



SAKARYA ÜNİVERSİTESİ

FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 e-ISSN 2147-835X Period Bimonthly Founded 1997 Publisher Sakarya University
<http://www.saujs.sakarya.edu.tr/>

Title: Length-Weight, Length-Length Relationships, and Condition Factor of Red Mullet
(*Mullus barbatus* Linnaeus, 1758) Inhabiting Mersin Bay

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Received: 2022-12-07 00:00:00

Accepted: 2023-01-31 00:00:00

Article Type: Research Article

Volume: 27

Issue: 2

Month: April

Year: 2023

Pages: 398-407

How to cite

Seda KONTAŞ; (2023), Length-Weight, Length-Length Relationships, and Condition
Factor of Red Mullet (*Mullus barbatus* Linnaeus, 1758) Inhabiting Mersin Bay.

Sakarya University Journal of Science, 27(2), 398-407, DOI:

10.16984/saufenbilder.1215970

Access link

<https://dergipark.org.tr/en/pub/saufenbilder/issue/76551/1215970>

New submission to SAUJS

<http://dergipark.gov.tr/journal/1115/submission/start>

Length-Weight, Length-Length Relationships, and Condition Factor of Red Mullet (*Mullus barbatus* Linnaeus, 1758) Inhabiting Mersin Bay

Seda KONTAŞ YALÇINKAYA *¹ 

Abstract

This study reports the condition factor, length-weight, and length-length relationships in females, males, and all samples of *Mullus barbatus* inhabiting Mersin Bay. A total of 152 individuals were sampled. The mean weight (W) was 18.01 ± 0.573 g, and the mean total length (TL), fork length (FL), and standard length (SL) were 12.0 ± 0.094 cm, 11.0 ± 0.086 cm, and 9.9 ± 0.080 cm for all *M. barbatus*, respectively. The total length-weight relationship was determined as $W=0.0033TL^{3.444}$ ($R^2=0.90$). The b value was calculated as 3.444 and it showed positive allometric growth for all *M. barbatus* inhabiting Mersin Bay. The LLRs were calculated as $TL=1.0706FL+0.1386$ ($R^2=0.95$), $TL=1.1634SL+0.371$ ($R^2=0.97$), and $FL=1.0541SL+0.543$ ($R^2=0.96$) for all individuals, respectively. The mean value of the condition factor was calculated as 1.00 ± 0.0093 for all *M. barbatus* samples. The values of the condition factor in *M. barbatus* ranged from 0.740 to 1.274. There are few studies about *M. barbatus* population inhabiting Mersin Bay. In this study, condition factor, length-weight and length-length relationships were determined for *M. barbatus* inhabiting this region (the northeastern Mediterranean Sea).

Keywords: Condition factor, length-weight relationship, length-length relationship, *Mullus barbatus*, Mersin Bay

1. INTRODUCTION

The length-weight relationship (LWR) data can be used in fish biology, fish ecology, fish physiology, and fisheries. WLR studies in fisheries research provide useful information in stock assessment models, biomass, and, estimation of fish condition [1-2]. In addition, the length-weight relationship provides morphological comparisons between populations inhabiting different habitats [3-4]. The

equation of the length-weight relationship is also used to explain the allometric or isometric growth pattern of fish species. The length-length relationships are very important parameters in fisheries management and especially in comparative growth studies where is preferred one size type [5]. It also allows the estimation of total, fork, and standard lengths using equations [6].

The condition factor is one of the population parameters and is used as a good indicator of

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the general health of fish populations and water quality living in a particular habitat or ecosystem [7]. It is possible to have information about the physiological state of the fish by using the condition factor [8]. Age, sex, gonad development, and fatness affect the condition factor [9].

Mullus barbatus (Red mullet) is a demersal and marine fish species. It is found on gravel, sand, and mud bottoms of the continental shelf and lives usually in 100 - 300 m depth ranges [10]. Its distribution is Eastern Atlantic, Mediterranean, and Black Sea [11]. It was also reported in the Sea of Marmara [12] and the Aegean Sea [13].

