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Estimation of a selected population parameters for Turkish marine waters' red mullet *Mullus barbatus ponticus* Essipov, 1927 (Actinopterygii: Perciformes: Mullidae)

Estimación de parámetros poblacionales seleccionados para salmonetes de aguas marinas turcas *Mullus barbatus ponticus* Essipov, 1927 (Actinopterygii: Perciformes: Mullidae)

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ABSTRACT

In order to calculate the length–weight and length–to–length relationships for red mullet *Mullus barbatus ponticus* Essipov, 1927 in Turkish marine waters, samples were collected from the Marmara Sea, the Northern Aegean Sea and the Western Black Sea by trawler from 2013 through 2016 fishing season. In the study in which 1,756 individuals were sampled, the number and proportion of individuals obtained from the Western Black Sea Region was 9.7% with 171 individuals from Amasra and 65.3% with 1,148 individuals from Ereğli; it was 1.7% with 30 individuals from the Marmara Sea, while it was 23.2% with 407 individuals from the North Aegean Sea. The total length was 6.3 to 20.5 cm, while the weight ranged from 2.54 to 89.53 g. In addition, 49 length–weight relationship values were examined from the literature of red mullet sampled in Turkish marine waters from 1977 to 2017. The smallest b value was determined as 2.84 from Iskenderun Bay and the highest was 3.3916 from the Izmir Bay. The median value of b was 3.188; it was observed that 50% of the b values ranged from 3.092 to 3.26.

Key words: *Mullus barbatus ponticus*; length–weight relationships; length–lenght relationships; growth parameters; positive allometry

RESUMEN

Para calcular las relaciones longitud–peso y longitud–longitud de los salmonetes *Mullus barbatus ponticus* Essipov, 1927 distribuido en aguas del mar turco, se tomaron muestras del mar de Mármara, del mar Egeo septentrional y del mar Negro occidental mediante una red barredera durante el periodo de pesca de los años 2013 a 2016. En el estudio se tomaron muestras de 1.756 individuos. El número y la tasa de ejemplos obtenidos de la región occidental del Mar Negro, según las estaciones, fue del 9,7% con 171 individuos de Amasra y del 65,3% con 1.148 individuos de Ereğli; mientras que el 1,7% con 30 individuos del mar de Mármara, es del 23,2% con 407 individuos del mar Egeo septentrional. La altura total osciló de 6,3 a 20,5 cm, y el peso de 2,54 a 89,53 g. Además, se examinaron 49 artículos que publicaron datos de la relación longitud–peso de los salmonetes mostrados en aguas del mar turco de 1977 a 2017. Se encontró que el valor b más bajo fue de 2,84 en la Bahía de İskenderun y el más alto de 3,3916 en la Bahía de İzmir. El valor promedio de b es 3,188; Se observó que el 50% de los valores b estaban en el intervalo de 3,092 a 3,26.

Palabras clave: *Mullus barbatus ponticus;* relación longitud–peso; relación longitud–longitud; parámetros de crecimiento; alometría positiva

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INTRODUCTION

According to fishbase [1], the goatfish family (Mullidae) includes 88 species belonging to 6 genera Worldwide. However, in Turkish marina waters the family Mullidae [2] is represented by *Mullus barbatus* Linnaeus, 1758, now *Mullus barbatus ponticus*, Essipov, 1927; *Mullus surmuletus* Linnaeus, 1758; *Parupeneus forsskali* (Fourmanoir & Guézé, 1976); *Upeneus moluccensis* (Bleeker, 1855) and *Upeneus pori* (Ben-Tuvia & Golani,1989).

The red mullet (*M. barbatus* Linnaeus, 1758) is found in the Eastern Atlantic, including the Mediterranean and the Black Sea, from Western Norway, the English Channel (rare in the North Sea), to Dakar, Senegal, and the Canary Islands [3]. Red mullet's scientific name was *Mullus barbatus* Essipov, 1927, but fishbase changed it to *Mullus barbatus ponticus* Linnaeus, 1758 [1]. Red mullet is a significant target species for Mediterranean fisheries because of its commercial value [4, 5]. As a result, numerous writers have looked at the red mullet's population dynamics and biological characteristics in the Mediterranean [6, 7, 8, 9, 10, 11, 12, 13]. Fish biology, physiology, ecology, and fisheries evaluation all heavily rely on the length-weight relationships (LWRs) and length-length correlations (LLRs) [14]. They are applied in the assessment of fish stocks and populations [14, 15], and they are useful for between-region comparisons of life histories of species and the general health of fishing species, conditions, and reproduction history [16, 17, 18, 19, 20, 21, 22, 23, 24]. The Sea of Marmara, Western Black Sea, and Northern Aegean Sea are considered Turkey's most significant fishing grounds, contributing a sizeable share of the country's total marine fish production [25]. The goal of the current study was to examine the length-weight and length-length connections of red mullet samples collected from Turkey's Black Sea, Northern Aegean Sea, and Sea of Marmara coasts. (FIG. 1). Additionally, a total of 31 research conducted from 1977 to 2017 in Turkish marine waters yielded 49 LWRs. The following study evaluates Turkish scientific studies from the past and present.

