**ARAŞTIRMA MAKALESİ** | **RESEARCH PAPER**

# Some Biological Characteristics of the Transcaucasian spirlin *Alburnoides fasciatus* (Nordmann, 1840) inhabiting Borçka Reservoir, NE Türkiye

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**Abstract:** The present study investigates for the first time some basic biological aspects such as sex ratio, size composition, length-length relationships (LLRs) and length-weight relationships (LWRs) of *Alburnoides fasciatus* inhabiting Borçka Dam Lake and its tributaries from the lower Çoruh River Basin located in the northeastern Türkiye. Fish samples were collected from February 2017 to June 2019. Totally 171 specimens ranging from 7.4 cm to 16.2 cm TL and 4.06 g to 46.56 g were sampled. The sex ratio (F:M) was calculated as 1.19:1.00 ($\chi^2$ test; P>0.05). The total length-weight relationships were determined as W= 0.008TL$^{3.154}$ (r$^2$=0.987, N=93) for females, as W= 0.007TL$^{3.183}$ (r$^2$=0.990, N=78) for males and as W= 0.007TL$^{3.205}$ (r$^2$=0.981, N=171) for combined sex. The b-values were significantly different from isometric growth (b=3) indicating positive allometric growth of Transcaucasian spirlin for all sexes (Pauly's t-test; P<0.05). The regression analysis of LWRs revealed that the coefficient of determination was r$^2$>0.9 showing a highly significant correlation between total length and weight. Results of the LLRs indicated that the values of correlation coefficient were highly correlated (r$^2$>0.9) for each sex and relationship. The differences in b values of the LWR were statistically significant for both sexes (ANCOVA; P<0.05). The present study also reports a new maximum total length and weight data as 16.2 cm and 46.56 g for this species. This study will provide a baseline on some basic biological parameters of Transcaucasian spirlin for the fisheries management authority and fisheries scientists for further investigations as well as presents the first known reference on the LLRs and size structure of this species for the FishBase database. Furthermore, the reported results may contribute to the conservation and sustainability of this species in the area as well.

**Keywords:** *Alburnoides fasciatus*, Borçka dam lake, growth pattern, LLRs and LWRs, sex ratio.

## Borçka Baraj Gölü'nde (KD Türkiye) Yaşayan Kafkas Noktalı İnci Balığı *Alburnoides fasciatus* (Nordmann, 1840)'nın Bazı Biyolojik Özellikleri

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**Öz:** Bu çalışma, kuzeydoğu Türkiye'de yer alan aşağı Çoruh Nehri Havzası'ndaki Borçka Baraj Gölü ve kollarında yaşayan *Alburnoides fasciatus*'un cinsiyet oranı, boy kompozisyonu, boy-boy ilişkileri (LLRler) ve boy-ağırlık ilişkileri (LWR'ler) gibi bazı temel biyolojik yönlerini ilk kez araştırmaktadır. Balık örnekleri Şubat 2017 - Haziran 2019 tarihleri arasında toplanmıştır. 7,4 cm ile 16,2 cm TL ve 4,06 g ile 46,56 g arasında değişen toplam 171 örnek alınmıştır. Cinsiyet oranı (D:E) 1,19:1,00 olarak hesaplanmıştır ($\chi^2$ test; P>0.05). Toplam boy-ağırlık ilişkileri dişilerde W=0,008TL$^{3.154}$ (r$^2$=0,987, N=93), erkeklerde W=0,007TL$^{3.183}$ (r$^2$=0,990, N=78) ve tüm bireyler için W=0,007TL$^{3.205}$ (r$^2$=0,981, N=171) olarak belirlenmiştir. b-değerleri, izometrik büyümeden (b=3) önemli ölçüde farklıydı ve tüm cinsiyetler için Kafkas Noktalı İnci balığı pozitif allometrik büyüme göstermiştir (Pauly's t-testi; P<0.05). LWR'lerin regresyon analizi, r$^2$>0,9 olduğunu ortaya koymuş ve toplam boy ve ağırlık arasında oldukça önemli bir korelasyon olduğunu göstermiştir. LLR'lerin sonuçları, her bir cinsiyet ve ilişki için korelasyon katsayısı değerlerinin yüksek düzeyde ilişkili olduğunu (r$^2$>0,9) göstermiştir. LWR'nin b değerlerindeki farklılıklar her iki cinsiyet için de istatistiksel olarak anlamlı bulunmuştur (ANCOVA; P<0.05). Bu çalışma ayrıca bu tür için 16,2 cm ve 46,56 g olarak yeni bir maksimum toplam boy ve ağırlık verisi bildirmektedir. Bu çalışma, Kafkas Noktalı İnci Balığı'nın bazı temel biyolojik parametreleri hakkında balıkçılık yönetimi otoritesi ve balıkçılık bilim adamlarına ileri araştırmalar için bir temel sağlamanın yanı sıra FishBase veri tabanı için bu türün LLR'leri ve boy kompozisyonu hakkında bilinen ilk referansı sunacaktır. Böylelikle, rapor edilen sonuçlar bu türün bölgede korunmasına ve sürdürülebilirliğine de katkıda sağlayacaktır.

