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Determination of some biological characteristics of Prussian carp (*Carassius gibelio*): the example of Bafra Balik lakes (Türkiye)

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Abstract
The aim of this study was to identify some biological properties (sex distribution, length frequency distribution, weight frequency distribution, length-weight relationship and condition factor) of Prussian carp (*Carassius gibelio*), an invasive species in Bafra Fish Lakes (Samsun, Turkey). The study was carried out in Bafra Balık Lakes (Samsun) between January and December 2019. Fish sampling was done monthly and using trammel net. A total of 630 individuals (477 females, 153 males) were examined in the study and the female: male ratio was 1:0.32. The lengths and weights of the fish were measured between 8.6-28.0cm and 10.2-366.53g, respectively. Length-weight relationship for female, male and all sampled Prussian carp was calculated as $W=0.0146L^{3,0423}$ ($R^2=0.98$ n=477), $W=0.016L^{3,0135}$ ($R^2=0.97$ n=153) and $W=0.0145L^{3,0347}$ ($R^2=0.96$ n=630), respectively. The condition factor (CF) of female individuals (1.67±0.01) was higher than the male individuals (1.60±0.01) and the average CF value of all individuals was determined as 1.65±0.01.

Keywords: Carassius gibelio, Prussian carp, length-weight relationship, condition factor

Introduction
Carassius is a genus that includes species very similar to the scaly carp (*C. carpio*) in terms of morphological appearance. There are three species of this genus in European waters: *C. auratus* (Linnaeus, 1758), *C. carassius* (Linnaeus, 1758), *C. gibelio* (Bloch, 1782) [1]. Of these, *C. carassius* naturally spreads in inland waters of Europe (including Turkey) [2, 3]. Natural occurrences of *C. gibelio* was documented throughout Northern Europe [4]. In a study conducted, they stated that the natural distribution area of this species covers a wide area as far as Russia, Europe, Korea and North-East China and Japanese islands [5].
It was reported that *C. gibelio* was transported to different environments and spread rapidly over large areas in streams, lakes and ponds from Europe to Asia [6]. Due to this feature, it has started to attract attention in many countries and monitoring studies have intensified in recent years [7, 8, 9, 10, 11, 12, 13, 14]. *C. gibelio* was reported as invasive in Turkish inland waters [15] and it stated that the population of this species is increasing rapidly [16]. It is estimated that this species has spread to inland waters during fish stockpiling studies or especially through transboundary streams and *C. gibelio* was first encountered in Gala Lake in 1986 in the Thrace region of Turkey, located on the European continent waters [15]. Many studies have been conducted on *C. gibelio* in our country, and these studies have focused on the determination of population density, growth, reproduction, nutrition, meat yield and biochemical composition [15, 17, 18,19, 20, 21]. In addition to these studies, the aim of this study was to identify some biological properties (sex distribution, length frequency distribution, weight frequency distribution, length-weight relationship and condition factor) of Prussian carp (*C. gibelio*), an invasive species in Bafra Fish Lakes (Samsun, Turkey).

Materials and Methods
The study was carried out in Bafra Balık Lakes (Samsun) between January and December 2019 (Figure 1). Bafra Balık Lakes is located in the east of Bafra district of Samsun province in the Central Black Sea Region. These lakes consist of six large lagoon lakes, whose surface areas differ from each other and are interconnected during rainy periods, located 20 km away from the district center.

Fig 1: Studing area (A- 41°42'25.57"N, 36°0'24.76"E; B- 41°32'4.47"N, 36°4'49.97"E)

Fish sampling was done monthly and using trammel net. Fish samples were transported to the laboratory of the Faculty of Fisheries and Aquaculture, in Sinop and were made biometric measurements. In the study, the total length of the fish was determined with a 1mm precision ruler and their weights were determined with a 0.1g precision digital balance. For sex determination of the samples, their internal organs were removed and their gonads were separated and examined.
The following formulas were used to calculate the length-weight relationship and the condition factor (CF):

$$W = aL^b \quad [22]$$

$$CF = W/L^b x100 \quad [23]$$

where W = fish weight (g), a and b = relationship constants and L = fish length (cm).
The results are given as mean± standard error. Statistical analysis was performed using the IBM SPSS 21 statistical package program. The differences between values were tested with one-way analysis of variance (ANOVA). The significance value was taken $p< 0.05$.
This study was conducted in compliance with the rules for animal experiments for scientific purposes and permission was given by the Sinop University Animal Experiments Local Ethics Committee with the permission No. 2019/07 on 13.05.2019.

