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RESEARCH ARTICLE

Age, growth and reproduction of *Mullus surmuletus* (Linnaeus, 1758) in Saros Bay (Northern Aegean Sea)

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Abstract

The age, growth, reproduction of *Mullus surmuletus*, caught in Saros Bay (North Aegean Sea) between November 2006 and June 2008, were investigated. The female-male ratio was 1.6:1. The total length (weight) of females ranged from 11.0 cm to 26.8 cm (15.3 g to 235.1 g) and of males from 11.8 cm to 19.8 cm (19.1 g to 91.2 g). The growth parameters for females were calculated as L_{∞}=28.38 cm K=0.19 year^{-1}, t_0=-2.16 year and for males L_{∞}=26.94 cm, K=0.20 year^{-1}, t_0=-2.34 year. The length at first maturity for females and males was 13.7 cm and 13.2 cm, respectively. Monthly values of the gonadosomatic index indicated that spawning occurred mainly between April and May.

Key words: *Mullus surmuletus*, age, growth, reproduction.

Introduction

The red mullet (*Mullus surmuletus*) is a major target species of Mediterranean demersal fisheries (Reňones *et al.* 1995; Mehanna 2009) and encountered in shallower soft bottoms, seagrass beds and rocky bottoms (Lombarte *et al*. 2000; Bautista-Vega 2008). This species is benthic carnivores and feed on small invertebrates (Gharbi and Ktari 1981b; Golani and Galil 1991; Mehanna 2009; N Da 1992; Labropoulou and Eleftheriou 1997; Vassilopoulou *et al.* 2001).

Several aspects of the red mullet biology have been studied, including feeding, reproduction, age and growth (Andaloro 1981; Morales-Nin 1986; 1991). The information on its dynamics and management, however, is very limited. There have been studies on the growth (Campillo 1992; Vassilopulou and Papaconstantinou 1992; Reňones *et al.* 1995; Pajeulo *et al.* 1997; Stergiou *et al.* 1997; Mehanna 2009), reproduction (Morales-Nin 1991; Campillo 1992; Renones *et al.* 1995) and feeding (Labropoulou *et al.* 1997; Vassilopoulou *et al.*

2001; El Bakali *et al.* 2010). In Turkish waters there are only a few studies on this species that refer to some aspects of their biology and length-weight relationship (Moldur 1999; Karakulak *et al.* 2006; Özaydın *et al.* 2007; İlhan *et al.* 2009; Üstün 2010). In particular, there is data deficiancyon the biology of *M. surmuletus* in the North Aegean Sea and Saros Bay.

The aim of this paper is, therefore, to describe the growth, reproduction and length-weight relationship of *M. surmuletus* in the North Aegean Sea. The result of the present work will contribute to the knowledge about the age composition and growth of *M. surmuletus* and also to better understanding of its role in the ecosystem. Consequently, this study will be a step forward to the improvement of the fisheries assessment and management of *M. surmuletus* in this area.

Materials and Methods

A total of 656 *M. surmuletus* specimens were collected between November 2006 and June 2008 from monthly samples at depths ranging from 0 to 500 m (0-50, 50-100, 100-200, 200-500 depth contour) in Saros Bay, Aegean Sea, using a commercial bottom trawl net (Figure 1). A total of 184 hauls were analyzed during the sampling period. At each station a bottom trawl net with a 44 mm stretched mesh size at the cod-end was towed for 30 minutes at the velocity of approximately 2.5 knots h^{-1}.

A subsample was taken from monthly samples for the biological examination later in the laboratory (302 specimens used for age, growth and reproduction). The total lengths (TL) of all fish were measured to the nearest cm and the nearest gram total weight (TW). Gonad weight was determined to the nearest 0.01 g, and the sex of each specimen was determined by examining the gonads macroscopically.

The length-weight relationships were determined according to the allometric equation (Sparre *et al.* 1989): $W = aL^b$, where W is the total body weight (g), L is the total length (cm), while *a* and *b* are constants. Statistical comparison of length-weight relationships between sexes was performed with t-tests (Zar 1999).