**Anahtar kelimeler: :** *Alburnoides fasciatus*, Borçka Baraj Gölü, büyüme şekli, cinsiyet oranı, LLRler ve LWRler.

## INTRODUCTION

Türkiye is situated between Europe and Asia, so that its fish fauna is highly diverse, comprising four major marine regions and 14 major freshwater fish regions, mainly distinguished by different watershed systems (Fricke et al., 2007). Turkish inland fish fauna includes 384 species belonging to 20 orders and 34 families with more than half of the ichthyofauna (96.1% of the fish species, 369 species) are native of which 54.2% (208 species) are considered endemic and 3.9% (15 species) are non-native (Çiçek et al., 2020).

The spirlins of the genus *Alburnoides* Jeitteles, 1861 (Teleostei:Leuciscidae) inhabit lakes and moderate to fast-flowing rivers and streams throughout western Eurasia from France east to Kazakhstan (Kottelat & Freyhof, 2007). *Alburnoides* species inhabiting tributaries of the whole Black Sea constitute the richest example of spirlin diversity (Kaya, 2020). Up to now, while nine species have been recognised from along all the Black Sea basin, this genus is represented by 13 valid species, which most of them (7 species) inhabit the Black Sea basin in Türkiye (Turan et al., 2017; Turan et al., 2019; Kaya, 2020; Çiçek et al., 2020).

*Alburnoides fasciatus* (Nordmann, 1840) also, commonly known as the Transcaucasian spirlin is a benthopelagic freshwater species which inhabits rivers and streams with fast running shallow water, often over gravel, pebble, or rocks. The Transcaucasian spirlin distributes in Eurasia in western Transcaucasia from eastern Black Sea basin in Russia south to Çoruh drainage in northern Anatolia (IUCN, 2022; Froese & Pauly, 2022). The Transcaucasian spirlin, *Alburnoides sciatus* is globally listed as Least Concern (LC) category by the IUCN Red List of Threatened Species (Freyhof, 2014), however, this species is considered as Vulnerable (VU) in inland waters of Türkiye due to dams' construction on rivers, habitat loss, water abstraction, eutrophication and pollution. This species was also reported to be sensitive to human activities and as a keystone species which has significant/regional decline that needs high priority for conservation action (Fricke et al., 2007).

Sex ratio and size structure are used to provide basic knowledge to assess the reproductive potential and estimating stock size in fish populations (Vicentini & Araújo, 2013). The size structure which describes the relative frequency of the fish sizes in the population plays a significant role in the assessment of a fish stock and the sustainability of its fishery. In fishes, age and size are closely coupled, even so a fish population can be described equivalently by the age or the size structure (Barneche et al., 2018; Andersen, 2020). Size structure also plays an important role in maintaining reproductive potential and stability of a fish population. Hence, investigating the change of size structure may provide insight of how resilient a fish population can be (Tu et al., 2018).

The biometric studies which give information on fish species for an estimated assessment of their biomass are keystone tools for research and management (Zargar et al., 2012). So that, it is essential to determine the growth characteristics related to the length and weight of the fish in biometric studies (Morato et al., 2001). The length-weight relationships (LWRs) in fishes provide significant information about the general health, growth pattern, life history, habitat conditions, fish fatness and condition, as well as morphological characteristics of the fish (Schneider et al., 2000; Froese, 2006). Hence, the length and weight data of fishes have commonly been studied to obtain biological information and has become one of the standard methods used in fisheries biology (Le Cren, 1951; Yesilcicek et al., 2015).