There are many studies conducted on Red mullets in Turkish seas and other seas. The previous studies were made on the length-weight relationship of *M. barbatus* in the Mediterranean Sea [4, 14-16], in the Black Sea [2, 17-20], in the Sea of Marmara [12, 21-22], and in Aegean Sea [5, 13, 23], the length-length relationships of Red mullet in Aegean Sea [5], and condition factor of *M. barbatus* in Black Sea [8, 24], and Egyptian Mediterranean coast [25]. Whereas there were many studies on the length-weight relationship, there was no study on the length-length relationship for *M. barbatus* inhabiting the northeastern Mediterranean Sea. Although there are many studies on this species on the coast of the Black Sea, Aegean Sea, and Sea of Marmara, there are limited studies in Mediterranean waters [26-29]. This study aimed to determine length-length (LLRs), length-weight (LWRs) relationships, and condition factors of *M. barbatus* from Mersin Bay in the northeastern Mediterranean Sea.

2. MATERIALS AND METHODS

Mullus barbatus samples were obtained from fish market in March 2021 from Mersin Bay (the northeastern Mediterranean Sea). The weight of fish individuals (W) was recorded (± 0.1 g). The total length (TL), fork length (FL), and standard length (SL)

were measured to the nearest ± 0.1 cm. The gender of *M. barbatus* samples was determined by macroscopic investigation of the gonads.

Length-weight relationship (LWR) was calculated from the formula: $W = a \times TL^b$, where W is weight, TL is total body length, *a* and *b* are constants [30]. The 95% confidence interval of *b* values of females, males, and all samples were calculated. “*a*” and “*b*” parameters were estimated from linear regression applied to the log-transformed variables, and the formula “ $\log W = \log a + b \log L$ ” was used for calculations. When *b* is equal to 3, the fish grows isometrically. When the *b* value is less than or greater than 3, it means negative or positive allometric growth. The growth status of the individuals was determined by the t-test according to the *b*=3 isometric growth hypothesis [31]. Length-length relationships (LLRs) such as total length-fork length, total length-standard length, and standard length-fork length were calculated from the following formula: $y = ax + b$. The coefficient of determination (R^2) was used to determine the degree of relationship between the variables. Fulton condition factor (K) was calculated from the formula: $K = (W/L^3) \times 100$ [9]. Whether there was a statistical difference between the length and weight values of females and males was tested using the t-test. The Minitab 16 software was used for all statistical analyses.

3. RESULTS AND DISCUSSION

In this study, a total of 152 *Mullus barbatus* samples were evaluated. The female rate of the total individuals was 29% (n=43) and the male rate of the total individuals was 71% (n=109).

The mean total length, fork length, and standard length were determined as 12.1 ± 0.211 cm, 11.3 ± 0.185 cm, 10.2 ± 0.183 cm for females; 11.9 ± 0.104 cm, 10.9 ± 0.096 cm, 9.9 ± 0.086 cm for males and 12.0 ± 0.094 cm, 11.0 ± 0.086 cm, 9.9 ± 0.080 cm

for all individuals, respectively. The mean weight was determined as 19.8 ± 1.22 g for females; 17.4 ± 0.634 g for males and 18.0 ± 0.573 g for all *M. barbatus* individuals. The length and weight values were statistically different between male and female individuals (t-test; $P < 0.05$). For this reason, the calculations were made for

females, males, and all individuals. The condition factor was 1.04 ± 0.0155 for females, 0.98 ± 0.0111 for males, and 1.00 ± 0.0093 for all *M. barbatus*, respectively. The descriptive statistics of total length, fork length, standard length, weight, and condition factor were given in Table 1.

Table 1 The descriptive statistics of variables for *Mullus barbatus* inhabiting Mersin Bay (TL: Total length (cm), FL: Fork length (cm), SL: Standard length (cm), W: Weight (g), K: Condition factor, S.E.: Standard error, Min: Minimum, Max: Maximum)

	Mean±S.E. (Min. - Max.)		
	♀	♂	♀+♂
TL (cm)	12.1 ± 0.211 (10.2 - 15.2)	11.9 ± 0.104 (10.0 - 15.0)	12.0 ± 0.094 (10.0 - 15.2)
FL (cm)	11.3 ± 0.185 (9.6 - 14.0)	10.9 ± 0.096 (9.5 - 14.1)	11.0 ± 0.086 (9.5 - 14.1)
SL (cm)	10.2 ± 0.183 (8.5 - 12.9)	9.9 ± 0.086 (8.5 - 12.5)	9.9 ± 0.080 (8.5 - 12.9)
W (g)	19.8 ± 1.22 (9.20 - 38.80)	17.4 ± 0.634 (9.60 - 38.60)	18.0 ± 0.573 (9.20 - 38.80)
K	1.04 ± 0.0155 (0.87 - 1.23)	0.98 ± 0.0111 (0.74 - 1.27)	1.00 ± 0.0093 (0.74 - 1.27)

