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Age, growth, length-weight relationship and reproduction of the striped seabream (*Lithognathus mormyrus* L., 1758) (Sparidae) in the Beymelek Lagoon (Antalya, Turkey)

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Abstract: Age, growth, length-weight relationship and reproduction were investigated for striped seabream (*Lithognathus mormyrus* L., 1758) collected from Beymelek Lagoon (Antalya, Turkey) between February 2006 and January 2007. The ages of striped seabream ranged from 0 to 3 years for males and from 0 to 4 years for females. Their total lengths and weights ranged between 14.4 and 26.4 cm and 42 and 297 g for males and 14.3 and 27.4 cm and 40 and 329 g for females, respectively. The growth parameters of the von Bertalanffy equation were: L_∞ = 28.3 cm, K = 0.456 year^{-1} and t_0 = -1.859 year for males, L_∞ = 28.1 cm, K = 0.466 year^{-1}, and t_0 = -1.982 year for females and L_∞ = 31.5 cm, K = 0.319 year^{-1} and t_0 = -2.201 year for all individuals (male, female, and immature). The fitted length-weight relationships of males and females were $W = 0.0089 \times L^{3.1599}$ (r^2 = 0.9591) and $W = 0.0076 \times L^{3.2187}$ (r^2 = 0.8982), respectively. Weight increased positive allometrically with the total length for males, while isometrically for females. First sexual maturity length was determined as 17.8 cm for male and 18.5 cm for female striped seabream in Beymelek Lagoon. According to trends of GSI values, it was assumed that the spawning was in April and May.

Key words: Beymelek Lagoon, *Lithognathus mormyrus*, age, growth, length-weight relationship, reproduction

Beymelek Lagünü'ndeki (Antalya, Türkiye) mırmır (*Lithognathus mormyrus* L., 1758) (Sparidae) balıklarında yaş, büyüme, boy-ağırlık ilişkisi ve üreme

Özet: Şubat 2006 - Ocak 2007 tarihleri arasında Beymelek Lagünü'nden yakalanan mırmır balıklarının (*Lithognathus mormyrus* L., 1758) yaş, büyüme, boy-ağırlık ilişkisi ve üremesi incelenmiştir. Mırmır balıklarının yaşları erkekler için 0 ile 3, dişiler için 0 ile 4 arasında değişmiştir. Total boy ve ağırlıkların da erkekler için 14,4-26,4 cm ve 42-297 g, dişiler için 14,3-27,4 cm and 40-329 g arasında değiştiği saptanmıştır. Von Bertalanffy büyüme denkleminin parametreleri erkekler için L_∞ = 28,3 cm, K = 0,456 yıl^{-1} ve t_0 = -1,859 yıl, dişiler için L_∞ = 28,1 cm, K = 0,466 yıl^{-1} ve t_0 = -1,982 yıl ve tüm bireyler (erkek, dişi ve eşeysel olgunluğa erişmemiş) için L_∞ = 31,5 cm, K = 0,319 year^{-1} and t_0 = -2,201 şeklinde bulunmuştur. Boy-ağırlık ilişkisi ise erkek ve dişi bireyler için sırasıyla $W = 0{,}0089 \times L^{3.1599}$ (r^2=0,9591) ve $W = 0{,}0076 \times L^{3.2187}$ (r^2=0,8982) olarak belirlenmiştir. Ağırlığın boy ile erkek bireylerde positive allometrik, dişi bireylerde ise isometric olarak arttığı saptanmıştır. İlk eşeysel olgunluk boyu erkeklerde 17,8 cm, dişilerde 18,5 cm olarak bulunmuştur. Üremenin ise, GSI değerlerinin seyrine göre Nisan ve Mayıs ayında gerçekleştiği tahmin edilmiştir.

