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Research article

Some biological characteristics of surmullet, *Mullus surmuletus* Linnaeus, 1758 in the Sea of Marmara

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Abstract: *Mullus surmuletus* is one of the economically important species which was investigated in this study. Length-weight relationship, age, growth parameters, reproductive season, length-at –first maturity and mortality parameters were determined in the Sea of Marmara. Samples were collected between March 2017 and December 2018 at 34 stations with trawl net. In totally 2486 *Mullus surmuletus* were sampled, total length and weight ranged from 8.7 cm to 23.7 cm in total length (TL) and from 6.01 g to 141.92 g in weight. The length-weight relationships were estimated as $W=0.0084*L^{3.09}$, $W=0.0081*TL^{3.10}$, $W=0.0099*TL^{3.03}$ for both sexes, females, and males respectively. The growth parameters were calculated for females $L_{\infty}=25.60$ cm TL, $K=0.21$ y^{-1} and $t_0=-2.69$ y, and for males as $L_{\infty}=17.72$ cm TL, $K=0.34$ y^{-1} and $t_0=-2.78$ y. The length-at-first maturity for female and male individuals were determined as L_{50} = 12.5 cm, L_{50} = 11.9 cm, respectively. According to monthly values of the gonadosomatic index and gonad stages, spawning period of *M.surmuletus* was found from May to July.

Keywords: Age, growth, reproduction, *Mullus surmuletus*, Sea of Marmara.

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Introduction

Surmullet, *Mullus surmuletus* (Linnaeus, 1758) is a commercially important species belonging to the Mullidae family. In Turkey, the species distributed in the Black Sea, Sea of Marmara, Aegean Sea, and Mediterranean Sea (Mater et al., 2003). And range from the East Atlantic (from the west of Norway to Dakar) to the Mediterranean, including Senegal and the Canary Islands (Froese & Pauly, 2022). It can grow up to 40 cm and live up to 10 years. It generally survives at depths of 5–409 m with a sandy bottom structure (Froese and Pauly, 2022).

It is catch intensively in our country due to its high economic and commercial value. It mostly caught in the Black Sea, Aegean Sea, Sea of Marmara and the Mediterranean Sea, respectively. Two percentage (56 tons) of the total catch (2775 tons) of surmullet were obtained in the Sea of Marmara in the 2020. In recent ten years the amount of production is showing declining trend in the capture volume since 2010 with 465 t until 2020 with 56 t were captured (TUIK, 2022). Due to the high economic value of the surmullet, the actual populations are being caught intensively. Withal, the amount of catching is declining rapidly in Turkish seas. Consequntly, the sustainability of stocks needs to be provide, it is possible by knowing the biological parameters of *M. surmuletus* in the Sea of Marmara.

Here, this study aims to enhance knowledge on some biological characteristics of *M. surmuletus* in the Sea of Marmara to this end we determined length-weight relationship (LWRs), length-age key, growth

characteristics, size-at-first maturity, spawning period and mortailty of this species. Our study represents the first information for size-at-maturity, spawning period and growth parameters of *M. surmuletus* in the Sea of Marmara.

Materials and Methods

Samples were collected between March 2017 and December 2018 at 34 stations from three different depth contours (20-50, 50-100, 100-200) from trawl net from the Sea of Marmara (Figure 1). Samplings were conducted via bottom trawl according to Mediterraean International Bottom Surveys (MEDITS) standards, at average speed of 3 miles and 30 min. duration.

