Age, growth and mortality of European pilchard, Sardina pilchardus in Edremit Bay (northern Aegean Sea, Turkey)

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Age, growth and mortality of European pilchard, *Sardina pilchardus* in Edremit Bay (northern Aegean Sea, Turkey)

by

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ABSTRACT. - Age, growth and mortality of the European pilchard, *Sardina pilchardus* (Walbaum, 1792) were determined from 503 specimens collected on the northwestern Aegean coast of Turkey from November 2005 to October 2006. Fork length ranged from 8.7 to 14.3 cm while weight varied between 7.05 and 32.66 g. The von Bertalanffy growth equation was fitted on the basis of mean length-at-age data resulting in parameter values of $L_\infty = 15.23$ cm, K = 0.47, $t_0 = -1.21$. The *b* value for males (*b* = 2.455) was somewhat lower than that for females (*b* = 2.642), showing negative allometry. The oldest male and female were estimated to be three years old. Total (Z), natural (M) mortality, fishing (F) mortality were 0.94, 0.64, 0.30 per year, respectively. The exploitation ratio E = 0.32 indicated that the population was slightly exploited. The sex ratio was skewed in favour of females (1:1.31). The monthly values of gonadosomatic index (GSI) of females indicated that spawning occurred mainly between September and May with a peak in February.

RÉSUMÉ. - Âge, croissance et mortalité de la sardine, *Sardina pilchardus* dans la baie d'Edremit (Turquie).

L'âge, la croissance et la mortalité de la sardine, *Sardina pilchardus* (Walbaum, 1972) ont été déterminés à partir d'échantillons (N = 503) collectés sur les côtes turques du nord-ouest de la mer Egée, entre novembre 2005 et octobre 2006. La longueur à la fourche a varié entre 8,7 et 14,3 cm, et le poids entre 7,05 et 32,66 g. L'équation de croissance de von Bertalanffy, basée sur les paramètres de longueur moyenne par âge, a donné les résultats de $L_\infty = 15{,}23$ cm, K = 0,47 et $t_0 = -1{,}21$. Le poids s'accroît de façon allométrique pour la femelle et le mâle (*b* = 2,642 et *b* = 2,455, respectivement). L'âge des plus vieux individus, mâles et femelles, a été estimé à trois ans. Les mortalités totale (Z), naturelle (M) et de pêche (F) ont été de 0,94, 0,64 et 0,30 par an, respectivement. Le taux d'exploitation E = 0,32 indique que la population n'est que faiblement exploitée. La sexe ratio est en faveur des femelles (1 : 1.31). Les valeurs mensuelles de l'indice gonadosomatique (GSI) des femelles suggèrent que la ponte a lieu entre septembre et mai, avec une pointe en février.

Key words. - Clupeidae - *Sardina pilchardus* - MED - Edremit Bay - Age - Growth - Mortality - Gonadosomatic index.

The sardine, *Sardina pilchardus* (Walbaum, 1792) is a pelagic fish species whose distribution extends generally from southern Morocco to British Channel, and from the Azores to the eastern Mediterranean and Black Sea (Parrish *et al*., 1989).

The European sardine is one of the most important small-sized pelagic species in Turkish waters. It has high commercial importance, being targeted by purse-seine fisheries across most of its distribution area and by pelagic trawlers mainly in Turkish waters. Namely, the mean annual catch of sardines raised up from 12,000 to 20,941 tonnes between 2003 and 2007, as main target of beach seine on the Turkey coasts (Turkstat, 2008). Sardine is an important species, widely caught: 15,681 tonnes in Edremit Bay during years 1995-1999 (Kara and Gurbet, 1999).

