using specimens collected from Saros Bay between January 2009 and December 2009. The length-weight relationship was calculated as $W=0.0061TL^{3.12}$ for females, $W=0.00691TL^{3.08}$ for males and $W=0.0066TL^{3.10}$ for all samples. Growth parameters of the populations were $L_\infty=37.3$ cm, $k=0.22$ year^{-1}, $t_0=-1.93$ year for females; $L_\infty=41.4$ cm, $k=0.17$ year^{-1}, $t_0=-2.37$ year for males and $L_\infty=39.0$ cm, $k=0.20$ year^{-1}, $t_0=-2.13$ year for all samples. It was observed that spawning period occured between June and August. The length at first maturity was estimated as 18.0 cm for all samples. Total mortality rate (Z), natural mortality rate (M), fishing mortality rate (F) and exploitation rate (E) of the chub mackerel were 0.91 year^{-1}, 0.34 year^{-1}, 0.57 year^{-1} and 0.62 year^{-1}, respectively

Keywords: Stock structure.

Saroz Körfezi'ndeki (Kuzey Ege Denizi, Türkiye) Kolyoz Balığı'nın (*Scomber japonicus*, Houttuyn, 1782) Yaşı, Büyümesi, Ölüm Oranı ve Üremesi

Özet

Kolyoz balığının (*Scomber japonicus* Houttuyn, 1782) yaş, büyüme, ölüm oranı ve üreme zamanı, Ocak 2009 ve Aralık 2009 tarihleri arasında Saros Körfezi'nden toplanan bireylerle saptanmıştır. Boy-ağırlık ilişkisi dişiler için $W=0,0061TL^{3,12}$, erkekler için $W=0,00691TL^{3,08}$ ve tüm bireyler için $W=0,0066TL^{3,10}$ olarak hesaplanmıştır. Büyüme parametreleri dişiler için $L_\infty=37,3$ cm, $k=0,22$ yıl^{-1}, $t_0=-1,93$ yıl, erkekler için $L_\infty=41,4$ cm, $k=0,17$ yıl^{-1}, $t_0=-2,37$ yıl ve tüm bireyler için $L_\infty=39,0$ cm, $k=0,20$ yıl^{-1}, $t_0=-2,13$ yıl şeklinde tahmin edilmiştir. Üreme zamanı'nın Haziran ve Ağustos ayları arasında olduğu gözlemlenmiştir. Tüm bireyler için ilk üreme boyu 18.0 cm olarak bulunmuştur. Kolyoz balığının toplam ölüm oranı (Z), doğal ölüm oranı (M), balıkçılıktan kaynaklanan ölüm oranı (F) ve sömürülme oran (E), sırasıyla, 0,91 yıl^{-1}, 0,34 yıl^{-1}, 0,57 yıl^{-1} ve 0,62 yıl^{-1}'dir.

Anahtar Kelimeler: Stok yapısı, Kuzey Ege Denizi, Türkiye, kolyoz balığı.

Introduction

The chub mackerel, *Scomber japonicus* (Houttuyn, 1782), is a cosmopolitan middle-sized species inhabiting in the temperate and warm transition waters of the Atlantic, Indian and Pacific oceans, and the Mediterranean Sea. It is a schooling and highly migratory species over the continental shelf, distributed from the surface down to 300 m depth (Collette and Nauen, 1983).

Owing to its worldwide commercial importance, there are numereous studies on length-weight relationship (Petrakis and Stergiou, 1995; Gonçalves *et al*., 1997; Moutopoulos and Stergiou, 2002; Santos *et al*., 2002; Mendes *et al*., 2004; Sinovčić *et al*., 2004; Karakulak *et al*., 2006; Özaydın and Taşkavak, 2006; İşmen *et al*., 2007), age - growth and reproduction (Fitch, 1951; Knag and Parish, 1973; Krivospitchenko, 1979; Mužinić, 1979; Westhaus-Ekau and Ekau,1982; Serra, 1983; Martins and Serrano-Gordo, 1984; Mendo, 1984; Seckendorff and Zavala-Camin, 1985; Aguayo and Steffens, 1986; Dawson, 1986; Perrotta, 1992; Lorenzo, 1992; Lorenzo *et al*., 1995; Gluyas-Millán and Quiñonez-Velázquez, 1997; Kiparissis *et al*., 2000; Carvalho *et al*., 2002; Perrotta *et al*., 2005; Gang *et al*., 2008;

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Hwang *et al*., 2008; Yukami *et al*., 2009; Cikeš Keč and Zorica, 2012) and feeding habit (Castro, 1993; Castro and Del Pino, 1995).