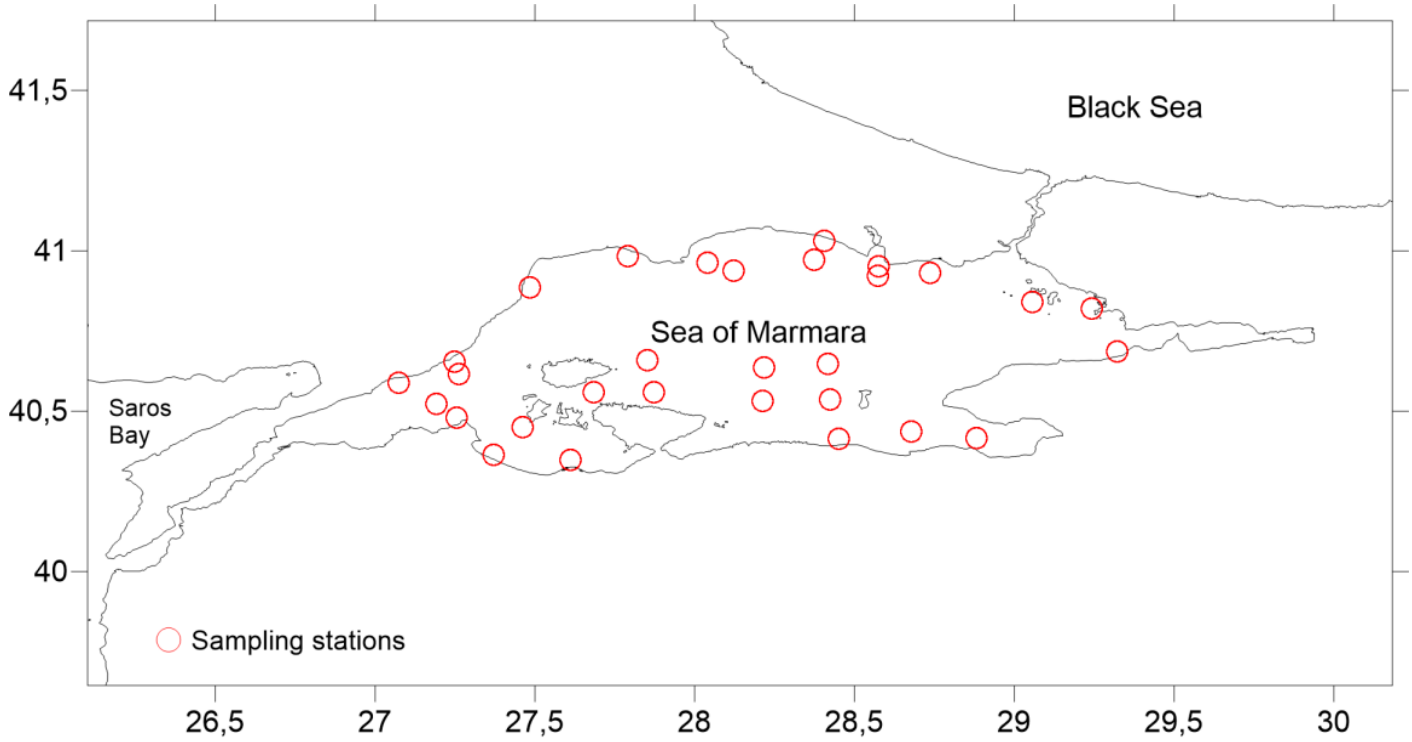

Figure 1. Sampling stations in the Sea of Marmara

The total length (TL) of the specimens were measured to the nearest 0.1 cm and total weight (W) was measured with 0.01 g. The length-weight relationship parameters were calculated using the Le Cren (1951)'s formula

$$W = a \times TL^b \quad (1)$$

where W is the total weight (g) and TL is the total length (cm), *a* and *b* are regression parameters. The growth type was identified with Student's t-test according to the equation (Sokal and Rohlf, 1987):

$$ts = (b-3)/SE(b) \quad (2)$$

where ts is t-test value, b is a slope, and SE(b) is a standard error of the slope. Significant difference of *b* values from 3, which represent isometric growth, was examined with the t-test (Pauly, 1993).

Sagittal otoliths were used for age determination (ICES, 2009). Growth parameters were estimated using the von Bertalanffy growth equation:

$$Lt = L_\infty \ [1-exp(\ k(t-t_0\ ))] \quad (3)$$

where L(t) is the length at age, L_∞ is the asymptotic length, K is the growth factor, and t_0 is the theoretical age when the size of fish is zero. Growth parameters were estimated using the FISAT II program package (Gayanilo et al., 2005). The φ growth performance index was calculated as follows;

$$\phi = logK + 2 \times log\ L_\infty \quad (4)$$

Total mortality (Z) was found using the length converted catch curve (Pauly, 1984). Natural mortality (M) was determined using Pauly's (1980) formula

$$Log(M) = (-0.0066) - 0.279 \times log(L) + 0.6543 \times log(K) + 0.4634 \times log(T) \quad (5)$$

Fishing mortality was calculated using the following formula

$$F = Z-M \quad (6)$$

The exploitation rate (E) was obtained using the formula

$$E = F/Z \quad (7)$$

Gonad maturity stages were determined by Holden and Raitt (1974): immature, maturing, ripening, ripe, and spent. The gonadosomatic index (GSI) was calculated using the formula developed by Gibson and Ezzi (1980):

$$GSI = (GW/W\text{-}GW)\times 100 \quad (8)$$

where GW is the gonad weight (g).

The length at first maturity (L_{50}) was estimated by fitting a logistic function using the Newton algorithm which is defined as:

$$P(1) = 1/1+e^{-(a+b1)} \quad (9)$$

where P(*1*) was the proportion of mature specimens at length *1*, and *a* and *b* the parameters of the logistic equation (Piñeiro and Saínza, 2003).