The age was determined using the otoliths. Sagitta otoliths were extracted through dissection of the otic bulla, otoliths were then cleaned, labeled and stored in plastic tubes. Whole otoliths (n=302) were examined with a stereomicroscope for the presence of growth bands. Annual rings on the whole otolith were counted in glycerin under Olympus SZX16 Stereomicroscope.

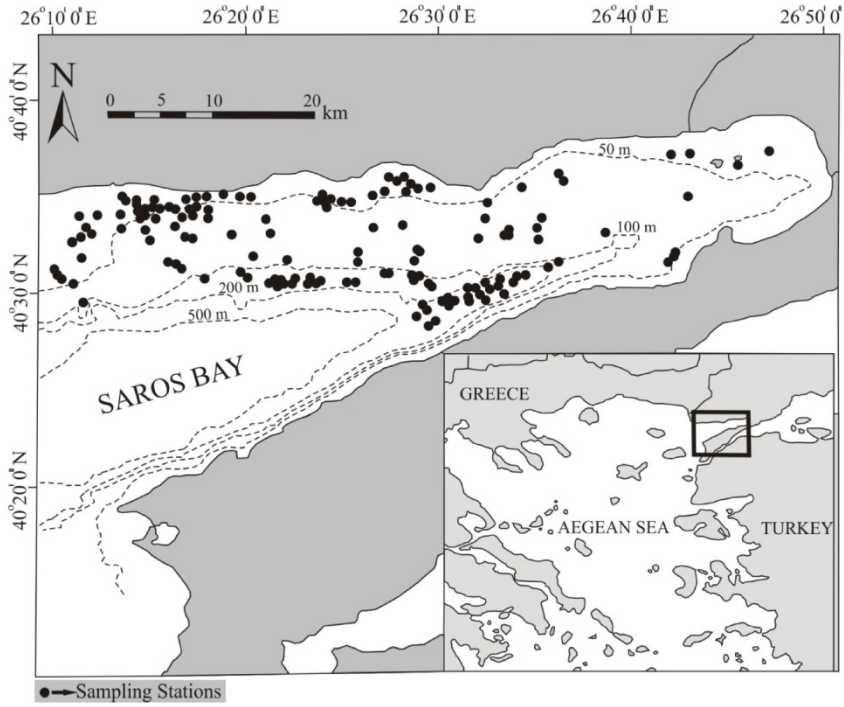

Figure 1. Trawl sampling stations (dots) in Saros Bay, the North Aegean Sea

Growth was expressed in terms of the von Bertalanffy equation (Beverton and Holt 1957): $L_t = L_\infty (1\text{-}e^{-K(t\text{-}t_0)})$, where L_∞ is the asymptotic total length, L_t the total length at age t, K the growth curvature parameter and t_0 is the theoretical age when fish would have been at zero total length. Growth parameters were estimated according to the non-linear method by using the FISAT program package (Sparre *et al*. 1989). Growth parameters obtained for males and females were compared using the multivariate Hotelling's T^2 test (Bernard 1981). For the sake of comparison, the index of overall growth performance Φ', proposed by Pauly and Munro (1984) was used. This test provided an indication of the reliability of age estimates since it had been suggested that phi-prime test values were similar for the same species and genera. The test was based on: $\Phi' = \log K + 2 \log L\infty$ (Piñeiro and Saínza 2003).

The gonadosomatic index (GSI) was calculated monthly by the equation: GSI = (gonad weight/fish weight without gonad)*100. Size at maturity (L_{50}) was defined as the size at which 50% of individuals were mature. Specimens were grouped in 1 cm size classes and the proportion of mature and immature individuals was recorded (Fontana 1969; Cherif *et al*. 2007). The percentages of maturity by length class and sex were fitted to a logistic function using the

Newton algorithm from ® Microsoft excel solver routine: $P(1) = 1/1+e^{-(a+bl)}$ where P(1) is the proportion of mature fish at length 1, and *a* and *b* the parameters of the logistic equation (Piñeiro and Saínza 2003).

