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Biological Characteristics of Siraz Fish, *Capoeta kosswigi* (Teleostei: Cyprinidae) and Host Relationship with Ectoparasitic Glochidia Larvae of Freshwater Mussel, *Unio stevenianus* (Bivalvia: Unionidae) in the Karasu River (Van, Türkiye)

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Abstract

Capoeta kosswigi (Karaman, 1969) and *Unio stevenianus* (Krynicki, 1837) are endemic species in the Karasu river, the Lake Van basin. This study was carried out to determine the biological characteristics of *C. kosswigi* and distribution and prevalence of *U. stevenianus* glochidia on this host fish. A total of 379 *C. kosswigi* were caught by electrofishing between March 2022 and February 2023. The maximum fork length and total weights of *C. kosswigi* were 29.2 cm and 421.8 g for females and 27.8 cm and 337.9 g for males. The length-weight relationships were calculated as W=0.017$L^{2.881}$ (r^2=0.986) for males (negative allometric growth) and W=0.016$L^{3.001}$ (r^2=0.953) for females (isometric growth). The Fulton condition factor was determined as 1.53±0.13 (1.23-1.99). The female:male ratio was calculated as 0.18:1.00. Additionally, a total of 12525 Unionid glochidia were detected on *C. kosswigi* samples in this study. Glochidia was more inclined to prefer male *C. kosswigi* as a host. The highest amount of glochidia was recorded in May, while the lowest in August. The amount of glochidia was statistically found the highest in the gill filaments (454.3±678.0) compared to all fins. Therefore, the native species, *C. kosswigi* is a suitable host for the freshwater mussel, *U. stevenianus.*

Introduction

Cyprinidae is the world's largest family of freshwater fish, with over 200 genera and around 2100 species (Shunping et al., 2007). The distribution of the *Capoeta* genus in this family in the world includes Anatolia, which covers a wide geographical area from Eastern Europe to Western Asia. There are 19 species of the *Capoeta* genus described worldwide (Ayata et al., 2017). Karaman (1969) determined that there are seven species of the *Capoeta* genus in Türkiye and Near East. In addition, 14 subspecies of *Capoeta capoeta* have been described. Some of the subspecies were reported as separate species by later researchers (Turan et al., 2006).

The genus *Capoeta* is usually Reofil (they like to live in running water) and some species can be found in lakes (Kuru et al., 2014). It can also be seen in areas where *Barbus* and trout species are found in the rivers (Karaman, 1969; Geldiay and Balık, 2009). All species and subspecies are economically important as human food (Geldiay and Balık, 2009). Only *C. kosswigi* species belonging to the *Capoeta* genus live in the Lake Van basin, and this species was reported for the first time by Karaman et al. (1969) (Elp et al., 2016). Additionally, *C. kosswigi* has been reported as Data Deficient (DD) in the IUCN Red List (Freyhof, 2014).

Length-weight relationships and condition factor stand out among the parameters commonly used in researching the population characteristics of the species

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(Ricker, 1975; Froese, 2006). These parameters have a very important place in fisheries management and fisheries science (Bostancı et al., 2022). These parameters provide researchers with information about population/stock assessments, determination of growth type, and relationships of fish with habitat (Yedıer, 2022). In addition, by making comparisons between regions with these data, the life history, reproductive history and more generally population ecology of fish species can be revealed (Kırankaya et al., 2014). There are many studies on the *Capoeta* genus in the Van Lake Basin (Şen et al., 1999; Elp and Karabatak, 2007; Şen et al., 2008; Elp and Şen, 2009; Atıcı et al., 2021; Atıcı and Kankaya, 2022).