Anahtar sözcükler: Beymelek Lagünü, *Lithognathus mormyrus*, yaş, büyüme, boy-ağırlık ilişkisi, üreme

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Introduction

The striped seabream, *Lithognathus mormyrus* (Linnaeus, 1758), is a marine fish belonging to the Sparidae family. It is a demersal species living in groups over various types of sea bottoms, especially rocky, sandy, and seagrass beds at depths ranging from 0 to 50 m (Pajuelo et al., 2002). This species is common in the Mediterranean Sea, the Atlantic Ocean from the Bay of Bicay to the cape of Good Hope, the Red Sea, and the south-western Indian Ocean (Kallianiotis et al., 2005). It is a gregarious species, entering exceptionally in coastal lagoons (Bauchout and Hureau, 1986; Suau, 1970; Tortonese, 1975). This species reproduce in the sea. In the summer period, especially young individuals enter into Beymelek Lagoon and adults of which migrate to sea in the following spring.

The striped seabream is a protandric hermophrodite fish (Bessau, 1990). Aspects of its reproduction, age, and growth have been studied in the northern and middle Adriatic Sea (Kraljevic et al., 1995; 1996), in eastern Spanish coastal waters (Suau, 1955; 1970), in the central-east Atlantic (Lorenzo et al., 2002; Pajuelo et al., 2002), and in the coastal waters of the Thracian sea (Kallianiotis et al., 2005). This species is commercially valuable and an important catch for the coastal and lagoon fisheries in Turkey. However, it has never been investigated in the lagoons of Turkey. Information published on its biologic characteristics on the coastal Turkey is also very scarce; only one study was published from Turkish coastal waters (Turkmen and Akyurt, 2003). Our study investigates aspects of the biology of the striped seabream in Beymelek Lagoon including age, growth, sexual maturity, spawning period, and sex inversion, which may be used to develop a management strategy for the species.

Materials and methods

Beymelek Lagoon is situated on Turkey's western Mediterranean coast (30°04′E and 36°16′N) and has a surface area of 255 ha. Its mean temperature and salinity are 22.4 °C and 12.8 psu, respectively. Samples were collected monthly using a variety of gillnets (stretched mesh sizes 40, 44, and 50 mm) and trammel nets (mesh sizes 56, 60, 70, and 80 mm) at 3 locations of Beymelek Lagoon (Figure 1) from February 2006 to January 2007.

For each fish, the total length (L, mm) and the total weight (W, 0.1 g) were measured. The sex of all specimens was recorded by macroscopic examination of the gonads as male, female, or immature. Thereafter, each gonad was removed from fish and weighed (W_G) to 0.01 g. Finally, about 10-15 scales were taken from each individual and stored dry in paper envelopes with a code number.

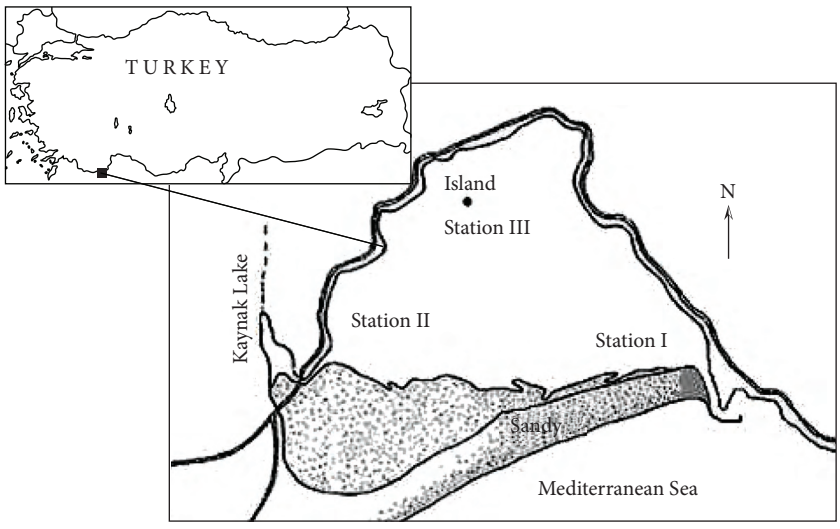

Figure 1. Sampling stations in Beymelek Lagoon.