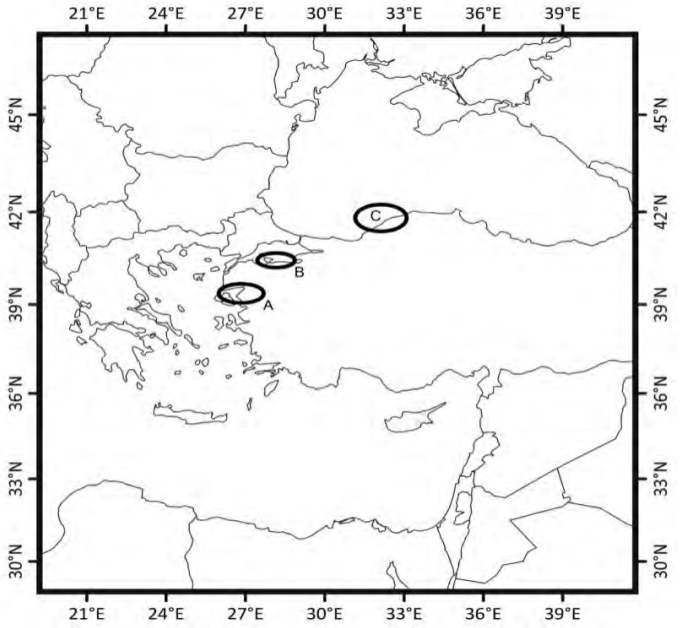

FIGURE 1. Sampling areas (A: Edremit Bay (Northern Aegean Sea) B: Bandırma, Sea of Marmara; C: Ereğli and Amasra (Western Black Sea)

MATERIAL AND METHODS

During the 2012-2013 fishing seasons, samples of red mullet were taken using a commercial trawl net between the depths of 20-90 meters in the Sea of Marmara, Western Black Sea (Amasra and Ereğli sites), and Northern Aegean Sea. (FIG 1). The weights were recorded with a digital balance (AND GF 6100 Model, Japan) to the nearest 0.01 g, while the total length (TL), fork length (FL), and standard length (SL) were measured with digital calipers (Mitutoyo 500-181-30 Digital Compass, Japan) to the nearest mm. The equation $W = aL^b$ [26, 27] was used to determine the length-weight relationships (LWRs), where W is the fish's body weight (g) and L is the entire length of the fish (cm). Least-squares regression was used to determine the parameters a and b as well as the coefficient of determination (r^2). Additionally, 95% confidence limits of the parameter b were estimated by the equation: $t = \left(\frac{Sd\log TL}{Sd\log W}\right) \times \frac{|b-3|}{\sqrt{1-r^2}} \times (\sqrt{n-2})$, where $SdlogTL$ is the standard deviation of the logTL values, $SdlogW$ is the standard deviation of the logW values, n is the number of samples used in the computation. If the estimated t value is greater than the tabular t values for $n-2$ degrees of freedom, then the value of b differs from b = 3 [27]. To determine whether parameter b and its confidence interval (= 0.05) covers 3 or is significantly different from 3, the student's t-test was used to determine the growth type. Froese [28] found that changing length measurements had an effect on a but not b. Of particular note is the fact that for the same sample, a rise from total to fork and total to standard length [28]. Additionally, using linear regression analysis for TL-FL, FL-SL, and SL-TL, respectively, length-length relationships (LLRs) for the samples from the Sea of Marmara and Northern Aegean Sea were established.

RESULTS AND DISCUSSION

A total of 1756 individuals were collected from Black Sea (9.7%; n=171 from Amasra and 65.3%, n=1148 from Ereğli), Sea of Marmara (1.7%, n=30) and Northern Aegean Sea (23.2%, n=407). The range of recorded total fish lengths and weights, parameters of LWRs and t-test results were calculated separately for each studied area and are presented in TABLE I.