Results

The length and weight of the *M. surmuletus* ranged from 9.6 cm to 26.8 cm in total length (TL) and from 9.8 g to 235.1 g in weight, respectively. The total length of females ranged from 11.0 cm to 26.8 cm (15.3 g to 235.1 g) and of males from 11.8 cm to 19.8 cm (19.1 g to 91.2 g) (Table 1). Most fish were 14-15 cm TL, accounting for 50% and 54% of females and males, respectively (Figure 2).

Table 1. Length- weight values of *M. surmuletus* in Saros Bay

Sex	L_{mean}	Min-Max	W_{mean}	Min-Max	N
Female	14.8±0.16	11.0-26.8	40.0±1.77	14.5-235.1	184
Male	14.8±0.15	11.8-19.8	39.3±1.36	19.1-91.2	118
Both*	14.6±0.07	9.6-26.8	38.3±0.71	9.8-235.1	656

*All of the specimens

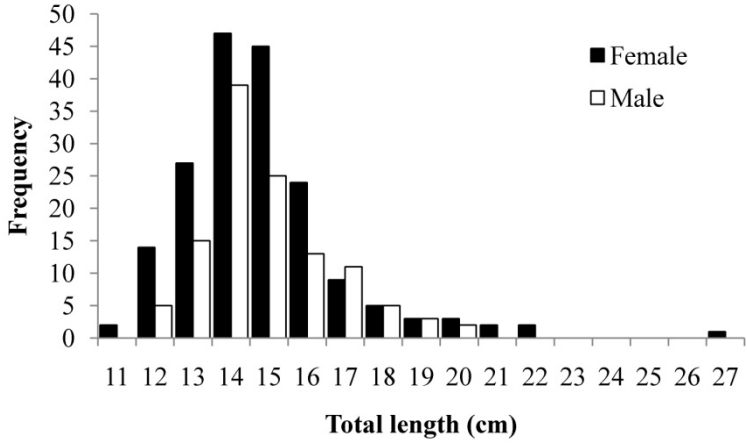

Figure 2. Length-frequency distribution by sex of *M. surmuletus*

Length-weight relationships were separately estimated for males and females.

Males: $W=0.011L^{3.020}$, $r^2=0.951$, n=118

Females: $W=0.007L^{3.162}$, $r^2=0.973$, n=184 (Figure 3)

There were statistically significant differences in length-weight relationships between males and females (d.f=1, f=7,48, P<0,05) (SPSS 18.0). Value of the

exponent *b* was 3.162 (r^2=0.97) for females and 3.020 (r^2=0.95) for males, which indicated a positive allomethric growth.

