Age, growth and mortality parameters of *Mullus barbatus* Linnaeus, 1758 (Perciformes: Mullidae) in Iskenderun Bay, northeastern Mediterranean

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Abstract: The objectives of this study were to determine the age, growth, mortality and exploitation of a commercially important fish of northeastern Mediterranean Sea, *Mullus barbatus* from the Karatas coast of Iskenderun Bay during September 2002 and April 2003. A total of 212 specimens of red mullet were collected by monthly sampling using traditional bottom trawl net by commercial vessel (Coskun Reis, 22m length and 285HP) from 3 stations in three depth contours in ≤20m, 20-50m and 50-100m, respectively. The age of *M. barbatus* specimens was estimated by examining sagittal otoliths and it found that the age composition varied from I to V age classes. The mean total length and total weight values was calculated as 10.07±1.83cm and 12.04±8.22g, respectively and the calculated length-weight relationship was $W=0.0072*L^{3.1618}$. The von Bertalanffy growth parameters were $L_{\infty}= 21.98$cm, $k= 0.194$ year-1 and $t_o= -1.168$ year. The instantaneous rate of total mortality (Z) was 1.39, the natural mortality (M) was 0.45 and the fishing mortality (F) was estimated to be 0.93. The exploitation rate (E) was calculated as 0.67 using value of M and F. As a result of the analysis, the population of *M. barbatus* from the Karatas coast of Iskenderun Bay was exploited over the optimum level because of overfishing pressure.

Keywords: Goatfish, Red mullet, Population dynamics, Length-weight relationship, Mortality, Exploitation rate.

Introduction

The red mullet, *Mullus barbatus* Linnaeus, 1758 (Mullidae) is distributed from the Eastern Atlantic, British Isles (occasionally Scandinavia) to Dakar, Senegal, Canary Islands, Mediterranean, and Black Sea. They are also found in the Azores (Froese & Pauly 2009). This fish is a benthic species, inhabiting mostly in the gravel, sandy and muddy bottoms at a depth range of 5 to 300m (Relini et al. 1999). Although the species is widely distributed, the relative index of the population abundance decreases with depth (Jukić-Peladić et al. 1999; Vrgoč 2000). Juveniles often dwell in shallow waters. Voliani et al. (1998) reported that individuals of *M. barbatus* below 14cm in total length (TL) inhabit in the depths less

than 100m. In the same study, larger individuals between 19 and 21cm in TL were documented to dwell in the depths of 100-200m.

Mullus barbatus is of major commercial importance to the bottom trawl fisheries in the Mediterranean Sea. The landings of this species were reported at 2035 tons for the Mediterranean coasts of Turkey and 13416 tons for the whole Mediterranean in 2007-2008 fishing season (FAO 2010). Both of these stocks have been almost exclusively fished by the bottom trawl fisheries (Gücü & Bingel 1994a; Anonymous 2010).

Distribution, age, growth, maturity and mortality of *M. barbatus* have already been determined in the Mediterranean Sea (see Mert et al. 1983; Türeli &
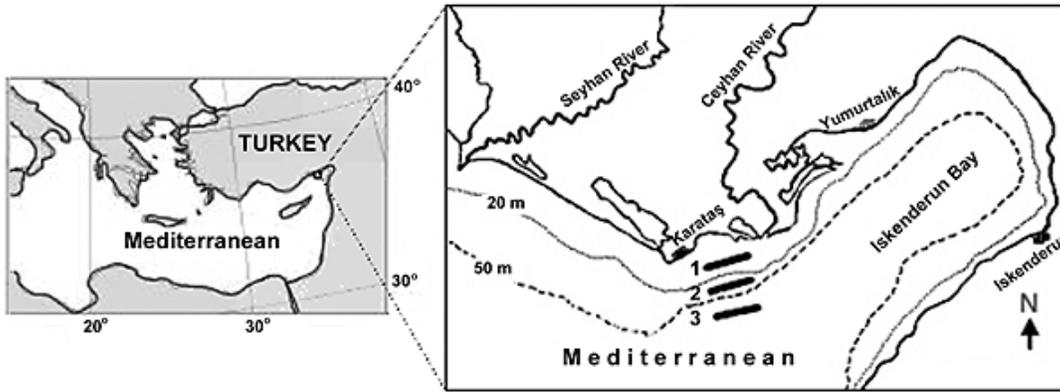
Fig.1. Study area and sampling stations. (1) ≤20m, (2) 20-50m, and (3) 50-100 m depth contour.