This study provided a new reference on length-weight relationships (LWRs), length-length relationships (LLRs), and condition factor (K) of females and males of *M. barbatus* inhabiting the Mersin Bay (Mediterranean Sea). The length-weight relationships of *M. barbatus* (♀, ♂, all samples) were shown in Figure 1. In the present study, the LWRs were determined as $W=0.0049TL^{3.299}$, $W=0.0029TL^{3.490}$, $W=0.0033TL^{3.444}$ for females, males, and all individuals of *M. barbatus*. In a previous study, LWRs were indicated as $W=0.0145TL^{2.949354}$ for females, $W=0.0397TL^{2.544816}$ for males, and $W=0.0211TL^{2.798398}$ for all individuals of *Mullus* sp. in Mersin Bay [26]. [24] reported that LWRs were $W=0.0065TL^{3.17}$, $W=0.0055TL^{3.25}$, and $W=0.0059TL^{3.21}$ for females, males, and all individuals of *M. barbatus barbatus* from the western Black

Sea. [32] reported that LWR was $W=0.0121SL^{2.939}$ for *M. barbatus* in the western Mediterranean Sea. [13] reported that LWR was $W=0.0049TL^{3.273}$ for *M. barbatus* inhabiting Gökceada Island. The length-weight relationship is affected by several abiotic and biotic factors [33]. In addition, the length-weight relationship parameters can be affected by locality differences, and biological and ecological factors [34-35].

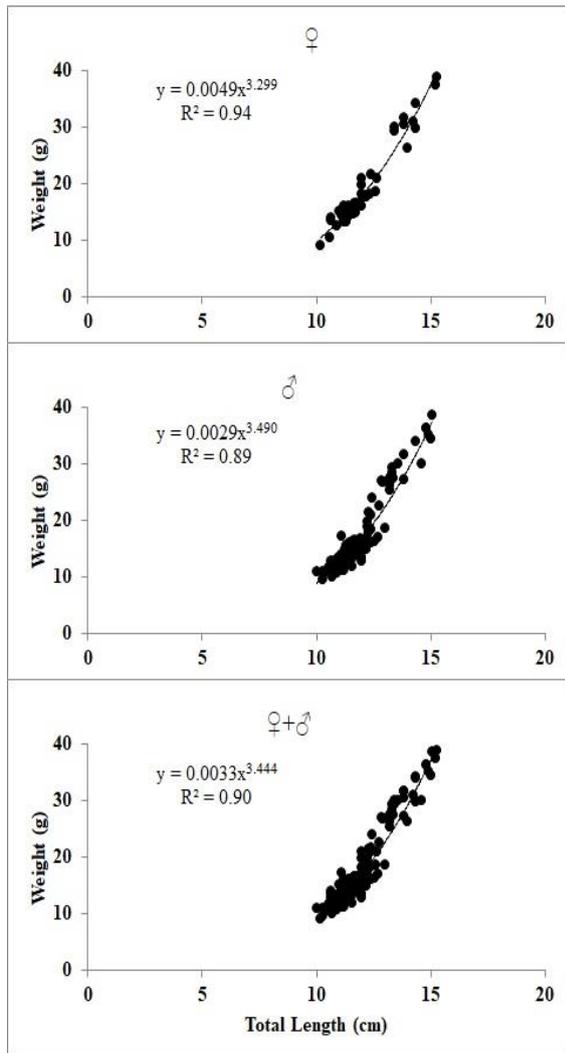


Figure 1 The length-weight relationships (LWRs) of *Mullus barbatus* (♀, ♂, ♀+♂) inhabiting Mersin Bay

