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RESEARCH ARTICLE/ARAŞTIRMA MAKALESİ

Length-Weight Relationship, Condition Factor, and Gonadosomatic Index of Endemic *Alburnus istanbulensis* (Battalgil, 1941) in Two Different Habitats: Karamenderes River and Bayramiç Reservoir (Çanakkale, Turkey)

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Abstract

Objective: The first aim of this study is to describe the length, weight, condition factor, and GSI of *Alburnus istanbulensis* (Battalgil, 1941) in two different connected habitats (stream habitat and reservoir lake) in Karamenderes River, Çanakkale. The second aim is to state the growth type of this species in the sampled habitat using the length-weight relationship (LWR) model.

Materials and Methods: The sampling areas are Bayramiç Reservoir and two tributaries on Karamenderes River, which feed the reservoir. Sampling was conducted between May 2016 and June 2017, and depending on the habitat types, different gears were used in the samplings. $W=aL^b$ equation was used to calculate the length-weight relationship, $K=100\times W/L^3$ equation for the condition factor, and $GSI=W_G\times 100/W$ equation for the gonadosomatic index.

Results: The results showed that the mean fork length of specimens in reservoir and stream habitats were 11.86±1.83 cm and 7.69±3.56 cm, respectively, and body weight of the specimens in the reservoir and stream habitats were 19.28±8.99 g and 8.17±10.82 g, respectively. The condition factor was higher in the reservoir habitat and GSI values were higher in the stream habitats. The growth for all the specimens was positive allometric (b=3.13), whereas in the reservoir habitat the growth was isometric (b=2.99) and in the stream habitat the growth was positive allometric (b=3.12).

Conclusions: Determining the biological characteristics of an endemic species makes an important contribution to the conservation of the species. In the Çanakkale region, data on LWR, growth, condition, and GSI values were not available with the valid name of the species. Therefore, this study is important in terms of presenting new data in the Çanakkale region with the valid name of the species. The findings of this study indicate that the *A. istanbulensis* species exhibited habitat-dependent differences in LWR, growth, and condition.

Keywords: Growth, Biological characteristic, Fish biology, Reservoir habitat, Stream habitat

Introduction

In fish biology, it is important to make estimations of biological traits for population growth characteristics, and this plays a crucial role in the conservation biology of the population. The length-weight relationship is an important parameter that gives information about population growth (Beverton & Holt, 1957; Froese, 2006). During the course of their lives, freshwater fish can be limited to newly developed habitats like reservoirs as an alternative to having access to a diverse range of natural habitats, or the natural stream continuity might be disrupted for them by the presence of a reservoir. As a result, it is reasonable to anticipate that fish species' biological characteristics, such as growth parameters, will change based on their respective habitats (Schlosser, 1995).

Due to the location at the crossroads of neighbouring regions with varying ecological and geographical characteristic, Türkiye's freshwater fish species have high diversity and endemism (Hrbek et al., 2004; Perea et al.,

2010; Çiçek et al., 2018; Bektaş et al., 2020). According to the present ichthyofauna, Türkiye is inhabited by 384 species of freshwater fish, 208 of which are endemic (Çiçek et al., 2020). The *Alburnus* genus has 24 species in Türkiye, 17 of which are endemic to Türkiye (Bektaş et al, 2020; Çiçek et al., 2020), while the genus has 48 species worldwide (Froese & Pauly, 2022). The species *Alburnus istanbulensis* (Battalgil, 1941) is one of the endemic species in Türkiye. Formerly named *Chalcalburnus chalcoides* and *Alburnus chalcoides*, it spreads throughout the Thrace region of Türkiye (Özuluğ & Freyhof, 2007) (Figure 1). According to the IUCN Red List, the species is in the Least Concern (LC) status (Freyhof, 2014). This species migrates upstream to spawn, and juveniles migrate downstream in the fall of that year or in the spring of the following year (Kottelat & Freyhof, 2007). Because the building of dams causes disruptions in the migration pathways of migratory populations, there is a loss of population quantities before they can reach their breeding sites. As a consequence, they attempt to live in tiny ponds and reservoir lakes as a result of this disruption (Kottelat & Freyhof, 2007; Freyhof, 2014).

