J. Black Sea/Mediterranean Environment
Vol. 20, No. 3: 184-199 (2014)

RESEARCH ARTICLE

Age, growth, reproduction and feeding of *Mullus barbatus* in Saros Bay (North Aegean Sea)

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Abstract

The age, growth, food and reproduction of *Mullus barbatus*, caught in Saros Bay (North Aegean Sea) between September 2006 and September 2008, were investigated. The female-male ratio was 1:0.6. The total length (weight) of females ranged from 9.2 cm to 23.6 cm (7.5 g to 177.3 g) and of males from 8.8 cm to 24.1 cm (7.8 g to 119.7 g). The growth parameters were estimated using otolith readings and length frequencies by ELEFAN program separately and growth parameters were calculated as L_{∞}=28.75 cm, K=0.16 year^{-1}, t_0=-1.92 year using otoliths and L_{∞}=26.25 cm, K=0.41 year^{-1}, t_0=-0.68 year using ELEFAN program. The length at first maturity for females and males was 11.9 cm and 12.1 cm, respectively. Monthly values of the gonadosomatic index indicated that spawning occurred mainly between March and June.

Keywords: *Mullus barbatus*, growth, reproduction, feeding, Saros Bay, North Aegean Sea

Introduction

The Red mullet, *Mullus barbatus* Linnaeus, 1758, which belongs to the Mullidae family, is a benthic species lives mainly on sandy and muddy bottoms of the continental shelf, with a widespread distribution along the Mediterranean coasts (Hureau 1986; Özbilgin *et al*. 2004). It is a major target species of Mediterranean demersal fisheries and is exploited by more than one gear type (Demestre *et al*. 1997). They are mainly exploited at depths of 3-90 m on sandy or muddy bottoms but also at times on rocky ground. This species is a benthic carnivor and feeds on small invertebrates mainly on Crustacea, Polychaeta, Mollusca, Echinodermata and small fishes that live on or within bottom substrates. Some studies have been made on the aspects of diet and trophic relationships in adults of the species (Togulga 1977; Gharbi and Ktari 1981; Katağan 1990; Golani and Galil 1991; Labropoulou and Eleftheriou 1997; Çelik and Torcu 2000; Mehanna, 2009).

In Turkey, the red mullet has great commercial value and is one of the main target species of small and large scale fishery. Several aspects of red mullet biology have been studied, including population dynamics, age and growth (Çelik and Torcu 2000; Kınacigil *et al.* 2001; Özbilgin *et al.* 2004; Genç 2014), sexual cycle and reproduction (Metin 2005; Cherif *et al*. 2007), stock size (Kara and Gurbet 1990; Tokaç *et al*. 1991; Kınacıgil 1994), and selectivity (Tokaç *et al*. 2004).

The biology and ecology of *M. barbatus* in Saros Bay, however, is poorly known. The main goal of this study was to describe the age, growth, reproduction and feeding habits of the red mullet in relation to sex and length. Consequently, this study is a step toward improvement of the fisheries assessment and management of *M. barbatus* in the area.

Materials and methods

A total of 9386 *M. barbatus* were collected between September 2006 and September 2008 by monthly samplings at depths ranging from 20 to 500 m (20-50, 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. At each station a bottom trawl net with a 44 mm stretched mesh size at the cod-end was towed for 30 minutes at approximately 2.5 knots/hour.