Red mullet showed negative allometric growth (b<3) for Western Black Sea (Amasra) and Northern Aegean Sea (Edremit Bay). However, red mullet exhibited positive allometric growth (b>3) for Western Black Sea (Ereğli) and Sea of Marmara. The parameters of LLRs were given in TABLE II.

Length and weight characteristics, sex, number of individuals, values of a, b, r^2 and sampling location of previous studies are given in TABLE III. The value of the parameter b in LWRs ranged from 2.84 in İskenderun Bay to 3.361 in Gökçeada Island for total length. The value of the parameter b in LWRs ranged from 2.9231 in İzmir Bay to 3.3916 in İzmir Bay for fork length [29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55].

According to Stergio and Moutopoulos [56] and Froese [28] a plot of log (a) versus b for all known LWRs of a species results in a linear relationship which can be used to identify outliers. This method was applied for red mullet and the plots of log (a) versus b for all available length-weight relationships (for each length type separately) are shown in FIG 2, 3, and 4.

There are various studies providing information about maximum length and also maximum weight of the species in coastal waters of Turkey (TABLE II). Results of the present study showed that minimum

TABLE I
Parameters of length–weight for red mullet

Location	Sex	n	Total Length (cm)		Weight (g)		Relationship Parameters			*t*–test	*t*–table (0.05)	GT
			Min	Max	Min	Max	r^2	*a*	*b*	*P*		
Black Sea (Amasra)	C	171	6.3	15.0	2.54	31.75	0.918	0.0097	2.9941	0.0056	1.98	-A
Black Sea (Ereğli)	C	1148	6.8	16.1	2.60	40.79	0.9275	0.0063	3.19	0.1074	1.96	+A
Aegean Sea (Edremit)	C	407	10.1	20.5	8.45	89.53	0.8157	0.0157	2.795	0.0548	1.97	-A
Sea of Marmara (Bandırma)	C	30	11.1	18.5	12.50	62.86	0.9791	0.0067	3.1408	0.0463	2.04	+A

n: Sample size, Min: Minimum, Max: Maximum, *a* and *b*, Intercept and Slope of Length–Weight Relationships, r^2: Coefficient of Determination, C, Combined, GT: Growth Type, -A: Negative Allometric, +A: Positive Allometric

TABLE II
Parameters of Length–Length Relationships for red mullet

Location	TL (cm)			FL (cm)			SL (cm)			Equation	n	*a*	*b*	r^2
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max					
Northern Aegean Sea										TL = *a* + *b*FL		0.2460	1.0821	0.9486
Northern Aegean Sea	12.66	10.1	20.5	11.47	9.2	18.8	10.08	8.0	16.6	FL = *a* + *b*SL	407	0.7321	1.0649	0.9482
Northern Aegean Sea										SL = *a* + *b*TL		-0.0724	0.8023	0.9505
Sea of Marmara										TL = *a* + *b*FL		0.5311	1.0824	0.9855
Sea of Marmara	14.26	11.1	18.5	12.68	9.5	16.5	11.24	8.5	14.4	FL = *a* + *b*SL	30	-0.2618	1.1514	0.9834
Sea of Marmara										SL = *a* + *b*TL		0.0236	0.7868	0.9921

TL: Total Length, FL: Fork Length, SL: Standard Length, Min: Minimum, Max: Maximum, n: Sample size, *a* and *b*: intercept and slope of Length–Length Relationship, r^2: coefficient of determination