All statistics were analyzed using the MINITAB 16 program. The normality assumptions were checked with Kolmogorov-Simirnov test. Student's t-test was used for analyzing the fish growth type.

Results

A total of 2486 *M. surmuletus* individuals were evaluated for analyses. Of the 2486 individuals 981 were determined as female (39.5%) and the remaining 917 of them were male (36.9 %), and 588 (23.7%) individuals could not be determined. The sex ratio was calculated as 1:1.07 in favor of females. Chi-square analysis showed that there was no significant difference between the numbers of male and female individuals (x^2, $p > 0.05$). Total length values were varied between 8.7 and 23.2 cm TL, with an average of 13.53±2.09cm TL. The total weight of the individuals was ranged from 6.01 to 141.92 g, with a mean of 28.55±14.84g (Table 1). The length composition and length-frequency distribution of the individuals are shown in Figure 2. The highest represented length group was determined as 12 cm TL for males and 15 cm TL for females.

Table 1. Length-weight parameters of *Mullus surmuletus* in the Sea of Marmara

Sex	N	Length distribution (cm)		Weight distribution (g)	
		Min-Max	Average±se	Min-Max	Mean±se
Female	981	8.8-23.2	14.69±2.22	6.01-141.92	36.82±17.64
Male	917	8.7-17.0	12.86±1.35	6.30-60.09	23.30±8.04
Combined	2486	8.7-23.2	13.53±2.09	6.01-141.92	28.55±14.84

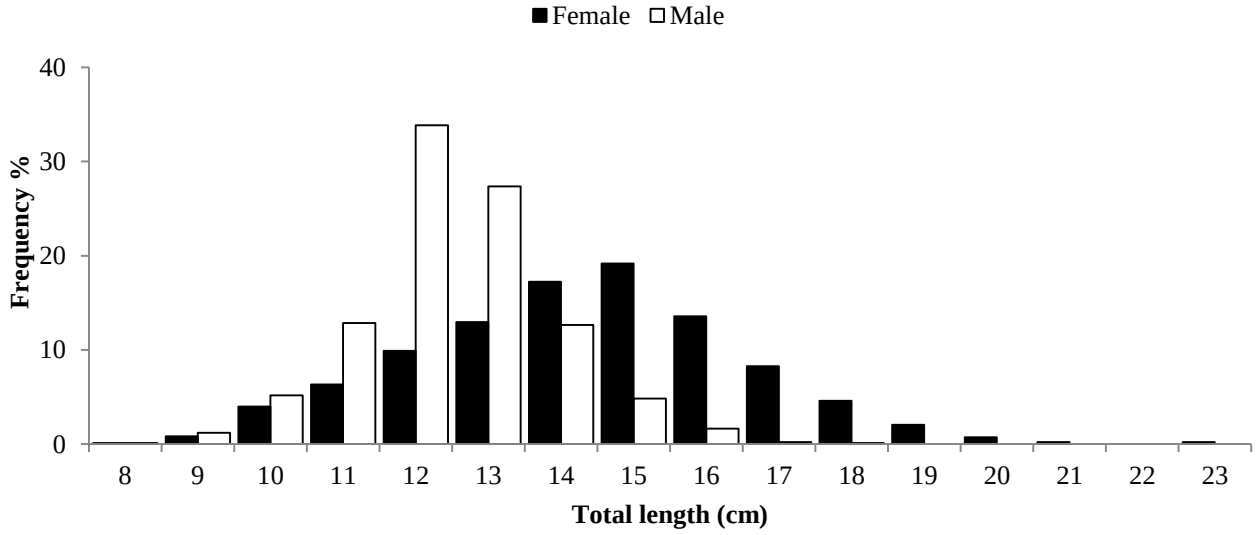

Figure 2. Length frequency distribution of female and male of *Mullus surmuletus*

The relationship between the total length (L) and weight (W) of *M. surmuletus* was calculated as $W = 0.0084*L^{3.09}$ ($R^2 = 0.95$), $W = 0.0081*TL^{3.10}$ $R^2 = 0.96$, $W = 0.0099*TL^{3.03}$ $R^2 = 0.88$ for both sexes, females, and males respectively. According to Student's t-test values, males showed isometric growth ($p>0.05$), females and combined sexes showed positive allometric growth ($p<0.05$) (Table 2).

GSI values of the individuals were ranged from 0.28 and 9.28. The maximum GSI for females was determined

in May in 2017 and May-June in 2018, the minimum GSI was found in October 2017 and 2018. According to GSI values and maturity stages during the study period, the spawning occurred from May to July (Figure 3). Length-at-first maturity respectively for female and male individuals were determined as L_{50} = 12.5 cm, L_{50} = 11.9 cm (Figure 4).