Based on the time of spawning, April 1 was assumed to be the birth date of the striped seabream. The age was determined by scale reading (Lagler, 1966). Firstly scales were soaked in 4% KOH solution for 24 h. Then they were rinsed with distilled water and subsequently put in 96% alcohol for 15-20 min. Scale reading was carried out using a binocular microscope under reflected light at 10-25× magnification. Scales of each fish were read 3 times by the authors, and reading for a given fish scales was accepted only when 2 readings agreed. The von Bertalanffy growth equation was used to describe the growth of male, female, and all (male, female, and immature) striped seabream (Pauly, 1984; Sparre and Venema, 1998): $L_t = L_\infty \times [1\text{-}\exp(-K \times (t\text{-}t_0))]$; where L_t is the total length at-age t, K is the growth rate coefficient, L_∞ is the asymptotic length, and t_0 is the theoretical age at length zero. Growth parameters were estimated by using the regression method. Differences of growth parameters between sexes were compared with the T^2 test of Hotelling (Bernard, 1981).

To compare the growth parameters obtained in this study with those reported by other authors for the same species, the growth performance index (Φ) was used (Munro and Pauly, 1983): $\Phi = \text{Ln}(k) + 2 \times \text{Ln}(L_\infty)$; where k is the growth coefficient, and L_∞ is the asymptotic length.

The length-weight relationship was calculated by the equation $W = a \times L^b$; where W is the total body weight (g), L is the total length (cm), a is a coefficient related to the body form and b is exponent indicating isometric growth when equal to 3 (Wootton, 1990; Anderson and Neumann, 1996). Parameters a and b were estimated by linear regression on the transformed equation: $\text{Log}_{10}(W) = \log_{10} a + \log_{10}(L)$.

In order to determine the length at first maturity (the length at which 50% of the fish had become mature) only individuals collected during the spawning period were used. A logistic curve was fitted to the proportion of sexually mature individuals by length and the parameters were estimated using the least square method applied to a non-linear fit (King, 1995).

Growth parameters, growth performance index, and length-weight relationship were determined separately for males, females and all individuals. All individuals included male, female, and immature individuals.

The reproductive period was determined by analysing the monthly variation in the gonadosomatic index [$GSI = (W_G / W) \times 100$]. Correlation between GSI and temperature was tested using the Spearman rank correlation coefficient (r_s) (Zar, 1999).

Results

Age and growth

A total of 339 striped seabream were investigated of which 109 were immature and in the age of 0 or 1. Their age-length-keys are presented in Table 1. The ages of the mature striped seabream ranged from 0 to 3 years for males and from 0 to 4 years for females. Most mature fish were observed in age 1 for both males and females. The number of fish decreased with increasing age.

Growth parameters determined for male, female, and all individuals (male, female, and immature) are presented in Table 2. Growth parameters of males and females were similar (Hotelling's T^2 test; $P > 0.05$). However, asymptotic length (L_∞) of all individuals was higher than those of males and females, while growth coefficient (K) was lower. Similarly, growth performance index (Φ) of all individuals (male, female, and immature) was also lower than those of males and females.

Length-weight relationship

Total lengths and total weights of striped seabream ranged from 14.4 to 26.4 cm and from 42 to 297 g for males, from 14.3 to 27.4 cm and from 40 to 329 g for females, and from 12.5 cm to 18.4 cm and from 35 to 88 g for immature individuals, respectively (Figure 2). In general, males were predominant in the smaller lengths and females in larger lengths (Figure 3).

The parameters of lenght-weight regressions for male, female, and all individuals are presented in Table 3. The slope (b value) of the length-weight regressions differed significantly between males and females (t-test; $P<0.05$). Furthermore, the slope of the lenght-weight relationship was not significantly different (χ^2-test; $P < 0.05$) from the theorethical value of 3 for females and all individuals, but different for males. These results showed that growth was

Table 1. Age-length-keys of immature (I), male (M) and female (F) striped seabream from Beymelek Lagoon.

