An investigation on age, growth and biological characteristics of red mullet (*Mullus barbatus ponticus*, Essipov, 1927) in the Eastern Black Sea

Aydın M.*; Karadurmuş U.

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Abstract

This study was carried out during May 2010 – April 2011 in order to determine various biological properties of red mullet occurring in the Eastern Black Sea region. The average length and weight of 1435 specimens were determined as 13.13 cm and 23.14 g, respectively. Weight-length relationship was determined as $W = 0.0088\ L^{3.0338}$. The age distribution of this population ranged between I and VII. The female constituted of 66.2% whereas male 33.8%. Von Bertalanffy growth equation was $L_t = 27.4\left(1 - e^{-0.1402(t+2.351)}\right)$, whereas for weight was $W_t = 202.46\left(1 - e^{-0.1402(t+2.351)}\right)^{3.0338}$. The GSI index reached its maximum value in June when relative fecundity was 2529.6 eggs g^{-1} body weight and the average egg size was 360.9 µm. The fecundity-total length and fecundity-weight relationships were calculated as $F= 0.0651\ TL^{5.1297}$ and $F= 338.5W^{1.5128}$, respectively.

Keywords: Red Mullet, *Mullus barbatus ponticus*, Age, Growth, Reproduction, Black Sea

-Ordu University, Faculty of Marine Sciences, 52400, Fatsa, Ordu, Turkey.
*Corresponding author's email: maydin69@hotmail.com

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Introduction

In the Black Sea Region of Turkey, red mullet is mostly caught using gillnet and bottom trawl. With encircling nets, the fish are caught as bycatch. Even though overfishing pressures are caused more frequently by trawls in this area, the contribution by gillnet cannot be underestimated. The catch of small size compared with legal size is very high**.** Small mesh size used for red mullet fishing has role in this detrimental activity for the population. For instance, fish in their spawning periods that approach the shore are heavily caught using gillnets.

From the previous studies, it is known that the species starts spawning activities at the end of the 1st year and that fish greater than 12 cm are the most economically beneficial (Samsun, 1992; Ozvarol et al., 2006). Although the catch amount of red mullet varied remarkably during 1982-2010, a closer look at the last decade reveals that there has been a relatively straight trend (Genc et al., 2002; TUIK, 2011).