Erdem 1997; Relini et al. 1999; Çelik & Torcu 2000; Vrgoč 2000; İşmen & İşmen 2001; Özyurt 2003; Joksimovic 2005) and bottom trawl selectivity parameters (Tokaç et al. 1995; Metin 1995; Lök et al. 1997; Gurbet et al. 1997; Tosunoğlu & Tokaç 1997; Genç 2000; Vrgoč 2000; Genç et al. 2002; Özyurt 2003; Tokaç et al. 2004; Joksimovic 2005). In order to have the sustainable exploitation of fish stock, knowledge of the demographic parameters for a given species can assist in developing management models. The objectives of this study were to determine the age, growth, mortality and exploitation of *M. barbatus* from the Karatas coast of Iskenderun Bay.

Materials and Methods

This study was carried out between September 2002 and April 2003 (2002-2003 fishing season) from the Karatas Coasts of Iskenderun Bay. The red mullet specimens were obtained monthly, using traditional bottom trawl net by commercial vessel (Coskun Reis, 22m length and 285HP) from 3 stations in three depth contours in ≤20m, 20-50m and 50-100m, respectively (Fig. 1). One trawl operation were done during the day time with a 1 hour haul duration using Mediterranean Type Bottom Trawl 44mm full mesh size, in each depth contour.

All of the collected specimens were transferred from field to the laboratory in the ice and stored at -18°C in the freezer. Then, the samples were defrosted and sorted by species and weighed in the laboratory

to estimate of Catch per Unit Effort (CPUE) for each depth contour. In order to determine the population parameters, the sub-sampling procedure was applied based on Holden & Raitt (1974). The total length and the total weight (TW) were measured and weighed to the nearest 1mm and 0.01g, respectively. The sagittal otoliths were examined under the microscope for age determination.

The total length-weight relationships were determined according to the allometric equation given by Sparre et al. (1989): $W=\alpha*L^b$. In this equation, W denotes weight (g), L denotes total length (cm) and α and b denote regression constants. Growth in length and weight were expressed in terms of the von Bertalanffy equation $L_t=L_\infty[1-e^{-k(t-to)}]$. The growth parameters k, L_∞ and t_o were estimated using the Least Squares Method based on Sparre et al. (1989).

Correspondence between empirical data and an expected distribution was tested by Khi^2 test. The b value was tested by t-test to verify that it was significantly different from the isometric growth ($b = 3$).

Total mortality rate (Z) was estimated based on the length in the first capture methods evaluated by Beverton & Holt (1957).

$$Z=k*(L_\infty-L_m)/(L_m-L_c).$$

Where; L_m is the average total length of the entire catch, where L_c is the length at which 50% of the fish entering the gear are retained (Sparre et al. 1989). Instantaneous natural mortality rates (M) were
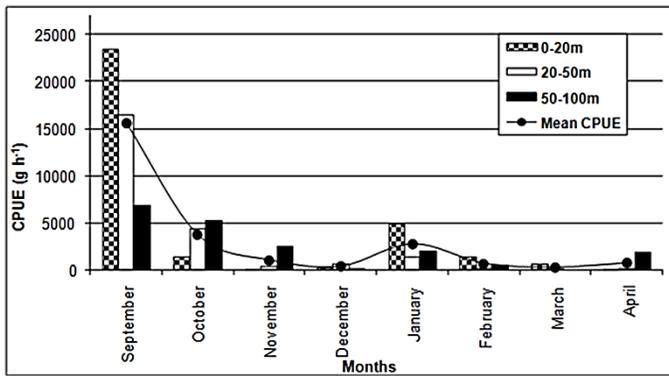
Fig.2. Monthly distribution of CPUE value in each depth range for *Mullus barbatus* from the Karatas coast of Iskenderun Bay.

estimated using the equation derived by Ursin (1967) based on the mean total length, where $M = W^{(1/b)}$ (W = mean total length; b = constant of length-weight relationship). Fishing mortality rates (F) was calculated as the difference between Z and M ($Z = F + M$). The value of the average annual exploitation rate (E) was obtained by $E = F/Z$ (Sparre et al. 1989).

Results

Monthly distribution of CPUE value of *M. barbatus* for each depth contour during study period is given in Figure 2. The highest CPUE value was obtained in September as 15.6kg h^{-1}. Thereafter, the CPUE value decreased and the lowest value was obtained in March (0.2kg h^{-1}). Overall the mean CPUE value was calculated as 3.1±5.2kg h^{-1}. 62.50% of the total catch was obtained in September which is the first month of the fishing season, followed by 14.78% in October.