There have been studies on *A. istanbulensis* species distribution (Sarı et al., 2006; Özuluğ, 2008; Geiger et al., 2014; Saç & Özuluğ, 2014; Boll et al., 2016; Gaygusuz et al., 2017; Saç & Özuluğ, 2017a,b,c; Özuluğ & Saç, 2019; Sarı et al., 2019; Çiçek et al., 2020), maturity and gonadosomatic index (Tarkan et al., 2005; Tarkan et al., 2012; Hamzaoğlu et al., 2015), parasites (Kırcalar & Soylu, 2014), and feeding characteristics (Yalçın Özdilek & Jones, 2014; Yalçın Özdilek et al., 2019). However, there are limited studies on length-weight relationships and length-weight distributions (Tarkan et al., 2005; Tarkan et al., 2006; Saç & Okgerman, 2016; Gaygusuz et al., 2017; Saç et al., 2019), and age distribution (Başdemir et al., 2010; Çiçek et al., 2015) with *A. istanbulensis*'s former name (*C. chalcoides* and *A. chalcoides*). Since endemic species are important species in their distribution ranges, it is also important to define their biological characteristic in different habitats. In this context, this study will fill the gap in the literature on *A. istanbulensis* and present the difference in the biological features between an interrupted habitat (reservoir) and native habitat (stream). The first aim of this study is to describe the length, weight, condition factor, and GSI of *Alburnus istanbulensis* (Battalgil, 1941) in two different connected habitats (stream habitat and reservoir lake) in Karamenderes River, Çanakkale. The second aim is to state the growth type of this species in the sampled habitat using the length-weight relationship (LWR) model.

Material and Methods

Sampling area and laboratory studies

Karamenderes River arises from the Kaz and Ağı Mountains and runs into the Dardanelles. The flow rate of the river is 65-1530 m^3 (min.-max.) and it is approximately 109 km long (Baba et al., 2007). The sampling area is Bayramiç Reservoir (39° 48.66′ N - 26° 41.09′ E) and two tributaries (Çalıoba 39° 46.72′ N - 26° 42.24′ E and Mollahasanlar 39° 47.33′ N - 26° 43.0′ E) which feed the reservoir. The reservoir was built in 1986-1996 for irrigation purposes, its body is filled with soil, the total body volume is 4.0 hm^3, its height is 55.5 m from the foundation, the total storage volume is 86.5 hm^3, and the lake area is 5.847 km^2 when the water level is at its normal level (Akbulut et al., 2006). The sampling areas map is shown in Figure 2.

The samplings were carried out monthly between the months of May 2016 and June 2017, and in accordance with the habitats, two separate catching techniques were applied in order to carry out the samplings. In the river habitats, electroshocks from a backpack were used, and

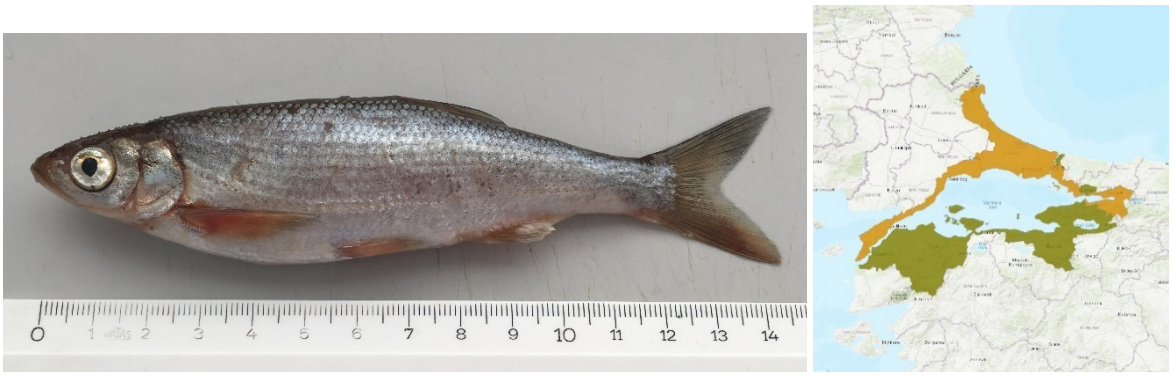

Figure 1. Photo of *Alburnus istanbulensis* specimens (photo: Partal N) and the distribution map according to IUCN (Freyhof, 2014).