In Europe, Quintanilla and Perez (2000) reported that sardina population is mostly composed of age group 2, due to changes in the distribution pattern by age. Cabral *et al*. (2003) investigated the abundance of sardine as the main target species in the central coast of Portugal. Silva (2003) gave morphometric variation among sardine populations from the northeastern Atlantic and the western Mediterranean with some biological characteristics. Voulgaridou and Stergiou (2003) discussed the decline in the mean TL and the increase in the slope b of the length-weight relationship, which are in relation to the recent increase in the effort expended on sardine populations and within the framework of density-dependent effects on growth in the Eastern Mediterranean Sea. Somarakis *et al*. (2006) reported that the peak of the spawning period occurred rather in the Aegean Sea (December) than in the less-productive Ionian Sea (February). Sinovčić *et al*. (2008) investigated the population structure of sardine stock from the Krka River estuary.

As to Turkish Seas, there are some scarce published studies concerning various aspects of sardine biology, ecology, genetics, and fisheries (reproduction: Cihangir, 1996; Akyol *et al*., 1996; age and growth: Mater and Bayhan, 1999; Karakayis and Togulga, 2000; and stock structure: Sarmasik *et al*., 2008). Nevertheless, there is an absence of regular and accurate data on growth, maturity, mortality of sardine in Edremit Bay, northern Aegean Sea.

With regard to commercial importance of sardine popu-

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lation in Turkish commercial fishery, particular attention has been given to biological aspects for a proper utilization and management purposes. The aim of this paper was to examine the population structure of sardine such as growth, length-weight relationship and condition, in order to provide better knowledge and comparisons with the relevant studies, and thus improve protection of the sardine stock in the Edremit Bay, northern Aegean Sea.

MATERIALS AND METHODS

Fish were obtained from commercial purse seining between November 2005 and October 2006 in Edremit Bay, northern Aegean Sea (26º57'-26º34'E and 39º17'-39º34' N) (Fig. 1). A total of 503 specimens were obtained from different boats each month and about 50 samples were selected randomly. Specimens were measured to the nearest 0.1 cm fork length (FL) and weighed to the nearest 0.1 g.

Sagittal otoliths were removed and kept in dry envelopes. Age was read from the whole otoliths immersed in glycerin (25%) and alcohol (75%). As a rule, only right otoliths were used for age determination. The number of opaque zones (summer rings, appearing bright under reflected light) and the presence of marginal translucent zone (winter rings, appearing dark under reflected light) were checked by two readers. In order to avoid subjectivity effect on age estimation, there was an interval of 1 month between readings. Translucent bands that were continuous around the entire otolith circumference were considered annuli and the total number of these bands was recorded as age. Age-classes were assigned based on the number of annuli and the month the fish were collected (Chugunova, 1963; Gordoa *et al.*, 2000). Length-weight relationships were calculated by applying an exponential regression equation $W = aL^b$, where W is the weight (g), L is the fork length (cm), and a and b are constants. Von Bertalanffy growth equations were calculated according to $L_t = L_\infty[1 - e^{-k(t - t_0)}]$ for FL, where L_t is the length of fish in cm at age t, L_∞ is the asymptotic fish length in cm, e is the base of natural log (2.71828), t is the fish age (year), t_0 is the hypothetical time at which the length of the fish is zero, K is the rate at which the growth curve reaches the asymptote (Ricker, 1975; Sparre and Venema, 1992).

Fulton's condition factor (CF) was calculated as $CF = [W / L^3) \times 100$ for each sex to assess the maturity and condition of specimens (Dulcic *et al.*, 2000).

The index of growth performance was calculated according to Pauly and Munro (1984) as follows: $\Phi = \text{Log}_{10}k + 2\log_{10}L_\infty$, where, k and L_∞ are Von Bertalanffy growth equation parameters.