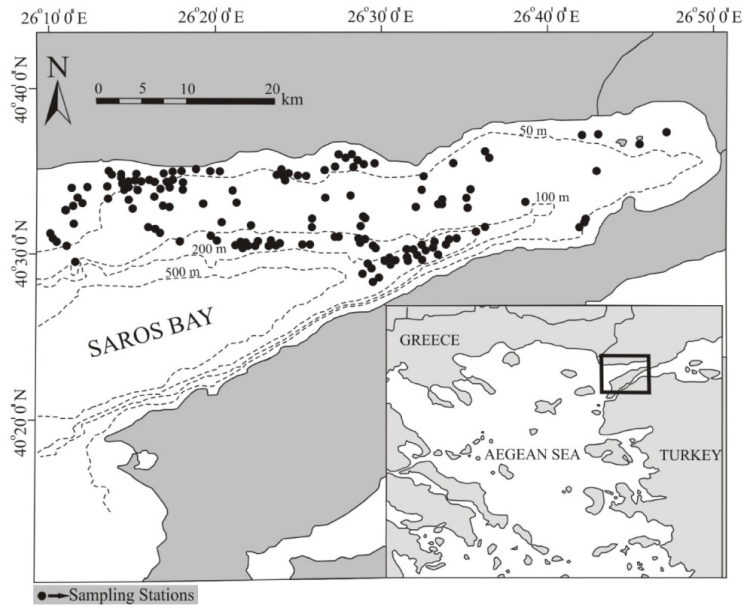

Figure 1. Trawl sampling stations (dots) in Saros Bay, the North Aegean Sea

The total length (TL) and total weight (TW) of all fish was measured to the nearest cm and nearest gram, respectively. 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:

$$W = aL^b$$

where W is the total body weight (g), L is the total length (cm), *a* and *b* are constants (Sparre *et al*. 1989).

Statistical comparison of length-weight relationships between sexes was performed applying the t-test (Zar 1999).

The age was determined using the otoliths. Sagittal otoliths were extracted through dissection of the otic bulla. Otoliths were then cleaned, labeled and stored in plastic tubes. Whole otoliths (n= 285) were examined with a stereo-microscope for the presence of growth bands. Annual rings on the whole otolith were counted in glycerin under a Olympus SZX16 Stereo-microscope. Growth was expressed in terms of the von Bertalanffy equation (Beverton and Holt 1957):

$$L_t = L_\infty (1-e^{-K(t-t_0)})$$

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 FISAT (Sparre *et al*. 1989). Growth parameters was also calculated using the ELEFAN I routine incorporated in the FISAT software (Gayanilo *et al.*1995). The ELEFAN estimates only two growth parameters (L_∞ and k), thus the third parameter (t_0) was computed by the equation of Pauly (1983):

$$\text{Log}(-t_0)=(-0,3932)–0,2752\text{log}L_\infty-1,038\text{log}k.$$

For the sake of comparison, the index of overall growth performance Φ, proposed by Pauly and Munro (1984), was calculated as:

$$\Phi=\log K+2\log L_\infty$$

The sex and maturity stage of each specimen were determined by visual and macroscobic examination of the gonads. The stages of maturation were classified according to Holden and Raitt (1974). Specimens were assigned to one of four categories: immature, resting, maturation and maturity.

The gonadosomatic index (GSI) was calculated monthly by the equation:

$$GSI = (\text{gonad weight/fish weight without gonad})*100$$

Size at maturity (L_{50}) was defined as the size at which 50% of individuals are 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 percentage mature 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).

Stomach contents were estimated according to the gravimetric method (Holden and Raitt 1974). Data on stomach contents were pooled in prey groups and feeding item to the diet of each group was expressed as percent of frequency of occurrence (F%); percent of numerical composition (N%); and percent of gravimetric composition (W%) (Hyslop 1980). The most important food items were identified using the Index of Relative Importance (IRI) of Pinkas *et al*. (1971):

$$IRI=(N+W)*F$$

Results and Discussion

Totally 9386 *M. barbatus* were collected at depths ranging from 20 to 500m and the largest amount was obtained from 20 –50 m and 50-100m depth ranges in Saros Bay. Tserpes *et al.* (2012) reported that *M. barbatus* were found mostly in depths down to 200m in the Mediterranean. The length and weight of *M. barbatus* ranged from 6.5 cm to 24.8 cm and from 2.5 g to 117.3 g, respectively. The total length of females ranged from 9.2 cm to 23.6 cm (7.5 g to 177.3 g) and of males from 8.8 cm to 24.1 cm (7.8 g to 119.7 g) (Table 1). Most fish were between 10-15 cm TL, accounting for 57% and 90% of females and males, respectively.