Based on the CPUE distribution data in each depth, nearly half of the catch (43.43%) was obtained in depths of ≤20m, 31.19% and 25.38% in depths of 20-50m and 50-100m, respectively. During the study period, the proportion of *M. barbatus* in the total catch was 12.37% in the depth of ≤20m, 8.75% in the depth of 20-50m, and 16.30% in the depth of 50-100m with the mean value of 11.83%. The population density of this species was estimated 32.45kg km^{-2}, 23.31kg km^{-2}, 18.97kg km^{-2} in each
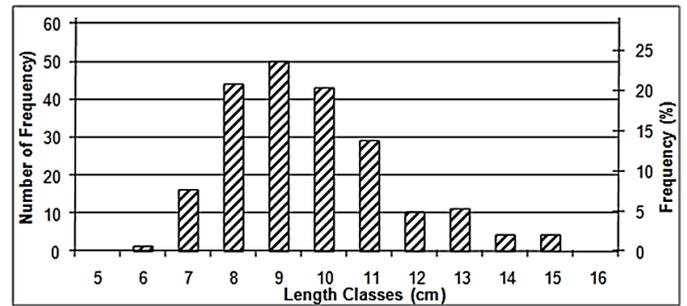

Fig.3. Length-frequency distribution for *Mullus barbatus* from the Karatas coast of Iskenderun Bay (10 mm length classes).
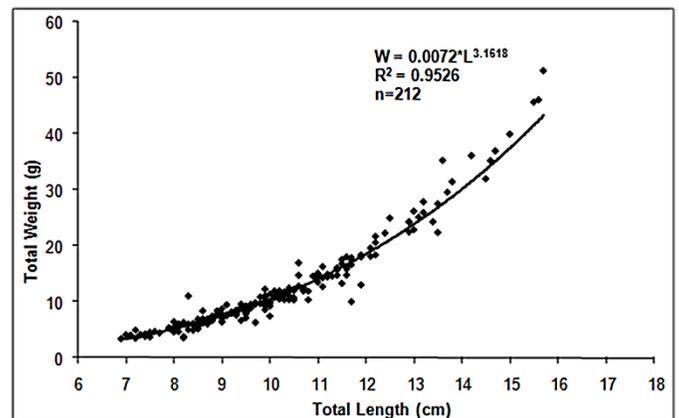

Fig.4. Length-weight relationship for *Mullus barbatus* from the Karatas coast of Iskenderun Bay.

depth stratum, respectively with the overall mean 24.91kg km^{-2}. Based on the CPUE results, *M. barbatus* was distributed in a wide depth range and the relative index of the CPUE and the population abundance decreased with depth.

The results revealed that, 212 collected specimens had a range size of 6.90 to 15.70cm (TL) and weight of 3.41 to 51.38g. Overall mean total length and weight were calculated as 10.07±1.83cm and 12.04±8.22g, respectively. Length-frequency distribution of *M. barbatus* was given in Figure 3. The dominant length group was 9cm (23.85%) followed by the 8cm (20.75%) and 10cm (20.28%). Length-frequency distribution, minimum, maximum and mean length and weight values of *M. barbatus* for each age class are presented in Table 1. The age of *M. barbatus* ranged from I to V age classes and the most dominant age class II was with the value of 50.5% followed by age class I with the value of

Table 1. Length-frequency distribution, minimum, maximum and mean length and weight values for each age class for *Mullus barbatus* from the Karatas coast of Iskenderun Bay.

Age Group	Frequency	Total Length (cm)		Total Weight (g)	
		Min-Max	Mean	Min-Max	Mean
I	77 (%36.3)	6.90-9.90	8.40±0.73	3.41-9.55	6.15±1.70
II	107 (%50.5)	8.70-12.50	10.40±0.87	6.89-25.00	12.00±3.50
III	20 (%9.4)	10.70-13.80	12.80±0.84	12.55-35.33	23.02±6.86
IV	7 (%3.3)	14.20-15.60	14.87±0.52	32.03-46.17	38.92±5.36
V	1 (%0.5)	15.70	15.70	51.38	51.80
Total	212	6.90-15.70	10.07±1.83	3.41-51.38	12.04±8.22

Table 2. Observed and calculated total length of *Mullus barbatus* using von Bertalanffy growth equations from the Karatas coast of Iskenderun Bay.