TABLE III
49 Length–Weight Relationships Obtained from Different Areas

Location	L min–L max (cm)	LT	W min–W max (g)	Sex	n	*a*	*b*	r^2	Reference
İzmir Bay	7.50–22.0	FL	6.00–115.00	C	6054	0.0165	2.9231	–	[29] Toğulga, 1977
İzmir Bay	8.60–18.3	FL	9.00–121.00	F	218	0.0059	3.3916	0.9890	[30] Akyol *et al.*, 2000
İzmir Bay	9.50–15.0	FL	12.00–51.00	M	110	0.0077	3.2834	0.9750	[30] Akyol *et al.*, 2000
İzmir Bay	8.60–18.3	FL	9.00–121.00	C	346	0.0063	3.3625	0.9880	[30] Akyol *et al.*, 2000
Edremit Bay	9.45–18.7	FL	13.45–87.65	C	474	0.0157	2.9811	0.9620	[31] Çelik and Torcu, 2000
İzmir Bay	–	FL	–	F	155	0.0073	3.2800	–	[11] Kınacıgil *et al.*, 2001
İzmir Bay	–	FL	–	M	65	0.0077	3.2500	–	[11] Kınacıgil *et al.*, 2001
İzmir Bay	8.10–16.1	FL	7.00–66.00	C	220	0.0071	3.2900	–	[11] Kınacıgil *et al.*, 2001
Babadillimani Bight	3.80–21.5	TL	0.39–119.90	C	2021	0.0076	3.1280	0.9760	[32] Çiçek *et al.*, 2006
SE Black Sea	6.80–18.0	TL	–	F	248	0.0047	3.2700	0.9800	[33] Demirhan & Can, 2006
SE Black Sea	6.80–14.6	TL	–	M	173	0.0057	3.1900	0.9400	[33] Demirhan & Can, 2006
SE Black Sea	6.80–14.6	TL	–	C	432	0.0051	3.2400	0.9700	[33] Demirhan & Can, 2006
N. Aegean Sea	12.70–22.3	TL	–	F	49	0.0038	3.3610	0.9350	[34] Karakulak *et al.*, 2006
N. Aegean Sea	12.50–18.6	TL	–	M	16	0.0067	3.1710	0.9420	[34] Karakulak *et al.*, 2006
N. Aegean Sea	12.50–22.3	TL	–	C	76	0.0049	3.2730	0.9410	[34] Karakulak *et al.*, 2006
İzmir Bay	7.50–20.0	FL	5.57–123.00	C	479	0.0102	3.1760	0.9600	[35] Özaydın&Taşkavak,06
İzmir Bay	8.00–19.6	TL	6.00–90.00	C	111	0.0091	3.1000	0.9700	[36] Gökçe *et al.*, 2007
Saros Bay	6.00–24.7	TL	2.00–200.00	C	3386	0.00762	3.0949	0.9630	[37] İşmen *et al.*, 2007
Middle Black Sea	6.60–18.4	TL	2.94–60.16		176	0.0111	2.9630	0.9800	[38] Kalaycı *et al.*, 2007
İzmir Bay	5.40–21.2	FL	–	C	1910	0.0089	3.2330	0.9810	[39] Özaydın *et al.*, 2007

TABLE III cont...