The length-length relationships (LLRs) are also important in fishery management due to different types of fish length measurements are used in fisheries studies. For instance, whereas total length (TL) and fork (FL) length are commonly used for estimation of fish growth, standard length (SL) is generally used in systematic studies. Standardization of length measurements of fishes helps comparison of different populations, therefore, LLRs in different populations should be known (Moutopoulos & Stergiou, 2002; Kırankaya et al., 2014). Hence, the comparison of the relationships between different length types in fisheries also plays a significant role in growth studies (Froese & Pauly, 1998).

The current study aims to contribute to the limited knowledge on some biological characteristics (LWRs, LLRs, sex and size composition) of *A. fasciatus* from Borçka Reservoir and its tributaries located in the lower part of Çoruh River basin. This study is the first one on this species in the research area and certainly will provide a significant contribution to the current literature and very important in terms of monitoring the populations and ensuring the sustainability of the Transcaucasian spirlin in this habitat. Evaluation of some bio-ecological characteristics of the species with this study will also make an important contribution to the reassessment of *A. fasciatus* for IUCN criteria. The results reported here are important in terms of understanding the life history of this species and will provide a baseline for further studies. The results of this study will also provide the opportunity to make comparisons between other *Alburnoides* species. The results will be helpful for researchers and fisheries management authority to better understand the life history patterns and ecology of this species to protect the inland fish biodiversity, also for conservation and sustainability of the species in the area as well.

## MATERIAL AND METHOD

***Study Area:*** The present study was conducted in Borçka Reservoir and its tributaries, which is located on the lower part of Çoruh River Basin in the northeastern Black Sea region of Türkiye. Coruh River has a total length of 431 km, within 410 km of borders of Türkiye and the last 21 km in Batumi (Georgia) where the river falls into the Black Sea. Borçka Dam is located approximately 300 m downstream of the junction of Çoruh River and Murgul Stream, 2.5 km upstream of Borçka district and 30 km northwest of Artvin province (Figure 1). The reservoir has 419 hm$^3$ volume at normal water level and a surface area of 10.84 km$^2$ (Yesilcicek & Kalayci, 2020).
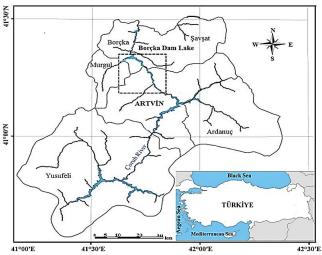


**Figure 1.** The map of the study area

***Fish Sampling:*** The Transcaucasian spirlin specimens were caught from February 2017 to June 2019 by using trammel nets with various mesh sizes, cast nets and by pulsed DC electrofishing device from reservoir and its tributaries. Each fish sample caught was measured in total length (TL), fork length (FL) and standard length (SL) to the nearest 1 mm and weighed to the nearest 0.01 g body weight (W). Sex was determined via macroscopic or microscopic observation of the gonads using morphological differences such as shape, color and structure.

***Length-Weight Relationships (LWRs):*** The relationship between the total length and total body weight of the Transcaucasian spirlin were determined by fitting the data to a potential relationship in the equation of $W = aTL^b$, which was converted to logarithmic form as $\log W = \log a + b \log TL$, where W is total body weight (g), TL is the total length (cm), a: intercept and b: slope regression coefficients. Then the length–weight relationship (LWR) parameters for each sex were estimated by linear regression analysis using the log-transformed values of this equation (Ricker, 1973; King, 2007).

***Length-Length Relationships (LLRs):*** The relationships among the length types (TL-FL, TL-SL, and FL-SL) were determined by applying linear regression analysis. The general linear equation; y = a + bx was used to estimate the length- length relationship parameters needed. Regression equations for the LLRs of Transcaucasian spirlin were established separately for each sex and combined sex as follows: FL = a + bTL, SL = a + bTL, SL = a + bFL.

***Statistical Analysis:*** Student's t-test was used to check out the differences in mean values of TL, and W between the sexes. Chi-square ($\chi^2$) test was performed to test whether the observed sex ratio between females and males is deviated from the expected ratio of 1:1. ANCOVA was used to determine if there was significant difference in slopes (b values) between the sexes (Zar, 1999). ANOVA was used to evaluate the statistical significance of the regression using the log-transformed values of length and weigth. To compare the slopes to confirm whether the b value was different from the isometric growth (b=3) for both sexes and all individuals, Pauly's t-test (Pauly, 1984) was performed using the formula as:

$$t = \frac{Sd_{logTL}}{Sd_{logW}} \frac{|b-3|}{\sqrt{1-r^2}} \sqrt{n-2}$$

where, $Sd_{logTL}$ is the standard deviation of the *log TL* values, $Sd_{logW}$ is the standard deviation of the *log W* values, $r^2$ is correlation coefficient, n is the number of fish specimens used in the calculation. If calculated t value is greater than the table *t* values for n-2 degrees of freedom the value of b is different from isometric growth (b=3) (Pauly, 1984; Bilgin et al., 2020). All tests applied in this study were performed at the 0.05 level of significance. Statistical analyses were performed using the SPSS and MS Excel software.