Sex was determined by macroscopic observation of the gonads. The overall sex ratio was determined. Deviations from 1:1 hypothesis were statistically tested by chi-squared analysis (Sokal and Rohlf, 1981). Spawning period was determined by analysing the monthly percentages of mature individuals (on the basis of macroscopic classification) and the mean gonadosomatic index (GSI) over the one-year study period. Individual GSI was calculated by the equation: GSI = (GW / SW) x 100, where GSI is the gonadosomatic

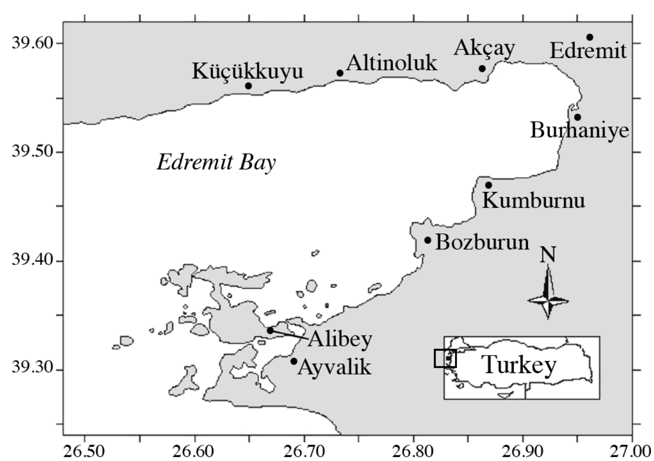

Figure 1. - Sampling area in Edremit Bay, in the Northern Aegean Sea.

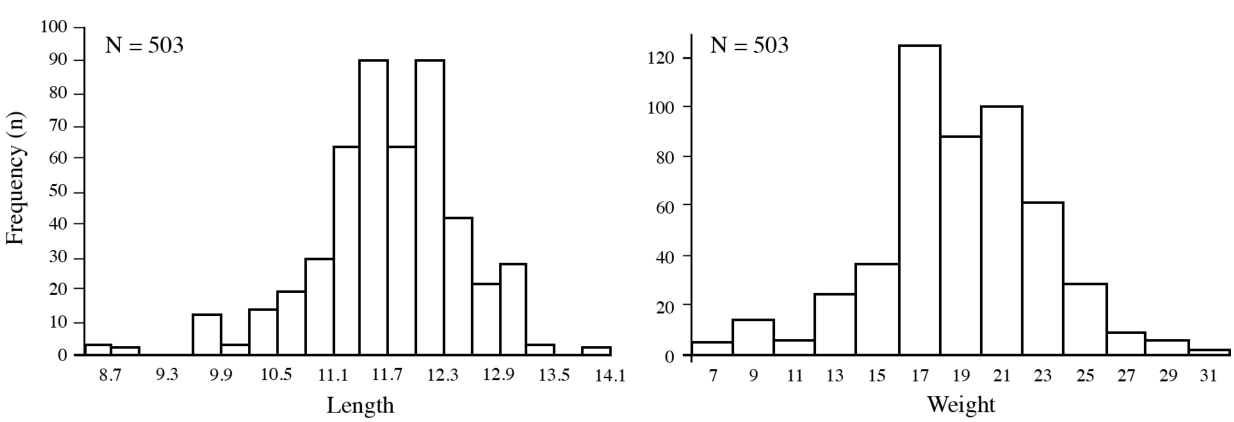

Figure 2. - Fork length and weight frequency distribution of *S. pilchardus*.

Table I. - Mean fork length (FL, cm), and mean weight (W, g), mean condition factor (CF), standard error (SE) for different age groups of *S. pilchardus* males and females. Min-max = minimum and maximum values; N = number of fish; P-value: significance level. * Significance values belong to length and weight values. ** Significance values belong to CF values.