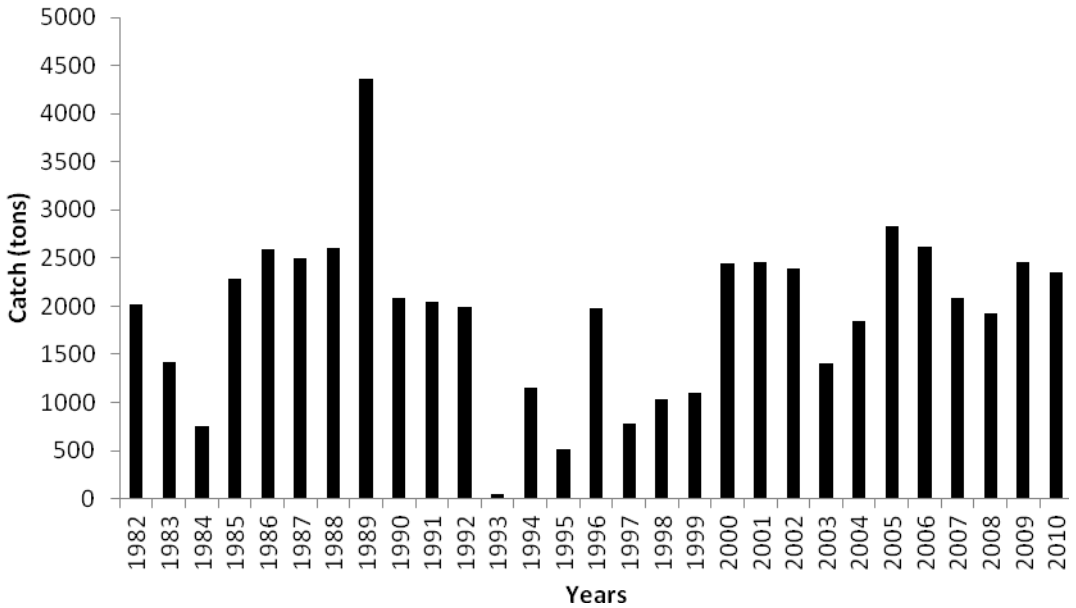

Figure 1: Amount of red mullet caught in Turkey based by the years 1982-2010

It is known that two genus (*Mullus and Upenus*) and four species (*M. barbatus, M. surmuletus, U. mollucensis, U. pori*) live in Turkish seas (Mater et al., 2003; Bat et al., 2008). Red mullet is among the important demersal fish of the Black Sea since it is both economically valuable and an export product of Turkish fisheries. Hence, there are many studies regarding the growth of the species, age distribution and selectivity in areas including the Black Sea region (Geldiay, 1969; Togulga, 1976; Togulga and Mater, 1992; Tokac and Gurbet, 1992; Kinacigil, 1994; Akyol et al., 2000; Kinacigil et al., 2001; Genc et al., 2002; Aksu et al., 2011). However, there is no information about this species in the Ordu region and this study was planned to fill

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this gap. This study has also importance in ensuring a sustainable red mullet fisheries management with incorporation of the yearly biological parameters.

Materials and methods

This investigation was carried out in the Eastern Black Sea region (between (41^0 37' 18" N-37^0 22' 26" E) and (40^0 58' 35" N-38^0 02' 58" E)) during the 2010–2011 period by monthly samplings of the red mullet based on random sampling method from the landing points of commercial boats (Figure 2).

The study included specimens caught by gillnet and commercial seine net fishing at fishing ports. A total of 1435 specimens were examined, 485males and 950 females.

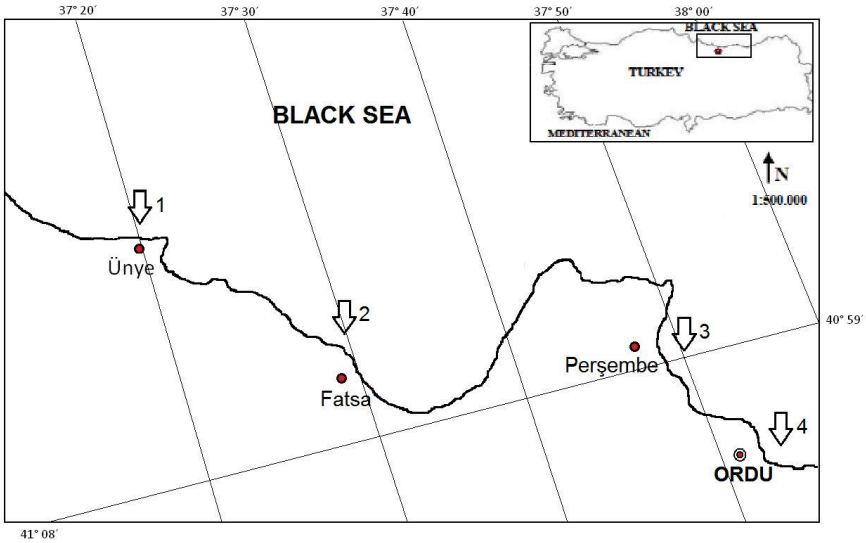

Figure 2: The map of study area

Total length (TL), weight (W) and gonad weight (GW) were measured in the laboratory to the nearest 1 mm and 0.01 g, respectively.

Age determination was carried out by scale inspection under the microscope. The preparation of the scales and age readings were performed according to Chugunova (1963).

The TL–W relationship was determined using the equation: $W = a\ TL^b$ (Le Cren, 1951; Pauly, 1980; Erkoyuncu, 1995). The parameters "a" and "b" of the TL-W relationship were estimated by the least squares regression method. The significance of the regression was assessed by ANOVA, and different from the predictions for isometric growth (*b*=3). The growth performance index ($\Phi' = \log K + 2 \log L_\infty$) of Pauly and Munro (1984) was calculated for comparison of growth parameters.

The von Bertalanffy growth equation (VBGE) was used to describe the growth of red mullet for male, female and all (Beverton and Holt, 1957; Gulland and Holt, 1959; Silliman, 1969; Ricker, 1975; Pauly, 1980; Sparre and Venema, 1992; Erkoyuncu, 1995); $L(t)= L_\infty (1-e^{-k\ (t-to)})$

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where L_t is the total length at-age t, K is the growth coefficient, L_∞ is the asymptotic length, and t_0 is the theoretical age at length zero. For the growth in weight, the same function was used: $W(t) = W_\infty (1-e^{-k(t-to)})^b$, where Wt is the total weight, W_∞ is the asymptotic weight and b is the power constant of the length-weight relationship. The software FISAT (Gayanilo et al., 1996) including Mardquart's algorithm as the non-linear estimation method was used to estimate the growth parameters.