Concerning Turkish waters, information about age, growth and reproduction of species come from Marmara Sea (Tuggac, 1957), Black Sea (Atli, 1959) and Izmir Bay (Bayhan, 2007). Sever *et al*. (2006) investigated the diet composition of juvenile chub mackerel in Izmir Bay, while Ergüden *et al*. (2009) made the morphometric and meristic analyses of *S. japonicus* from Black, Marmara, Aegean, and Mediterranean Seas and Özekinci *et al*. (2009) observed the hermaphroditism of chub mackerel in the Dardanelles.

A major proportion of *S. japonicus* catch in the Mediterranean and Black Seas is taken by Turkey, but its catch has drastically decreased in the last few years from an annual catch of 10,200 tonnes (t) during 1,999 to 1,500 t during 2002 (Sever *et al*., 2006). Total catches were averagely 2,004 t in 2,010 (TUIK, 2011).

Although Saros Bay had been closed to bottom trawl fishery since 2000, fishery is open to other fishing gears. There is no industry in the area surrounding the Bay and main source of fresh water and sediments to the Bay are Meriç River in the northwest and Kavak Creek in the east. (Sarı and Çağatay, 2001). This study provides preliminary information on age, growth, sex ratio, mortality, reproduction and the length at first maturity of *S. japonicus* for area and compares these results with those of the relevant studies and recommends the precautions necessary in order to maintain the sustainability of stock.

Materials and Methods

Samples were collected randomly, monthly, between January 2009 and December 2009 by handlines, gill nets and purse seines at depths ranging from 0 m to 50 m in Saros Bay (Figure 1).

Specimens were measured to the nearest 1 mm (total length, TL) and weighed to the nearest 0.01 g (total weight, W). The chi-square (X^2) test was used to determine differences in the sex ratio. Student's *t*-test was used to analyze differences in the mean total lengths and total weights of the sexes. Length-weight relationships were calculated by applying an exponential regression equation $W=aL^b$, where W is the weight (g), L is the total length (cm), and a and b are constants (Ricker, 1973).

Age was determined by the sagittal otoliths with three independent researchers results for a given otolith were accepted only when two researchers agreed. Otoliths were analyzed as whole, using a stereoscopic zoom microscope under reflected light against a black background filled with the water. Opaque and transparent zones were counted; one opaque zone together with one transparent zone was assumed to be an age mark.

The von Bertalanffy growth parameters were calculated according to $L_t=L_\infty\,[1-e^{-k(t-t_0)}]$ for TL, where L_t is length of fish (cm) at age t, L_∞ is the asymptotic fish length (cm), t is the fish age (year), t_0 is the hypothetical time at which the length of fish is zero and k is the growth coefficient (year^{-1}) (Sparre and Venema, 1992). To compare the growth parameters obtained in this study with those reported by other authors for the same species, as growth performance index (Pauly and Munro, 1984) ($\Phi'=\log(k)+2\log(L_\infty)$) was used.

Total mortality rate (Z) was estimated from linearized catch curve based on age composition data (Sparre and Venema, 1992). Natural mortality rate (M) was computed from Pauly (1980)'s multiple regression formula: M=0.8*exp(–0.0152–0.279*lnL_∞+0.6543*ln K+0.463*ln T), where L_∞ and K are the parameters obtained from the von Bertalanffy

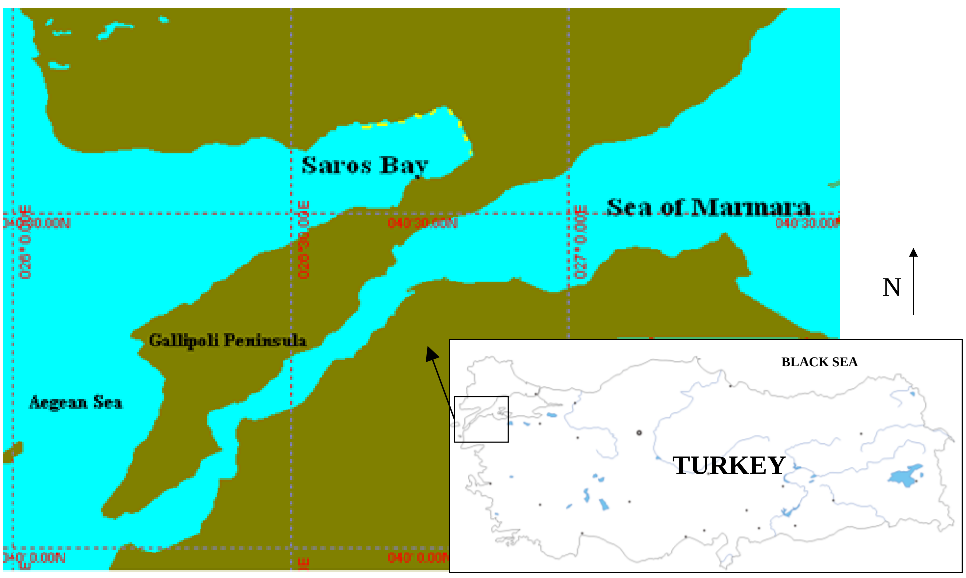

Figure 1. Study area.

growth equation and T°C is the annual mean water temperature at the study locality. Fishing mortality rate (F) was estimated from F=Z–M, and the exploitation rate (E) from E=F/Z.