		Males				Females				
Age	N	FL ± SE (min-max)	W ± SE (min-max)	CF ± SE (min-max)	N	FL ± SE (min-max)	W ± SE (min-max)	CF ± SE (min-max)	p = 0.05*	p = 0.05**
I	12	98.67 ± 2.12	7.18 ± 1.42	1.19 ± 0.09	13	10.0 ± 1.24	11.51 ± 0.78	1.11 ± 0.056	p > 0.05	p > 0.05
		(8.7-10.4)	(7.18-23.64)	(0.89-2.10)		(8.7-10.9)	(7.05-16.12)	(0.79-156)		
II	183	11.91 ± 0.43	19.34 ± 0.21	1.15 ± 0.01	239	12.01 ± 0.39	19.89 ± 0.22	1.14 ± 0.01	p > 0.05	p > 0.05
		(10.6-13.5)	(10.74-32.66)	(0.67-2.01)		(10.5-13.5)	(10.76-29.9)	(0.65-2.01)		
III	23	13.22 ± 0.70	24.65 ± 0.61	1.08 ± 0.02	33	13.19 ± 0.81	24.76 ± 0.63	1.08 ± 0.02	p > 0.05	p > 0.05
		(12.7-14.3)	(17.94-30.83)	(0.78-1.28)		(12.7-14.3)	(21.63-32.66)	(0.89-1.28)		
	218				285					

Table II. - Age-length key for *S. pilchardus* in Edremit Bay, based on otolith readings.

TL (cm)	Age groups I	II	III	Total
8.7	3			1
9.0	2			4
9.5	1			21
10.0	14			66
10.5	5	27		80
11.0		52		100
11.5		131		90
12.0		116		53
12.5		89	7	28
13.0		5	44	9
13.5		2	3	5
14.0			2	2
TOTAL	25	422	56	503
% N	4.97	83.89	11.13	100
FL	99.8 ± 1.28	11.9 ± 0.28	13.20 ± 0.40	12.00 ± 0.82
W	11.78 ± 1.12	19.65 ± 0.24	24.71 ± 0.53	19.81 ± 0.18
Females	13	239	33	285
Males	12	183	23	218
F:M	1:1.08	1:1.31	1:1.43	1:1.31

index, GW is gonad weight and SW is somatic weight (body weight minus gonad weight). Sex ratio was analysed monthly (on the basis of macroscopic classification). Deviations from 1:1 null hypothesis were statistically tested by chisquared analysis. Total mortality rate (Z) was estimated using the following equation (Beverton and Holt, 1957): $Z = 1/(\bar{t} - t')$, where $\bar{t}$ is the average age of the samples and t' is the age at the smallest length of the fish. Natural mortality (M) was estimated for shoaling fish using Pauly's empirical formula (Pauly, 1980):

$$M = 0.8 * \exp(-0.015 - 0.28 \mathrm{Ln} L_{\infty} + 0.65 \mathrm{Ln} K + 0.46 \mathrm{Ln} T^{o}C)$$

where L_{∞} and K are the parameters derived from Von Bertalanffy equation and T°C the mean annual environmental temperature at the surface of the study area (10ºC). Following the estimation of Z and M, the fishing mortality rate (F) was estimated as: $F = Z - M$, and the exploitation rate as $E = F / Z$ (Pauly, 1980).

RESULTS

Length and weight frequency distribution

The fork length of all individuals (n = 503) ranged from 8.7 to 14.3 cm and weight from 7.05 and 32.66 g (Fig. 2). Mean fork length and weight were similar for females and males (Tab. I), and the differences were not significant (t-test, $p > 0.05$).

Age composition and sex ratio

Age and sex distribution data are summarized in table I. Age of captured fish ranged between I and III, while the second year classes were dominant. Because of selectivity of the nets, the '0' age group was not represented in the samples. There were about 43% males and 57% females, and differences between sexes according to age were not statistically significant ($p > 0.05$). The sex ratio (F:M) was 1:1.31.