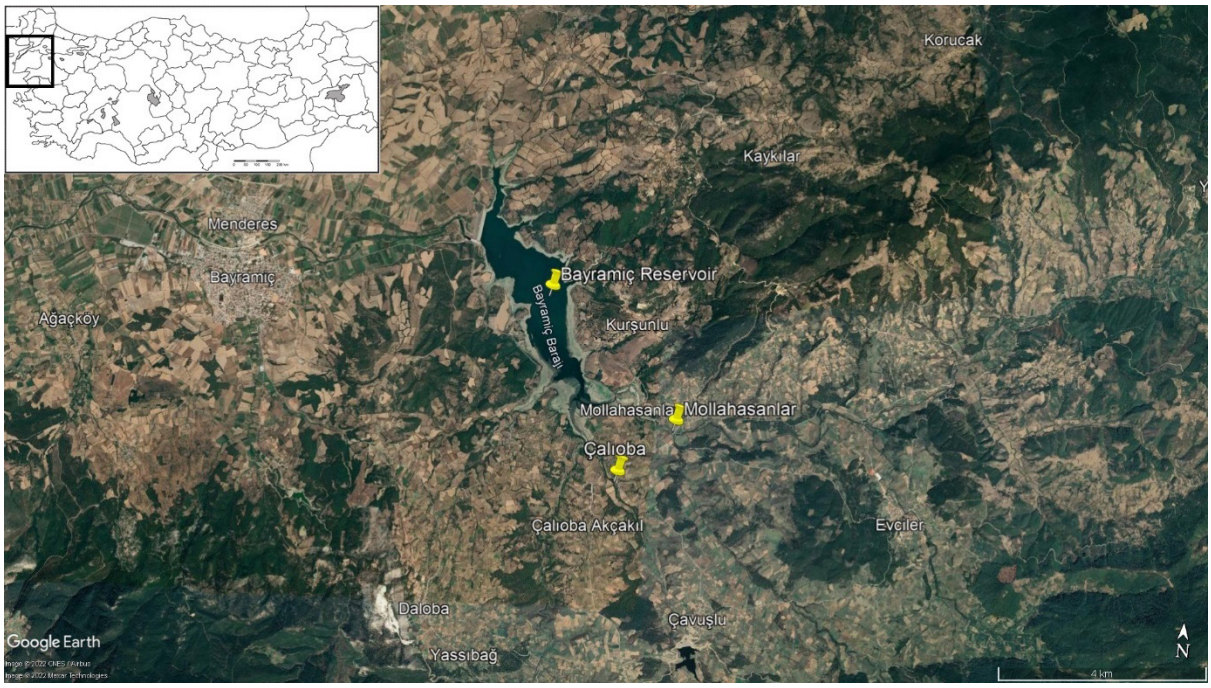

Figure 2. Map of sampling areas (Google Earth, 2022).

in the reservoir, a seine net with a 10-mm mesh, a 2-meter depth, and a 70-meter length was utilized. Despite monthly samplings, there were several months when fish could not be caught in both reservoir and stream habitats.

Following sampling, the specimens were kept in clove oil treatment under ethical guidelines before being transported to the laboratory (Prince & Powell, 2000). After the sampling, fish were brought to the laboratory and kept at -20ºC until the dissection process. The fork length (FL) of the specimens was measured with a ruler to the nearest 0.1 mm. The body weight (W) and gonad weights of the specimens were weighed with a digital balance to the nearest 0.1 g. The maturity and sexes (juvenile, female, and male) of the specimens was determined by macroscopic identification (Wootton, 1990).

Data analysis

The descriptive analysis of species characteristics is given as mean values, standard deviation, and minimum and maximum values. Descriptive statistics were grouped as all specimens, habitats, sex/maturity and given according to body weight, fork length, condition factor, and GSI. The LWR equation was determined from $W=aL^b$ and it was transformed to the linear model equation as $\log W=\log a+b\log L$. According to both equations, W is the body weight (g) of fish, L is the fork length (cm) of fish, *a* is the regression intercept, and *b* is the slope/growth coefficient. The estimate of 95% confidence limits (Cl) for *a*, *b*, and the coefficient of determination (r^2) was determined (Froese, 2006). The growth type was determined according to the *b* value as suggested by Bagenal (1978). The Fulton's condition factor was determined from the $K=100\times W/L^3$ equation (Le Cren, 1951). The specimens' gonadosomatic index (GSI) was determined from the $GSI=W_G\times 100/W$ (W_G: Weight of gonad, g) (Wootton, 1990). The GSI was calculated according to the determined sexes of the specimens.