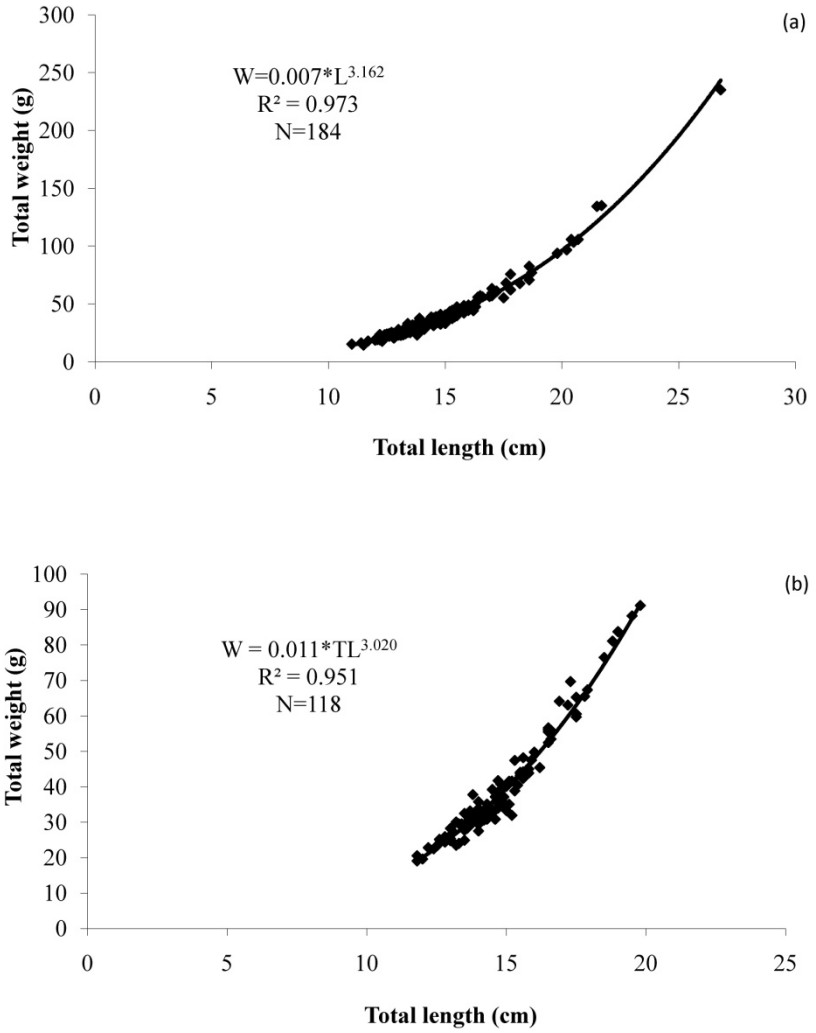

Figure 3. Length-weight relationship of *M. surmuletus*, females (a) and males (b)

The age was determined by counting the annual ring marks on the surface of the otoliths in 272 specimens; and the ring marks were unreadable for other 30 individuals. The von Bertalanffy population growth parameters for *M. surmuletus* were estimated as L_∞=28.38 cm, K=0.19 $year^{-1}$ and t_0=-2.16 year for females, and L_∞=26.94 cm, K=0.20 $year^{-1}$ and t_0=-2.34 year for males (Figure

4). However the comparison of von Bertalanffy growth curves in two sexes by the Hotelling's T^2 test showed no statistically significant difference ($F_{2;209}$=1.212, P>0.05, T^2=0.00013).

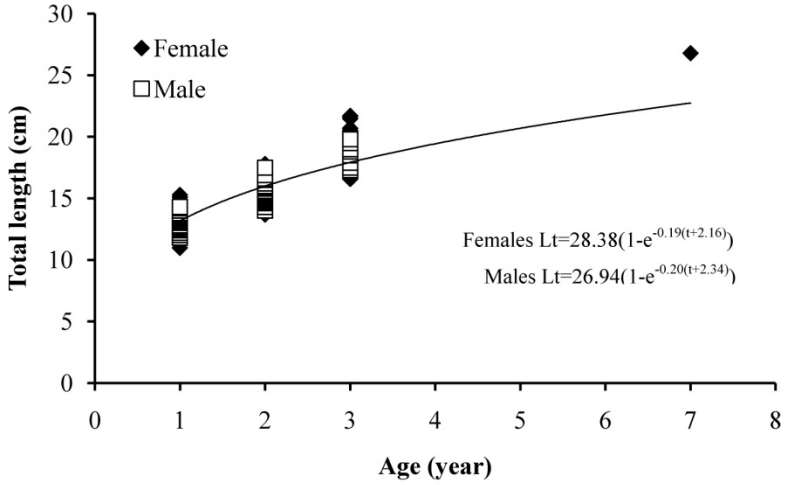

Figure 4. The von Bertalanffy growth curve for female (a) and male (b) of *M. surmuletus*

The calculated growth performance index (φ) was 2.18 for females and 2.16 for males and 2.19 for both combined. This finding is in agreement with the considerable similarity between the growth performance indices (φ) calculated for each sex. In order to compare the growth of the *M. surmuletus* population with others, all available literature data of von Bertalanffy growth parameters and φ values, including results from the present study are compiled (Table 2).

Ages were determined for 124 females, 89 males and 59 specimens unidentified of sex. The maximum age of fish calculated was 7 years for females and 3 years for males (Table 3 and 4). In females, the age group 1 (51 %) and 2 (38 %) were dominant, followed by age groups 3 (10 %) and age group 7 had one specimen (1 %). Likely in males, age group 1 (40 %) and 2 (49 %) were dominant, followed by age group 3 (10 %) (Figure 5).

Among 302 specimens measured, 184 were female and 118 were male. The female-male ratio was 1.6:1. The gonadosomatic index ranged from 0.33% to 0.99%. The GSI values started to increase after the winter months, and then decreased after May (Figure 6).