Results

A total of 630 individuals (477 females, 153 males) were examined in the study and the female:male ratio was 1:0.32 (Figure 2).

Fig 2: *C. gibelio* (original)

The lengths of the sampled fish ranged from 8.6 to 28.0 cm. When the length distributions were examined, there were individuals with a maximum size of 15 cm (13.5%) (Figure 3). Fish larger than 23 cm (3.2%) were less common.

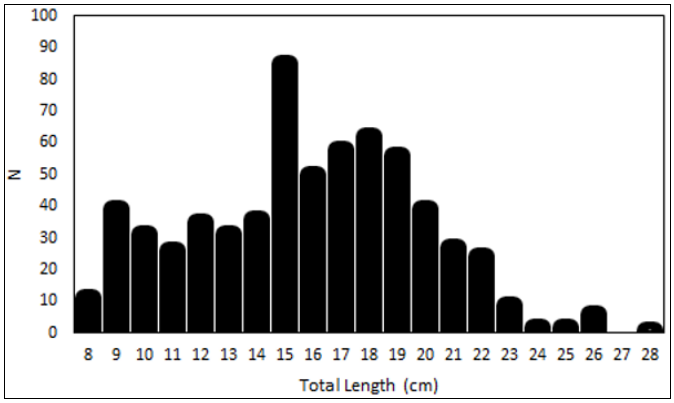


Fig 3: Total length frequency distribution of sampled *C. gibelio*

The length frequencies of female and male individuals are given in Figure 4. When the length frequencies of female and male individuals are examined, they show different intensities.

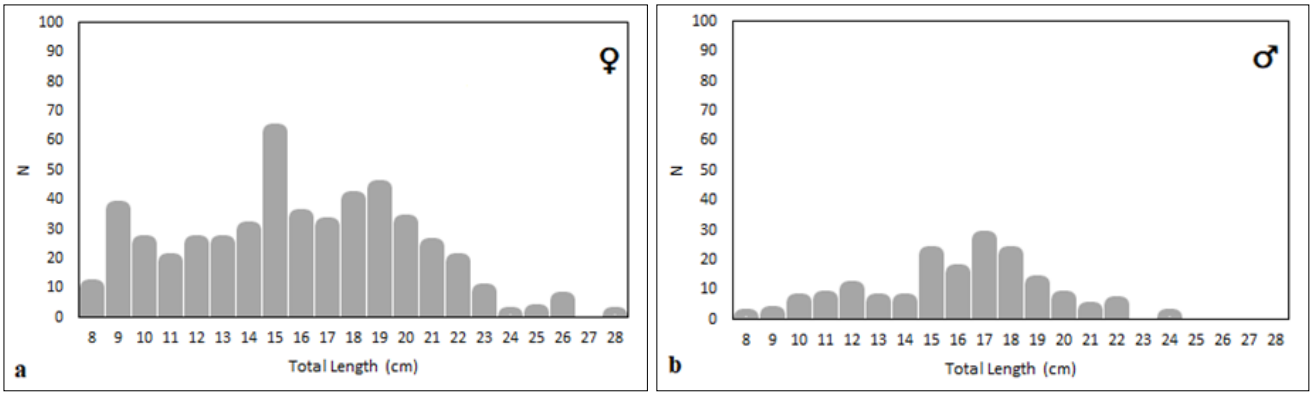


Fig 4: Female (a)-male (b) *C. gibelio* length frequency distribution

The length of the female *C. gibelio* ranged between 8.6-28.0 cm and individuals with a maximum of 15 cm (13.2%) were encountered (Figure 4-a). In male *C. gibelio's*, it was determined that 17 cm (17.7%) individuals were more and the length range of these individuals ranged between 8.9-24.5 cm (Figure4-b).
Total weight frequency distribution of *C. gibelio* in the study is given in Figure 5. It was determined that the weights of the *C. gibelio* obtained varied between 10.2 and 366.53g.