Growth

According to von Bertalanffy growth equations of all individuals, a theoretically maximal length of 15.23 cm is realistic because the largest specimen sampled during the surveys was 14.3 cm. The age-length key is given in table II. Age classes covered in the study by otolith sample analysis

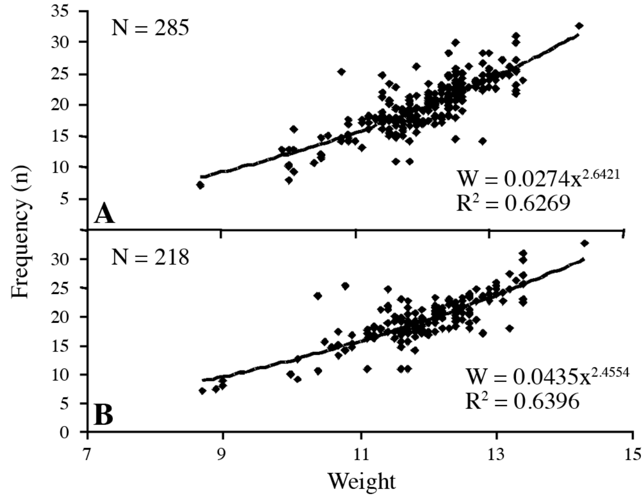

Figure 3. - Length- weight relationships in females (**A**) and males (**B**) of *S. pilchardus*.

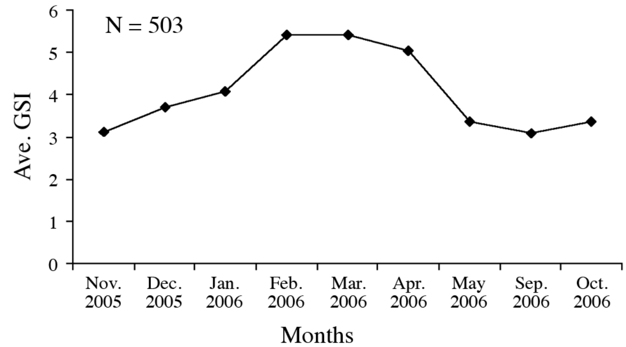

Figure 4. - Average of monthly gonadosomatic index (Ave. GSI) of female *S. pilchardus*, from Edremit Bay.

ranged from I to III. Growth performance index (Φ) of *Sardina pilchardus* is estimated as 2.04.

Length-weight relationships

The fork length-weight relationships were evaluated separately for males and females (Fig. 3). The calculated length-weight equation for females was: $W = 0.0274L^{2.642}$ ($r^2 = 0.6269$) and for males, $W = 0.0435L^{2.455}$ ($r^2 = 0.6396$). Weight increased negative allometrically with size since the value of b = 2.642, b = 2.455, respectively had a significant difference from the value 3.0 (t-test , $p < 0.05$) (Fig. 3).

Condition factor

The mean condition factor for females was similar to that of males, and the differences between sexes were not significant ($p > 0.05$, t-test, Tab. I).

Gonadosomatic index

Gonad development was followed using the GSI%. Monthly changes are plotted in figure 4. Spawning occurred between September and May with a peak in February. Differences between values of GSI according to months, especially April 2006, are statistically significant (d.f.: 7.836; F: 43.252; $p < 0.05$; one-way ANOVA).

Mortality

Total mortality for combined sexes was $Z = 0.94$ year^{-1}. The natural mortality was found to be $M = 0.64$ year^{-1}. Then, the calculation of fishing mortality gave $F = 0.30$ year^{-1}. The exploitation rate was computed as $E = 0.32$.

Discussion

In this study, a total of 503 specimens of *S. pilchardus* from the Edremit Bay were examined from November 2005 to October 2006. Sardine is a short living species in Edremit Bay. Sardine size ranged from 8.7 to 14.3 cm and the age of captured fish between groups I and III, having young individuals. These ranges vary with different studies, apart from the similar to those recorded in Aegean Sea, which is close to our studying area (Mater and Bayhan, 1999; Karakayis and Togulga, 2000; Silva *et al.*, 2008) (Tab. III). This variation may be due to different stages in ontogenetic development, as well as differences in condition, length, age, sex, gear selectivity, gonadal development, and geographical variations (Ricker, 1975; Tirasin, 1993). In addition, as seen in table III, the relevant literature reported the ages to IV. But, the fact that fishing by purse seine has not been forbidden in Edremit Bay has lead to catch young sardines named as papalina, which are chosen as target species (Ceyhan *et al.*, 2006).