The freshwater mussel, *Unio stevenianus* (Krynicki, 1837) is distributed in the *Karasu River* in the Lake Van basin except for *C. kosswigi*. *U. stevenianus*, which is endemic to the basin, is in the Unionidae family (Cetinkaya, 1996). The Unionidae family has about 153 genera and 753 species worldwide (Graf and Cummings, 2021). Unionid mussels have spread to many continents outside of Antarctica, including North America, Europe, Asia, Africa, and the Indonesian Archipelago (Graf and Cummings, 2006). It has been reported that the migration of freshwater mussels to Türkiye occurs in four different ways (Çanakkale forms, Asi River and Amik Lakes forms, Euphrates and Southeastern forms, Northwest Anatolian forms) (Modell, 1951).

Freshwater mussels, which are of ecological and economic importance worldwide, remove organic particles such as phytoplankton biomass and inorganic particles (e.g. nutrient salts and/or heavy metals) from the water column through filtration (Ziertitz et al., 2019). Freshwater mussels have a complex life history that includes the temporal ectoparasitic larval stage (Kat, 1984; Watters, 2007). In some freshwater mussel species (usually Veneroida), the eggs develop on the mature mussels and are released directly into the water (Korniushin and Glaubrecht, 2003). In many other species (Unionoida), the eggs develop and become living larvae by clinging to the host fish (Graf, 2013). In this type of reproduction, the eggs are fertilized in the special chambers of the female individuals' gills known as marsupia, and the embryos are incubated here until the larval stage (Bauer and Wächtler 2001). After reaching the larval form (lasidium or glochidium), they are released into the water and must soon settle on the gills, skin, or fins of the fish (Hart, 2018). The first evidence that glochidia are parasites for fish was observed on wild-caught fish by Houghton (1862) (Kelly and Watters, 2010). Glochidia, which undergo metamorphosis on the host after the development period depending on the water temperature, settle in the sediment (Wachtler et al., 2001). After spending a few years juvenile in the sediment, they continue to live long (up to decades) as adults (Strayer et al., 2004). The continuity of such a specialized life cycle is highly dependent on external factors such as environmental conditions; these conditions must be within the tolerance limits of mussels at each stage of the cycle (Güler et al., 2017). As with the glochidia of almost all freshwater unionoid mussels, *U. stevenianus* is an obligate ectoparasites on fish. Therefore, *U. stevenianus* has to use *C. kosswigi* as a temporary host for breeding in the Karasu River.

Although there is no fishing pressure for the *C. kosswigi* population in the Karasu River, it has been reported that the *C. kosswigi* is under a negative impact due to the intense pollution (such as household waste and agricultural activities) and destructive activities (such as sand pits and sand extraction activities) of the river (Atici et al., 2018; Atici et al., 2023). Atici (2022) also reported that *U. stevenianus* was intensively contaminated with microplastics due to pollution in the Karasu River.

With the other studies, freshwater mussels are generally included in the group at high risk for extinction worldwide. The effects of human activities on freshwater systems, especially in Central Europe and North America, have caused a decrease in bivalves to a level that requires protection (Geist, 2010). An important part of the basic data to be used in studies for the continuation of the generations of freshwater mussel species is related to their reproductive biology (Vaughn and Hakenkamp, 2001).

All these negative factors in the Karasu River may damage *C. kosswigi* populations and the reproductive cycle of *U. stevenianus*, which prefers *C. kosswigi* as a host. Therefore, in this study, the biological parameters (length-weight relationships, condition factor, and sex ratio) of *C. kosswigi* in the Karasu River and the distribution and prevalence of glochidia in wild-caught *C. kosswigi* for one year were determined. In addition, this study is the first document showing glochidia of *U. stevenianus* on a host fish.

Materials and Methods

The Karasu River is located in the east of Eastern Türkiye in the Lake Van basin (Figure 1). *C. kosswigi* samples were caught monthly between March 2022 and February 2023 (n=379) from two different stations (38°35′45″ N, 43°13′57″ E and 38°36′25″ N, 43°14′38″ E) in the river with an electrofishing device (SAMUS 725 MP portable electroshockers; 650 W, 12V DC, frequency 50-55 Hz). During the study, water temperature (WT), dissolved oxygen (DO), pH, salinity, and electrical conductivity (EC) were measured monthly in situ with a multimeter (HACH model HQ-40d, Loveland, USA).