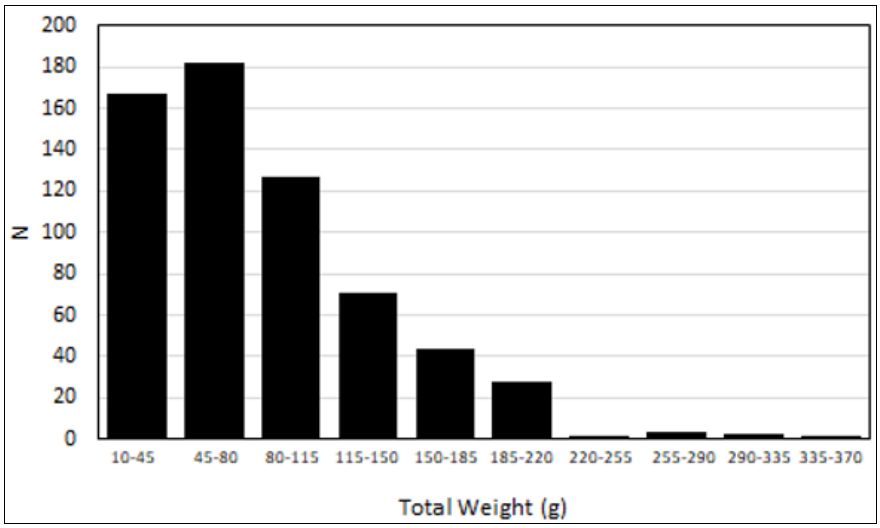


Fig 5: Total weight frequency distribution of *C. gibelio*

When the total weight frequency distribution of *C. gibelio* was evaluated, it was determined that the weight of the individuals was concentrated between 45 and 80 g (28.9%), and individuals weighing more than 220 g (1.8%) were less. Weight frequency distributions of female and male individuals show different intensities (Figure 6).

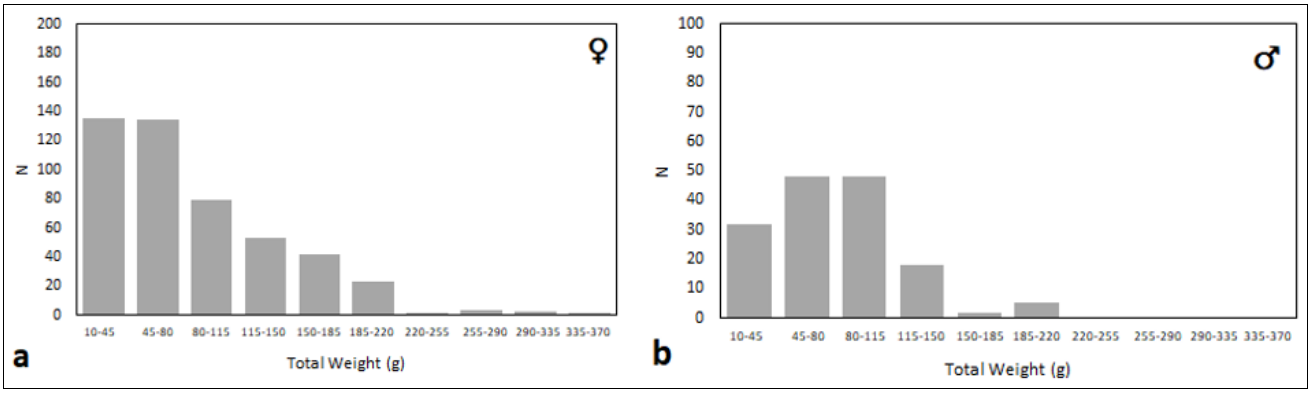
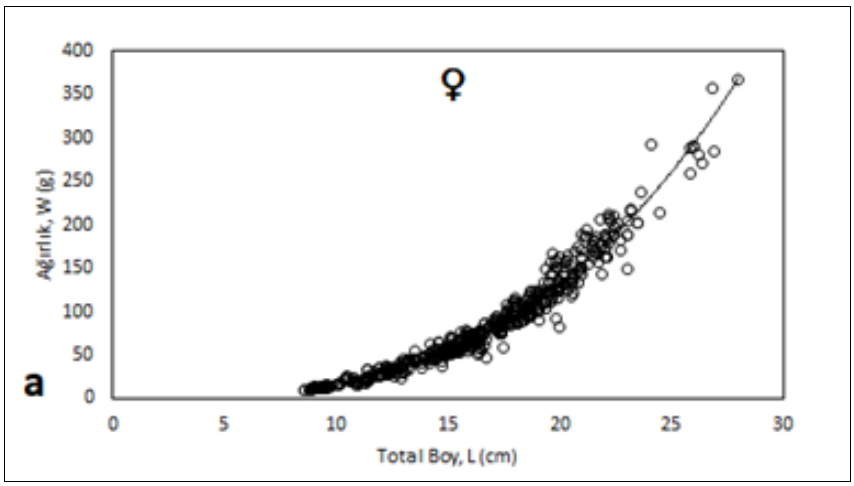