Sex and maturity stages were determined macroscopically and gonads were weighed to an accuracy of 0.01 g. Maturity stage was assessed according to Gunderson's (1993) scale: stage I immature, stage II resting, stage III developing, stage IV ripe, and stage V spent. The spawning period was determined by analysing, monthly, the changes of the gonadosomatic index (GSI) using the equation $GSI=[Wg/(W\text{-}Wg)]*100$, where Wg is the gonad weight (g) and W is the total weight (g) of fish (Ricker, 1975).

To estimate the length at first maturity, logistic function was fitted to the proportion of the mature individuals by size class using non-linear regression. The function used for calculating length at first maturity was $P=1/\{1+\exp[-r(L-L_m)]\}$, where P is the proportion mature in each size class, r ($-b$ slope) is a parameter controlling the slope of the curve and L_m is the size at 50% maturity. $L_m=a/r$, where a is the intercept (Saila *et al*., 1988).

Results

A total of 452 individuals were collected randomly, monthly, between January 2009 and December 2009 by handlines, gill nets and purse seines in Saros Bay. The otoliths of 432 individuals were successfully extracted and they were analyzed for age determination by three independent researchers. Agreement was achieved for 402 (93%) otoliths. The remaining 30 (7%) of otoliths were rejected due to disagrement between researchers or because the otoliths were impossible to analyze. For this reason, the other individuals were not further considered.

Among the 402 examined specimens, 218 were females and 184 were males. The sex ratio was calculated as 1:0.84 (F:M). The chi-square test showed that there was a significant difference in the sex ratio as 0.5:0.5. The mean total length and total weight of females were 22.9±0.24 (13.8-31.1 cm), 115.87±3.76 (21.17-314.70 g), males were 21.8±0.24 (15.1-30.8 cm), 99.89±3.55 (25.27-272.23 g) and those of combined sexes were 22.4±017 (13.8-31.1 cm), 108.58±2.67 (21.17-314.70 g). No significant difference was statistically found between mean total lengths and total weights of sexes (P>0.05).

The length-weight relationship was estimated as $W=0.0061TL^{3.12}$ (r^2=0.97) for females; $W=0.0069TL^{3.08}$ (r^2=0.96) for males and $W=0.0066TL^{3.10}$ (r^2=0.96) for all samples (Figure 2). While the *b*-values and *t*-test results indicated positive allometric growth for females and all samples, there was isometric growth for males. The *b*-values showed no significant difference for both females and all samples (P>0.05).

Age distribution ranged from I to V years. Year class II (42.0%) was dominant, followed by year classes I (26.4%), III (20.6%), IV (8.3%) and V (2.7%) (Table 1).

Gonad development was observed by using the the gonadosomatic index (GSI%). The spawning period of chub mackerel occurred between April and August with a peak in June (Figure 3). Thus, 1 June was considered as the birth day to compute the parameters with von Bertalanffy growth equation.

The length at first maturity was estimated as 18.0 cm (TL) for all samples (Figure 4).

The von Bertalanffy growth parameters were computed as L_∞=37.3 cm, k=0.22 year^{-1}, t_0=-1.93 year for females; L_∞=41.4 cm, k=0.17 year^{-1}, t_0=-2.37 year for males; L_∞=39.0 cm, k=0.20 year^{-1}, t_0=-2.13 for all samples. The growth performance index (Φ') was found to be 2.49, 2.46 and 2.48 for females, males and all samples, respectively (Figure 5).

Total mortality rate (Z) for all samples was 0.91 year^{-1} (Figure 6). The annual water temperature mean in the study locality was 14.1°C. Thus, natural mortality rate (M) was estimated as 0.34 year^{-1}. Fishing mortality rate (F) was found to be 0.57 year^{-1}. The exploitation rate(E) was calculated as 0.62 year^{-1}.

Discussion

Some of available studies on length-weight relationship and length range of *S. japonius* from different localities are shown in Table 2. İşmen *et al*. (2007) suggested that the size selectivity of the sampling gear may affect the weight-length relationships. Besides, these relationships could be attributed to the combination of one or more factors, such as preservation techniques area, season, gonad maturity, habitat, health, degree of stomach fullness, length range, sex (Baganel and Tesch, 1978).