Table 2. Parameters of von Bertalanffy growth equation (K, L_∞, t_0) obtained by different authors for *M. surmuletus*

Author	Region	Sex	L∞	K	t_0	Φ'
Andalora (1981)	Mediterranean Sea	-	27.60	0.27	0.39	2.31
Gharbi and Ktari (1981b)	Tunus	♀	21.80	0.51	-0.11	2.38
Gharbi and Ktari (1981b)	Tunus	♂	19.90	0.49	-0.03	2.29
Andalora (1982)	Mediterranean Sea	♀	30.10	0.24	-2.68	2.34
Andalora (1982)	Mediterranean Sea	♂	25.00	0.30	-2.39	2.27
Andaloro and Prestipino (1985)	Sicily	♀	27.50	0.45	0.43	2.53
Morales-Nin (1986)	Catalan Sea	-	30.94	0.11	3.85	2.21
Morales–Nin (1991)	Mallorca	-	29.76	0.24	-2.06	2.19
Morales–Nin (1991)	Mallorca	♀	34.53	0.14	-3.82	2.32
Morales–Nin (1991)	Mallorca	♂	23.29	0.29	-3.33	2.18
Campillo (1992)	Lion Gulf	♀	33.40	0.43	-0.60	2.68
Campillo (1992)	Lion Gulf	♂	28.50	0.53	-0.44	2.63
Vassilopou and Papaconstantinou (1992)	Aegean Sea	♀	41.30	0.10	-2.80	2.23
Vassilopou and Papaconstantinou (1992)	Aegean Sea	♂	38.00	0.10	2.76	2.18
Papaconstantinou *et al.* (1994)	Greece	♀	24.80	0.26	-1.58	2.21
Papaconstantinou *et al.* (1994)	Greece	♂	22.00	0.27	-1.46	2.11
Reňones *et al.* (1995)	Majorca	-	31.28	0.21	-2.35	-
Machias *et al.* (1998)	Crete Reef	-	34.50	0.23	-1.19	-
Moldur (1999)	Marmara Sea	♀	34.48	0.21	-2.97	-
Moldur (1999)	Marmara Sea	♂	27.30	0.25	-2.11	-
Moldur (1999)	Marmara Sea	-	32.83	0.23	-2.13	-
Jabeur *et al.* (2000)	Gabes Gulf	♀	21.20	0.43	-0.65	2.29
Jabeur *et al.* (2000)	Gabes Gulf	♂	22.60	0.27	-1.07	2.14
N'DA *et al.* (2006)	Biscay Bay	♀	42.70	0.28	0.641	-
N'DA *et al.* (2006)	Biscay Bay	♂	35.90	0.30	0.74	-
Mehanna (2009)	Egypt	-	31.74	0.47	-0.30	2.67
İlhan *et al.* (2009)	İzmir Bay	-	27.85	0.19	-1.58	2.18
Üstün (2010)	Edremit Bay	-	25.09	0.14	-2.48	-
Present study	Saros Bay	♂	26.94	0.20	-2.34	2.16
Present study	Saros Bay	♀	28.38	0.19	-2.16	2.18
Present study	Saros Bay	Σ	27.82	0.20	-2.16	2.19

Table 3. Age-TL key for all individuals of *M. surmuletus*

TL(cm)	0	1	2	3	4	5	6	7	Total
9-9.9	1								1
10-10.9	1	1							2
11-11.9		9							9
12-12.9		34							34
13-13.9		51	1						52
14-14.9		36	27						63
15-15.9		4	42						46
16-16.9			24	2					26
17-17.9			12	8					20
18-18.9				5					5
19-19.9				6					6
20-20.9				5					5
21-21.9				2					2
26-26.9								1	1
Total	**2**	**135**	**106**	**28**	**0**	**0**	**0**	**1**	**272**