As seen, the population consisted of 57% females and 43% males. Although sex ratio in most species was close to 1, this may vary from one species to another, differing from one population to another of the same species, and may also vary year after year within the same population (Nikolsky, 1963). While sex ratio in sardine was found being close to 1 in some studies (Mater and Bayhan, 1999), it was pointed out that the sex ratio of females was higher than males (Karakayis and Togulga, 2000).

The exponent *b* of the length-weight relationships in each sex ($b = 2.642$ for females, $b = 2.455$ for males) showed that weight increased with length in negative allometry. *b* values in the Edremit Bay were found to be close to estimates in Adriatic and Ionian Seas (Petraikis and Stergio, 1995; Koutrakis and Tsikliras, 2003; Mustac and Sinovčić, 2007), but also different from the data found in other studies with positive allometry in Tunisian waters by Khemiri (2006) (Tab. III). The *b* values are often 3.0 and generally comprised between 2.5 and 3.5. As fish grows, changes in weight are relatively greater than changes in length, due to approximately cubic relationships between fish length and weight. The *b* values in fish differ according to species, sex, age, seasons and feeding (Ricker, 1975; Bagenal and

Table III. - Age structure, parameters of length-weight relationships (a and b), growth (L_∞, K, t_0, Φ) and CF of *S. pilchardus* in this and previous studies. – indicates absence of data.

Literature	Locality	Sex	Age	N	L	Length (cm)	W (g)	CF	a	b	L∞	K	To	r²	Φ
Krzeptowski (1983)	Central-east Atlantic										24.6	0.37			
Sinovčić (1984)	E. Adriatic (Croatia)										20.0	0.46			
Porteiro and Alvarez (1985)	Bay of Biscay										22.93	0.53			2.447
Morales-Nin and Pertierra (1990)	N.W. Mediterranean		0-8	9662	TL	6.5-20.0					19.9	0.35	2.733		2.14
Sinovcic (1991)	Adriatic	F+M	1-8	1516	TL	7.5-20.3	2.3-56.6	-	0.0033	3.2764	20.5	0.46	-0.5	0.9997	
Alemany and Alvarez (1993)	W. Mediterranean										20.69	0.69			
Petrakis and Stergiou (1995)	Ionian Sea	F+M	-	82	FL	11.8-17.2	-	-	0.000033	2.754	-	-	-	0.82	-
Voulgaridou and Stergiou (1999)	Ionian Sea	F+M	-	2500	TL	-	-	-	0.006876	3.05	-	-	-	0.85	-
Mater and Bayhan (1999)	Izmir Bay (Aegean Sea)	F+M	I-III	364		-	-	1.009-1.220	0.0045	3.3591	18.89	0.136	5.824	-	
Mater and Bayhan (1999)	Izmir Bay (Aegean Sea)	M	I-III	-			-	-	-	-	19.90	0.114	-6.335	-	
Mater and Bayhan (1999)	Izmir Bay (Aegean Sea)	F	I-III	-		-	-	-	-	-	17.38	0.18	-5.015	-	
Karakayic and Togulga (2000)	Izmir Bay (Aegean Sea)	F+M	I-IV	332		9.3-14.3	6.89-36.8	0.99-1.11	0.0062	3.214	-	-	-	-	
Quintinella and Perez (2000)	North Atlantic Spanish		IX												
Silva (2003)	N. Atlantic-W. Medit.	F+M	1-X	2375		12.0-24.7									
Voulgaridou and Stergiou (2003)	Eastern Mediterranean			51246					0.0050	3.153	20.80	0.86		0.894	
Koutrakis and Tsikliras (2003)	Ionian Sea	-	-	-		-	-	-	-	2.75	-	-	-	-	-
Mendes *et al*. (2004)	Portuguese West Coast	F+M	-	304	TL	16.9-23.7	38.0-150.0	-	0.0092	2.980				0.761	
Sinovčić *et al*. (2004)	Adriatic Sea	M	-	1590		7.5-18.4	2.32-45.23	-	0.0038	3.23	-	-	-	0.983	
Sinovčić *et al*. (2004)	Adriatic Sea	F	-	1343		7.3-19.3	2.6-45.03	-	0.0034	3.27	-	-	-	0.9816	
Sinovčić *et al*. (2004)	Adriatic Sea	F+M	-	4441		5.5-19.3	1.77-45.2	-	0.0040	3.22				0.981	
Santoyanni *et al*. (2005)	Adriatic Sea		0-6												
Mustac and Sinovčić (2007)	Adriatic Sea	F+M	-	1292	TL	13.0-19.0	16.72-51.45	-	0.0261	2.5538	-	-	-	0.6976	-
Sinovčić *et al*. (2009)	Off Dugi Otok			105	TL	13.5-17.5			0.004	3.214				0.928	
Sinovčić *et al*. (2009)	Zrmanja River Estuary			194	TL	7.5-19.5			0.003	3.319				0.919	
Sinovčić *et al*. (2008)	Krka River (Croatia)	unidentified	-	656	TL	-	-	-	0.0063	3.0143					
Sinovčić *et al*. (2008)	Krka River, (Croatia)	M	-	220	TL	7.2-12.1	-	-	0.053	3.0746				0.9188	
Sinovčić *et al*. (2008)	Krka River, (Croatia)	F	-	249	TL	7.2-12.5	-	-	0.034	3.2657				0.9177	
Sinovčić *et al*. (2008)	Krka River, (Croatia)	F+M	-	1125	TL	4.9-12.5	1.01-11.18	-	0.007	2.9587				0.9626	
Silva *et al*. (2008)	Aegean Sea	F+M	1-4	69	TL	11.0-16.0									
Silva *et al*. (2008)	N. Atlantic-W. Medit.	F+M	0-14	3827	TL	11.0-27.2									2.20-2.67
This study (2005-2006)	Edremit Bay	F+M	I-III	503	FL	8.7-14.3	7.05-32.66	0.65-2.10	0.0274-0.0435	2.642-2.455	15.23	0.47	1.21	0.6269-0.6396	2.04