The analysis of LWR was made with the FSA package in R Software (Ogle, 2018; R Core Team, 2022). The figures were produced with the ggplot2 package in R Software (Wickham, 2016; R Core Team, 2022).

Results

The specimens of *A. istanbulensis* were sampled from Karamenderes Rivers' two stream tributaries and Bayramiç Reservoir and the specimens were grouped as stream and reservoir specimens. The total number of *A. istanbulensis* specimens was 352 in the whole samplings. The specimens' percentage in reservoir (52.3%) was higher than stream specimens (47.7%). The specimens' descriptive statistics are given in Table 1. The sex of 262 out of 352 specimens was determined, and the weight, fork length, condition, and GSI values of the specimens whose sex could not be determined were not included in the analyses related to sex.

Table 1. Descriptive statistics of *A. istanbulensis* specimens (n: Number of specimens; sd: Standard deviation; min: Minimum value; max: Maximum value).

	Weight, g			Fork length, cm			Condition factor			GSI		
	n	**mean±sd**	**min-max**	**n**	**mean±sd**	**min-max**	**n**	**mean±sd**	**min-max**	**n**	**mean±sd**	**min-max**
All specimens	352	13.98±11.35	0.27-53.5	351	9.9±3.5	3.1-17.0	349	1.03±0.13	0.56-1.88	249	1.63±1.87	0.03-9.73
Habitat												
Stream	168	8.17±10.82	0.27-53.5	168	7.69±3.56	3.1-17.0	166	0.98±0.15	0.56-1.88	159	1.91±2.06	0.03-9.73
Reservoir	184	19.28±8.99	0.79-52.61	183	11.86±1.83	4.2-16.5	183	1.07±0.1	0.86-1.76	90	1.14±1.34	0.06-8.25
Sex/Maturity												
Juvenile	63	0.87±0.43	0.27-2.91	63	4.48±0.65	3.1-7.0	62	0.93±0.17	0.56-1.88	57	0.49±0.59	0.03-2.9
Female	52	14.08±10.38	1.73-47.66	52	10.47±2.69	5.9-16.8	53	1.02±0.1	0.79-1.3	51	2.54±2.52	0.36-9.73
Male	147	15.43±11.69	0.93-53.5	146	10.52±2.9	4.6-17.0	145	1.04±0.11	0.8-1.3	141	1.76±1.71	0.06-6.78

The monthly variation of the FL, W, condition factor, and GSI values were illustrated in Figure 3. In the stream, smaller specimens were captured throughout the autumn and winter months, whilst larger specimens were captured during the spring months. On the other hand, larger individuals were found in the habitat of the reservoir during the hot summer days. The reproductive period of this species is represented by an increase in GSI and