Table 4. The mean lengths by ages of *M. surmuletus*

Age	Male			Female			Both		
	N	TL (cm)	Mean (cm)	N	TL (cm)	Mean (cm)	N	TL (cm)	Mean (cm)
0	-	-	-	-	-	-	2	9.6-10.0	9.8 (±0.20)
1	36	11.8-14.3	13.32 (±0.12)	63	11.0-15.3	13.39 (±0.12)	135	10.8-15.3	13.32(±0.08)
2	44	14.0-17.5	15.47(±0.13)	47	13.7-17.8	15.41(±0.13)	106	13.7-17.8	15.58(±0.09)
3	9	17.2-19.8	18.39(±0.32)	13	16.6-21.7	19.31 (±0.47)	28	16.5-21.7	18.83(±0.28)
4	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-
7	-	-	-	1	26.08	26.08	1	26.08	26.08

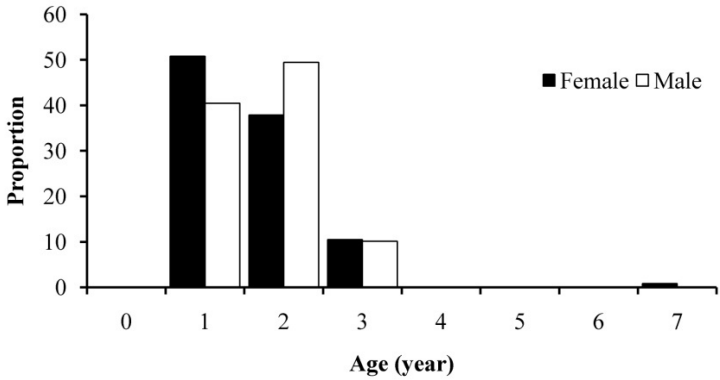

Figure 5. Proportion of ages for female and male of *M. surmuletus*

The gonadosomatic index (GSI) was used to determine the reproductive period, which was calculated from samples taken monthly from males and females. The analysis (two-way t-test) showed statistically significant difference in the GSI values between males and females ($P<0.05$).

Examination of the male and female maturity stages indicated that length at 50% maturity (L_{50}) was 13.7 cm TL for males and 13.2 cm for females (Figure 7).