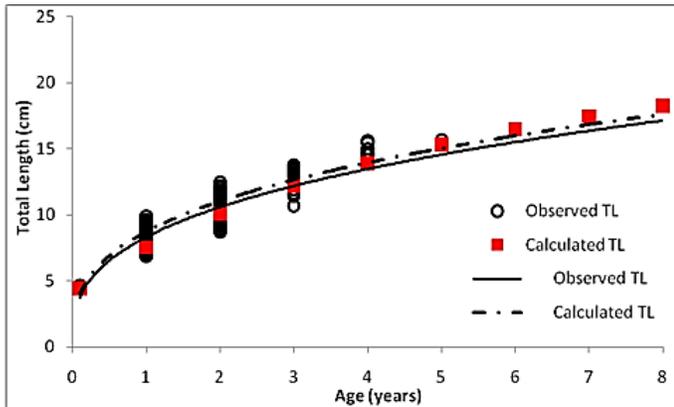| Age Group	Total Length (cm)		Total Weight (g)	
	Observed	Calculated	Observed	Calculated
I	8.40	7.54	6.15	4.27
II	10.40	10.08	12.00	10.71
III	12.80	12.17	23.02	19.47
IV	14.87	13.90	38.92	29.60
V	15.70	15.32	51.38	40.28

Fig.5. von Bertalanffy length-at-age growth curve for *Mullus barbatus* from the Karatas coast of Iskenderun Bay.

36.3% (Table 1).

The relationship between TW and TL is presented in Fig. 4. The length-weight relationships were expressed as W=0.0072L$^{3.162}$. The calculated von Bertalanffy growth parameters were L_∞=21.98cm, k=0.194year^{-1} and t_o=-1.168year. The back-calculated lengths were determined using von Bertalanffy growth parameters and the observed and calculated growths in total length were listed in Table 2. The growth curves were not significantly different between observed and calculated length (*P*>0.05). The von Bertalanffy growth curve was fitted to lengths-at-age for *M. barbatus* (Fig. 5). Growth is fast until the II age classes and with growth in length slightly reduced beyond the age class II.

The annual instantaneous rate of natural mortality (*M*) was estimated at 0.45yr^{-1} and instantaneous total mortality rate was estimated at 1.39yr^{-1}. Using the estimate of *Z* from the mean total length and the estimate of *M* obtained using the based on the length at first capture methods an estimate of fishing mortality was obtained at 0.93yr^{-1}. The exploitation rate was estimated at 0.67 using the value of *Z* and the estimated *F*.

Discussion

The highest CPUE value was obtained in September with more than half of the total catch (62.50%), and 14.78% of the total catch was obtained in October. In other words, most of the yield was exploited in just two months at the beginning of the fishing season.

Table 3. Length-weight relationship and von Bertalanffy growth parameters of *Mullus barbatus* from Turkish coasts.

b	a	R^2	L_∞ (cm)	k (year^{-1})	t_0 (year)	n	Author/s
-	-	-	24.80	0.52	-0.330	-	Bingel et al. (1993)
-	-	-	24.26	0.565	-0.305	110891	Özbilgin et al. (2004)
2.981	0.0157	0.96	26.08	0.127	-3.530	474	Çelik & Torcu (2003)
3.001	0.01	0.94	24.4	0.716	-0.450	106	Bingel (1987)
3.011	0.0132	0.97	22.42	0.089	-8.125	765	Kınacıgil (1994)
3.026	0.1695	-	19.10	0.176	-3.923	348	Türeli & Erdem (1997)
3.103	0.00729	0.98	-	-	-	1220	Bingel et al. (1993)
3.105	0.0121	0.99	-	-	-	-	Hekimoğlu (1992)
3.106	0.0000091	0.99	-	-	-	636	Anonymous (1993)
3.117	0.0078	0.97	26.09	0.239	-0.949	-	Avşar et al. (2000)
3.134	0.00644	0.98	-	-	-	6098	Bingel et al. (1993)
3.143	0.0000078	0.98	-	-	-	1090	Anonymous (1993)
3.182	0.0063	-	23.82	0.227	-1.624	-	Genç (2000)
3.218	0.00527	0.99	21.26	0.231	-1.943	-	Şahin & Akbulut (1997)
3.221	0.00537	0.99	21.03	0.204	-2.327	-	Şahin & Akbulut (1997)
3.290	0.0071	-	19.04	0.438	-0.777	220	Kınacıgil et al. (2001)
3.392	0.000312	0.98	-	-	-	628	Bingel et al. (1993)
3.162	0.0072	0.95	2.1.98	0.194	-1.168	212	This study

The same trend was reported for yield of the other trawlable species and total catch in the studied area (Çiçek 2006).