The probable reasons of variations in length range between different localites may be related to used different sampling gears (beach seine, gill net, longline etc.), samples collected from different areas and depths (Soykan *et al*., 2010) and the selectivity of sampling gears (İlkyaz *et al*., 2010).

The mean lengths at ages of *S. japonicus* presented by various authors are displayed in Table 3. Maxim *et al*. (1990) observed as 10 years-old in north-west Africa. Watanabe (1970) noted that the oldest fish caught was 11 years-old in Japan. Perrotta and Pertierra (1993) found that the oldest fish caught off the waters of Argentina was 12 years-old. The oldest fish caught in Canary Islands was 13 years-old (Lorenzo *et al*., 1995). Krivospitchenko (1980) reported the maximum age as 18 years in Sahara. In this connection, the growth of fish is associated with the environmental conditions and fishing efforts (Weatherley and Gill, 1987).

Comparasion of growth parameters and growth performance indexes obtained from previous studies for *S. japonicus* are summarized in Table 4. In

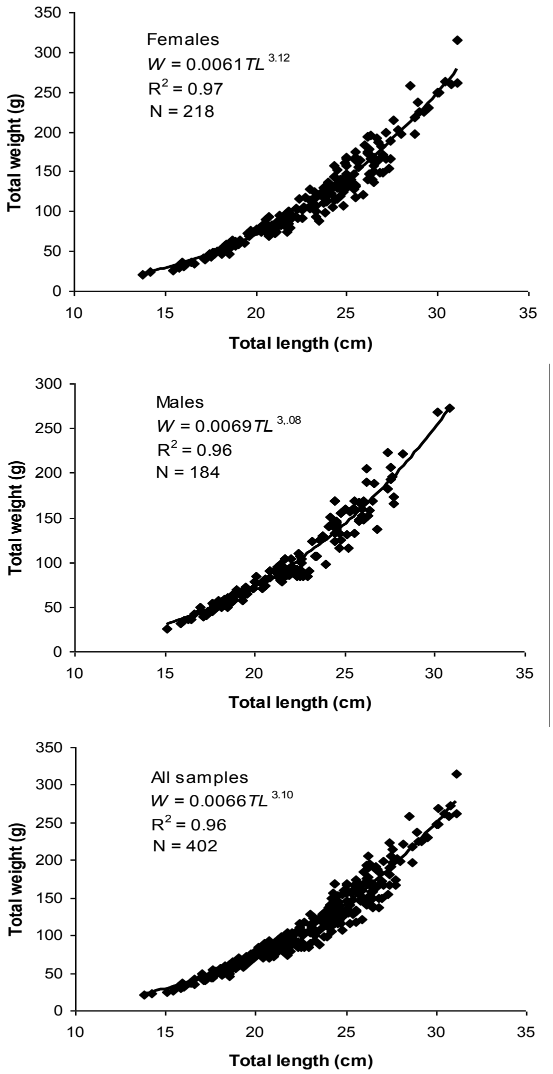

Figure 2. The length-weight relationships for females, males and all samples of *S. japonicus* from Saros Bay.

general, the differences in length at age and growth parameters between different localities could be related to differences in length at first maturity (Champagnat, 1983), diet and water temperature (Santic *et al*., 2002), selectivity of fishing gear (Ricker, 1969; Potts *et al*., 1998), incorrect age interpretation (Matić-Skoko *et al*., 2007), combination of sampling (sampling gear used, sample size and length ranges of samples examined), geographical differences and ageing methodology used (Monterio *et al*., 2006).

Although Gordoa and Balbina (1997) stated that a species which remains in the same habitats during its life could maintain the same growth rate, Avşar (1995) proposed that the reason for differences in growth parameters computed from data gathered at different periods from the same locality could be attributed to interannual variations in average length with age.

The *t*-test showed no significant differences between growth performance indexes in the other localities ($P>0.05$).

Results of earlier studies concerning mortality rates of chub mackerel in different localities are represented in Table 5. In this study, the high exploitation rate (E) indicated that chub mackerel in Saros Bay is heavily exploited. It is quite possible this case arises from the intensive fishing activities of purse seine vessels in area.

The discrepancies between the mortality rates from different localities can probably be attributed to various factors such as different ecological conditions and intensive fishing activities between the localities and unequal precision of employed various methods (Joksimović *et al*., 2009)

Some of the results in previous studies about spawning period and length at first maturity of *S. japonicus* in different localities are given in Table 6.