Age	0			1			2		3		4		
L (cm)	I	M	F	I	M	F	M	F	M	F	M	F	Total
12-13	11			8									19
14-15	48	1	6	14	2								71
16-17	25	1	2		3								31
18-19	3		3		5	6							17
20-21			2		31	53	4	5					95
22-23					12	23	12	25	1	1			74
24-25						3	5	5	2	6			21
26-27								1	2	7		1	11
Total	87	2	13	22	53	85	21	36	5	14	0	1	339
$\bar{L}$	14.8	16.2	17.2	13.5	20.7	21.5	23.1	23.0	25.2	25.6		27.4	19.7
SD	0.8	0.6	2.2	0.5	1.8	1.1	1.1	1.2	1.3	1.0		-	3.6
Min.	12.5	15.7	14.3	12.5	14.4	18.3	21.2	20.3	23.3	23.5		-	12.5
Max.	18.4	16.6	21.5	14.5	23.5	24.2	24.7	26.0	26.4	27.0		-	27.4

Table 2. Parameters (L_∞, K, and t_0) of the von Bertalanffy growth curve and growth performance indexes (Φ) for male, female, and all (male, female, and immature) striped seabream in Beymelek Lagoon.

Sex	N	L∞ (cm)	K (year^{-1})	t_0 (year)	Φ
Male	81	28.3	0.456	-1.859	5.900
Female	149	28.1	0.466	-1.982	5.908
All	339	31.5	0.319	-2.201	5.757

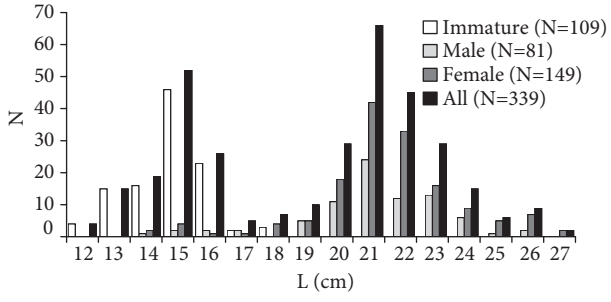

Figure 2. Length-frequency distribution of striped seabream from Beymelek Lagoon.

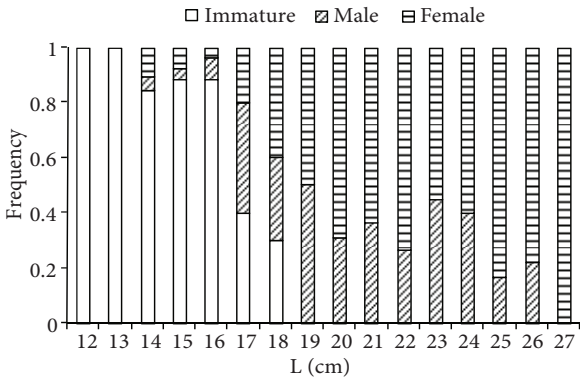

Figure 3. Frequency of immature, male, and female striped seabream in Beymelek Lagoon by length.

Table 3. Parameters of length-weight relationship for male, female, and all (male, female, and immature) striped seabream in Beymelek Lagoon.

Sex	N	a	b	S.E.(b)	r^2	95% C.I.
Male	81	0.0089	3.1599	0.0738	0.9591	2.8554-3.1446
Female	149	0.0076	3.2187	0.1263	0.8982	2.7524-3.2476
All	339	0.0132	3.0362	0.0490	0.9714	2.9040-3.0960

isometric for females and all individuals, but positive allometric for male striped seabream in Beymelek Lagoon. The curves of length-weight relationships for male, female, and all individuals (male, female, and immature) are presented in Figure 4.