All obtained fish were measured for fork length (*FL*) (±0.1 cm) and total weight (*W*) (±0.1 g) before being fixed in 4% formaldehyde solution and then transported to the laboratory. The length values were grouped into 2 cm and the length frequency distributions were examined and the weight-frequency distributions were investigated according to 30 g sample groups. To determine the length-weight relationship (*LWR*) in fish, the allometric growth model equation ($W = aL^b$) was used

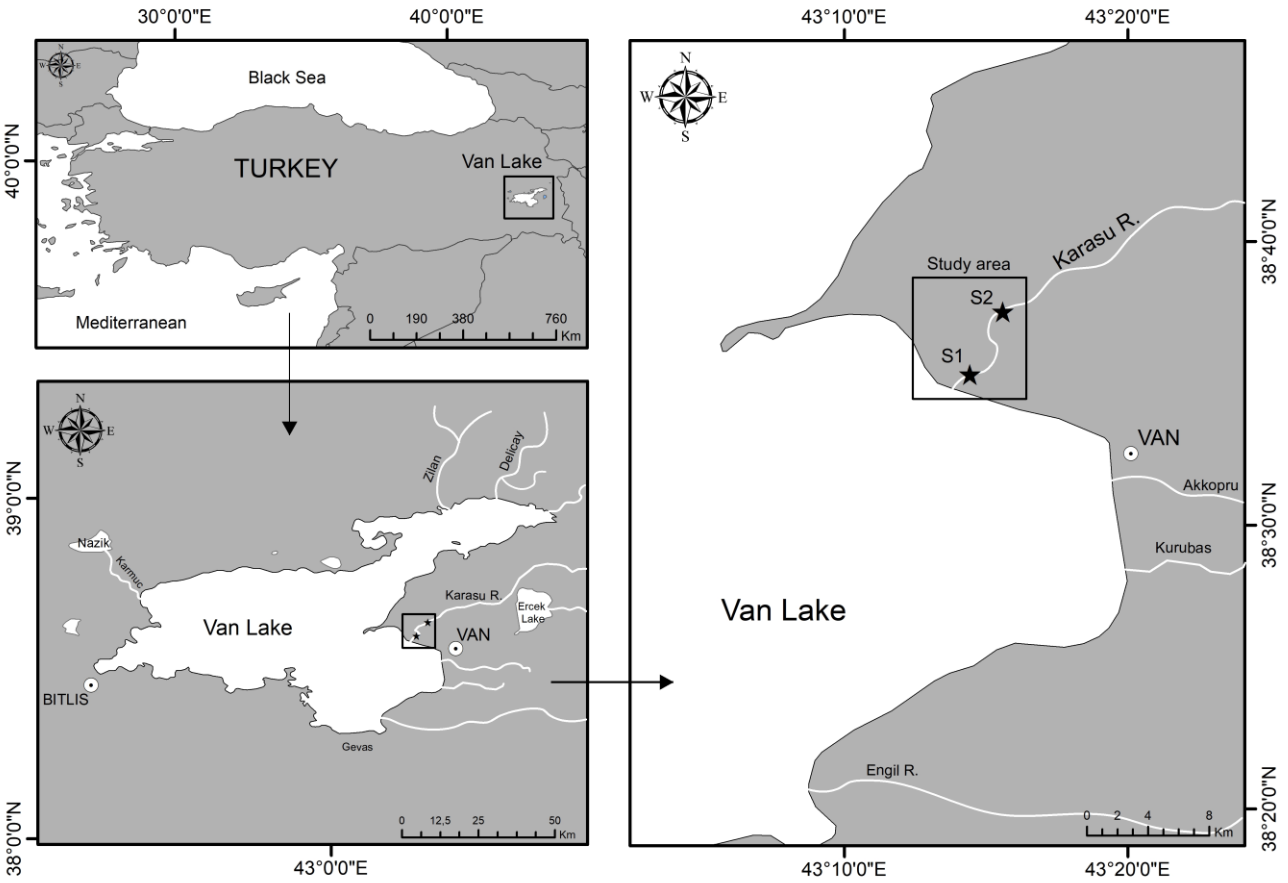

Figure 1. Map of the Karasu River in the Van Lake basin showing the study area: (★) stations