Fig 6: Female (a)-male (b) *C. gibelio* weight frequency distribution

The weight distribution of female *C. gibelio* ranged from 10.2 to 366.53g and the weights were concentrated between 10-80g (28.3%). It was determined that the weights of male *C. gibelio* varied between 10.77-213.99g and the weights were the highest between 45-80g (31.4%) and 80-115g (31.4%). The lenght-weight relationship graphs of female, male and total *C. gibelio's* are given in Figure 7.



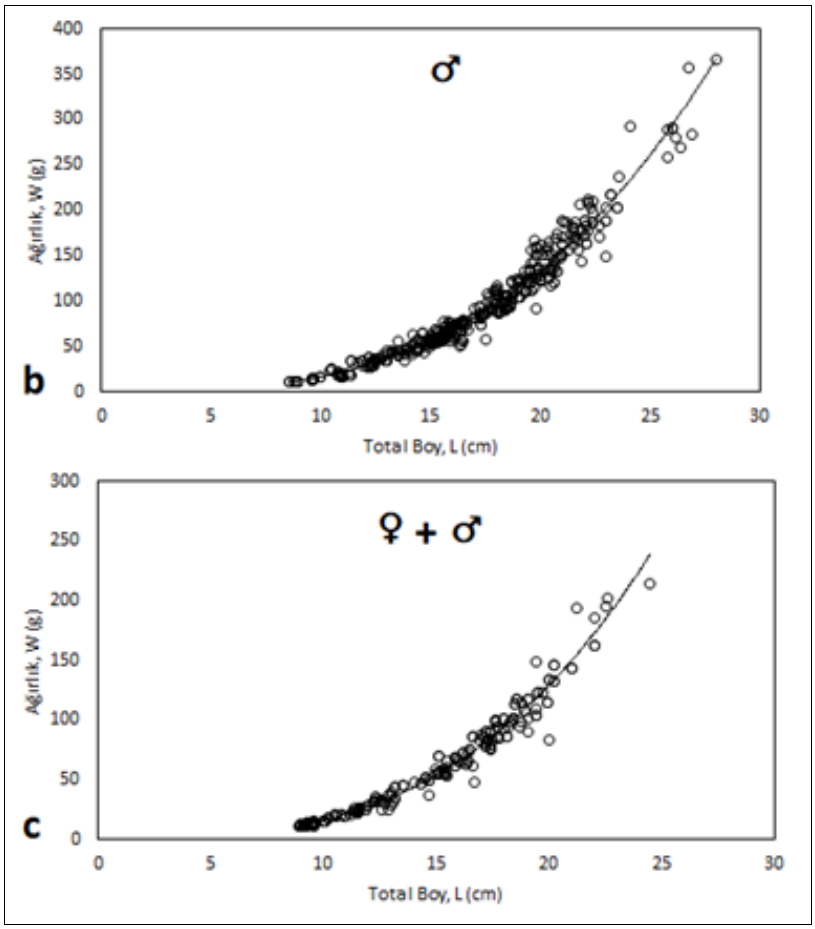


Fig 7: Length-weight relationship of female (a), male (b) and all *C. gibelio* (c)