Sex ratio and first sexual maturity length

Of the total 339 individuals examined, 81 (23.9%) were males and 149 (44.0%) females. The sex of the remaining 109 (32.1%) individuals could not be identified macroscopically because they had thin and translucent gonads and so were classified as immature. The overall ratio of males to females 1:1.84 and χ^2- test revealed that this ratio was significantly different from the theoretical 1:1 sex ratio ($P < 0.05$). During the study, no intersexual striped individual was observed.

The first sexual maturity total length (L_m) was determined as 17.8 and 18.5 cm for males and females, respectively. Percentages of male and female mature striped seabream for different lengths calculated using the formula $P_L = 100 / [1 + e^{-0.7194 \times (L - 17.8)}]$ and $P_L = 100 / [1 + e^{-0.8047 \times (L - 18.5)}]$are presented in Figures 5 and 6.

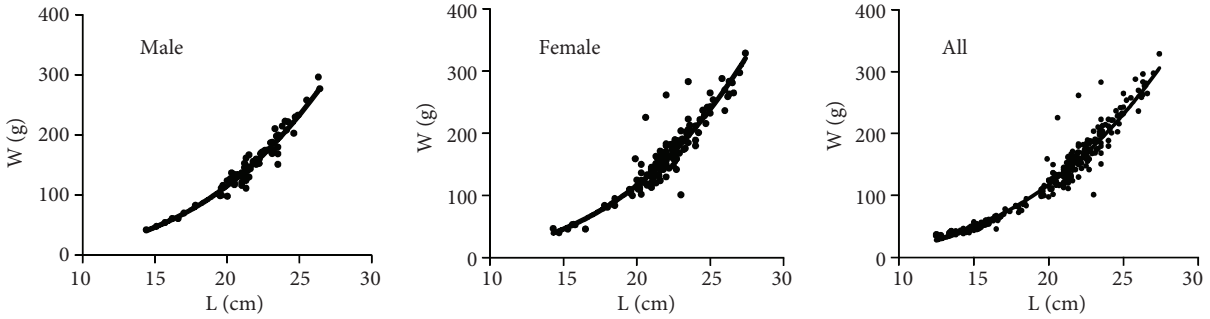

Figure 4. Length-weight relationships of male, female, and all (male, female and immature individuals) striped seabream from Beymelek Lagoon.

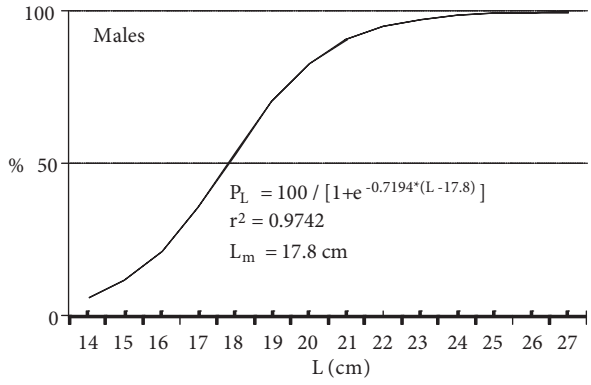

Figure 5. Sexual maturity ogive of male striped seabream from Beymelek Lagoon.

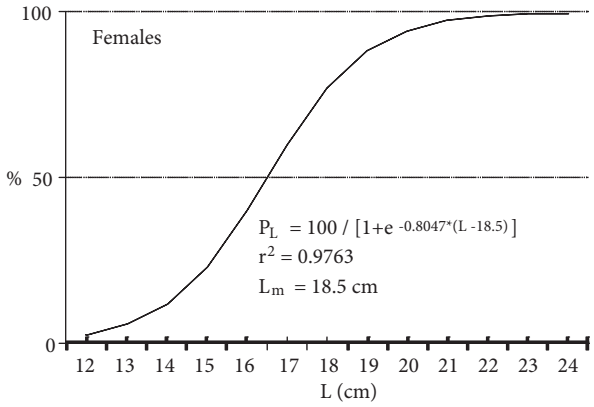

Figure 6. Sexual maturity ogive of female striped seabream from Beymelek Lagoon.