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

Sex	L_{mean}	LMin-Max	SE	W_{mean}	WMin-Max	SE	N
Female	15,3	9.2-23.6	0,05	40.3	7.5-177.3	0.45	2302
Male	13,5	8.8-24.1	0,04	26.2	7.8-119.7	0.31	1308
Both*	13,8	6.5-24.8	0,02	29.6	2.5-177.3	0.16	9386

*: Male, female and Unidentified

Length-weight relationships were separately estimated for males and females. Length-weight relationship equation for males was $W=0.080*L^{3.089}$, $r^2=0.92$, n=1308, and for females $W=0.061*L^{3.190}$, $r^2=0.94$, n=2302. There was no statistically significant difference in length-weight relationships between males and females (P>0.05) (Zar 1999). Value of the exponent *b* was 3.190 ($r^2=0.94$) for females and 3.089 ($r^2=0.92$) for males, which indicated positive allometric growth for both sexes. The equation for the relationship for sexes combined was $W=0.0084*L^{3.077}$ ($R^2=0.94$) (Figure 2). The size range 6.5-24.8 cm in our study was similar to those in other studies in the Mediterranean (Sarugn *et al*. 2007; İlkyaz *et al*. 2008). Previous studies providing length-weight relationships and length size range for *M. barbatus* are given in Table

2 for comparison. Differences in the number of individuals and length size range may also affect the relationships.

The age was determined by counting the annual ring marks on the surface of the otholiths. The von Bertalanffy population growth parameters for *M. barbatus* were estimated as L_∞=26.58 cm, K=0.18 year^{-1} and t_0=-1.75 year for females, L_∞=28.30 cm, K=0.14 year^{-1} and t_0=-2.39 year for males and L_∞=28.75 cm, K=0.155 year^{-1} and t_0=-1.92 year for sexes combined (Figure3). The maximum age of fish determined was 8 years for females and 5 years for males. Other study reported that up to a maximum 11 years (Stergiou *et al.* 1997), the reason for this might be the size range is lower than the other studies.

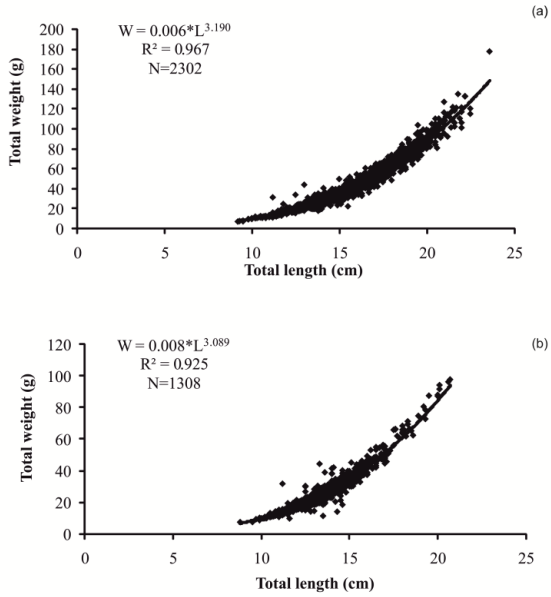

Figure 2. a) Relationship for total weight vs total length for female *M. barbatus,* b) relationship for total weight vs total length for male *M. barbatus*

The parameters of von Bertalanffy growth equation are given in Table 3. Φ-test indicated that there were no significant differences of growth parameters between our results and the other studies's results ($p>0.05$). The calculated growth performance index (φ) was 2.11 for females and 2.06 for males and 2.10 for both. This finding is in agreement with the considerable similarity between the growth performance indices (φ) calculated for each sex. Length frequency data may represent valuable information concerning the life history of fish species (Pauly 1987; Özbilgin *et al.* 2004) and ELEFAN is the most effective method to determine L_∞ (Özbilgin *et al.* 2004). In our study the ELEFAN analysis calculated length frequencies (Figure 4) and growth

parameters as L_∞=26.25 cm, K=0.41 year^{-1}, t_0=-0.68 year for both sexes combined. In the Turkish seas, a few studies (Gücü 1995; Özbilgin *et al.* 2004) used the ELEFAN analysis for estimating growth parameters and the results were similar with our estimates. In order to compare the growth of the *M. barbatus* population with others, all available literature data of von Bertalanffy growth parameters and φ values, including results from the present study, are provided (Table 3).