Length-weight relationship for female, male and all sampled *C. gibelio's* was calculated as $W=0.0146L^{3,0423}$ ($R^2=0.98$ n=477), $W=0.016L^{3,0135}$ ($R^2=0.97$ n=153) and $W=0.0145L^{3,0347}$ ($R^2=0.96$ n=630), respectively. The b value in the lenght-weight relationship is statistically different for female, male and all individuals ($p< 0.05$).

Condition factor (CF) of female, male and all *C. gibelio* are shown in Table 1. The condition factor (CF) of all individuals ranged between 1.02 and 2.29, with an average of 1.65±0.01.

Table 1. Condition factor (CF) of female, male and all *C. Gibelio*

	N	Mean	SE	Min-Max	p
Female ♀	477	1.67	0.01	1.08-2.29	<0.05
Male ♂	153	1.60	0.01	1.02-2.04	
All *C. gibelio*	630	1.65	0.01	1.02-2.29	

N= Number of samples SE=standard error

When the CF of the sexes was evaluated, the CF of female *C. gibelio* was greater than that of male *C. gibelio*. The statistical difference between the CF values of the sexes was significant ($p< 0.05$).

Discussion and Conclusion

In this study, it was aimed to determine some biological characteristics of *C. gibelio* such as female:male ratio, lenght and weight distribution, lenght-weight relationship and condition factor, which has been reported in Bafra Balık Lakes (Samsun, Turkey) [24]. The female-male ratio, length-weight values and length-weight relationships determined in different studies with *C. gibelio* are summarized in Tables 2, 3 and 4, respectively.

Table 2: Studies on the female:male ratio of *C. Gibelio*

Studing area	N (♀ / ♂)	ratio (♀ / ♂)	Reference
Marmara Lake	142/300	1:2.11	[29]
Eğirdir Lake	329/287	1:1.15	[30]
Zegrzynski Reservoir, Vistula River (Poland)	-	1:0.21	[31]
Eğirdir Lake	112/230	1:2.05	[19]
Inland Waters of Estonia	-	1:0.67-0.85	[13]
Ömerli Dam Lake	241/17	1:0.07	[32]
İznik Lake	210/134	1:0.64	[32]
Lake Pamvotis, Kalamas R., the Ionian Sea basin (Greece)	-	1:0.03	[14]
Bafra Dam Lake	168/5	1:0.03	[33]

Beyşehir Lake	251/231	1:0.92	[34]
Eğirdir Lake	823/894	1:1.09	[35]
Dyje River, Morava River, Black Sea basin (Czech Rep.)	-	1:0.29	[36]
Buldan Dam Lake	2312/13	1:0.01	[37]
Topçam Dam Lake	170/2	1:0.01	[38]
Lake Pamvotis (Greece)	1323/31	1:0.02	[39]
Dyje River, Morava River, Black Sea basin (Czech Rep.)	-	1:0.26	[40]
Uluabat Lake	-	1:0.52	[41]
Uluabat Lake	419/153	1:0.37	[42]
Aksu River Estuary	81/47	1:0.58	[43]
İkizcetepeler Baraj Lake	374/106	1:0.28	[44]
Gelingüllü Barajı	139/193	1:1.39	[45]
Ladik Lake	140/10	1:0.07	[46]
Seyitler Dam Lake	125/24	1:0.19	[47]
Seyhan Dam Lake	142/18	1:0.13	[27]
Seyhan Dam Lake	299/18	1:0.06	[48]
Dyje River, Morava River, Black Sea basin (Czech Rep.)	-	1:0.31	[49]
İznik Lake	2054/1060	1:0.51	[50]
Beyşehir Lake	708/780	1:1.10	[51]
Marmara Lake	809/249	1:0.31	[52]
Siemianowka Reservoir, Narew R., Poland	-	1:0.32	[53]
Ulugöl Plateau Pond	14/10	1:0.71	[54]
Bafra Balık Lake	477/153	1:0.32	Present study