(Le Cren, 1951). The values of Student t-test statistics were calculated and compared with critical values from the T-Table to check if the growth type is isometric (*b*=3) or allometric (*b*≠3) (Pajuelo and Lorenzo, 1998). The Fulton's Condition factor (*K*) was calculated using the formula $K=(W/L^3)\times100$, where W-weight of fish (g), L-fork length of fish (cm) (Ricker, 1975). The gonads were removed and observed morphologically. Sex was recorded for each fish and categorized as male or female. The sex ratio was calculated for all samples by months and it was tested by the chi-square test ($\chi2$) to indicate whether there was a deviation from a 1:1 ratio (Zar, 1999). The prevalence (P), mean intensity (I), and mean abundance (A) levels of the glochidia were calculated according to Bush et al. (1997).

The average, variance, standard deviation, regression, correlation values, and the comparisons of population parameters obtained from the study were performed with SPSS 21.0 and Microsoft Excel 2016.

Results

Water Quality Measurements

Over the course of a year in the river, WT, DO, pH, salinity, and EC were measured and the mean (min-max values) with standard deviation were determined as 13.8±7.1 (3.2-25.6)°C, 12.0±2.6 (8.0-15.8) mg/L, 8.53±0.19 (8.28-8.88), 0.31±0.03 (0.23-0.34)‰ and 496.0±92.9 (338.5-634.0) µS/cm, respectively. WT, DO, and pH values are shown in Figure 2, and salinity and EC changes are also given in Figure 3.

Biological Characteristics

Fork length values of *C. kosswigi* ranged from 7.0 to 29.2 cm (n=379) for all samples, 7.0 to 27.8 cm (n=322) for males, and 17.0 to 29.2 cm (n=57) for females. When examining the overall fork length frequency distribution of fish, it was determined that the most dominant groups in the samples were 13.0-14.9 cm range for males (20.8%), 23.0-24.9 cm range for females (4.5%) and 13.0-14.9 cm range for all samples (20.8%) (Figure 4a).

The ranges of total weight were found between 5.3-421.8 g for all the samples, 5.3-337.9 g for males, and 68.9-421.8 g for females. It was observed that the dominant weight groups were determined as 30.0-59.9 g group for all samples (30.9% for all samples, 30.9% for males, and 2.9% for females) (Figure 4b).

Sex determination was made on 379 individuals. In the population, 57 samples (15%) were female and 322 samples (85.0%) were male. F:M ratio was determined as 0.18:1.00 for all samples (χ^2-test, $p<0.05$). Males were dominant throughout the study and the difference was statistically significant ($p<0.05$) (Table 1).