Fulton's coefficient of condition factor was calculated by $C = (W/TL^3) \times 100$, where TL is the total length (cm) and W is the body weight (g) (Le Cren, 1951; Bagenal, 1978; Sparre and Venema, 1992; Erkoyuncu, 1995).

Gender determination was made macroscopically via gonads. Sex ratio of red mullet was analyzed using Chi-square test (χ^2).

The gonadosomatic index was calculated by using the formula: GSI = 100 x (GW/W) (Nikolsky, 1969). Where GW is the gonad weight and W is the total fish weight.

Fecundity and egg size were evaluated from 20 females. The gonads of fish were removed and placed in 5% formalin solution to facilitate the counting. The weights of the ovaries were also taken. Excess of water was removed from the surface of the ovaries with blotting paper. To estimate the fecundity, gravimetric method was used. Relative fecundity was calculated as Fr= F/W (g). Fecundity (F)–total length (TL), fecundity–weight (W) relationships were determined from the equation $F= aX^b$ where F= fecundity, X= length or weight, a= intercept constant and b= an exponent (Bagenal, 1978).

Egg size was determined by using a sensitive micrometer (at 0.01 mm sensitivity). Long and short axes of eggs were measured. Mean egg diameter were calculated as follows: Mean Egg Diameter (mm) = (length of long axes + length of short axes) / 2 (Murua et al., 2003; Jakobsen et al., 2009).

Student's t-test was employed for statistical comparisons (Sokal and Rohlf, 1969; Duzgunes et al., 1983).

Results

The age composition of red mullet population changed between I and VII. Two and three age groups accounted for the majority of the population. The population was composed of 66.2% females and 33.8% males. The χ^2 test revealed that the difference between the sexes was significant (χ^2 =150.7; d.f =1; P<0.05).

The minimum length was 6.4 cm belonging to the age group I. The average length and weight were determined as 13.13±1.98 cm and 23.14±10.39 g, respectively. The length distribution of red mullet is given in Figure 3. The averages of the length and weight of samples with and standard deviations are presented in Table 1.

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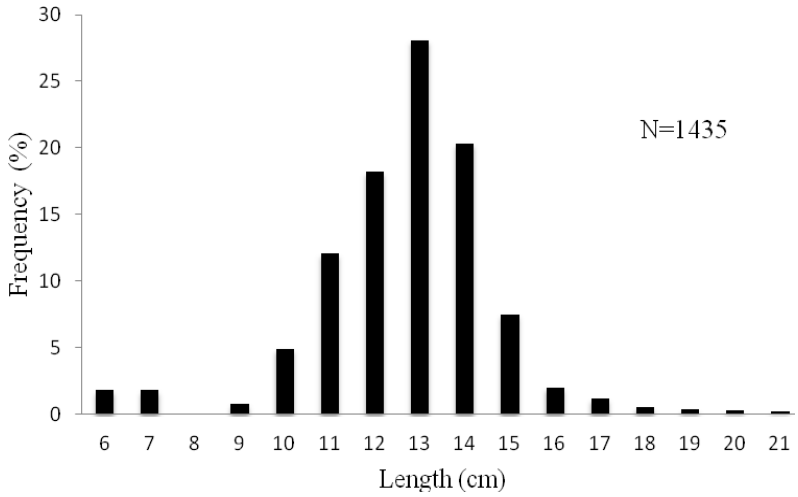

Figure 3: Length frequency distribution of red mullet

Table 1: Average weight and length of red mullet (±SD)

	N	TL (cm)			Weight (g)		
		Average	Min	Max	Average	Min	Max
Overall	1435	13.13±1.98	6.4	21.5	23.14±10.39	2.09	105.40
Female	950	13.73±1.62	9.5	21.5	25.93±10.55	8.54	105.40
Male	485	11.96±2.11	6.4	17.0	17.68±7.49	2.09	43.43

Age II group fish comprised of the majority of the population whereas age VII group did the smallest part. The distributions of the length and weight of the specimens according to age are given in Table 2.

The length-weight relationship was calculated as $W= 0.0088L^{3.0338}$ (R= 0.97, N=1435) (Figure 4).