Generally, the b values for all fish species were reported between 2.5-3.5 [33]. b values may range from 2 to 4 according to [30]. In the present study, the b value was 3.444 ± 0.042 , and 95% C.I. of b ranged between 3.437 - 3.451 for all *M. barbatus* from Mersin Bay. The b value was 3.299 ± 0.035 for females and 3.490 ± 0.043 for males, respectively. The growth was positive allometric ($b > 3$) in *M. barbatus* (♀, ♂, all samples) inhabiting Mersin Bay ($P < 0.001$). Similarly, the b values were reported as 3.17 for females, 3.25 for males, and 3.21 for all *M. barbatus barbatus* individuals in the western Black Sea, and the females, males, and all individuals of *M. barbatus barbatus* had positive allometric growth in the western Black Sea [24]. [8]

reported that b values of *M. barbatus* were 3.0855 for females, 3.0688 for males, and 3.1267 for all individuals and the growth type was positive allometric for all samples. [16] were determined as positive allometric for all specimens of *M. barbatus* in Babadilli Bight (the northeastern Mediterranean Sea). However, [13] determined as isometric for males ($b=3.171$) and as positive allometric for females ($b=3.361$) and all samples ($b=3.273$) of *M. barbatus* in Gökceada Island (northern Aegean Sea), respectively. [20] reported isometric growth type ($b=3.045$) for *M. barbatus* inhabiting the eastern Black Sea Turkey. In another study, the b values were 2.993 for males, 3.134 for females, and 3.119 for all *M. barbatus* individuals in the southern Black Sea. While the growth type was isometric in males, it was reported as positive allometric in females and all individuals [36]. The sampling methods, the number of samples, and length ranges may cause a difference in b values [13]. In addition, the difference in b values can originate from the hydrographical differences among the Mediterranean Sea, Aegean Sea, Black Sea, and Sea of Marmara [20].

The obtained b values from other studies were determined as 3.060 for *M. barbatus* in the Mediterranean Sea [4], 2.949354 (♀), 2.544816 (♂), and 2.798398 (♀+♂) for *Mullus* sp. in Mersin Bay [26], 3.16 in Antalya Bay [37], 3.128 in Babadillimani Bight [16], 3.16 in İskenderun Bay [38], 3.12 in the Black Sea [2], 3.24 in the southeastern Black Sea [17], 3.23 in the eastern Black Sea [39], 3.12 in the eastern and central Black Sea [40], 3.139 in the eastern Black Sea [19], 3.36 in the western Black Sea [41], 3.326 in Sea of Marmara [12], 3.004 in Sea of Marmara [21], 2.873 in Sea of Marmara [22], 3.17 in İzmir Bay [42], 3.10 in the north Aegean Sea [23], 2.832 in the Aegean Sea [5]. The b value is characteristic for each species and, in general, it does not change significantly throughout the year [3, 12]. The b value of the length-weight relationship is affected by

habitat, seasons, temperature, salinity, sex, gonad maturity, length range, health, and diet differences [30, 33]. Thus, these values can vary from species to species and population to population. The b value for *M. barbatus* in this study was slightly higher than the obtained from the other studies in the Mediterranean Sea [4, 16]. It may be differences between the fish specimens and populations that grew in the same region [43]. The number of samples and the differences in the length ranges of the individuals affect the b values for the same species [13]. These differences may also be appeared due to temporal variations in the sampling sites [39].

The LLRs of *M. barbatus* (♀, ♂, all samples) were shown in Figure 2-4. The LLRs of females were determined as $TL=1.1277FL-0.5864$, $TL=1.1434SL+0.5291$, $FL=0.9991SL+1.1403$ and the LLRs of males were determined as $TL=1.0523FL+0.3676$, $TL=1.1807SL+0.2154$, $FL=1.0818SL+0.2544$, respectively. The LLRs of all individuals were determined as $TL=1.0706FL+0.1386$, $TL=1.1634SL+0.371$, and $FL=1.0541SL+0.543$, respectively. In the present study, it was determined that the total length, fork length, and standard length values of *M. barbatus* showed strong linear relations with each other (Table 2). The LLRs were reported as $FL=-1.78+0.96TL$, $SL=-1.25+0.87TL$, and $SL=0.40+0.90FL$ for *M. barbatus* ($n=15$) in the Aegean Sea (Greece), respectively [5]. The length-length relationships are important and they use in comparative growth studies. The fish tails can break for various reasons. This makes it difficult to accurately measure the total length. If the standard length or fork

length is known, they allow the determination of the total length.