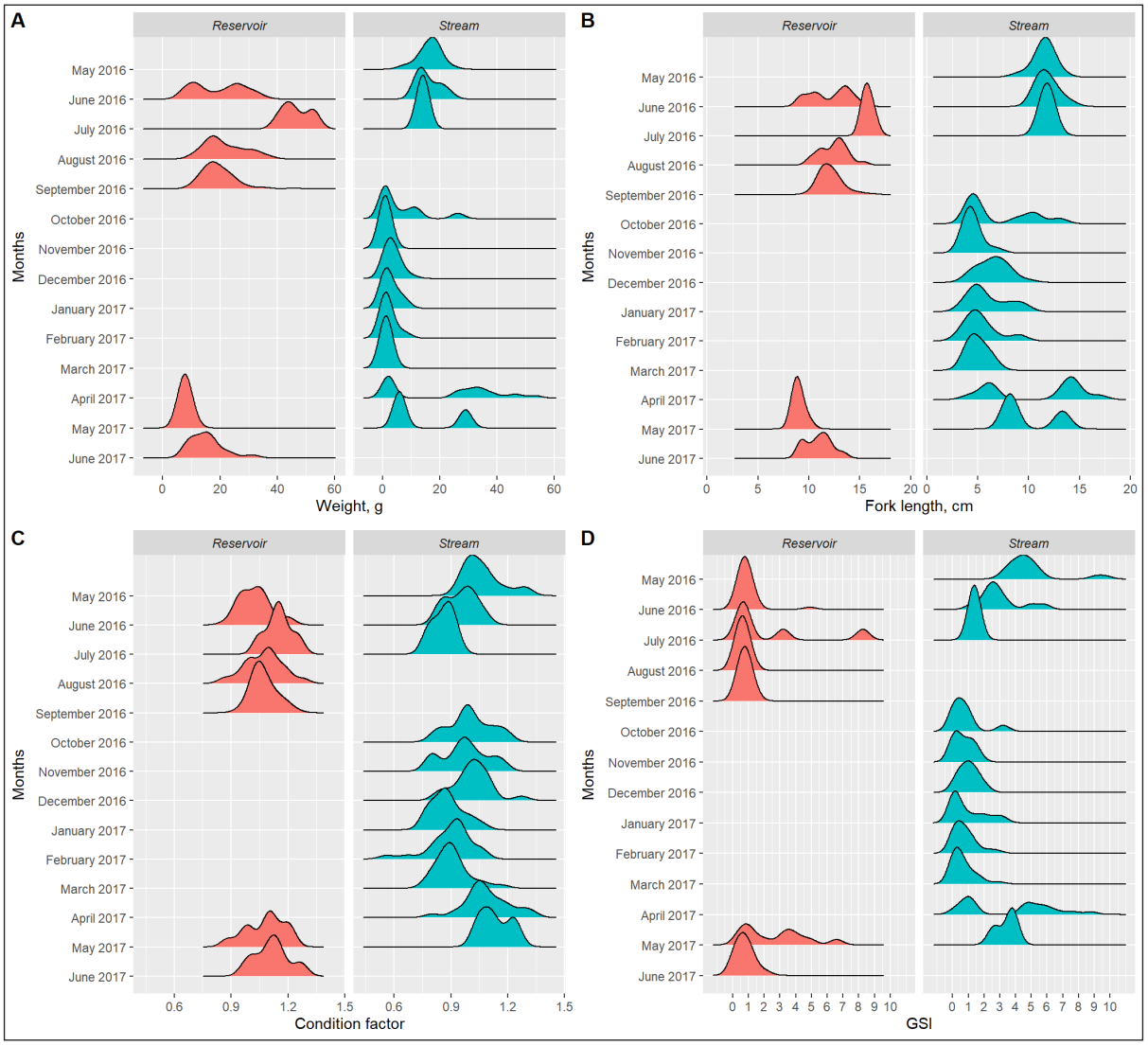

Figure 3. The monthly variation of the W (A), FL (B), condition factor (K), and GSI (D) values.

condition factor values during the spring months, which is consistent with the size distribution seen in stream and reservoir habitats. The maturity percentage of the mature specimens was 75.95% and of the immature specimens was 24.05%. There were no immature specimens in the reservoir. The sexes of 199 specimens were determined by macroscopic identification and the female:male ratio was determined to be F:M = 1:2.83. In the reservoir habitat F:M was determined to be 1:3.04 and in stream habitat F:M was 1:2.55.

The weight frequencies were evaluated according to the habitats, and it was determined that the frequent weights in stream habitats were 0.27-2.91 g (Figure 4A). In the reservoir habitat, the highest weight frequency was determined to be 18.01-19.88 g. The fork length frequencies of the specimens were evaluated according to the habitats, and it was determined that the small specimens were frequently present in streams while the larger specimens were in the reservoir habitats (Figure 4B). When the condition factors of the specimens were evaluated, it was determined that the condition factors of the specimens in the reservoir habitat were higher than in the stream habitat (Figure 4C). The GSI frequency values of the specimens were between 0.06-1.33% both in reservoir and stream habitats (Figure 4D). These values were more frequent in the reservoir habitats than in the stream habitats.

The difference in both fork lengths and body weights between reservoir and stream specimens was statistically significant (fork length t: 13.97; $p<0.05$; body weight t: 10.5; $p<0.05$). Additionally, the condition factor values were statistically significant between the reservoir and stream habitat specimens (t: 7.8; $p<0.05$). According to the GSI values, the difference between the reservoir and stream habitats was statistically important (t: 3.36; $p<0.05$). While the GSI values in the reservoir habitats for females and males were statistically important (t: 2.25; $p<0.05$), on the other hand, stream habitats for females and males were not statistically important (t: 1.6; $p>0.05$).