## RESULTS

***Sex Composition:*** Of the totally sampled 171 Transcaucasian spirlin specimens in the study, 54.39 % (N= 93) were females and 45.61% (N=78) were males, accordingly the ratio of female to male was calculated as 1.19:1.00 in favor of females, but F:M ratio did not deviate from the expected ratio of 1:1 ($\chi^2 = 1.316$; *P>0.05*).

***Length and Weight Distribution:*** A total of 171 Transcaucasian spirlin individuals were sampled from Borçka Reservoir and its tributaries during the study. Total length (TL) of all samples distributed between 7.4 cm and 16.2 cm (mean 10.65±0.162 cm) and the body weight ranged from 4.06 to 46.56 g (mean 14.98±0.738 g). Females ranged from 7.5 to 16.2 cm (mean 10.76±0.225) and 4.31 to 46.56 g (mean 16.09±1.050), while males ranged from 7.4 to 15.7 cm (mean 10.51±0.235) and 4.06 to 42.83 g (mean 13.65±1.012). Females were slightly heavier and longer than that of males, however there was not a statistically

significant difference in mean TL (Student's t-test; P = 0.457, *P>0.05*) and mean W values (Student's t-test; P = 0.062, *P>0.05*) between females and males. The descriptive length and weight characteristics of the Transcaucasian spirlin by sexes were presented in Table 1.

**Table 1.** Total length (TL), Fork Length (FL), Standart Length (SL) and Weight characteristics of the Transcaucasian spirlin, *Alburnoides fasciatus* by sexes.

| Sex | N | TL (cm) Min-Max Mean±S.E | FL (cm) Min-Max Mean±S.E | SL (cm) Min-Max Mean±S.E | Weight (g) Min-Max Mean±S.E |
|---|---|---|---|---|---|
| **Female** | 93 | 7.5-16.2 10.76±0.225 | 6.7-14.4 9.73±0.203 | 5.9-12.7 8.52±0.176 | 4.25-46.56 16.09±1.050 |
| **Male** | 78 | 7.4-15.7 10.51±0.235 | 6.7-14.4 9.47±0.213 | 5.9-12.6 8.30±0.187 | 4.06-42.83 13.65±1.012 |
| **Combined** | 171 | 7.4-16.2 10.65±0.162 | 6.7-14.4 9.61±0.147 | 5.9-12.7 8.42±0.128 | 4.06-46.56 14.98±0.738 |

N: Sample Size, S.E: Standard Error, Min.: Minimum, Max.: Maximum

The total length - frequency distribution of 171 Transcaucasian spirlin samples ranging from 7.4 cm to 16.2 cm TL was plotted based on 1 cm class intervals for female and male individuals. The length-frequency distribution showed that most of the individuals of females (86.02%, N=80), males (85.90%, N=67) and all samples (85.96%, N=147) distributed in the length classes between 8 and 13 cm (Figure 2).
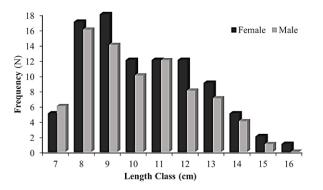