Spawning season

The highest GSI (6.438) occurred in April (22.1 °C) and it declined sharply from April to May (27.1 °C) and June (29.5 °C) as seen in Figure 7. According to the variations of GSI values, it was assumed that the spawning period was between April and May.

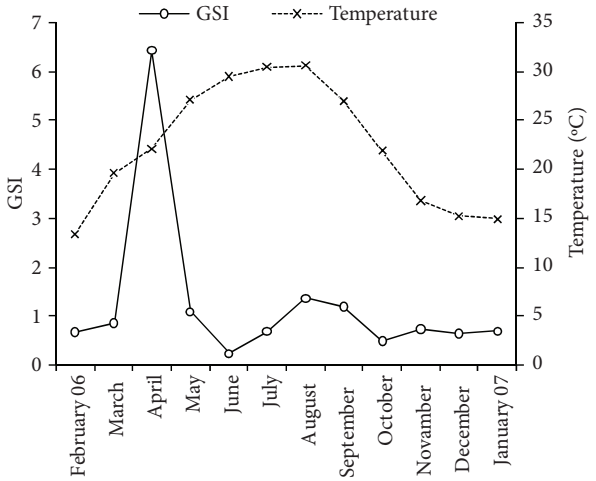

Figure 7. Monthly variation of the gonad somatic index (GSI) for female striped seabream and water temperature in Beymelek Lagoon.

Discussion

The population structure analysis provides a valuable insight into the migration strategies of sparid fish coastal lagoons (Mariani, 2006). About 70% of the striped seabream were at the age of 0 or 1 in Beymelek Lagoon. The maximum age was also determined as 3 years for males and 4 years for females. Whereas the maximum age was reported as 7 years in the Spanish Mediterranean coast (Suau, 1970), 12 years in the Northern Adriatic (Kraljević et al., 1996), 8 years off the Canary Islands (Pajuelo et al., 2002), 10 years off the Canary Islands (Lorenzo et al., 2002), 7 years in İskenderun Bay (Turkmen and Akyurt, 2003), and 11 years in the coastal waters of the Thracian Sea (Kallianiotis et al., 2005). This difference may be due to the characteristics of the study areas since all of the other maximum ages reported above were for populations living in the sea. It is generally known that lagoons are preferred especially by young individuals of many fish species.

The *K* and *Φ* values of males and females were similar and they were higher than those of all individuals (male, female, and immature). Especially K value may be affected by many ecological factors. These results showed that immature individuals' growth was slower compared to mature individuals in Beymelek Lagoon. On the other hand, the asymptotic length (L_∞ = 31.5 cm) was found similar to values estimated by Suau (1970), Turkmen and Akyurt (2003), and Kallianiotis et al. (2005), but smaller than those estimated by Kraljević et al. (1996), Erzini et al. (2001a), and Lorenzo et al. (2002). Both growth rate (K = 0.319 year^{-1}) and growth performance index (Φ = 5.803) of the striped seabream in Beymelek Lagoon grow faster than values reported by the other authors for some populations of the same species (Table 4). Compared to the results of the same species in other regions, it was shown that striped seabream in

Table 4. Growth parameters of von Bertalanffy and growth performance indices reported for the same species in other regions.