Table 2. Length weight relationship parameters of *Mullus surmuletus*

	N	a	b	r^2	SE_b	Growth type
Female	981	0.0081	3.10	0.96	0.020	+A
Male	917	0.0099	3.03	0.88	0.037	I
Combined	2486	0.0084	3.09	0.95	0.015	+A

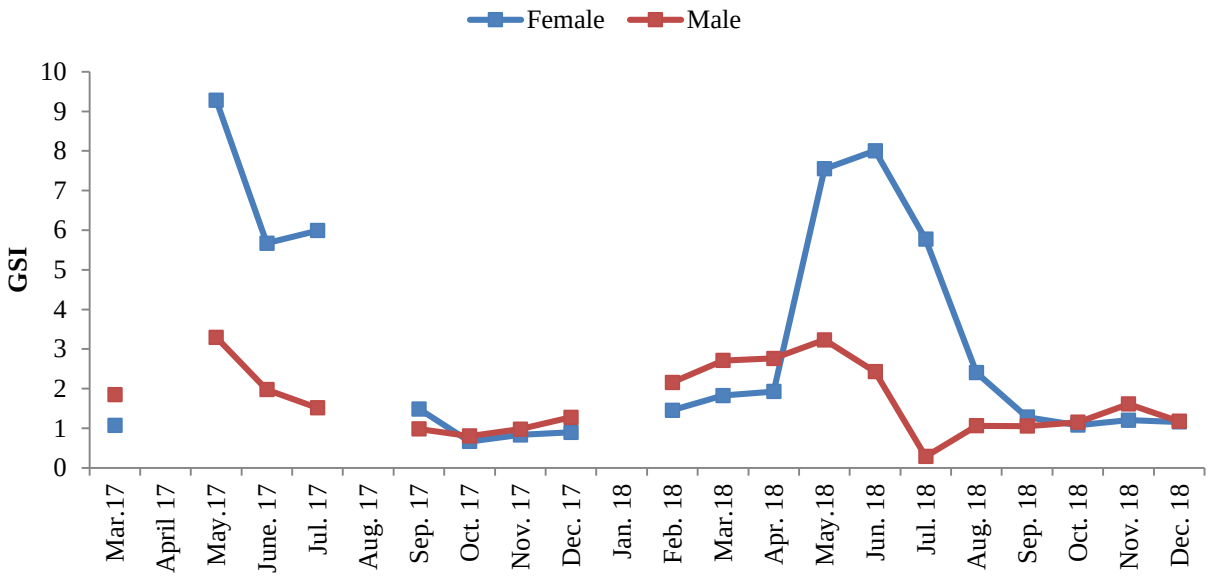

Figure 3. Monthly variation of gonadosomatic index in females and males of *Mullus surmuletus*

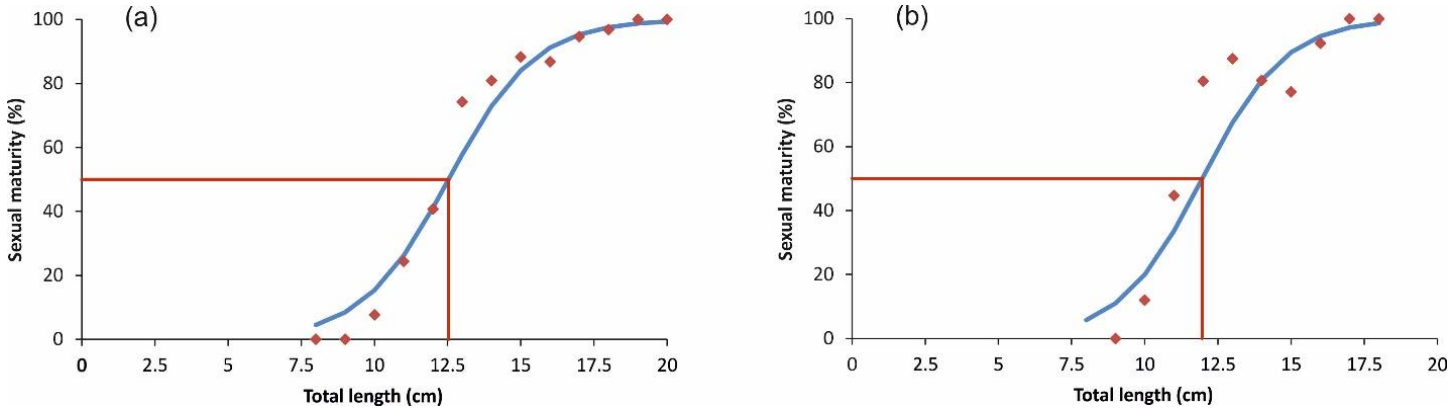

Figure 4. The first reproductive length (L_{50}) of *Mullus surmuletus* in female (a) and male (b) individuals.