Table 2: The length and weight values of red mullet according to age for overall (O), female (F), male (M)

Age	Number			Length (cm) (Average ± SD)			Weight (g) (Average ± SD)		
	O	F	M	O	F	M	O	F	M
1	153	38	115	9.37±1.77	10,74±0.47	8.91±1.81	8.96±4.64	12.83±1.89	7.68±4.57
2	572	327	245	12. 38±0.67	12.41±0.67	12.35±0.68	18.68±2.93	19.09±2.84	18.13±2.97
3	515	404	111	14.01±0.46	14.05±0.47	13.85±0.39	25.85±3.48	26.06±3.45	25.06±3.51
4	106	94	12	15.16±0.34	15.18±0.34	15.04±0.34	33.18±4.16	33.20±4.15	33.04±4.61
5	60	58	2	16.09±0.55	16.10±0.56	17±0	40.01±5.96	40.16±5.99	35.57±0
6	16	16	0	17.63±0.55	17.63±0.55	0	55.06±9.17	55.06±9.17	0
7	13	13	0	19.77±0.92	19.77±0.92	0	80.57±13.78	80.57±13.78	0

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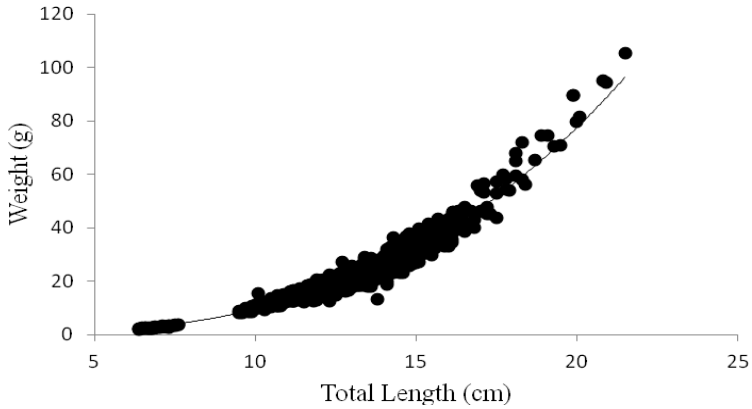

Figure 4: The length-weight relationship of red mullet

Parameter values of VBGE for both sexes pooled are L_∞ = 27.4 cm, W_∞ = 202.5 g, k=0.1402 per year and t_0 = -2.351. The growth equation calculated according to von Bertalanffy, with respect to age was determined to as $L_t = 27.4(1 - e^{-0.1402\,(t+2.351)})$, whereas the weight growth as

$$W_t = 202.46\left(1 - e^{-0.1402\,(t+2.351)}\right)^{3.0338}$$

Growth parameters of von Bertalanffy equation for females and males are displayed in Table 3. There were no significant differences among overall, female and male *M. barbatus ponticus* in terms of growth parameters (P>0.05). The growth performance index (Φ') estimated in this study was 4.36. The relationship between age and length is given in Figure 5.

Table 3: The von Bertalanffy growth parameters and growth equations for red mullet population

Sex	Growth Parameters					Growth Equation (L(t))	Growth Equation (W(t))
	L_∞	W_∞	K	t_0	b	$L(t)= L_\infty (1-e^{-k(t-to)})$	$W(t)= W_\infty (1-e^{-k(t-to)})^b$
F	25.4	171.4	0.1436	-2.696	2.816	$L(t)=25.4(1-e^{-0.1436\,(t+2,6967)})$	$W(t)=171.4(1-e^{-0.1436\,(t+2,6967)})^{2.8161}$
M	19.3	72.47	0.3526	-0.748	3.133	$L(t)=19.3(1-e^{-03526\,(t+0.7485)})$	$W(t)=72.47(1-e^{-0.1402\,(t+2.351)})^{3.133}$
F+M	27.4	202.4	0.1402	-2.351	3.033	$L(t)=27.4(1-e^{-0.1402\,(t+2.351)})$	$W(t)=202.46(1-e^{-0.1402(t+2.351)})^{3.0338}$

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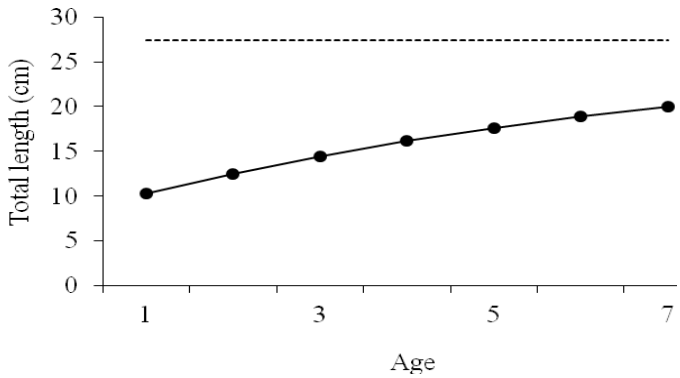

Figure 5: Relationship between age(year) and length for red mullet

The Fulton's coefficient of condition factor (C) calculated according to age groups ranged between 0.94 and 1.03 and average C of population were 0.96 ± 0.03.