As a result of the study, the female:male ratio of the *C. gibelio* was determined as 1:0.32. In studies, it is stated that female *C. gibelio* are more dominant in the populations of this species [25], and this is due to the reproductive (gynogenetic) characteristics of these fish [3, 26, 27, 28]. On the contrary, there are studies in the literature in which the male population of *C. gibelio* is higher [19, 29, 30, 35, 45, 51].

Table 3: Studies conducted with the length-weight values of *C. Gibelio*

Study area	N	L	W	Reference
Eğirdir Lake	616	9.0-33.08(ÇB)	42.0-857.5	[30]
Eğirdir Lake	342	12.8-27.3(TB)	40.12-564.19	[19]
Ömerli Dam Lake	258	12.5-35.7(TB)	40.5-860.6	[32]
İznik Lake	344	5.2-32.0(TB)	3.3-565.6	[32]
Bafra Dam Lake	173	16.9-30.0(ÇB)	125.0-730.0	[33]
Beyşehir Lake	482	9.2-26.7(TB)	14.2-492.5	[34]
Eğirdir Lake	1717	7.5-33.3(TB)	8-1073	[35]
Buldan Dam Lake	2325	9.7-25.5(ÇB)	23.6-269.10	[37]
Uluabat Lake	572	8.1-27.3(SB)	14-111	[42]
Aksu River Estuary	128	10.3-30.5(TB)	25-607	[43]
İkizcetepeler Dam Lake	480	23.0-34.3(TB)	150.88-622.02	[44]
Gelingüllü Dam	344	5.6-27.0(ÇB)	3.8-597	[45]
Ladik Lake	155	13.4-26.5(ÇB)	58-550	[46]
Seyitler Dam Lake	149	14.8-32.5(ÇB)	43.1-807.30	[47]
Seyhan Dam Lake	160	11.1-29.5(TB)	40.10-412.9	[27]
Seyhan Dam Lake	317	10.7-31.0(TB)	26-450	[48]
İznik Lake	3114	7.8-32.2(ÇB)	5-829	[50]
Beyşehir Lake	1868	8.5-28.4(TB)	14-408	[51]
Seyhan Dam Lake	530	14.5-32.7(TB)	52-607.46	[54]
Lake Marmara	1058	10.0-27.5(TB)	17.1-378.4	[52]
Lake Marmara	56	7.59-22.85(TB)	6.36-216.6	[55]
Ulugöl Plateau Pond	24	6.9-22.5(TB)	3.6-159.8	[53]
Bafra Balık Lake	630	8.6-28.0(TB)	10.2-366.53	Present study

In the study, the minimum and maximum total height values were determined as 8.6 and 28.0cm. The height values found in the present study are similar to the literatüre (Table 3). In the current study, the weights were between 10.2-366.53 g, and it was determined that the weight distribution of C. gibelio in the literature given in Table 3 was similar. Although the length-weight distribution of the *Carassius gibelio* in the current study is within the limits given in the literature given in Table 3, the differences arising from the study with natural fish are striking. It is thought that the number of samples used in the studies, the environmental parameters of the lakes from which the samples were taken, and the feeding conditions of the fish affected these differences.