Table IV. - Spawning seasons of *S. pilchardus* at various localities and average temperatures according to previous studies.

References	Months												Locality
	J	F	M	A	M	J	J	A	S	O	N	D	
Ré *et al*. (1990)	–	–	–							–	–	–	Portugal
Hossucu (1992)	–	–	–	–	–						–	–	Izmir Bay
Sola *et al*. (1992)	–	–	–	–	–	–	–			–	–	–	Cantabrian Sea
Cihangir, 1996	–	–	–	–	–				–	–	–	–	Aegean Sea
Karakayis and Togulga (2000)	–	–	–	–						–	–	–	Izmir Bay
Guisande *et al*. (2001)			–	–									Atlantic-Iber.
Zwolonski *et al*. (2001)	–	–	–	–					–	–	–	–	Portugal
Tekinay *et al*. (2002)	–	–	–	–					–	–	–	–	Dardanels
Ettahiri *et al*. (2003)	–	–	–							–	–	–	Northern Atlantic
Voulgaridou and Stergiou (2003)	–	–	–	–						–	–	–	Thermaikos Gulf
Stratoudakis *et al*. (2004)	–	–	–							–	–	–	Northern Atlantic
Bellier *et al*. (2004)		–	–	–	–	–	–	–	–	–	–		Biscay Bay
Tsikliras and Antonopoulou (2006)	–	–	–							–	–	–	NorthernMedit.Sea
Silva *et al*. (2006)	–	–	–	–	–						–	–	NorthernAtlantic
Amenzoui *et al*. (2006)	–	–	–	–	–	–	–			–	–	–	Morocco
This study (2005-2006)	–	–	–	–	–				–	–	–	–	Edremit Bay

Table V. - Total (Z), natural (M) and fishing (F) mortality rate and the exploitation ratio (E) of *S. pilchardus* in this and previous studies.