Table 1. Age-length key for females, males and all samples of *S. japonicus* from Saros Bay

Length class (cm)	Age I	Age II	Age III	Age IV	Age V	Total	Females	Males
13.0-14.0	1	-	-	-	-	1	1	-
14.1-15.0	1	-	-	-	-	1	1	-
15.1-16.0	8	-	-	-	-	8	5	3
16.1-17.0	8	-	-	-	-	8	3	5
17.1-18.0	27	3	-	-	-	30	11	19
18.1-19.0	31	8	-	-	-	39	20	19
19.1-20.0	19	7	-	-	-	26	10	16
20.1-21.0	6	22	-	-	-	28	18	10
21.1-22.0	5	55	-	-	-	60	27	33
22.1-23.0	-	29	-	-	-	29	11	18
23.1-24.0	-	17	10	-	-	27	20	7
24.1-25.0	-	23	27	-	-	50	30	20
25.1-26.0	-	4	28	-	-	32	16	16
26.1-27.0	-	1	18	12	-	31	23	8
27.1-28.0	-	-	-	14	1	15	8	7
28.1-29.0	-	-	-	5	1	6	5	1
29.1-30.0	-	-	-	2	2	4	4	-
30.1-31.0	-	-	-	-	5	5	3	2
31.1-32.0	-	-	-	-	2	2	2	-
Total								
N	106	169	83	33	11	402	-	-
Mean	18.3	22.1	25.2	27.5	30.1	22.4	-	-
Min.	13.8	17.7	23.1	26.1	27.4	13.8	-	-
Max.	21.7	26.3	26.8	29.5	31.1	31.1	-	-
S.E.	0.15	0.14	0.10	0.15	0.32	0.17	-	-
%	26.4	42.0	20.6	8.3	2.7	100.0	-	-
Females								
N	51	81	52	26	8	-	218	-
Mean	18.1	22.2	25.1	27.4	30.3	-	22.9	-
Min.	13.8	18.1	23.1	26.1	29.0	-	13.8	-
Max.	21.4	25.6	26.5	29.5	31.1	-	31.1	-
S.E.	0.23	0.18	0.13	0.19	0.24	-	0.24	-
%	23.4	37.1	23.9	11.9	3.7	-	100.0	-
Males								
N	55	88	31	7	3	-	-	184
Mean	18.4	21.9	25.3	27.7	29.4	-	-	21.8
Min.	15.1	17.7	23.6	27.4	27.4	-	-	15.1
Max.	21.7	26.3	26.8	28.2	30.8	-	-	30.8
S.E.	0.19	0.20	0.15	0.10	1.04	-	-	0.24
%	30.0	47.8	16.8	3.8	1.6	-	-	100.0

N=Sample size; S.E=Standard Error; Min=Minimum; Max=Maximum

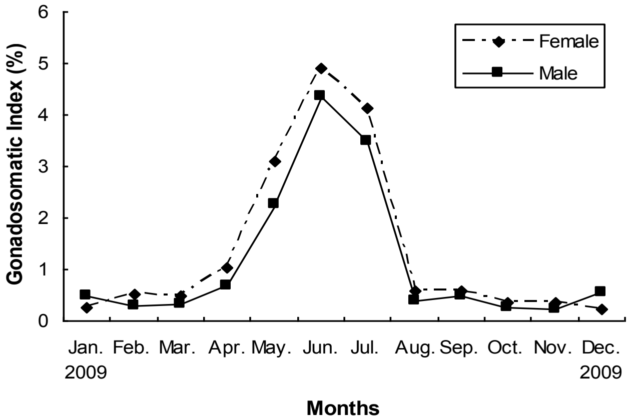

Figure 3. Monthly average GSI% values for females and males of *S. japonicus* from Saros Bay.

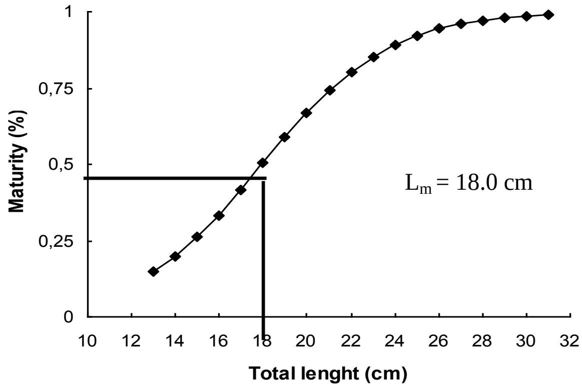

Figure 4. Sexual maturity curves for all samples of *S. japonicus* from Saros Bay.