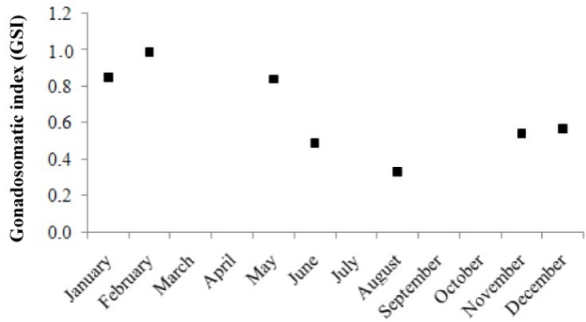

Figure 6. The gonadosomatic index values (GSI) of *M. surmuletus* by month

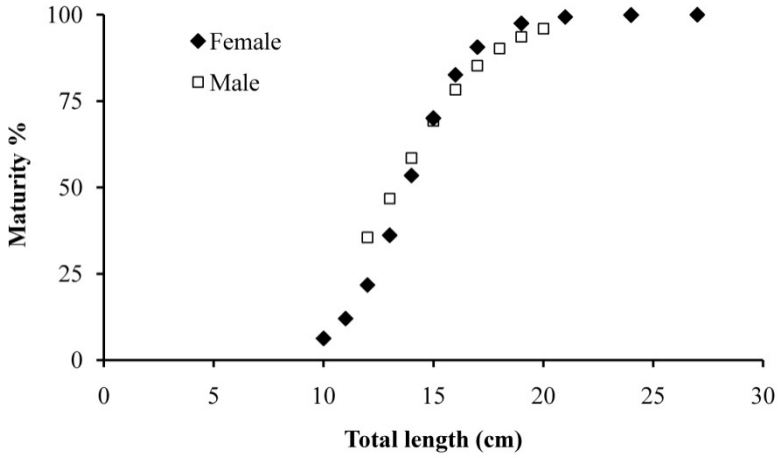

Figure 7. Total length at first maturity for females and males *M. surmuletus*

Discussion

Length-weight relationships are widely available for commercial fishes as they allow easy conversion of length in weight and vice versa (Cherif *et al*. 2007). The same equation is useful for the comparison among geographic regions and for the application of stock assessment models (Kolher *et al*. 1995; Gonçalves *et al*. 1996; Frose and Pauly 1998; Moutopoulos and Stergiou 2002; Cherif *et al*. 2007). The functional regression *b* values (3.16 for females, 3.02 for males) of *M. surmuletus* showedpositive allometric growth for females and males, similar to the results reported in previous studies. The analysis of the length-weight relationships given by several authors show, however, some differences in *b* values (Table 5). Such differences in *b* values can be caused by one or more of the following factors, such as salinity, temperature, sex, food, time of year and stage of maturity (Shepherd and Grimes 1983; Pauly 1984; Cherif *et al*. 2007).

Otolith readings are reliable and valid method for age determination of *M. surmuletus* (Morales-Nin 1991; Mehanna 2009). Sagittal otoliths were used for age determination of *M. surmuletus*. Morales-Nin (1986) used otoliths for age determination and reported that the age composition of *M. surmuletus* caught in the Katalan Sea ranged from 1 to 10 years. In addition, Moldur (1999), İlhan *et al*. (2009) and Üstün (2010) reported a maximum of 5, 6 and 4 years of age for *M. surmuletus* from the Marmara Sea, Aegean Sea and Edremit Bay, respectively.

Maturation during the first year of life is apparently a common trait in both species of *Mullus* (Reňones *et al*. 1995). The results showed that the total length (TL) at *M. surmuletus* reached first maturity were 13.7 cm (1 yr) for females and 13.2 cm (1 yr) for males. The calculated of first maturity length shows some differences on the other studies, but also age at first maturity calculated for both females and males was 1 yr. This result agreed well with the findings of other studies on this species (Gharbi and Ktari 1981 b; Sanchez *et al.* 1983; Morales-Nin 1991; Reňones *et al*. 1995), although Dorel (1986) reported the mean length at first maturity in males (TL=18 cm) and females (TL=16cm) in France. Morales-Nin (1991) reported that the mean length of females and males at first maturity was TL=15.0 cm in Mallorca. Campillo (1992) reported that the mean length of first maturity was TL=14 cm in Lion. Similarly, in the other study describing the size of first sexual maturity is 16.8 cm for females and 14.0 cm for males (Reňones *et al*. 1995). In the Aegean Sea, Stergiou *et al*. (1997) indicated that FL=13.8 cm in females as first maturity length. Mehanna (2009) showed that the mean length of first maturity was TL=15.1 cm.

The reproductive period of *M. surmuletus* recorded in our study is similar to that reported for this species in other areas. In this study, the reproduction period was defined based on the gonadosomatic index (GSI). The GSI values started to increase after the winter months, and then decreased in summer (Figure 6). The results showed that the spawning period was in spring months in Saros Bay. In earlier studies, Morales-Nin (1991), Campillo (1992), N'Da and Deniel (1993) reported that the spawning season of *M. surmuletus* occurred between April-May, May-August and May-June, respectively. Additionally, Moldur (1999) and Üstün (2010) reported that the spawning season of summer in the Marmara Sea.

The results of the present work will contribute to the knowledge on age composition, growth and maturity of *M. surmuletus* in Saros Bay and also to better understanding of its role in marine ecosystem. Furthermore, this is the first report on the length at first maturity of this species in the Turkish Aegean Sea. This information will help fisheries scientists for future studies on *M. surmuletus* populations and may also help to enforce regulations on commercial fisheries with regard to minimum landing size restrictions for this species.

Table 5. Total length-total weight relationships of *M. surmuletus* reported by various studies