271 otoliths were determined that the age distribution was ranged from 0 and 4 (Table 3). The asymptotic length (L_∞), growth coefficient (K), and hypothetical age (t_0) were calculated for females as 25.60 cm TL, 0.21 y^{-1} and -2.69 y, and for males as 17.72 cm TL, 0.34 y^{-1} and -2.78 y, respectively (Figure 5). The total mortality (Z), natural mortality (M), and fishing mortality (F) were detected as 2.39, 0.57 and 1.82, respectively. The exploitation rate (E) was found as 0.76. In this study exploitation rate (E = 0.76) was found much higher than the optimal value (0.40) which implies high fishing mortality for *M. surmulteus* in the Sea of Marmara.

Table 3. Length-age key of *Mullus surmuletus*

Age	Female			Male			Combined		
	Min- Max	Mean	N	Min- Max	Mean	N	Min- Max	Mean	N
0	10-11.5	10.92±0.24	6	10-12	10.94±0.18	14	10-12	10.9±0.12	22
1	11.5-17.7	14.26±0.28	40	10.9-15	12.82±0.16	40	10.5-17.7	13.45±0.16	91
2	12.4-19.9	16.08±0.19	86	12.2-17.5	14.15±0.26	28	12.2-19.9	15.59±0.16	121
3	15.7-21.2	18.13±0.26	32	18	18	1	15.7-21.2	18.17±0.23	36
4	23.2	23.2	1	-	-	-	23.2	23.2	1

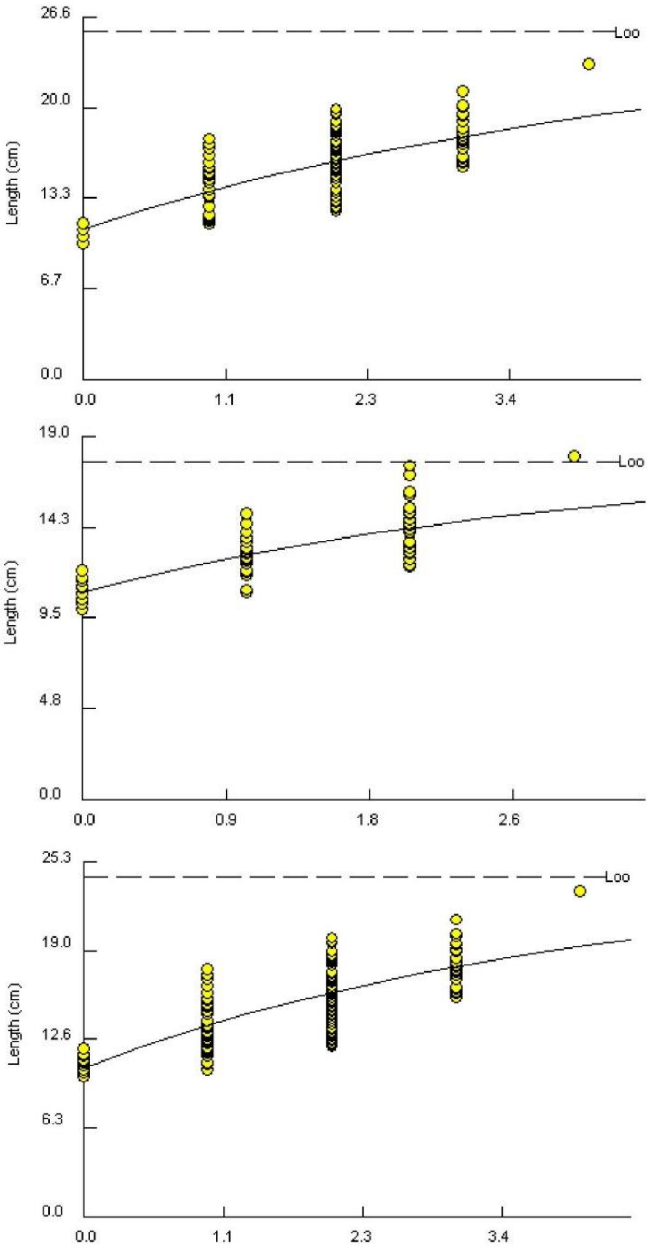

Figure 5. The von Bertalanffy growth curve of female (A), male (B) and combined (C) of *Mullus surmuletus*