Table 2. Total length – total weigth relationships of *M. barbatus*

Reference	Region	Sex*	a	b	N	Length range
Çiçek *et al*. 2006	Babadillimanı	T	0.0076	3.128	2021	3.8-21.5
Karakulak *et al*. 2006	Gökçeada	T	0.0049	3.273	76	12.5-22.3
Karakulak *et al*. 2006	Gökçeada	F	0.0038	3.361	49	12.7-22.3
Karakulak *et al*. 2006	Gökçeada	M	0.0067	3.171	16	12.5-18.6
İsmen *et al*. 2007	Saros Bay	T	0.0076	3.095	3386	6-24.7
Kalaycı *et al*. 2007	Central Black Sea	M	0.0134	2.890	75	9.1-16.1
Kalaycı *et al*. 2007	Central Black Sea	F	0.0094	3.025	86	8.7-18.4
Kalaycı *et al*. 2007	Central Black Sea	T	0.0111	2.963	176	6.6-18.4
Sangun *et al*. 2007	NE Mediterranean	T	0.0032	3.060	451	8.2-22
Demirhan *et al*. 2007	SE Black Sea	M	0.0057	3.190	173	6.9-14.6
Demirhan *et al*. 2007	SE Black Sea	F	0.0047	3.270	248	6.8-18
Demirhan *et al*. 2007	SE Black Sea	T	0.0051	3.240	432	6.8-14.6
İlkyaz *et al*. 2008	İzmir Bay	M	0.0064	3.190	909	8.2-19
İlkyaz *et al*. 2008	İzmir Bay	T	0.0060	3.220	1879	8.2-28.2
İlkyaz *et al*. 2008	İzmir Bay	F	0.0056	3.240	970	8.2-28.2
Süer 2008	Black Sea	M	0.0070	3.170	800	8.5-20.5
Süer 2008	Black Sea	F	0.0070	3.140	480	7.5-22.5
Gürkan *et al*. 2010	Çandarlı Bay	T	0.0040	3.344	13	4.6-9.9
Gökçe *et al*. 2010	İzmir Bay	T	0.0102	3.176	479	7.5-20
Bök *et al*. 2010	Sea of Marmara	T	0.0049	3.326	99	10-15.7
Aydın and Karadurmuş 2013	Black Sea	T	0.0088	3.034	1435	6.4-21.2
This study	Saros Bay	F	0.0610	3.190	2302	9.2-23.6
This study	Saros Bay	M	0.0800	3.089	1308	8.8-24.1

*F: female, M: male, T: total.

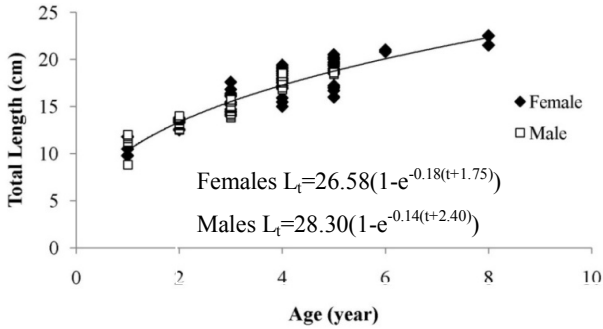

Figure 3. The von Bertalanffy growth curve for males and females of *M. barbatus*

Table 3. Parameters of von Bertallanfy growth equation (K. L_{∞}. t_0)