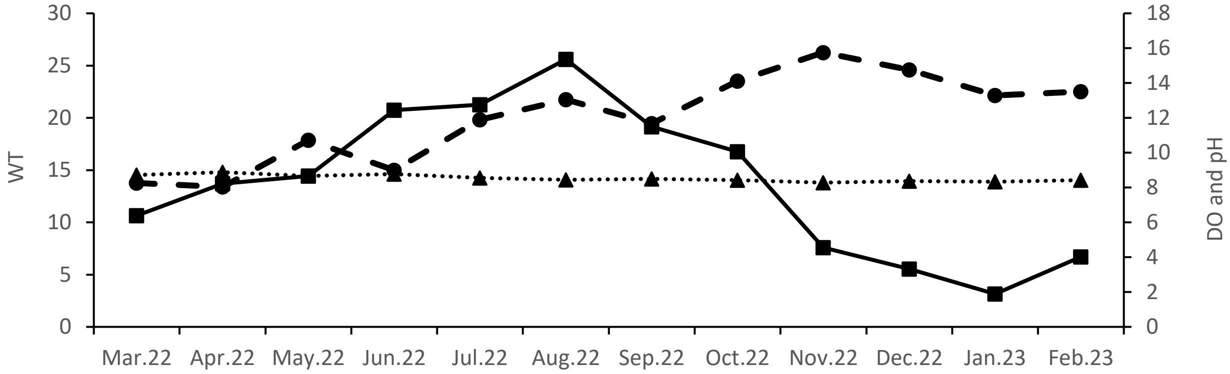

Figure 2. Changes in water temperature (WT, °C) (■), dissolved oxygen (DO, mg/L) (●) and pH (▲) values in the river throughout the year.

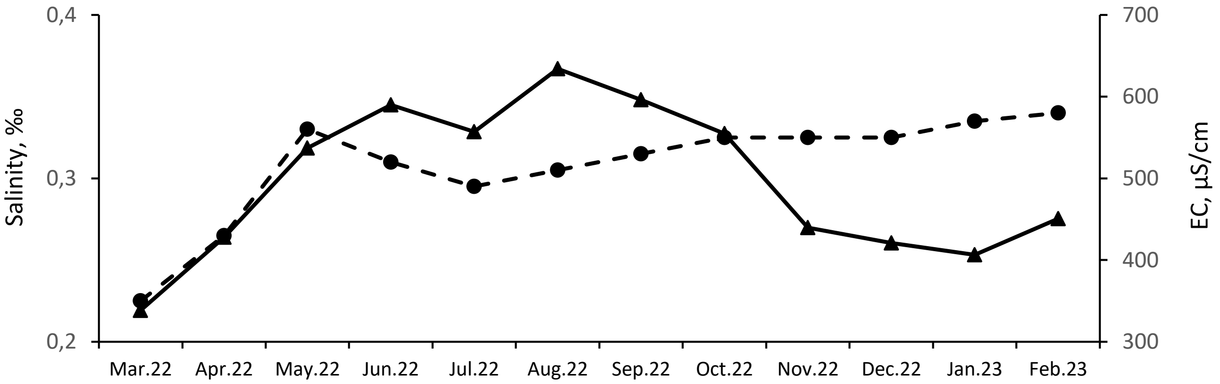

Figure 3. Changes in salinity (●) and electrical conductivity (EC) (▲) values in the river throughout the year.