**Figure 2**. The total length - frequency distribution of the Transcaucasian spirlin, *A. fasciatus* by sexes.

*Length-Weight Relationships (LWRs):* In the present study, the length-weight relationships (LWRs) of the Transcaucasian spirlin were estimated using total length and weight by each sex and all individuals. The b-values indicating the fish body shape of the LWRs pointed out that the growth type of males, females, and all individuals (combined) were positive allometric growth (b>3) pattern deviating statistically significant from the isometric growth with a 95% confidence interval for the b-value of 3.154 (3.076-3.232) for females, of 3.183 (3.190-3.316) for males, and of 3.205 (3.149-3.277) for combined sex of the Transcaucasian spirlin, *A. fasciatus* (Paulys' t-test; $t_{female}$ = 3.934, $t_{male}$ = 8.020, $t_{sexes\ combined}$ = 6.572, P<0.05). Significant differences obtained from the statistical comparison of the length-weight relationships between males and females (ANCOVA; F = 207.87, *P*<0.05). The length-weight relationships (LWR) for *A. fasciatus* by sexes were presented in Figure 3. The correlation coefficient ($R^2$) for regression analysis indicated that the Transcaucasian spirlin has a high correlation ($R^2$>0.9) between the total length and weight variables for both sexes and all individuals. Descriptive statistics and estimated parameters of the LWRs of Transcaucasian spirlin by sexes were presented in Table 2.

*Length- Length Relationships (LLRs):* The LLRs between TL vs. FL, TL vs. SL and FL vs. SL were established based on the general linear equation y = a + bX by applying the linear regression analysis. Results of the LLRs indicated that the values of correlation coefficient ($R^2$) were highly correlated ($R^2$>0.9) for each sex and relationship. Descriptive statistics and estimated parameters of regression and equations of LLRs for Transcaucasian spirlin by sexes were presented in Table 3.

**Table 2.** Descriptive statistics and estimated parameters of length-weight relationships of Transcaucasian spirlin, *A. fasciatus* by sexes in Borçka Reservoir.

| Sex | N | a | b | S.E. (b) | 95% CI of b | $R^2$ | Growth Type | P-value | Pauly's t-test |
|---|---|---|---|---|---|---|---|---|---|
| Female | 93 | 0.008 | 3.154 | 0.039 | 3.076-3.232 | 0.987 | +A | 3.934 | p<0.05 |
| Male | 78 | 0.007 | 3.183 | 0.032 | 3.190-3.316 | 0.990 | +A | 8.020 | p<0.05 |
| Combined | 171 | 0.007 | 3.205 | 0.032 | 3.149-3.277 | 0.981 | +A | 6.572 | p<0.05 |

N: number of individuals; S.E: Standart Error, Min: minimum; Max: maximum; a: intercept; b: slope; CI: confidence interval limits; $R^2$: correlation coefficient, +A: +Allometric.

**Table 3.** Length-Length relationship (LLR) parameters of the Transcaucasian spirlin, *Alburnoides fasciatus* by sexes in Borçka Reservoir.

| Sex | N | Equation | SE (a) | CI of a (95%) | SE (b) | CI of b (95%) | $R^2$ |
|---|---|---|---|---|---|---|---|
| **F** | 93 | FL= 0.0302 + 0.9010TL | 0.0659 | -0.1010-0.1613 | 0.0062 | 0.8887-0.9133 | 0.9964 |
| | | SL= 0.1511 + 0.7772TL | 0.0684 | 0.0149-0.2873 | 0.0064 | 0.7645-0.7899 | 0.9948 |
| | | SL= 0.1472 + 0.8603FL | 0.0795 | -0.0111-0.3056 | 0.0082 | 0.8439-0.8767 | 0.9930 |
| **M** | 78 | FL= 0.0291 + 0.8983TL | 0.0765 | -0.1245-0.1827 | 0.0075 | 0.8832-0.9134 | 0.9964 |
| | | SL= 0.0448 + 0.7846TL | 0.1166 | -0.1894-0.2789 | 0.0114 | 0.7616-0.8075 | 0.9893 |
| | | SL= 0.0363 + 0.8715FL | 0.1207 | -0.2061-0.2787 | 0.0131 | 0.8451-0.8979 | 0.9885 |
| **C** | 171 | FL= 0.0192 + 0.9010TL | 0.0497 | -0.0792-0.1176 | 0.0047 | 0.8916-0.9103 | 0.9964 |
| | | SL= 0.1022 + 0.7807TL | 0.0608 | -0.0182-0.2226 | 0.0058 | 0.7692-0.7922 | 0.9929 |
| | | SL= 0.1055 + 0.8644FL | 0.0663 | -0.0257-0.2366 | 0.0070 | 0.8505-0.8782 | 0.9916 |

N: number of individuals, S.E: Standard Error, a: intercept; b: slope; CI: confidence interval limits; $R^2$: correlation coefficient, F: Female, M: Male, C: Combined (F+M).
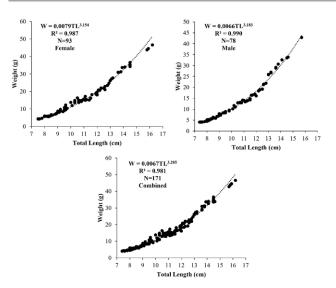
**Figure 3**. The length-weight relationships (LWRs) for the Transcaucasian spirlin, *A. fasciatus* by sexes.