Discussion

A total of 2486 individuals were sampled during the study period. Total length and weight values was measured between 8.7 cm (6.01 g) - 23.2 cm (141.92 g). During the sampling period, the females were found to be dominant. Male individuals show isometric growth, females and combined show positive allometric growth. This may be due to the differences of season, habitat, gonadal maturity, diet and length ranges of specimens. The results of the length-weight relationship parameters in the previous studies are given in Table 4. Only three researches conducted with in the Sea of Marmara. Keskin and Gaygusuz (2010) studied on beach seine in shallow waters of Erdek Bay, Bök et al. (2011) studied only Northern part of the Sea of Marmara with bottom trawl and beam trawl, and Demirel and Murat-Dalkara (2012) were investigated in enclosed basin in the Sea of Marmara with bottom trawl. There researchers were found the *b* value was 3.39, 2.72 and 3.17, respectively. Our study compared to a previous study (b = 2.72, negative allometry, n = 142) (Bök et al. 2011). The reason for this difference may be sampling only a small part of the Sea of Marmara (Northern Sea of Marmara), the number of individuals measured and sampling gear.

Table 4. Length-weight relationship parameters of *Mullus surmuletus* in the different areas

Author	**Area**	**Sex**	***a***	***b***	R^2
Dorel 1986	Biscay Bay		0.004	3.35	0.998
	North and South Channel		0.007	3.19	0.998
Coull et al. 1989	North Sea		0.005	3.31	
Campillo 1992	Lion Bay	E+D	0.082	3.00	
Morales-Nin 1991	Mallorca, Spain		0.032	2.67	0.959
			0.016	2.91	0.972
Djabali et al. 1993	Ionian Sea		0.007	3.00	
	Sicilia		0.009	3.00	
Reñones et al. 1995	Mallorca	E	0.010	3.07	0.970
		D	0.010	3.11	0.970
			0.009	3.12	0.980
Dulčić and Kraljevic 1996	North Adriatic		0.001	3.51	0.885
Goncalves et al. 1996	Portugal		0.003	3.09	0.920
Merella et al. 1997	Balearic Islands		0.008	3.09	0.986
Morato et al. 2001	Azorian Islands	E	0.013	3.00	0.933
		D	0.010	3.11	0.974
		E+D	0.007	3.22	0.992
Stergiou and Moutopoulos 2001	Evvoikos	E+D	0.012	3.14	0.970
	North Aegean Sea	E	0.009	3.25	0.970
		D	0.009	3.23	0.990
		E+D	0.015	3.04	0.940
		E+D	0.012	3.15	0.960
	Kyclades	E+D	0.018	2.90	0.920
Abdallah 2002	Alexandria		0.011	3.03	0.731
Moutopoulos and Stergiou 2002	Kyclades,	E+D	0.014	2.95	0.940
Santos et al. 2002	Algarve		0.008	3.16	0.953
Koutrakis and Tsikliras 2003	Strymon Bay		0.005	3.51	0.988
Morey et al. 2003	Balearic Island		0.007	3.17	0.995
Valle et al. 2003	Spain	E+D	0.010	3.08	0.996
Mendes et al. 2004	Nazaré to St André		0.010	3.08	0.970
			0.004	3.37	0.946
Mahé et al. 2005	Manche	E	0.006	3.25	0.976
		D	0.007	3.18	0.952
Quetglas et al. 2005	Balearic Island		0.008	3.12	
Çiçek et al. 2006	Babadillimanı, Mediterranean		0.008	3.11	0.984
Dulčić and Glamuzina 2006	Balearic Islands		0.009	3.07	
	North Adriyatic		0.004	3.37	0.963
Karakulak et al. 2006	Gökçeada, North Aegean Sea	E	0.009	3.10	0.967
		D	0.007	3.21	0.977
		E+D	0.007	3.19	0.976
			0.010	3.09	0.984
			0.008	3.12	0.925
			0.006	3.21	0.978
			0.006	3.27	0.985
Özaydın and Taşkavak 2006	İzmir Bay		0.017	3.01	0.960
Özaydın et al. 2007	İzmir Bay		0.011	3.20	0.990
İlkyaz et al. 2008	İzmir Bay	E+D	0.006	3.27	0.982
Karachle and Stergiou 2008	North Aegean Sea	E	0.003	3.50	0.990
		D	0.003	3.50	0.990
			0.003	3.49	0.990
Mata et al. 2008	South Atlantic		0.008	3.20	0.980
Ceyhan et al. 2009	Gökova Bay		0.007	3.21	0.979