When the monthly GSI of female specimens are examined, there was an increase starting from April reaching maximum values in June. It has been determined that spawning period occurred between April and September (Figure 6).

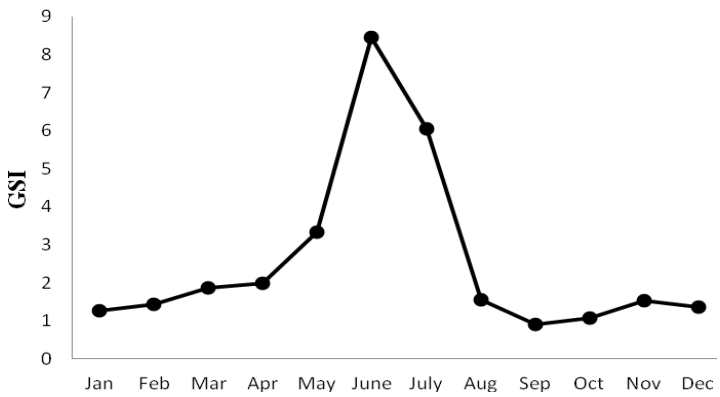

Figure 6: Monthly gonadosomatic index (GSI) for *M. barbatus ponticus*

The maximum number of eggs obtained from the female specimens in June, when the GSI value was also maximum. The minimum, maximum and mean egg number in 1 g ovary values was 22000, 42000 and 31239.9±7178.5 in June, respectively. The relative fecundity was 2529.6±1016 eggs g^{-1} (minimum 1669 and maximum 5193.8 eggs g^{-1}) per total body weight. The relationships between fecundity-length and fecundity-weight are given in Figure 7 and 8. Fecundity-total length and fecundity-weight equations were calculated as $F=0.0651\ TL^{5.1297}$ ($R^2=0.84$) and $F=338.5W^{1.5128}$ ($R^2=0.87$) respectively. The egg diameter ranged from 157.6 to 611.8 µm with a mean value of 360.9 µm±98 in June.

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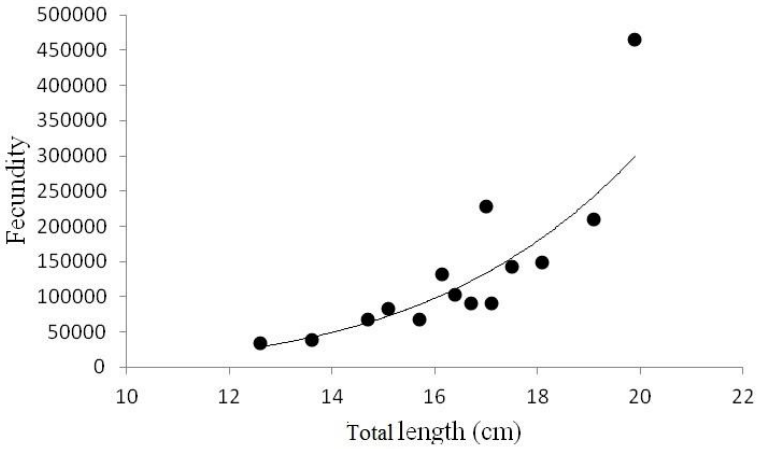

Figure 7: Relation between fecundity and Total length for *M. barbatus ponticus*

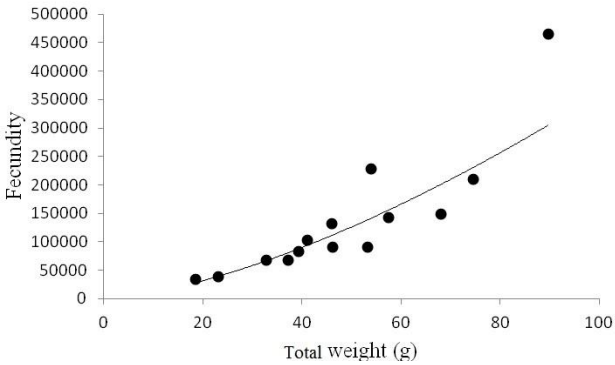

Figure 8: Relation between fecundity and Total weight for *M. barbatus ponticus*

Discussion

The maximum recorded total length for this fish was 21.5 cm in the present study, but Aksu et al. (2011) reported the maximum total length, 18.7 cm in the Black Sea. The maximum lengths of 23 cm Ozbilgin et al. (2002) and 18.7 cm Celik and Torcu (2000) have also been reported for *M. barbatus* from Aegean Sea.