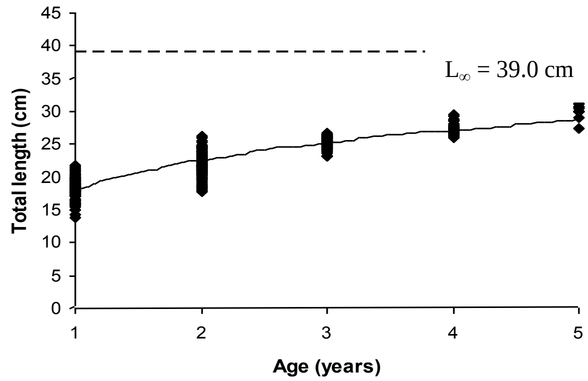

Figure 5. The von Bertalanffy growth curve for all samples of *S. japonicus* from Saros Bay.

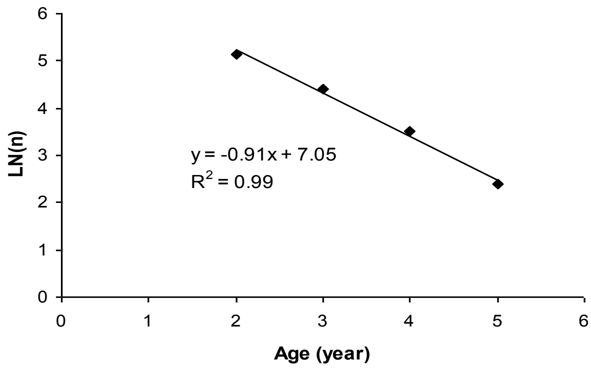

Figure 6. Age structured catch curve for estimation of total mortality (Z) for *S. japonicus* from Saros Bay.

Spawning periods of fish vary with respect to their species and could attributed to the ecological differences such as stagnant or running water, temperature and quality of food (Nikolsky, 1963). According to Wootton (1990), temperature appears to be the most important factor among those that may influence the reproduction of fishes.

The differences in lengths at first maturity between different localities may related to food availability and temperature (Nikolsky, 1963; Hempel, 1965), genetic factors (Wootton, 1998) and long-term fishing pressure and selectivity (Trippel, 1995; Helser and Almeida, 1997; Jennings *et al*., 2001) and and used different methods (Trippel and Harvey, 1991; Froese and Binohlan, 2000).

As a consequence, this study presents the first

Table 2. Some of available studies on length-weight relationship and length range of *S. japonius* from different localities

References	Locality	Sampling Gears	Sex	LT	N	L_{min}	L_{max}	a	b	r^2
Petrakis and Stergiou (1995)	South Euboikos Gulf (Greece)	Beach seine-Gill net-Trammel net	Σ	TL	57	18.7	29.6	$1.30*10^{-5}$	2.96	0.97
Gonçalves *et al*. (1997)	South-west coast of Portugal	Gill net-Longline-Trammel net	Σ	TL	216	15.8	39.5	$2.15*10^{-6}$	3.22	0.96
Gluyas-Millán and Quiñonez-Velázquez (1997)	Gulf of California	Purse seine	Σ	SL	1554	14.5	31.2	$1.17*10^{-6}$	3.48	0.88
			♀	SL	1257	15.1	31.2	$2.22*10^{-6}$	3.36	0.87
			♂	SL	1297	14.5	29.6	$6.68*10^{-6}$	3.58	0.89
Carvalho *et al*. (2002)	Azores	-	Σ	FL	349	9.0	53.0	0.0049	3.26	0.97
Moutopoulos and Stergiou (2002)	Aegean Sea (Greece)	Gill net-Longline	Σ	-	46	22.9	33.0	0.0008	3.70	0.94
Santos *et al*. (2002)	Algarve coast (southern Portugal)	Gill net-Longline-Pound net Trammel net-Trap-Trawl	Σ	TL	805	15.1	47.2	0.0021	3.41	0.98
Mendes *et al*. (2004)	Portuguese west coast	Gill net-Trammel net	Σ	TL	323	19.5	46.4	0.002	3.44	0.96
Sinovčić *et al*. (2004)	Adriatic Sea (Croatia)	Beach seine-Purse seine	Σ	-	1607	19.6	38.8	0.0066	3.14	0.91
			♀	-	647	20.1	38.2	0.0106	3.00	0.82
			♂	-	453	19.6	38.4	0.0047	3.25	0.90
Perrotta *et al*. (2005)	NE Mediterranean	-	Σ	TL	158	11.0	39.0	-	-	-
	SW Atlantic		Σ	TL	392	14.0	45.0	-	-	-
Karakulak *et al*. (2006)	Gökceada Island	Gill net-Trammel net	Σ	TL	25	18.1	31.2	0.0064	3.10	0.97
Özaydın and Taşkavak (2006)	Izmir Bay	Beach seine-Bottom trawl Gill net-Trammel net	Σ	FL	129	12.5	26.0	0.0115	2.94	0.98
Bayhan (2007)	Izmir Bay	Purse seine	Σ	FL	520	12.5	27.2	0.0030	3.40	0.98
			♀	FL	244	13.0	27.2	0.0030	3.41	0.97
			♂	FL	276	12.5	26.2	0.0030	3.39	0.96
İşmen *et al*. (2007)	Saros Bay	Bottom trawl	Σ	TL	45	12.2	22.0	0.0016	3.52	0.97
Gang *et al*. (2008)	East Chine-Yellow Sea	-	Σ	FL	352	21.5	41.1	$4.26*10^{-6}$	3.20	0.99
Hwag *et al*. (2008)	Korea	Purse seine	Σ	FL	747	-	-	0.0012	3.69	0.97
This study	Saros Bay	Gill net-Handline-Purse seine	Σ	TL	402	13.8	31.1	0.0066	3.10	0.96
			♀	TL	218	13.8	31.1	0.0061	3.12	0.97
			♂	TL	184	15.1	30.8	0.0069	3.08	0.96