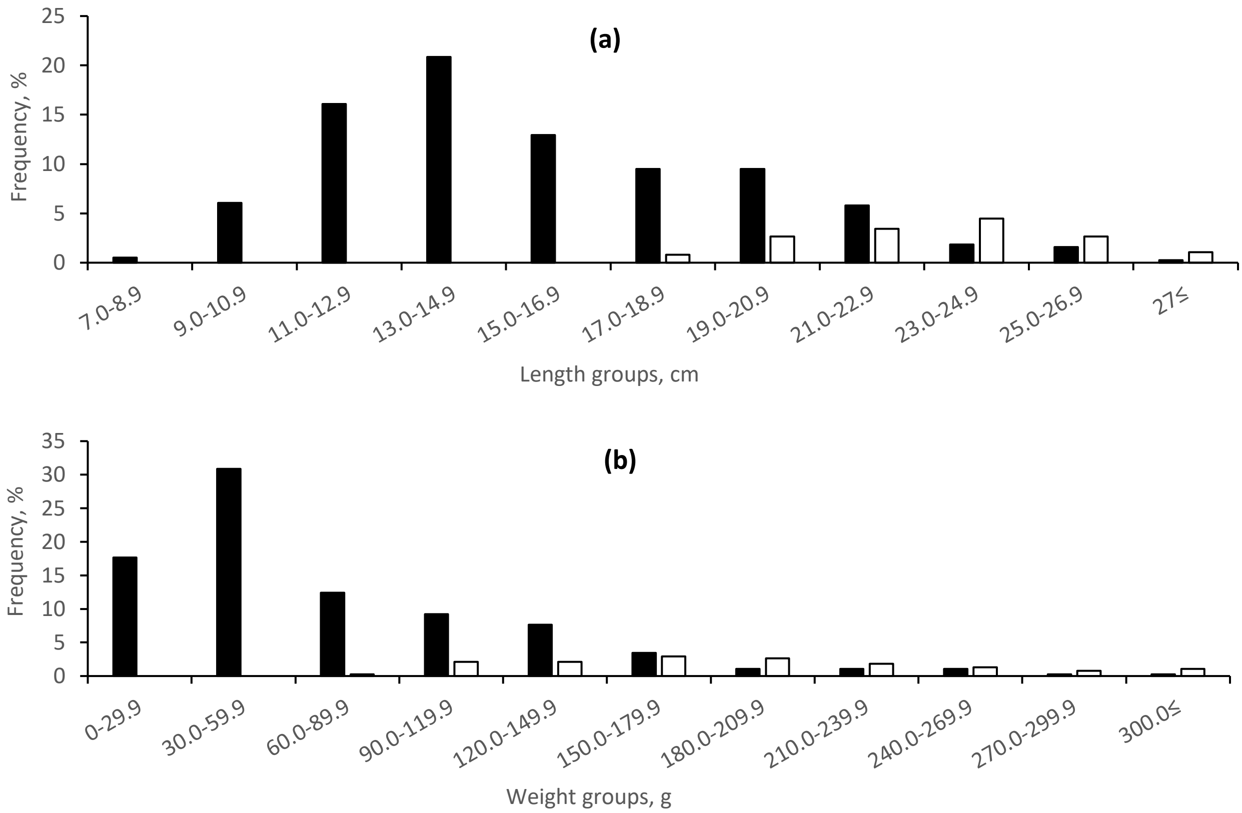

Figure 4. Length (a) and weight (b) frequency distributions of *C. kosswigi*: male (■), female (□).

Length and Weight Relationships

The LWRs of *C. kosswigi* were calculated as W=0.017$L^{2.881}$ (r^2=0.986) for males, W=0.016$L^{3.001}$ (r^2=0.953) for females, and W=0.018$L^{2.878}$ (r^2=0.989) for both sexes (Figure 5). The b values of males and all the population were statistically different from 3 (p<0.05) and determined as negative allometric, whereas the growth pattern for females was found as isometric (p>0.05) (Table 2).

Condition Factor

The mean Fulton's condition factor was calculated as 1.53±0.13 (1.23-1.99) for all samples, 1.49±0.11 (1.27-1.74) for females and 1.54±0.13 (1.23-1.99) for males. The mean condition values ranged from 1.43±0.10 in August to 1.64±0.14 in November for all samples (Figure 6).

Table 1. Monthly changes in female to male ratio (F:M) in the Karasu river.

Sampling dates	Female		Male		Both sexes	F:M	χ^2	Result
	n	%	n	%				
March 2022	8	24.2	25	75.8	33	0.32:1.00	8.76	p<0.05
April 2022	3	10.3	26	89.7	29	0.12:1.00	18.24	p<0.05
May 2022	5	17.9	23	82.1	28	0.22:1.00	11.57	p<0.05
June 2022	4	15.4	22	84.6	26	0.18:1.00	12.46	p<0.05
July 2022	4	11.8	30	88.2	34	0.13:1.00	19.88	p<0.05
August 2022	5	15.6	27	84.4	32	0.19:1.00	15.13	p<0.05
September 2022	5	13.5	32	86.5	37	0.16:1.00	19.70	p<0.05
October 2022	5	12.2	36	87.8	41	0.14:1.00	23.44	p<0.05
November 2022	4	9.5	38	90.5	42	0.11:1.00	27.52	p<0.05
December 2022	4	15.4	22	84.6	26	0.18:1.00	12.46	p<0.05
January 2023	2	9.1	20	90.9	22	0.10:1.00	14.73	p<0.05
February 2023	8	27.6	21	72.4	29	0.38:1.00	5.83	p<0.05
Total	57	15.0	322	85.0	379	0.18:1.00	185.29	p<0.05

Here and in Table 2-5: n is the number of specimens.