The LWR of all specimens was determined to be logW=-2.12+3.13logFL (r^2=0.99) (Figure 5A). The *LWR* of specimens was determined in the reservoir habitat to be logW=-1.96+2.99logFL (r^2=0.97*)* and in stream habitats to be logW=-2.11+3.12logFL (r^2=0.99) (Figure 5B). All specimens' growth was defined positive allometric (b=3.13), the reservoir specimens' growth was defined isometric (b=2.99), and the stream specimens' growth was defined positive allometric (b=3.12) (Table 2). The LWRs linear model parameters are given in Table 2.

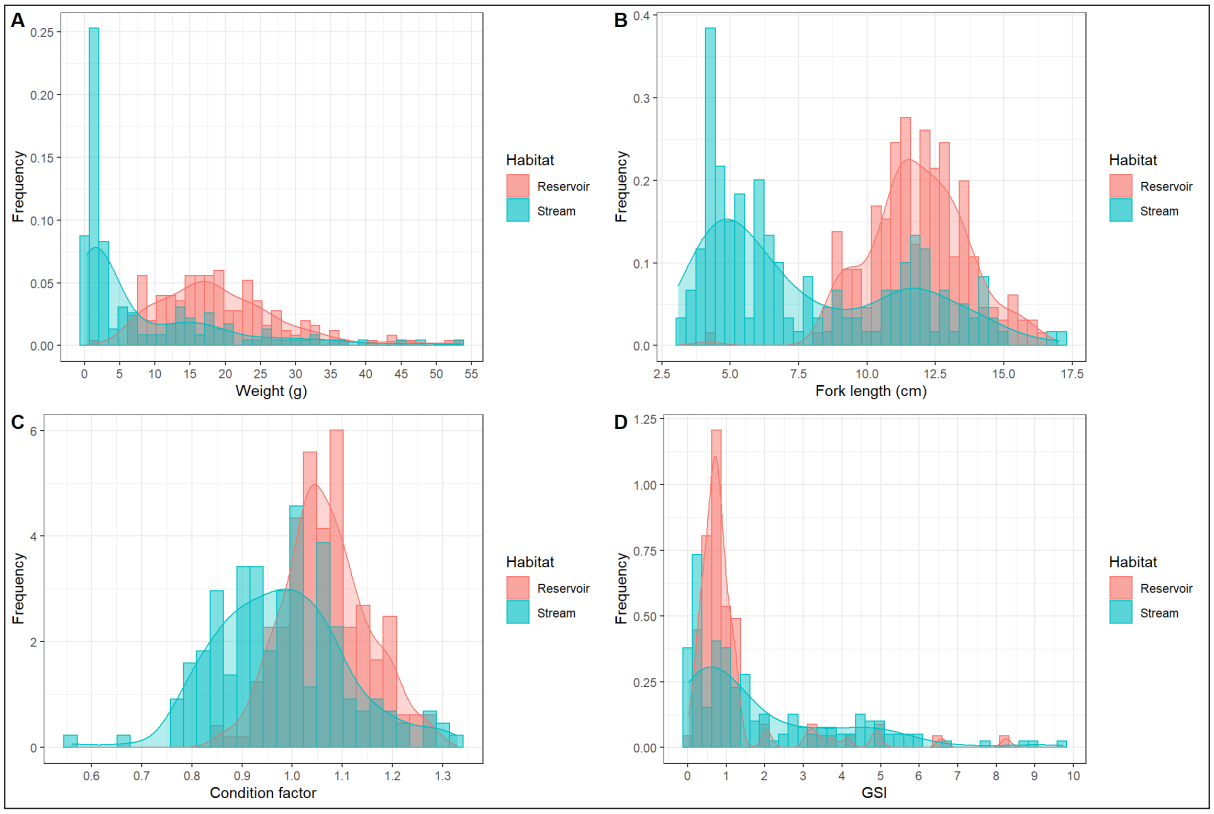

Figure 4. The frequencies and densities of weight (A), fork length (B), condition factor (K), and GSI (D) according to habitats.