The female-male ratio was 1.9:1.0 (950/485, female/male). There is a contradictory finding in the sex ratio of red mullet. For instance higher ratio in favor of male than the present value was reported by Okur (1990, 1991) whereas an equality between the sexes by (Genc, 2000). Moreover, in line with our findings higher occurrence of females is in the population has been reported (Togulga and Mater, 1992; JICA, 1993; Samsun and Ozdamar, 1995). It has also been stated in this study that as the length groups increase, the male ratio decreases.

In the present study, the length-weight relationship equation was determined as $W= 0.0088L^{3.0338}$. The length-weight relationships reported in the literature were $W= 0.06855L^{3.1563}$, $W= 0.0157L^{2.9811}$ (for *M. barbatus*), $W= 0.02117L^{2.7983}$(for *M. barbatus*), $W= 0.0063L^{3.182}$, $W= 0.0107L^{2.9717}$ by Samsun (1992), Celik and Torcu (2000), Atar and Mete (2009), Genc (2000), Aksu et al. (2011), respectively. The asymptotic

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length (L_∞) and weight (W_∞) were 27.4 cm and 202.46g respectively for the examined specimens (Table 3). The value of W_∞ obtained in other regions was determined as 274.28 g by Celik and Torcu (2000), 190.12 g by Atar and Mete (2009) and 149.4 g by Genc et al. (2002). Growth parameters of von Bertalanffy equations were found as L_∞=25.4cm, W_∞=171.34g and L_∞=19.3 cm, W_∞=72.47 g for females and males respectively. In a study carried out by Ozvarol et al. (2006) in the Mediterranean Region for *M. barbatus*, L_∞ values for female and male specimens were determined as 30.3 and 24.2 cm whereas the W_∞ values as 336.5 and 182.5 g When different results obtained for this species from Black Sea regions are examined, an inconsistency is noticed compared with this study (Table 4).

Table 4: Parameters of the length-age relationship and von Bertalanffy growth parameters for different studies in the Black Sea

Researchers	Year	L_∞ (cm)	k	t_o
This study	**2011**	**27.4**	**0.140**	**-2.351**
Samsun	1992	29.58	-	-
Samsun and Ozdamar	1995	24.99	0.120	-3.284
Bingel et al.	1995	24.80	0.120	-0.326
Genc	2000	23.83	0.227	-1.624
Genc et al.	2002	24.22	0.218	-
Aksu et al.	2011	20.15	0.011	-

The differences among the studies could be due to the variations of sampling methods, sampling time and the number of specimens in the Black Sea. It should be noted that sometimes different populations of the same species or the same population in different years can display changeable values perhaps due to different feeding conditions (Erkoyuncu, 1995).

The fecundity varied between 1669 and 4224 in the present study, which are within the range of literature values reported as 1923-13600 by Metin (2005), who carried out the study in the Aegean Region.

The relationships between fecundity with total length $F=0.0651\ TL^{5.1297}$ (R^2=0.84) and weight $F=338.5W^{1.5128}$ (R^2=0.87) were highly strong in the current investigation (Figure 7, 8). Weaker relationships have been obtained by Metin (2005) who reported the correlation coefficient as R^2=0.66 and R^2=0.71 for length and weight respectively.

In this study, the eyed egg diameters were between 157.6 to 611.8 µm with a mean of 360.9 µm±98 in June. Mater and Coker (2002) stated the egg diameters in the İzmir Bay were between 650 and 770 µm whereas these values have been determined as 610-720 µm in another study carried out in the Aegean Sea (Metin, 2005). These values are unequivocally higher than those obtained in the present

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study, suggesting that the regional differences play a significant role. In conclusion, the present monitoring study indicates that biological parameters of red mullet can exhibit variations depending on the regions. Therefore it is critical that fish with highly economical value are monitored regionally to ensure the sustainable management of stocks.

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