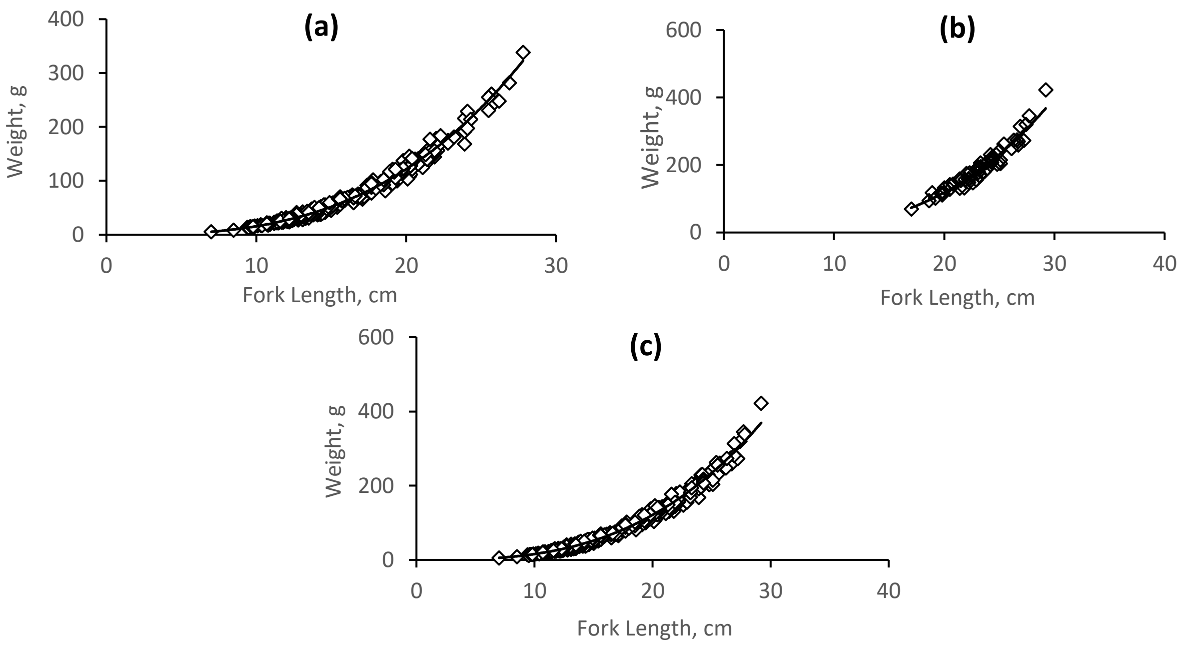

Figure 5. Length-weight relationships for males (a) (W=0.017$L^{2.881}$, r^2=0.986, n=322), females (b) (W=0.016$L^{3.001}$, r^2=0.953, n=57), and both sexes (c) (W=0.018$L^{2.878}$, r^2=0.989, n=379).

Table 2. The descriptive statistics and estimated parameters of length-weight relationships of *C. Kosswigi*

Sex	n	Regression parameters				Student's *t*-test	*p*-value	Growth type
		a	b	SE_b	r^2			
Female	57	0.016	3.001	0.125	0.953	0.005	0.996	I
Male	322	0.017	2.881	0.036	0.986	-3.333	0.007*	A(-)
Total	379	0.018	2.878	0.029	0.989	-4.264	0.001*	A(-)

I= isometric growth, A(–)= negative allometric growth,* statistically different (p<0.05).