Tablo 4: Studies on the length-weight relationship parameters of *C.gibelio*

Çalışma Alanı	N	a	b	r^2	CF	References
Marmara Lake	142/300	0.054	2.80	-	-	[29]
Eğirdir Lake	616	0.0165	3.152	0.999	2.50	[30]
Eğirdir Lake	112/230	0.021	3.060		2.52	[19]
Ömerli Dam Lake	258	0.0128	3.088	0.987	-	[32]
İznik Lake	344 ♀	0.0088	3.230	0.992	-	[32]
	♂	0.0099	3.180	0.991	-	
Lake Pamvotis,	-	0.004-0.220	2.33-3.38	0.72-0.99	-	[14]
Bafra Dam Lake	173	0.0265	2.978	0.970	2.49	[33]
Eğirdir Lake	283	0.0151	3.177	0.98	2.53	[56]
Beyşehir Lake	482	0.0139	3.186	0.941	2.21	[34]
Eğirdir Lake	1717	0.016	3.128	-	2.34	[35]
Buldan Dam Lake	2325	0.0310	2.870	0.985	1.96	[37]
Uluabat Lake	572	0.026-0.068	2.754-3.068		♀ 3.67	[42]
					♂ 3.56	
Danube River	314	0.0298	2.866	0.903	-	[57]
Aksu River Estuary	128	0.0138	3.114	0.976	1.96	[43]
İkizcetepeler Dam Lake	480	0.0617	2.597	0.930	1.49	[44]
Gelingüllü Dam	344 ♀	0.19	2.80	-	2,52	[45]
	♂	0.25	3.05	.	2.27	
Ladik Lake	150	0.017	3.149	-	2.68	[46]
Seyitler Dam Lake	149	0.027	2.938	-	2.28	[47]
Seyhan Dam Lake	160	0.0519	2.651	0.933	1.81	[27]
Seyhan Dam Lake	317	0.0673	2.257	0.927	-	[48]
Büyük Menderes basin	172	0.036	2.880	0.99	2.0-2.9	[58]
İznik Lake	3114	0.0158	3.125	0.993	2.35	[50]
Beyşehir Lake	1868	0.0175	2.959	0.925	1.5-1.7	[51]
Seyhan Dam Lake	530	0.017	3.010	0.939	-	[54]
Lake Marmara	1058	0.018	2.965	0.986	1.5-2.0	[52]
	56	0.0167	3.032	0.985	-	[55]
Bafra Balık Lake	630	0.0145	3.035	0.985	1.65	Present Study

When the length-weight relationship parameters were examined in the study, a, b and r^2 values were determined as 0.0145, 3.035 and 0.985, respectively. When Table 4 is evaluated, it has been determined that the a value in the present study is similar to the a values of C. gibelo found in Marmara, Iznik, Beyşehir, Seyhan Dam, Eğirdir and Ömerli Dam Lake [30, 32, 56, 34, 46, 50, 51, 54]. On the contrary, the a value in different studies conducted in the same lakes was higher than the current study [19, 27, 29, 33, 37, 42, 44, 45, 47, 48, 57, 58]. The b value calculated in this study higher than the b value of C. Gibelo studied in Danube River, Bafra Dam, İkizcetepeler Dam, Gelingüllü Dam, Seyitler Dam, Büyük Menderes basin, Beyşehir and Marmara Lake [52, 51, 58, 48, 27, 47, 44, 45, 57, 33].

The length-weight relationship parameters can be affected by factors such as sampling period, nutritional status, height-weight distribution, reproductive period, age, and gonad maturity. It is thought that the differences between the current study and the literature are due to these reasons.

The condition factor (CF) of all individuals (male+female) ranged between 1.02 and 2.29, with an average of 1.65±0.01 (Table 1). As can be seen in Table 4, the condition factor (CF) values of *C. gibelio* are quite variable in studies. It is thought that the differences between the CF determined in the current study and the CF determined in the other studies with *C. gibelio* are caused by the season in which the fish were sampled, the environmental conditions, the age, the breeding period, and the gonad development related to it.

Due to the high ecological tolerance and hybridization characteristics of the *C. gibelio* species, it has negative effects on the natural populations of other fish in the water resources they are included in, and even causes the extinction of the species [13, 59]. Therefore, taking necessary precautions against invasive species in all water resources is very important for sustainable biodiversity. Whatever the reason, determining the biological characteristics of populations of this invasive species, which is dominant in all water resources, is necessary for sustainable biodiversity.

This study includes some biological parameters of *C. gibelio* in Bafra Balık Lakes (Samsun, Turkey). It is thought that the results obtained will be a source for different studies to be carried out especially on *C. gibelio* in the future.

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