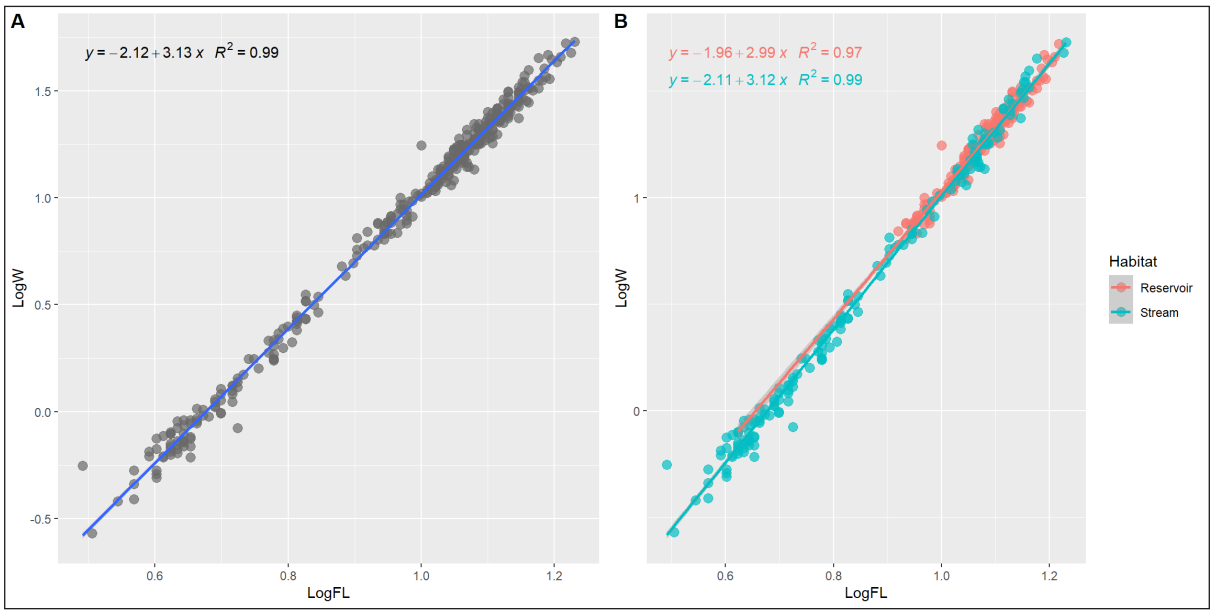

Fig. 5. The length-weight relationship of *A. istanbulensis* for all specimens (A) and habitats (B).

Table 2. The length-weight relationships parameters according to all, reservoir, and stream specimens (*n*: Number of specimens; *a*: Intercept of linear regression; *b*: Slope of linear regression; *CI*: Confidential interval; r^2: Coefficient of determination ($R<0.05$)).

	Parameters of the length-weight relationships								
Group	***n***	***a***	***95% CI of a***		***b***	***95% CI of b***		***r²***	***Growth type***
All specimens	352	0.0076	0.007	0.008	3.1333	3.105	3.161	0.99	Positive allometric
Reservoir specimens	184	0.0109	0.009	0.014	2.9858	2.896	3.068	0.97	Isometric
Stream specimens	168	0.0078	0.007	0.008	3.1219	3.077	3.166	0.99	Positive allometric

Discussion

There are limited studies on the biological characteristics of *A. istanbulensis* in the literature. The majority of the studies in the literature include information on their distribution area and/or abundance in the communities in distribution areas (Sarı et al., 2006; Özuluğ, 2008; Geiger et al., 2014; Saç & Özuluğ, 2014; Boll et al., 2016; Gaygusuz et al., 2017; Saç & Özuluğ, 2017a, b, c; Özuluğ & Saç, 2019; Sarı et al., 2019; Çiçek et al., 2020). Therefore, this study is important in terms of filling the gaps in the literature about the biological characteristics of *A. istanbulensis*.

Although the length and weight distributions of *A. istanbulensis* species in river habitats are comparable to those found in the literature (Başdemir et al., 2010; Yalçın Özdilek & Jones 2014), they are not the same as those found in reservoir habitats. In reservoir habitats, the length and weight distributions of *A. istanbulensis* species are more variable. The weight and fork length ranges of specimens were found to be lower in the Bayramiç Reservoir compared to what was described in the literature for the reservoir (Çiçek et al., 2015; Saç & Okgerman, 2016). Except in Darlık Dam, the specimens' fork lengths were lower than in Bayramiç Reservoir (mean: 6.0±2.7 cm; min-max: 1.9–14.5 cm) (Gaygusuz et al., 2017). In the current research, the seine net was used along the coastline of the reservoir; however, in the aforementioned literature, a broad variety of mesh sizes were utilized, which most likely sampled the pelagic, deeper area of the reservoir. Therefore, the gear selectivity might be the reason why smaller specimens were sampled in the reservoir's habitat as compared to what was reported in the literature, because it is well documented that the genus *Alburnus* spreads via pelagic herds in the environs of reservoirs and lakes (Kottelat & Freyhof, 2007).