Literature	Z	M	F	E
Zupanovic (1955)			0.17	
Sinovcic (1986)		0.5		
Sinovcic (1991)		0.3		
Pertierra and Perrotta (1993)		0.29-0.62		
Voulgaridou and Stergiou (2003)	5.65	1.34	4.31	0.77
Santoyanni *et al*. (2005)		0.5		
This study (2006)	0.94	0.64	0.30	0.32

Tesch, 1978). In addition, changes in fish shape, physiological conditions, different amounts of food available, life span or growth increments can all affect the *b* growth exponent (Frost, 1945; Treer *et al*., 1998, 1999; Koc *et al.,* 2007). Changes in fish shape, physiological changes, hydrological environmental conditions, different food availability during life span, growth increment can all affect growth exponent *b* (Sinovčić, 2000). The *b* values in fish differ according to species, sex, age, seasons and feeding (Ricker, 1975; Bagenal and Tesch, 1978).

The theoretical maximal length of 15.23 is realistic because the largest specimen sampled during the survey was 14.3 cm. The maximal recorded lengths prior to our study are given in table III. Weight-at-age estimates were more variable as a measure of growth length estimates.

Geographic location and environmental conditions such as temperature, organic matter, quality of food, time of capture, stomach fullness, disease, parasitic loads (Bagenal and Tesch, 1978), temperature, organic matter, quality of food and the water system in which the fish live (Wootton, 1992; Treer *et al.,* 1998, 1999) can also effect weight-at-age estimates.

In our estimations, the asymptotic fork length of sardine was L_∞ = 15.23 and K value was 0.47 for all individuals, indicating that sardine is a fast growing species in Edremit Bay. The estimations of L_∞ and K values in relevant literature are shown in table III. A trade-off between growth rate (K) and maximum size (L_∞) is often found. The trade off is influenced by several factors, like temperature, mortality or food availability. Increased food availability causes a shift towards larger maximum size, but may not increase growth rate (Tserpes and Tsimenides, 2001). Growth performance index of *Sardina pilchardus* estimated in this study (Φ = 2.04) confirms the relevant literature (Tab. III).

Our findings in CF are higher than those estimated in the literature (Tab. III). Edremit Bay, in the northern Aegean Sea, is a place where two currents meet and is rich in plankton because of upwelling. In addition, the area is fed by waters rich in nutrient from erosion through the Sea of Marmara and the Black Sea. With these facilities, Edremit Bay has a high potential for sea food, especially fish (Bilecik, 1989; Togulga, 1997). It can be pointed out that sardine in the Edremit Bay was in good condition.

In the present study, the mean monthly gonadosomatic index values were the highest in February for Edremit Bay population (Fig. 4). Spawning occurred between September and May. Spawning seasons in Edremit Bay are in accordance with relevant studies, except for those of Guidande *et al*. (2001) in Atlantic-Iberian Peninsula. Due to different ecological and climate conditions, the starting and finishing time of reproduction may include different months. Spawning periods of fish vary with respect to their species; the ecological characteristics of fish are determined by such ecological differences as stagnant or running water, as well as altitude, temperature and quality of food (Nikolsky, 1963) (Tab. IV).

The high exploitation rate (E = 0.76) estimated for the study period in the northwest Aegean Sea, indicated that intensive fishing, by removing the largest individuals, may be implicated in such a decline in maximal and mean TL of sardine during 1996-2000 (Voulgaridou and Stergiou, 2003) (Tab. V). The exploitation rate for the studied period (E = 0.30), which is lower than the expected optimal exploitation level (E = 0.50), revealed light to moderate exploitation of stocks in the studied area.

As a conclusion, our results lead to consider that the efficient management of the fisheries of small pelagic species along Edremit Bay would be obtained by creating marine protected areas on spawning grounds and in directing fishing efforts farther offshore. The fisheries strategy should be planned so that the fishing period follows the reproductive period.

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