49 Length–Weight Relationships Obtained from Different Areas

NE Mediterranean	8.20–22.0	TL	4.96–106.26	C	451	0.0032	3.0600	0.9400	[40] Sangun *et al.*, 2007
İzmir Bay	8.20–28.2	TL	–	F	970	0.0056	3.2400	0.9800	[41] İlkyaz *et al.*, 2008
İzmir Bay	8.20–19.0	TL	–	M	909	0.0064	3.1900	0.9640	[41] İlkyaz *et al.*, 2008
İzmir Bay	8.20–28.20	TL	–	C	1879	0.0060	3.2200	0.9780	[41] İlkyaz *et al.*, 2008
İskenderun Bay	11.00–20.40	TL	15.98–91.30	C	8	0.0184	2.8400	0.9900	[42] Gökçe *et al.*, 2010
Çandarlı Bay	4.60–9.90	TL	0.55–8.01	C	13	0.0040	3.3440	0.9540	[43] Gürkan *et al.*, 2010
N. Sea of Marmara	10.00–15.70	TL	9.54–46.59	C	99	0.0049	3.3260	0.9160	[44] Bök *et al.*, 2011
Sea of Marmara	9.60–22.70	TL	–	C	94	0.0150	3.0040	0.8600	[45] Demirel&Dalkara,2012
Gallipoli Peninsula and Dardanelles	8.70–20.10	TL	6.83–99.13	C	102	0.0062	3.2200	0.9800	[46] Cengiz, 2013
HomaLagoon,İzmir	5.10–11.10	TL	1.15–13.82	C	90	0.0060	3.1800	0.9910	[47] Acarlı *et al.*, 2014
Saros Bay	9.20–23.60	TL	7.50–177.30	F	2302	0.0610	3.1900	0.9400	[48] Arslan & İşmen, 2014
Saros Bay	8.80–24.10	TL	7.80–119.70	M	1308	0.0800	3.0890	0.9200	[48] Arslan & İşmen, 2014
Saros Bay	6.50–24.80	TL	2.50–177.30	C	9386	0.0084	3.0770	0.9400	[48] Arslan & İşmen, 2014
S. Aegean Sea	5.60–38.20	TL	–	C	2009	0.0065	3.3550	0.9700	[49] Bilge *et al.*, 2014
Gulf of Antalya	8.70–21.50	TL	–	C	1565	0.0071	3.1650	0.8940	[50] Özvarol, 2014
Black Sea	5.30–19.00	TL	1.20–73.40		2693	0.0074	3.1230	0.9600	[51] Kasapoğlu & Düzgüneş 2014
Çandarlı Bay	5.20–22.40	FL	1.50–146.10	C	970	0.0064	3.3340	0.9890	[52] Akalın *et al.*, 2015
İskenderun Bay	6.90–15.70	TL	3.41–51.38	C	212	0.0072	3.1618	0.9530	[12] Çiçek, 2015
Eastern Black Sea	11.10–21.40	TL	12.41–96.22	F	433	0.0064	3.1340	0.9240	[53] Yeşilçiçek *et al.*, 2015
Eastern Black Sea	9.40–19.80	TL	8.49–66.21	M	212	0.0090	2.9930	0.8890	[53] Yeşilçiçek *et al.*, 2015
Eastern Black Sea	7.40–22.60	TL	2.68–102.50	C	672	0.0066	3.1190	0.9250	[53] Yeşilçiçek *et al.*, 2015
İzmir Bay	9.50–13.40	TL	9.00–27.10	C	47	0.0068	3.1930	0.9997	[54] Kara *et al.*, 2016
Western Black Sea	9.10–18.90	TL	8.81–62.42	F	1986	0.0103	3.0127	0.9407	[13] Yıldız & Karakulak, 2016
Western Black Sea	9.00–15.80	TL	7.18–47.97	M	1829	0.0137	2.8993	0.9283	[13] Yıldız & Karakulak, 2016
Western Black Sea	6.30–18.90	TL	3.62–62.42	C	4928	0.0109	2.9886	0.9554	[13] Yıldız & Karakulak, 2016
İzmir Bay	4.50–11.90	TL	0.75–16.80	C	107	0.0062	3.1900	0.9970	[54] Kara *et al.*, 2016
Gülbahçe Bay	–	FL	–	F	301	0.0113	3.1520	0.9660	[55] Kurtul &Özaydın, 2017
Gülbahçe Bay	–	FL	–	M	229	0.0102	3.1880	0.9590	[55] Kurtul &Özaydın, 2017
Gülbahçe Bay	5.10–15.30	FL	–	C	629	0.0100	3.2010	0.9720	[55] Kurtul &Özaydın, 2017

LT: Length Type, C: Combined, F: Female, M: Male, TL: Total Length, FL: Fork Length, n: Sample Size, *a* and *b* Intercept and Slope of Length–Weight Relationships, r^2: Coefficient of Determination) (SE: Southeastern, N: Northern, S: Southern

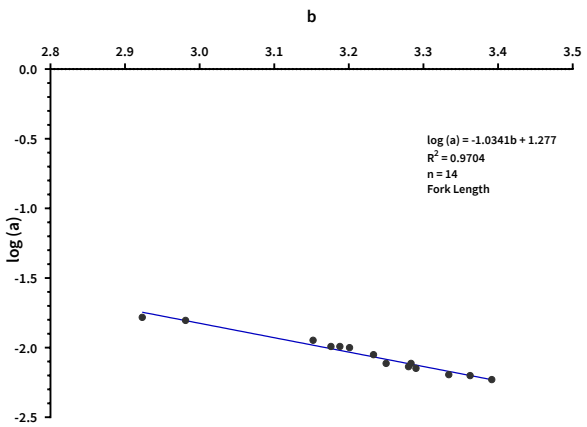

FIGURE 2. The log (*a*) vs *b* of red mullet for Fork Length

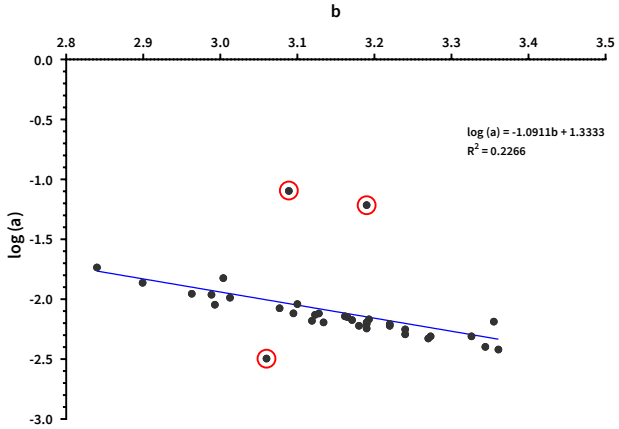

FIGURE 3. The log (*a*) vs *b* of red mullet for Total Length. The circled points are outliers