N	Author	Region	Sex	Size range (cm)	a	b
382	Dorel 1986	France	-	6.0-42.0	0.0073	3.19
-	Morales-Nin (1986)	Catalan Sea	-	5.0-20.0		
49	Coull *et al.* (1989)	North Atlantic	-	20.5-46.5	0.047	3.30
1092	Morales-Nin (1991)	Majorca	-	-	0.016	2.91
	Campillo (1992)	Gulf of Lion	-	-	0.082	3.00
336	Vassilopou and Papaconstantinou (1992)	Aegean Sea	♂+♀	-	0.0095	3.22
451	Vassilopou and Papaconstantinou (1992)	Aegean Sea	♂	-	0.0091	3.22
390	Papaconstantinou *et al.* (1993)	Greece		7.4-24.4	0.015	3.03
307	Petrakis and Stergiou (1995b)	Greece		10.1-20.1	0.0124	3.14
3541	Reñones *et al.* (1995)	Majorca Island		10.0-32.0	0.0091	3.12
-	Sanches *et al.* (1995)	Spain		-		
127	Dulcic and Kraljevic (1996)	Croatia		15.4-30.9	0.001	3.51
299	Gonçalves *et al.* (1996)	Portugal		21.5-38.0	0.029	3.08
13	Merella *et al.* (1997)	Balaeric Islands		10.3-16.7	0.0082	3.09
-	Stergiou *et al.* (1997)	Aegean Sea		-		
-	Moutopoulos and Stergiou (1998)	Aegean Sea		14-32	0.0176	2.89
-	Moldur (1999)	Marmara Sea	♂+♀	-	0.0167	3.86
-	Moldur (1999)	Marmara Sea	♂	-	0.0154	2.92
-	Moldur (1999)	Marmara Sea		-	0.0089	3.12
257	Stergiou and Moutopoulos (2001)	Aegean Sea		13.8-32.0	0.014	2.95
122	Abdallah (2002)	Egypt		5.4–20.8	0.011	3.03
146	Valle *et al.* (2003)	West Mediterranean		7.7– 25.4	0.0097	3.07
48	Koutrakis and Tsikliras (2003)	Greece		4.4-9.7	0.0045	3.51
108	Mendes *et al.* (2004)	Portugal		17.0-38.2	0.039	3.36
47	Dulcić and Glamuzina (2006)	Adriatic		12.5-28.5	0.0039	3.36
601	Karakulak *et al.* (2006)	Gökçeada Island		10.9–29.9	0.0069	3.19
199	Karakulak *et al.* (2006)	Gökçeada Island	♂+♀	12.5-29.9	0.0065	3.21
143	Karakulak *et al.* (2006)	Gökçeada Island	♂	11.6-22.9	0.0087	3.10
145	Çiçek *et al.* (2006)	Babadillimanı Bight		5.0–22.2	0.082	3.11
117	Özaydın *et al.* (2007)	Aegean Sea		7.4-21.9	0.0106	3.20
192	İlhan *et al.* (2009)	Izmir Bay		6.6-22.6	0.0083	3.12
520	Üstün (2010)	Edremit Bay		7.7-17.0	0.0044	3.35
190	Üstün (2010)	Edremit Bay		-	0.0042	3.38
330	Üstün (2010)	Edremit Bay		-	0.0052	3.29
184	Present study	Saros Bay	♂+♀	11.0-26.8	0.0075	3.16
118	Present study	Saros Bay	♂	11.8-19.8	0.0114	3.01
656	Present study	Saros Bay	Σ	9.6-26.8	0.0084	3.12

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Saroz Körfezi'nde (Kuzey Ege Denizi) tekir balığının (*Mullus surmuletus* Linnaeus, 1758) yaşı, büyümesi ve üremesi

Özet

Kasım 2006-Haziran 2008 tarihleri arasında Saroz Körfezi'nden örneklenen tekir balıklarının yaşı, büyümesi ve üremesi incelenmiştir. Dişi-erkek oranı 1:16'dır. Dişiler için boy ve ağırlık değerleri 11,0 cm - 26,8 cm (15,3 g - 235,1 g) erkekler için 11,8 cm-19,8 cm (19.1 g - 91.2 g) olarak belirlenmiştir. Büyüme parametreleri dişiler için L_∞=28,38 cm K=0,19 yıl^{-1}, t_0=-2,16 yıl, erkekler için L_∞=26,94 cm, K=0,20 yıl^{-1}, t_0=-2,34 yıl olarak tespit edilmiştir. İlk üreme boyu dişiler ve erkekler için sırasıyla 13,7 cm ve 13,2 cm bulunmuştur. Gonadosomatik indeks değerleri incelendiğinde üreme döneminin Nisan ve Mayıs ayları olabileceği sonucuna varılmıştır.

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