İlhan et al. 2009	İzmir Bay		0.008	3.13	0.960
Maci et al. 2009	Acquatina, Lecce		0.011	3.29	0.994
Mehanna 2009	Alexandria, Demietta and Port Said		0.010	3.06	0.979
Veiga et al. 2009	Algarve		0.006	3.34	0.993
Keskin and Gaygusuz 2010	Erdek Bay, Marmara Sea	E+D	0.005	3.39	0.993
Lamrini 2010	M'diq Bay	E	0.005	3.19	
		D	0.004	3.25	
Bök et al. 2011	Marmara Sea		0.024	2.72	0.886
Demirel and Murat-Dalkara 2012	Marmara Sea	E+D	0.006	3.18	0.932
Torres et al. 2012	Cadiz Bay		0.005	3.28	0.980
Arslan and İşmen 2013	Saros Bay, North Aegean Sea	E	0.011	3.01	
		D	0.008	3.16	
		E+D	0.008	3.12	
Crec'hriou et al. 2013	Catalan coast		0.012	3.01	0.937
Moutopoulos et al. 2013	Korint Bay, Greece		0.004	3.38	0.979
Wilhelms 2013	North Sea		0.015	2.92	0.970
Kasapoglu and Duzgunes 2014	Black Sea, Turkey		0.004	3.40	0.957
This study	Marmara Sea	C	0.0084	3.09	0.95
		F	0.0081	3.10	0.96
		M	0.0099	3.03	0.88

The GSI values of some months could not be calculated because they could not be captured in all months during the study period. In the females, maximum GSI was determined in May (2017) minimum GSI was in October (2017). The number of mature individuals were more in the summer period. The reproductive period was determined as May, June and July. Muus and Nielsen (1999) reported that the spawning time was May-July in the British Channel, Mediterranean and the Black Sea. İlhan et al. (2009) stated that the reproductive period between April-September in the İzmir Bay. Arslan and Ismen (2013) reported that the spawning season was between the beginning of the summer months - end of the spring months in the North Aegean Sea (Table 5).

Length-at-first maturity were analysed 12.5 cm in female and 11.9 cm in male individuals. The minimum landing size is 11 cm for *M. surmuletus* on the regulation of commercial fishing prepared by the Ministry of Agriculture and Forestry in Turkey (Communique no. 2020/20). Our results for length-at first maturity indicated, MLS regulation for *M. surmuletus* is much below than its maturity size as indicating catch of juveniles. The MLS is should be larger than the first reproductive length for sustainable fishing management.

There are some researchers detected the first reproductive length. In the North Aegean Sea only one study indicated that the first reproductive length as 13.7 cm in females 13.2 in males (Arslan and İşmen, 2013). The results of our study were found to be smaller than the previous ones, this is due to the regional differences with different ecological conditions (Table 5). This study has the first results on the first reproductive length for *M. surmuletus* in the Sea of Marmara.

The growth parameter results of *M. surmuletus* was mentioned for the first time in the Sea of Marmara. When we compare the values (L_∞, K, t_0) with previous studies conducted in Turkish seas (İlhan et al. 2009; Arslan and Ismen 2013), we found that the other studies were in the Aegean Sea and found the paremeters of L_∞ to be greater than our results. It is thought that the differences in the results due to the regions There were not statistically significant difference between the growth parameters on the other studies ($p>0.05$, Table 6).

Considering the calculated mortality parameter results the exploitation rate is above the optimum value, the population have under the fishing pressure. The results obtained from this study will help fisheries scientists for future studies on *M. surmuletus* populations and may also help to enforce regulations on commercial fisheries concerning minimum landing size restrictions for this species. It's our suggestion, that according to first-maturity length results, the MLS regulation should be revise so that the value declared in the Comminuque No 2020/20 is at least above 12.5 cm.

Table 5. Reproductive time and first reproductive length of *Mullus surmuletus* in the other areas

Author	Area	Sex	Reproductive time	Lm (cm)	Length
Dorel 1986	Biscay Bay	M		16.0	TL
		F		18.0	TL
Morales-Nin 1991	Mallorca	M		17.0	
		F	April-May	15.0	
			April-May		
Oliver and Morillas 1992	Balear Island			15.0	
N'Da and Déniel 1993	Balear Island		May-June		
	Algeria		May-July		
Golani 1994	Hayfa and Aşdod port		March-June		
Reñones et al. 1995	Mallorca	M	March-June	15.0	TL
		F	March-June	16.8	TL
Jardas 1996	Adriyatic Sea		May-July		
Stergiou et al. 1997	Aegean Sea	F		13.8	FL
Muus and Nielsen 1999	English Channel		May-July		
Lloret et al. 2000	Lion Bay and Gül Bay		May-July		
Anonymous 2001	Biscay Bay				
Ragonese et al. 2004	Sicilian Channel	F	April-September	19.5	TL
İlhan et al. 2009	Izmir Bay		April-September		
Mehanna 2009	Alexandria	M	April-June	13.0	
		F	April-June	15.0	
	Alexandria		April-June	15.1	
	Canary Islands			16.0	TL
	Mallorca	M		15.0	
		F		16.8	
Alsayes et al. 2010	Eagypt	M	April-June	12.5	
		F	April-June	11.5	
Lamrini 2010	M'diq Bay, Morocco	M	May-July	16.7	TL
		F	May-July	17.8	TL
Tsikliras et al. 2010	Adriatic Sea		May-June		
ICES, 2012	English Channel	M		16.2	
		F		16.7	
Arslan and İşmen, 2013	Saros Bay, North Aegean Sea	M	May-June	13.2	TL
		F		13.7	
This study	Sea of Marmara	M	May-July	11.9	TL
		F		12.5	