References	Region	Sex*	Length type**	L∞	K	t_o	Φ
Ananiadis 1950	Aegean Sea	T	-	28.3	0.17	-	2.13
Nümann and Denizci 1955	İskenderun	T	-	17.8	0.19	-	1.78
Akyüz, 1957	İskenderun Bay	T	-	23.0	0.64	-	2.53
Livadas 1984	Cyprus	T	FL	19.0	0.59	-	2.33
Papaconstantinou *et al*. 1986	Patraikos	T	TL	23.3	0.05	-	1.42
Papaconstantinou *et al*. 1986	Korinthiakos	T	TL	21.5	0.04	-	1.24
Papaconstantinou *et al*. 1988	Ionian Sea	T	TL	24.5	0.14	-	1.91
Karlou-Riga and Vrantzas 1989	Saranikos Gulf	M	TL	21.5	0.27	-	2.10
Karlou-Riga and Vrantza 1989	Saronikos Gulf	F	TL	28.6	0.15	-	2.09
Togulga and Mate 1992	İzmir Bay	T	-	26.5	0.16	-2.7	2.05
Vassilopoulou 1992	Aegean Sea	F	FL	31.6	0.11	-2.87	2.03
Vassilopoulou and Papaconstantino 1992	Aegean Sea	M	FL	22.7	0.25	-1.13	2.11
Vrantzas *et al*. 1992	Saronikos	T	TL	23.5	0.51	-0.86	2.45
Vassilopoulou 1992	Aegean Sea	M	FL	23.6	0.18	-3.01	2.00
Vassilopoulou and Papaconstantinou 1992	Aegean Sea	F	FL	25.5	0.21	-2.13	2.14
Voliani *et al*. 1995*	Central Mediterranean	F	-	29.2	0.68	-	-
Voliani *et al*. 1995*	Central Mediterranean	M	-	22.0	0.74	-	-
Gücü 1995*	İskenderun Bay	T	TL	24.2	0.63	-	2.57
Voliani *et al*., 1998	Elba Island	M	TL	20.6	0.70	-	2.47
Voliani *et al*. 1998	Elba Island	F	TL	27.0	0.70	-	2.71
Çelik and Torc 2000	Edremit Bay	T	FL	26.1	0.13	-3.54	1.94
Akyol and Özekinci 2000	İzmir Bay	T	TL	27.0	0.16	-2.05	2.08
Kınacıgil *et al*. 2001	İzmir Bay	T	FL	19.0	0.44	-0.78	2.20
Özbilgin *et al*. 2004*	İzmir Bay	T	TL	24.3	0.57	-0.35	2.52
Süer 2008	Black Sea	M	TL	25.3	0.54	-1.59	2.53
Süer 2008	Black Sea	F	TL	29.4	0.08	-1.92	1.84
Aydın and Karadurmuş 2013	Black Sea	T	TL	27.4	0.14	-2.35	2.02
This study	Saros Bay	F	TL	26.6	0.18	-1.75	2.11
This study	Saros Bay	M	TL	28.3	0.14	-2.39	2.06
This study	Saros Bay	T	TL	28.7	0.16	-1.92	2.10
This study***	Saros Bay	T	TL	26.2	0.41	-0.68	2.45

*F: female, M: male, T: total,** TL:Total length, FL: Fork length,***ELEFAN method

The gonadosomatic index (GSI) was used to estimate the reproductive period which based on monthly samples. The maturation stages and GSI values indicated that spawning season was from March to June (Figure 5). In a few studies which reported about the reproduction of this species (Hureau 1986; Stergiou *et al.* 1997; Akyol *et al.* 2000; Metin 2005), they indicated that the length at first maturity is between 10.3 cm to 14.4 cm and reproduction period is from April to August. Our results showed that the total length (TL) for the first maturity was for males 11.9 cm and for females 12.1 cm. According to the gonadic maturation stages 19% of the total female fish were immature (I), 60% were maturing (II), 15% were mature (III), and 4% were ripe (IV). Therefore, 19% of the fish were in the reproductive stage. In the males, 29% of all fish were immature (I), 54% were maturing (II), 12% were mature (III), and 4% were ripe (IV).