In terms of the condition factor values, the results were comparable to those found in the previous research conducted in reservoir habitats (Çiçek et al. 2015; Saç

& Okgerman, 2016). The estimated mean value of the condition factor for the samples from the Bayramiç Reservoir was higher than the calculated value for the samples from the Karamenderes River. The higher condition factor value in reservoir habitat than that in the stream habitat might be explained by various reasons such as age, sex, sexual maturity, feeding characteristics, gonad status, habitat, and length and weight distribution of specimens (Le Cren, 1951; Kırankaya et al., 2014). Even though every single specimen in the Bayramiç Reservoir had attained maturity, the mean GSI value of the reservoir was lower than that of the stream specimens. This was due to the fact that the reservoir was much larger. Therefore, it is not entirely accurate to suggest that reaching sexual maturity is the sole factor contributing to the higher condition value. There is no information available on condition factors in river habitats; nevertheless, the current condition factor value that was estimated for stream specimens represented the first data for this species.

Regarding the GSI values of the species, the GSI values are higher for both sexes in the Darlık Dam (Female: 0.19-16.05; Male: 0.25-8.63) (Hamzaoğlu et al., 2015) than that in this study (Female: 0.36-8.25; Male: 0.06-4.91) for Bayramiç Reservoir specimens. Additionally, the GSI values of the species in the earlier study, which was carried out in the Ömerli Reservoir, ranged from 8.2 to 9.9 between 2002 and 2007 (yearly values) (Tarkan et al., 2012). Among the general characteristics of the *Alburnus* genus, it is known that populations in lakes with reservoirs lay eggs in the entrance branches of the reservoirs (Kottelat & Freyhof, 2007). The results of this study support the general reproduction characteristics of the genus *Alburnus* due to its higher GSI values in stream habitats (mean GSI: 1.91±2.06; min-max: 0.03-9.73).

When the length-weight relationships of the species were compared with the studies conducted in the stream habitats, it was ascertained that while isometric (b=2.99) growth was reported in the study of Çakırköy Stream in Çanakkale (Başdemir et al. 2010), positive allometric growth (b=3.12) was found in Karamenderes River. However, it was found that the growth of specimens in the reservoir habitats was isometric in both Bayramiç and Büyükçekmece Reservoirs (Saç & Okgerman, 2016). In the previous study conducted in the Marmara region, positive allometric growth was observed in Ömerli Reservoir, Terkos Reservoir, and Sapanca Lake, whilst negative allometric growth was observed in Büyükçekmece Reservoir (Tarkan et al., 2006). It has been observed that the *A. istanbulensis* species growth in Bayramiç Reservoir differed from that in other Marmara region reservoirs and natural lakes (Tarkan et al., 2006). According to this study, the population of *A. istanbulensis* in Bayramiç Reservoir grows slowly compared to the stream habitat. It is possible to conclude that both the length-weight relationship and the growth parameters were influenced by hereditary and environmental factors (Svanbäck & Eklö, 2002). The *A. istanbulensis* populations in this research were influenced by the ecological circumstances of the habitats in which they are found, suggesting that the Karamenderes and Bayramiç Reservoir populations are not genetically isolated. Further research is needed about the habitat and ecological preferences of this species.

The occurrence of the alien species *Atherina boyeri* was reported in the previous study at the Bayramiç Reservoir (Partal et al., 2019). It is known that *A. boyeri* species are distributed in the pelagic zone in reservoir/lake habitats (Kottelat & Freyhof, 2007). Considering that the two species share the same habitat, the effects of *A. boyeri* on *A. istanbulensis* are highly likely in the following years. For this reason, the community relations of the endemic *A. istanbulensis* species with other alien/invasive and native species in the distribution area should be studied in detail.

Determining the biological characteristics of an endemic species makes an important contribution to the conservation of the species. In the Çanakkale region, data on LWR, growth, condition, and GSI values were not available with the current name of the species. Therefore, this study is important in terms of presenting new data in the Çanakkale region with the current name of the species. The conclusions of this study Show that *A. istanbulensis* species showed different LWR, growth, and condition characteristics according to the stream and reservoir habitats.

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