## DISCUSSION

In the current study, the size structure, sex ratio, LWRs and LLRs for the Transcaucasian spirlin, *A. fasciatus* inhabiting Borçka Reservoir were reported for the first time. Also, this study reports a new maximum length and weight data for Fishbase database. In addition to the present study, a comparison of length-weight relationship parameters of *A. fasciatus* previously reported from different areas in Türkiye is given in Table 4.

There are some important differences in TL and W ranges between this study and other some previously reported studies given in Table 4. The ranges and values of TL and W parameters in the present study were found wider and higher than others. The number of individuals, sampling period and fishing gear used in samplings, bio-ecological characteristics of the habitats may cause the above parameters to differ from each other.

**Table 4.** The LWR parameters of *A. fasciatus* previously reported from different areas in Türkiye.

| Sex | N | a | b | $R^2$ | TL range | W range | Locality | Reference |
|-----|-----|-------|-------|-------|----------|---------|----------|-----------|
| C | 18 | 0.002 | 3.625 | 0.977 | 8.3–13.8 | 4.8–32.0 | Barhal River | Erk'akan et al., (2014) |
| F | 207 | 6E-06 | 3.164 | 0.978 | 5.2-12.5 | - | İyidere Stream | Pilatin, (2015) |
| M | 167 | 9E-06 | 3.052 | 0.978 | 4.6-11.2 | - | İyidere Stream | Pilatin, (2015) |
| C | 54 | 0.098 | 3.310 | 0.990 | 5-10.4 | 1.11-11.04 | Çoruh River(Bayburt) | Hüyüklü, (2018) |
| C | 92 | 0.080 | 3.600 | 0.980 | 4.4-11.3 | 0.60-16.97 | E. Black Sea(Giresun-Trabzon) | Hüyüklü, (2018) |
| F | 93 | 0.008 | 3.154 | 0.987 | 7.5-16.2 | 4.25-46.56 | Borçka Reservoir | This study |
| M | 78 | 0.007 | 3.183 | 0.990 | 7.4-15.7 | 4.06-42.83 | Borçka Reservoir | This study |
| C | 171 | 0.007 | 3.205 | 0.981 | 7.4-16.2 | 4.06-46.56 | Borçka Reservoir | This study |

C: Combined (F+M), F: Female, M: Male, TL: Total length, W: Body weight.

## CONCLUSION

Continuous monitoring of natural populations is necessary for sustainable fisheries management. Especially, determination of the length-weight relationship is crucial in terms of fisheries biology and management (Garcia et al. 1989; Haimovici & Velasco, 2000; Yeşilçiçek et al., 2015). The knowledge of some biological parameters such as length values (minimum, maximum and mean), length relationships (length-weight and length-length) of fish species provide very important contributions to the sustainability and rational management of fishery resources. However, when the FishBase database is checked, the LLRs and length-frequency distribution of *A. fasciatus* is not yet available, therefore, the present study reports this data for the first time. Also, this study reports a new max TL and weight data for this species.

The red list status of *A. fasciatus* has been globally assessed as least concern (LC) by the International Union for Conservation of Nature (IUCN). However, the status of the species is listed as vulnerable (VU) for inland waters of Türkiye. Evaluation of some bio-ecological characteristics of the species with this study will also make an important contribution to the reassessment of *A. fasciatus* for IUCN criteria.

In conclusion, the present study provides the first data on the sex ratio, size composition, LWRs and LLRs of *A. fasciatus* in the study area that would be useful for fisheries management authority and fish biologists in Türkiye. Potential conservation plans need much more data on the biology of this species. The results of the present study will provide a primary dataset to fisheries management authority and fisheries scientists for further investigations to fully understand the bio-ecological characteristics of this species in addition to take conservation measures and to ensure sustainability of its populations in the area. The results reported here are also important in terms of understanding the life history of this species and will provide a baseline for further studies. The results of this study will also provide the opportunity to make comparisons between other *Alburnoides* species. The results may also be useful for fisheries management to protect the inland fish biodiversity, also for conservation and sustainability of the species in the area as well.

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