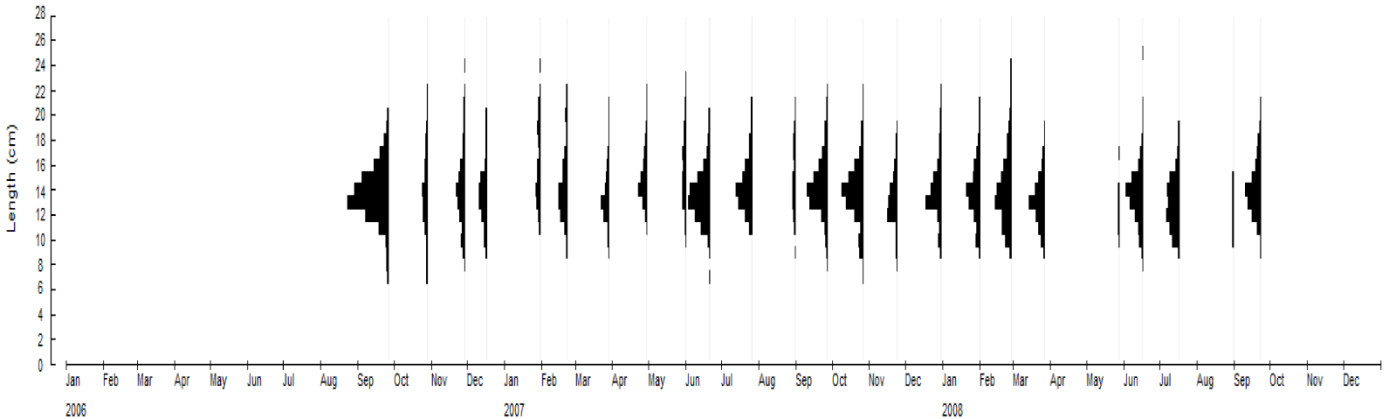

Figure 4. The von Bertallanffy growth function plot and length frequencies of *M. barbatus* in Saros Bay

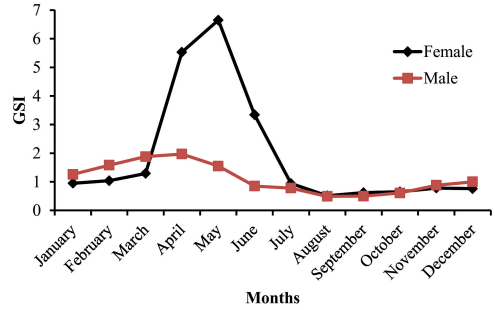

Figure 5. Monthly variation of gonadosomatic index values (GSI) of *M. barbatus* in females and males

Therefore 16% of the fish were in the reproductive stage. The highest proportion of average gonadal maturity stage (IV) in females was observed in June (Figure 6). The male and female maturity stages indicated that length at 50% maturity (L_{50}) were 11.9 cm TL for males and 12.1 cm for females (Figure 7).

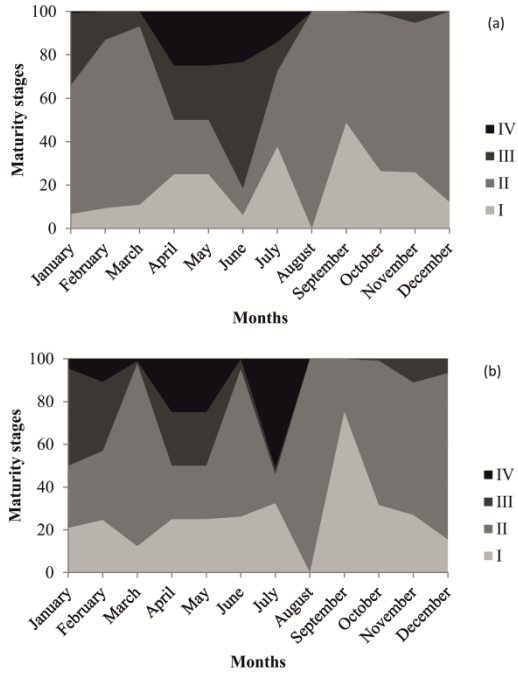

Figure 6. Monthly variation of maturity stages for *M. barbatus* in females (a) and males (b) (I: immature; II: maturing; III: mature; IV: ripe)