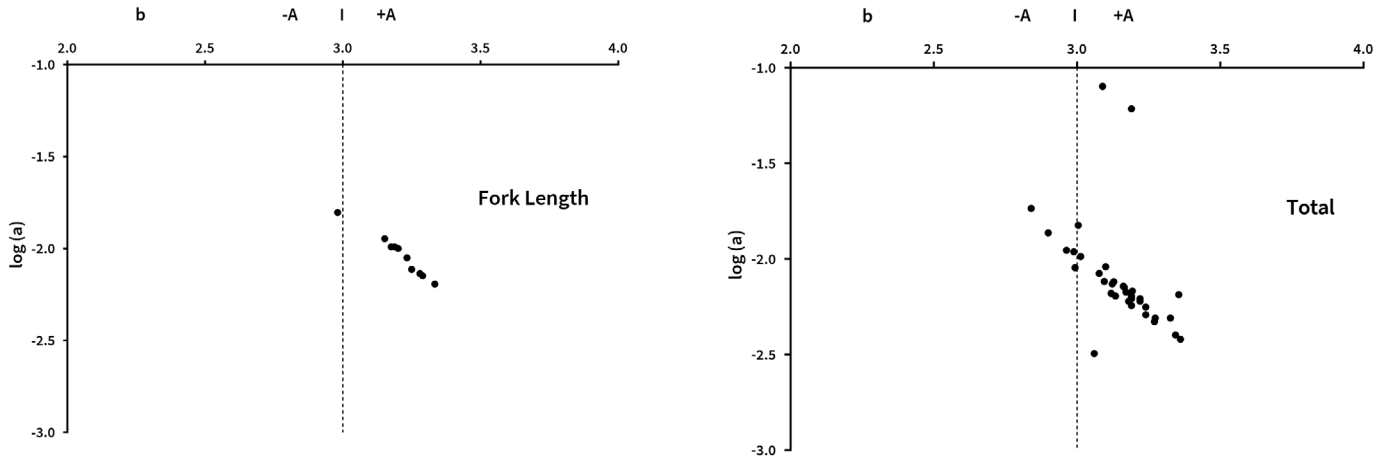

FIGURE 4. Scatter plot of mean log (*a*) over mean *b* for red mullet. Areas of negative allometric, isometric, positive allometric change in body weight relative to body length are indicated

total length of studied locations was longer than some previous studies, but the maximum total length of studied locations was shorter than some previous studies (TABLE I). There may be many reasons for this situation, but the ecological conditions of the fish sampled from stations representing three different marine environments (Black Sea, Marmara Sea and Aegean Sea) are perhaps the most important reason. In addition, it is thought that the use of different fishing gear, due to the characteristics of these three different marine environments and the decisions of policy makers, causes different results.

The red mullet LWRs' b values from this study are comparable to those from earlier research by Toğulga [29] and Kurtul and Zaydn [55]. The habitat, region, seasonal effects, degree of stomach fullness, gonad maturity, sex, health, preservation methods, and variations in the observed length ranges of the samples caught may all have an impact on fish LWRs [20, 39, 57]. However, all of these factors were taken into consideration in this study. If there are numerous studies of LWRs for a species, outliers can be found using a scatter plot of log (a) and b values, according to Stergiou and Moutopoulos and Froese [28, 56]. As a result, 31 studies on red mullet from Turkish maritime waters from 1977 to 2017 were examined. (FIG 2 and 3). Problematic studies for red mullet are shown by the circled outliers. Froese [28] claims that a stronger regression analysis conducted after removing outlier observations would be powerful enough to explain the %99 of the variance [28]. These outliers also result in a decline. FIG 4 demonstrates that several of the estimations were higher than 3 when a scatter plot for log (a) and b was produced. This enables the conclusion to be drawn that red mullet found in Turkish waters primarily exhibit positive allometric growth in both fork and total length.

CONCLUSIONS AND IMPLICATIONS

This study presents LWRs and LLRs from Sea of Marmara, Western Black Sea and Northern Aegean Sea and a collected list of the LWRs parameters for red mullet in Turkish marine waters from previous published studies. These important data and results may be used by fishery management authorities and further academic studies. Therefore, relevant studies could be supportive in future for the management of red mullet fisheries in Turkey. Additionally, updating information about the maximum size of a species that might be commercially or recreationally exploited in the future is important.

Conflicts of interest

The authors declare that there is no conflict of interest in this work.

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