LT=Length Type; TL=Total Length; FL=Fork Length; SL=Standard Length; Min and Max=Minimum and Maksimum; N=Sample size; *a* and *b* is the parameters of the relationships: r^2 is the coefficient of determination. Σ=All samples; ♀=Females; ♂=Males

Table 3. The mean lengths at ages of *S. japonicus* presented by various authors

References	Locality	LT	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Fitch (1951)*	Southern California	FL	-	27.0	30.5	32.7	35.0	37.2	37.5	37.7	37.8	-	-	-	-	-
Tuggac (1957)	Marmara Sea	TL	-	14.8	18.1	20.5	22.2	22.6	26.3	32.6	-	-	-	-	-	-
Atli (1962)	Black Sea	-	-	14.9	18.9	21.2	23.3	25.1	25.8	27.5	-	-	-	-	-	-
Knaggs and Parish (1973)*	Southern California	FL	-	27.3	30.8	33.6	35.7	37.4	38.8	39.8	40.6	-	-	-	-	-
Mendo (1984)*	Peru	FL	-	14.1	23.0	28.8	32.8	35.4	37.1	38.2	-	-	-	-	-	-
Aguayo and Steffens (1986)*	North of Chile	FL	-	15.1	19.5	23.3	26.4	29.1	31.4	33.4	-	-	-	-	-	-
Dawson (1986)*	Ecuador	FL	-	19.5	23.5	26.8	29.4	31.5	33.2	34.6	35.8	-	-	-	-	-
Perrotta (1992)	Argentine Sea	TL	16.3	18.7	30.1	33.0	36.7	37.8	40.1	41.1	42.4	42.8	44.3	-	-	-
Lorenzo *et al*. (1995)	Canary Islands	TL	-	19.2	25.2	29.8	33.8	35.8	39.1	41.1	48.6	50.9	52.2	53.8	55.6	56.5
Gluyas-Millán and Quiñonez-Velázquez (1997)	Gulf of California	FL	-	19.2	21.4	23.1	24.5	25.7	26.6	27.3	27.9	-	-	-	-	-
Carvalho *et al*. (2002)	Azores	TL	9.8	18.9	27.3	32.0	36.6	40.2	43.6	46.3	37.1	-	-	-	-	-
Perrotta *et al*. (2005)	NE Mediterranean	TL	12.2	23.0	24.8	30.1	33.4	34.8	35.3	36.0	42.6	-	43.5	-	-	-
	SW Atlantic	TL	16.3	18.7	30.5	33.5	36.2	38.1	40.1	41.2	-	-	-	-	-	-
Bayhan (2007)	Izmir Bay	FL	-	16.2	18.9	20.4	22.4	-	-	-	-	-	-	-	-	-
This study	Saros Bay	TL	-	18.3	22.1	25.2	27.5	30.1	-	-	-	-	-	-	-	

LT=Length Type; TL=Total Length; FL=Fork Length, *from Gluyas-Millán and Quiñonez-Velázquez (1997)

data concerning the population structure of chub mackerel in Saros Bay. Minimum landing size for chub mackerel is 18.0 cm in Turkish Fishery Regulations. Although this corresponds to the length at first maturity in present study, the exploitation rate (E) showed that the species was exposed to over-fishing pressure. If intensive fishing activities last, it is quite clear that the sustainability of stock will be under increased threat in the near future. Hence, fishing efforts and fishing gears of purse seine vessels must be accommodated and the selectivity studies on other fishing gears, such as handlines and gill nets, used for fishing of chub mackerel should be carried out. Besides, although this study has added to

Table 4. Comparasion of growth parameters and growth performance indexes obtained from previous studies for *S. japonicus*