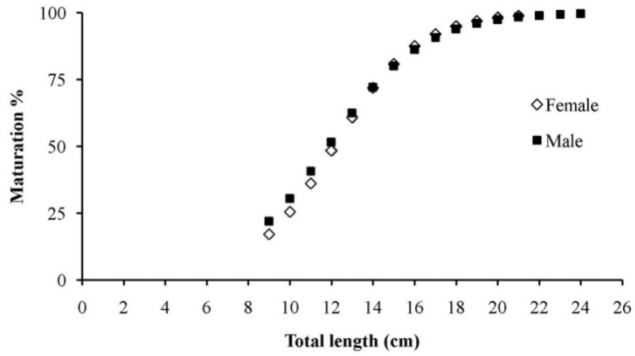

Figure 7. Length and proportion of mature specimens for males and females of *M. barbatus*

M. barbatus is a benthic predator and mainly feeds on small crustaceans and polychaetes (Cherif *et al.* 2011). A total of 174 individuals were analysed for stomach content. A total of 629 prey belonging to 4 taxa were identified; Mollusca, Crustacea, Echinodermata and Annelida. Stomach content analysis of *M. barbatus* indicated that the most important prey group was Bivalvia (34.7 IRI%), followed by Polichaeta (31.5 IRI%) and Crustacea (22.1 IRI%) (Table 4). Toğulga (1977) reported that the most important prey groups were Crustacea, Echinodermata, Mollusca, and Fish, while Çelik and Torcu (2000) indicated that Crustacea, Mollusca, Polychaeta and Echinodermata were prey groups of *M. barbatus* diet in the Aegean Sea. Dominancy of benthic organisms in different areas may also affect variability of diet.

Table 4. Percentages by number (N%), weight (W%), occurrence (F%), and index of relative importance (IRI%) for prey items observed in the stomachs of *M. barbatus*

Prey group	N%	W%	F%	IRI%
Bivalvia	20.83	23.27	47.22	34.71
Gastropoda	0.32	0.02	1.39	0.01
Crustaceans	17.01	13.98	32.64	16.86
Amphipoda	8.74	6.35	12.50	3.14
Mycidacea	1.59	0.25	6.25	0.19
Brachyura	1.75	0.51	6.00	0.23
Natantia	2.54	16	5.56	1.72
Ophiuroidea	1.91	4.98	7.64	0.88
Policheta	21.94	23.5	41.67	31.56
Others	7.15	3.61	9.03	1.62

In conclusion, the results of the present study will contribute to the knowledge on the age composition, growth, maturity and feeding of *M. barbatus* in Saros Bay. These informations will help future studies on *M. barbatus* populations.

Acknowledgement

The present study was carried out with the financial support of TUBITAK (project number 106Y035). The authors would like to thank all the staff who helped in the field work and in the laboratory.

Saroz Körfezi'nde (Kuzey Ege Denizi) Barbun balığının *Mullus barbatus* yaşı, büyümesi ve üremesi

Özet

Eylül 2006-Eylül 2008 tarihleri arasında Saroz Körfezi'nden örneklenen barbun balıklarının yaşı, büyümesi ve üremesi incelenmiştir. Dişi-erkek oranı 1:0,6'dır. Dişiler için boy ve ağırlık değerleri 9,2 cm – 23,6 cm (7,5 g – 117,3 g) erkekler için 8.8 cm – 24,1 cm (7,8 g – 119,7 g) olarak belirlenmiştir. Büyüme parametreleri otolit okunmaları ve ELEFAN programı kullanılarak ayrı ayrı hesaplanmıştır. Tüm bireyler için hesaplanan değerler sırasıyla L_{∞}=28,75 cm, K=0,16 yıl^{-1}, t_0=-1.92 yıl ve L_{∞}=26,25 cm, K=0,41 yıl^{-1} , t_0=-0,68 yıl olarak tespit edilmiştir. İlk üreme boyu dişiler ve erkekler için sırasıyla 11,9 cm ve 12,1 cm bulunmuştur. Gonadosomatik indeks değerleri incelendiğinde üreme döneminin Mart ve Haziran ayları arasında olabileceği sonucuna varılmıştır.

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Received: 04.08.2014
Accepted: 03.09.2014