Table 6. Growth parameters of *Mullus surmuletus* in the different areas

Author	Area	Sex	L∞	Length	K (y^{-1})	t_0(y)	Ø
Gharbi and Ktari 1981	Tunusia	M	19.9	SL	0.490	-0.03	2.29
		F	21.8	SL	0.510	-0.11	2.38
Andaloro 1982	Tiren Sea and Ionian Sea	M	25.0	TL	0.300	-2.39	2.27
		F	30.1	TL	0.240	-2.68	2.34
Sánchez et al. 1983	Palma de Mallorca Island	M	25.5	TL	0.273	-2.45	2.25
Andaloro and Prestipino 1985	Sicilian Sea		27.5	TL	0.450	0.43	2.53
Morales-Nin 1986	Catalan Sea		30.9	TL	0.113	-3.85	2.03
Morales-Nin 1991	Mallorca	M	23.3	TL	0.282	-3.33	2.18
		F	34.5	TL	0.137	-3.82	2.32
Campillo 1992	Golfe du Lion	M	28.5	TL	0.530		2.63
		F	21.2	TL	0.430		2.68
Oliver and Morillas 1992	Spain		29.8	TL	0.490	-0.31	2.64
Djabali et al. 1993	Ionian Sea		22.6	TL	0.270		2.31
Reñones et al. 1995	Catalan Sea		32.5	TL	0.110	-3.65	2.07
Reñones et al. 1995	Palma de Mallorca Island	F	31.9	TL	0.205	-2.61	2.33
Stergiou et al. 1997	North Aegean Sea	M	22.0	FL	0.267	-1.46	2.11
		F	24.8	FL	0.262	-1.58	2.21
	North Aegean Sea	M	38.0	FL	0.104	-2.76	2.18
		F	41.3	FL	0.100	-2.80	2.23
Machias et al. 1998	Kritiko Pelagos		35.4	TL	0.225	-1.19	2.45
Voliani et al. 1999	Tiran Sea	M	26.4		0.690		2.68
		F	32.2		0.710		2.87
Jabeur et al. 2000	Gabes Bay	M	27.6	TL	0.270	-1.07	2.14
		F	33.4	TL	0.430	-0.65	2.29
Ragonese et al. 2004	Sicilian Channel	M	25.0	TL	0.500	-0.20	2.49
		F	29.0	TL	0.480	-0.84	2.61
Mahé et al. 2005	Manche, France		53.3	TL	0.183	-1.23	2.72
Quetglas et al. 2005	Spain		40.1	TL	0.164	-1.88	2.42
İlhan et al. 2009	İzmir Bay, Aegean Sea		27.9	TL	0.103	-1.58	2.18
Mehanna 2009	Alexandria		31.7	TL	0.470	-0.30	2.67
Lamrini 2010	M'diq Bay, Morocco	M	30.3	TL	0.520	-0.16	2.68
		F	32.3	TL	0.540	-0.62	2.75
Arslan and İşmen 2013	Saros Bay, North Aegean Sea	M	26.94	TL	0.200	-2.34	2.16
		F	28.38	TL	0.190	-2.16	2.18
		M+F	27.82	TL	0.200	-2.16	2.19
Colloca et al. 2013	Balearic Islands		40.1	TL	0.160	-1.88	2.41
Mahé et al. 2013	Eastern British Channel and North Sea	M	36.0	TL	0.218	-3.23	2.45
		F	51.2	TL	0.190	-2.90	2.70
This study	Sea of Marmara	F	25.6	TL	0.21	-2.69	2.14
		M	17.72	TL	0.34	-2.78	2.03

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Conflicts of Interest

No potential conflict of interest was reported by the authors.

Ethical Approval

All applicable national guidelines for the care and use of animals were followed.

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