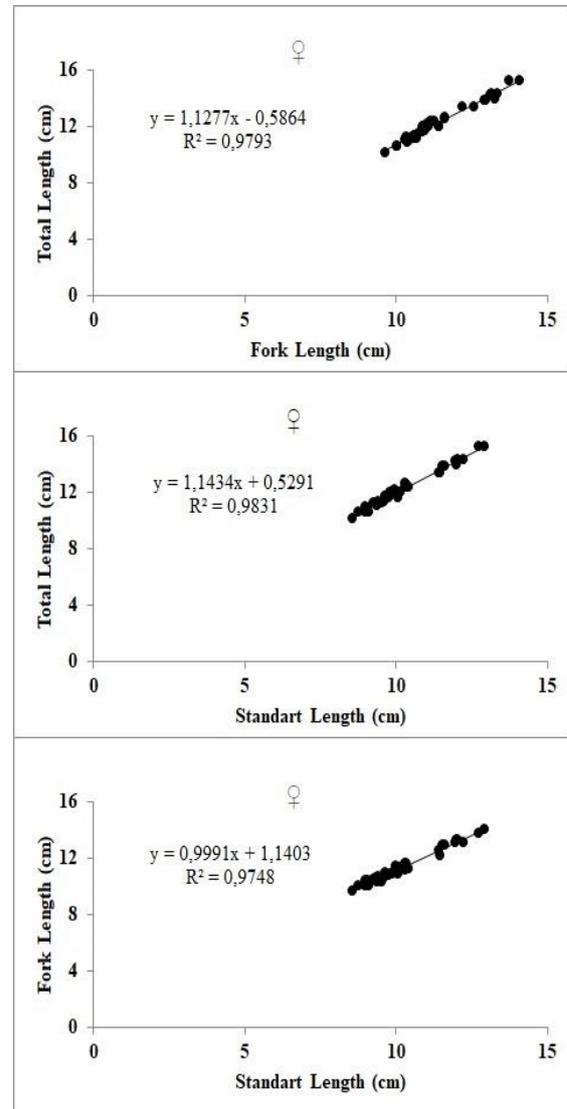


Figure 2 The length-length relationships (LLRs) for females of *Mullus barbatus*

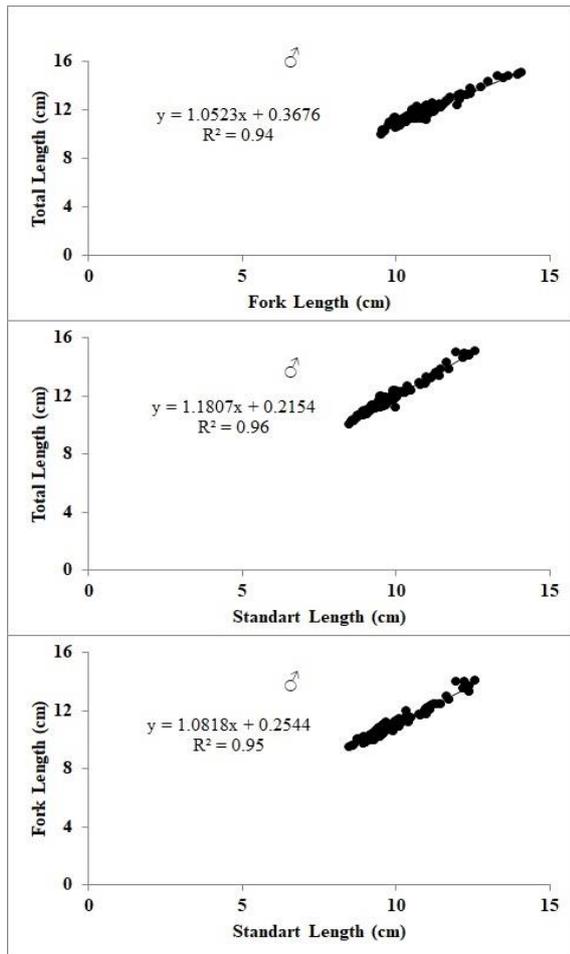


Figure 3 The length-length relationships (LLRs) for males of *Mullus barbatus*

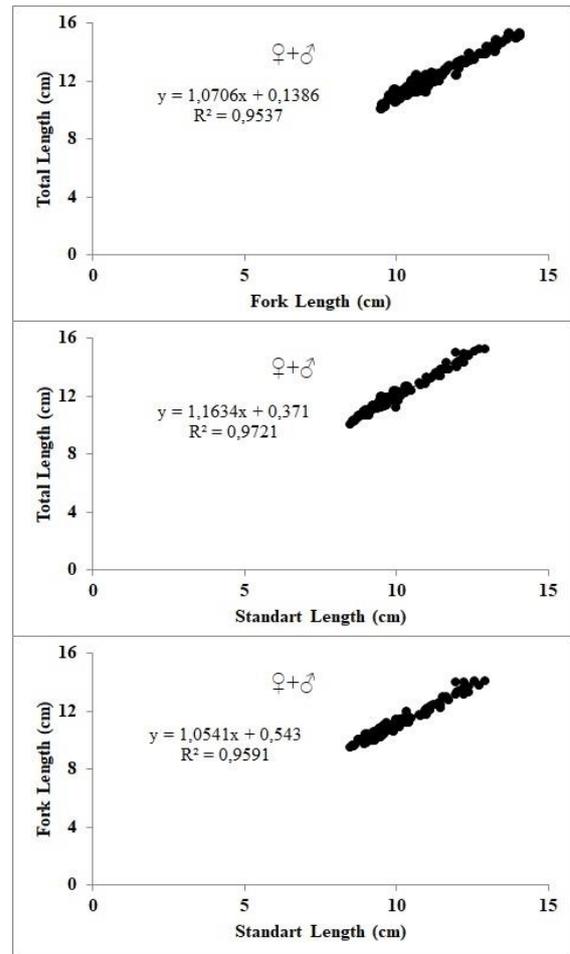


Figure 4 The length-length relationships (LLRs) for all individuals of *Mullus barbatus*

Table 2 The length-length (LLRs) relationships for *Mullus barbatus* inhabiting Mersin Bay (TL; total length (cm), FL; fork length (cm), SL; standard length (cm), R²; Determination Coefficient)

	The Length-Length Relationships	R ²
♀	TL = 1.1277FL - 0.5864	0.97
♂	TL = 1.0523FL + 0.3676	0.94
♀+♂	TL = 1.0706FL + 0.1386	0.95
♀	FL = 0.9991SL + 1.1403	0.97
♂	FL = 1.0818SL + 0.2544	0.95
♀+♂	FL = 1.0541SL + 0.543	0.95
♀	TL = 1.1434SL + 0.5291	0.98
♂	TL = 1.1807SL + 0.2154	0.96
♀+♂	TL = 1.1634SL + 0.371	0.97

The condition factor was an important parameter for the assessment of fish stock and it was used in fish biology. [25] reported that the condition factor was 0.894 for *M. barbatus* along the Egyptian Mediterranean coast. The condition factor was determined as 1.375 (♀), 1.292 (♂), and 1.3195 (♀+♂) for *Mullus* sp. in Mersin Bay [26]. [24] determined that the condition factors of females, males, and all *M. barbatus* samples inhabiting the western Black Sea were 0.968, 0.970, and 0.974, respectively and it showed insignificant variation between sexes in the western Black Sea ($P > 0.05$). In the present study, the condition factors were determined as 1.04 for females, and 0.98 for males, and the condition factor showed statistically significant variation between females and males of *M. barbatus* ($P < 0.001$).

The condition factor in fish can vary from species to species, as well as within the species. Differences in size, growth, sex, gonad development, age, stomach contents, and seasons can change the condition factor values of fish populations [9, 33].

4. CONCLUSION

This research has new data and it ensures new contributions on condition factors and relationships of length-length and length-weight for *Mullus barbatus* from the northeastern Mediterranean Sea. The length-length relationships for females, males, and all *M. barbatus* individuals in the northeastern Mediterranean Sea (Mersin Bay) are also presented for the first time. If the mean, minimum, and maximum variables of the weight and length of fish and the relationships between these variables are known, it helps the sustainable use of natural resources. Therefore, the results of the present study will contribute to the stock assessment and management of fisheries in this region. It is expected that the scientists and fishermen benefit from the outcomes of future studies as part of their stock conservation and management programs. In addition, the study was evaluated according to gender. The results that may vary by gender can apply to other studies as well. The results obtained from this present study will also allow comparison with populations from other regions. The related studies on LWRs of other populations caught in the Mediterranean Sea should be also evaluated and developed in the future.

Funding

The author (s) has not received any financial support for the research, authorship, or publication of this study.

Authors' Contribution

All process of the study was done by the author.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the author.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical, and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification of the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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