References	Locality	Sex	L_∞	k	t_0	Φ’
Tuggac (1957)	Marmara Sea	Σ	33.0	0.47	-	2.71
Knaggs and Parish (1973)	Southern California	Σ	43.6	0.24	-3.02	2.66
Krivospitchenko (1979)	Morocco	Σ	44.1	0.32	-0.83	2.80
Martins and Serrano-Gordo (1984)	Morocco	Σ	51.2	0.20	-1.56	2.72
Mendo (1984)	Peru	Σ	40.6	0.41	-0.05	2.83
Aguayo and Steffens (1986)	North of Chile	Σ	44.3	0.16	-1.54	2.50
Dawson (1986)	Ecuador	Σ	40.5	0.21	-2.07	2.54
Perrotta (1992)	Argentine Sea	Σ	46.0	0.28	-1.54	2.77
Lorenzo *et al*. (1995)	Canary Islands	Σ	49.2	0.21	-1.40	2.71
Gluyas-Millán and Quiñonez-Velázquez (1997)	Gulf of California	Σ	28.1	0.22	-3.50	2.24
Kiparissis *et al.* (2000)	Hellenic Seas	Σ	47.6	0.15	-2.18	2.53
		♀	34.5	0.30	-1.53	2.55
		♂	46.4	0.16	-1.88	2.54
Carvalho *et al*. (2002)	Azores	Σ	57.5	0.20	-1.09	2.82
Perrotta *et al.* (2005)	NE Mediterranean	Σ	39.7	0.29	-1.40	2.66
	SW Atlantic	Σ	44.2	0.32	-1.38	2.80
Bayhan (2007)	Izmir Bay	Σ	29.8	0.20	-0.36	2.25
		♀	27.1	0.26	-0.48	2.28
		♂	29.6	0.23	-0.39	2.30
Gang *et al*. (2008)	East Chine and Yellow Sea	Σ	40.4	0.49	-0.90	2.90
This study	Saros Bay	Σ	39.0	0.20	-2.13	2.48
		♀	37.3	0.22	-1.93	2.49
		♂	41.4	0.17	-2.37	2.46

Σ=All samples; ♀=Females; ♂=Males.

Table 5. Results of earlier studies concerning mortality rates of chub mackerel in different localities

References	Locality	Z	M	F	E
Castello and Cousseau (1976)	Argentina	0.91	0.33	0.58	-
Serra (1983)	Northern Chile	-	0.30		-
Maxim *et al.* (1990)	Mauritania	-	0.40	0.38	-
Zhenbin *et al*. (1991)	Taiwan	1.02	0.63	0.39	-
Mendoza (1993)	Northeastern Venezuela	-	0.58	0.02	-
Carvalho *et al*. (2002)	Azores	-	0,19	-	-
This study	Saros Bay	0.91	0.34	0.57	0.62

Z=Total mortality rate; M=Natural mortality rate; F=Fishing mortality rate; E=Exploitation rate

Table 6. Some of the results of previous studies on spawning period and length at first maturity of *S. japonicus* from different localities

References	Locality	Months	Length at first maturity
Tuggac (1957)	Marmara Sea (Turkey)	April-July	-
Atli (1962)	Black Sea (Turkey)	June-August	-
Mužinić (1979)	Adriatic Sea	April-September	26.0 (-) cm
Westhaus-Ekau and Ekau (1982)	Azores	April-June	-
Serra (1983)	Southern Brazil	January-May	30.0 (FL) cm
Martins and Serrano-Gordo (1984)	Portugal	February-April	-
Seckendorff and Zavala-Camin (1985)	Northern Chile	July-December	18.0 (FL) cm
Lorenzo (1992)	Canary Islands	December-March	-
Gluyas-Millán and Quiñonez-Velázquez (1997)	Gulf of California	November-April	19.3 (SL) cm
Carvalho *et al*. (2002)	Azores	March-August	27.7 (TL) cm
Hwang *et al*. (2008)	Korea	May	28.8 (FL) cm
Yukami *et al*. (2009)	East China Sea	February-June	-
Cikeš Keč and Zorica (2012)	Eastern Adriatic Sea	May-August	18.3 (FL) cm
This study	Saros Bay	June-August	18.0 (TL) cm

TL=Total Length; FL=Fork Length; SL=Standard Length.

knowledge on the biology of species, *S. japonicus* population needs to be investigated much more. For example, further research could be conducted to determine the growth parameters and mortalities as well as the spawning periods, fecundities and lengths at first maturity between different localities according to Turkish waters for successful fisheries management. Possible causes of the differences in life-history parameters between these results to those of previous studies could be attributed to differences in environmental conditions and/or sampling strategy. The data from this study can be used for stock assessment investigations in future.

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