Mean CPUE value was calculated at 3.1±5.2kg h^{-1}. In the previous studies this value was estimated at 1.5kg h^{-1} in 1983 and 3.3kg h^{-1} in 1984 in İskenderun Bay (Gücü & Bingel 1994b). In the period from 1989 to 1994, the CPUE ranged from 0.3 to 2.54kg h^{-1} in the southern Adriatic, from 0.96 to 1.43kg h^{-1} in the central and eastern Adriatic and 5.4kg h^{-1} in the open sea off the Montenegrin coastal area (Joksimovic 2005). The average biomass index was calculated at 16.36kg km^{-2} in the central and eastern Adriatic and 104.8kg km^{-2} in off the Montenegrin waters. The population density of *M. barbatus* is not the same throughout the year in the Mediterranean Sea.

The LW relationships parameters and the von Bertalanffy growth parameters based on previous studies in Turkey are listed in Table 3. The b value ranged from 2.9811 to 3.3916 in the previous studies. All these results indicate that there was an isometric or positive allometric growth pattern in the previous studies. Çelik & Torcu (2000) reported positive allometric growth pattern (b= 3.162, SE= 0.049; 95% confidence intervals of b = 3.066-3.258). According to Froese & Pauly (2009), b value was in the range of 2.508 and 3.295 with mean value of 3.060 for the fishes of different regions of the Mediterranean Sea. It is obvious that there are many similarities between this study and previous studies in term of b values. The k observed in this study is lower than previous studies except Çelik & Torcu (2000) and Türeli & Erdem (1997). The k values lower than 0.3 imply that the growth of the *M. barbatus* population inhabiting the Karatas coasts was slow (Froese & Pauly 2009).

The L_∞ value based on the previous studies ranged from 19.04 to 26.08cm from Turkish coasts and varied from 17.8 to 32.9cm with a mean value of 24.0cm for different parts of the Mediterranean Sea (see Froese & Pauly 2009). There is a close similarity for the estimated L_∞ values among this study and previous studies in Turkish coasts population (see Table 3). Although the estimated L_∞ value of this

study was not so different, the L_∞ value of this study was lower than the mean value that was calculated for this fish from whole Mediterranean Sea (see Table 3). However, the estimated parameters may vary due to a variety of factors such as region, sampling methods, year, methodology etc. (Gonçalves et al. 2003).

The length at first sexual maturity determined in the previous studies ranged from 10.2 to 13.5cm (Mert et al. 1983; Türeli & Erdem 1997; Çelik & Torcu 2000; İşmen & İşmen 2001; Özyurt 2003) and 78% of the total catch consisted of immature individuals off the Karatas coasts (Cicek 2006). On the other hand, when the age at first maturity of this species is considered II years old (Türeli & Erdem 1997; Genç et al. 2002), 86.8% of the total catch consisted of immature or just matured individuals. All of these results indicate that most of the catch consisted of immature and fast growing specimens (Çoral 1988), i.e it is obvious that there was overfishing on the stock of *M. barbatus* off the Karatas coasts.

Voliani et al. (1998) reported that individuals of *M. barbatus* below 14cm in total length were inhabiting depths less than 100m and their average length value increase with depth as individuals between 19 and 21cm in length were distributed in depths of 100-200m. Similarly Somarakis & Machias (2002) found that immature specimens of *M. barbatus* were distributed in shallow waters less than 60-80m. Therefore bottom trawl fishing must be conducted deeper than 50m for *M. barbatus*.

The estimated fishing mortality rates and exploitation rates were found high in the study area. These results indicated that this species was exposed to an extensive fishing pressure. The previous bottom trawl selectivity and fishing mortality showed a high fishing pressure not only in the Iskenderun Bay (Gücü & Bingel 1994a; Çiçek 2006) but also other parts of the Mediterranean (Anonymous 2010).

To ameliorate this problem, the nets that have high selectivity and applied cutting formulas must be used instead of the traditional Mediterranean type

bottom trawl net (Gücü & Bingel 1994a; Tokaç et al. 1995) as the protection of juveniles and their habitats is a key factor for the sustainability of these resources (Ehrhardt & Ault 1992).

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