Locality	L_∞ (cm)	K (year^{-1})	t_0 (year)	Φ	Author
Castellón coast (East Spain)	33.3	0.275	-0.057	5.720	Suau (1970)
Northern Adriatic	40.1	0.196	-0.945	5.753	Kraljević et al. (1996)
Southern coast of Portugal	35.3	0.26	-0.81	5.781	Erzini et al. (2001a)
Off Canary Islands	42.7	0.188	-1.37	5.846	Lorenzo et al. (2002)
Thracian Sea	30.9	0.21	-0.996	5.301	Kallianiotis et al. (2005)
İskenderun Bay	32.6	0.136	-2.12	4.974	Turkmen and Akyurt (2003)
Beymelek Lagoon	31.5	0.319	-2.201	5.803	The present study

Beymelek Lagoon grow faster than the other populations. It is known that lagoons are highly productive systems (Kapetsky, 1984; Labourg et al., 1985). Kjerfve (1994) pointed that lagoons often exhibit very high primary and secondary production rates and are valuable for fisheries. This is probably related to environmental conditions, such as temperature, salinity, and food ability. Especially temperature has been shown to be a major influence on fish growth. Temperatures recorded in Beymelek Lagoon were higher than 15 °C (except for February = 13.4 °C) during a year. Minimum and maximum temperature in Beymelek Lagoon were determined 13.4 °C (February) and 30.5 °C (July and August). Annual mean water temperature was determined as 22.4 °C in Beymelek Lagoon. This value is very high for sea and oceanic areas. Although high temperatures can encourage growth, temperatures above a certain limit will stress fish and may also be associated with low oxygen levels.

In Beymelek Lagoon, although female individuals grow isometrically, male individuals grow positive allometrically. The length-weight relationship may be influenced by sex, maturity, geographical location, and environmental conditions (Bagenal and Tesch, 1978; Balon, 1984).

Isometric growth was determined for the striped seabream population (all individuals) in Beymelek Lagoon. For the same species, similar results were reported by Santos et al. (2002) in the Algarve coast (b = 3.020), Turkmen and Akyurt (2003) in Iskenderun Bay (b = 3.046), Morey et al. (2003) off Balearic Islands and in the Iberian coast (b = 3.0327), Mariani (2006) in Fagliano Lagoon (b = 2.85) and in Caprolace Lagoon (b = 3.04) and Gökçe et al. (2007) in the Northern Eagean (b = 3.10). The growth of striped seabream off the Canaries Islands (b = 2.9071) was allometric (Lorenzo et al., 2002). According to Kallianiotis et al. (2005), the growth was allometric for immature individuals (b = 3.342), and isometric for matured individuals (b = 2.960) in the Thracian Sea.

The overall ratio of males to females (1:1.84) agree with the results reported in the Thracian Sea (Kallianiotis et al., 2005), Northern Adriatic (Kraljević et al., 1996) and off Canary Islands (Pajuelo et al., 2002), while the ratio of males were higher in İskenderun Bay (Turkmen and Akyurt, 2003) and off Canary Islands (Lorenzo et al., 2002). These differences may be due to the sampling methods. The sex ratio of this species, which is hermaphroditic (Suau, 1970; Kraljević et al., 1996) may alter with fish size as small individuals are usually male whilst larger fish are female (Figures 3 and 5).

First sexual maturity lengths (17.8 cm for males and 18.5 cm for females) were similar to values reported by Kallianiotis et al. (2005) in the Thracian Sea. However, it was higher than those in the seuthern coast of Portugal (16.1 cm) (Erzini et al., 2001b) and in İskenderun Bay (13.9 cm) (Turkmen and Akyurt, 2003). Minimum mesh size of the nets using in the commercial fishing in Beymelek Lagoon was 60 mm. The rate of immature striped seabream captured in our experimental nets having mesh size of 60 mm and above was very low. Therefore, the mesh size of nets used in the commercial fishing is suitable to protect immature individuals. It was determined that the striped seabream in Beymelek Lagoon spawn earlier (April) than in the southern coast of Portugal (from August to September) (Erzini et al., 2001b), İskenderun Bay (from April to the begining of August) (Turkmen and Akyurt, 2003), and the Thracian Sea (from May to September) (Kallianiotis et al., 2005). This difference may be attributed especially to environmental factors. According to Wootton (1990), temperature appears to be the most important factor among those that may influence the reproduction of fishes.

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