Freshwater Mussel (*U. stevenianus*) Larvae, Glochidia

290 (76.5%) fish were infested by glochidia in the *Karasu* River population (Table 3). The highest prevalence values in all samples of *C. kosswigi* were found as 100.0% in April, May, and June, while the lowest was 37.5% in August (Table 3). The highest mean abundance and mean intensity values in all samples of *C. kosswigi* were determined in May (164.3) for both parameters (Table 3). Additionally, a total of 12525 glochidia were detected on *C. kosswigi* samples in this study (Figure 7). While 9407 (75.1%) of them were isolated from male fishes and 3118 (24.9%) of them were from female fishes, indicating that glochidia were more inclined to prefer male *C. kosswigi* as a host in this population from Karasu River (Table 3). The highest amount of glochidia in this study was recorded in May, while the lowest was in August. The number of glochidia was statistically found the highest in the gill filaments (454.3±678.0) compared to all fins ($p<0.01$) (Table 4). A negative correlation was found between the mean intensity levels and the condition factor of all samples in *C. kosswigi,* but it was not statistically significant ($p>0.05$) (Table 5).

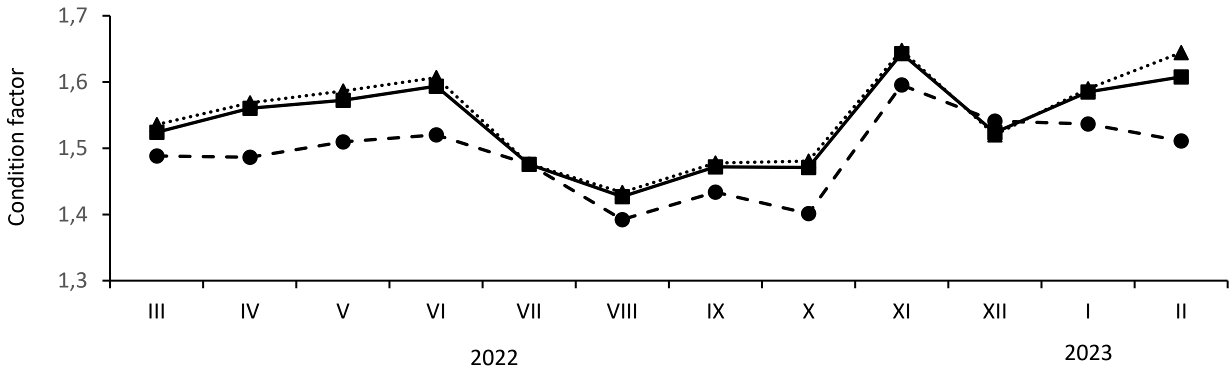

Figure 6. Fulton's condition factor changes for *C. kosswigi*: male (▲), female (●) and both sexes (■).

Table 3. Prevalence, mean intensity, and mean abundance of glochidia of *C. kosswigi*

Months	Number of examined fish samples - Number of infected fish samples			P (%)			Number of glochidia determined in male, female and total of *C. kosswigi*			A-I		
	Male	Female	Total	Male	Female	Total	Male (%)	Female (%)	Total (%)	Male A-I	Female A-I	Total A-I
Mar.22	25-25	8-7	33-32	100.0	87.5	97.0	1070 (8.5)	494 (3.9)	1564 (12.5)	42.8-42.8	61.8-70.6	47.4-48.9
Apr.2022	26-26	3-3	29-29	100.0	100	100.0	2670 (21.3)	304 (2.4)	2974 (23.7)	102.7-102.7	101.3-101.3	102.6-102.6
May.22	23-23	5-5	28-28	100.0	100	100.0	2486 (19.8)	2113 (16.9)	4599 (36.7)	108.1-108.1	422.6-422.6	164.3-164.3
Jun.2022	22-22	4-4	26-26	100.0	100.0	100.0	950 (7.6)	27 (0.2)	977 (7.8)	43.2-43.2	6.8-6.8	37.6-37.6
Jul.2022	30-27	4-4	34-31	90.0	100.0	91.2	833 (6.7)	46 (0.4)	879 (7.0)	27.8-30.9	11.5-11.5	25.9-28.4
Aug.2022	27-9	5-3	32-12	33.3	60.0	37.5	48 (0.4)	36 (0.3)	84 (0.7)	1.8-5.3	7.2-12.0	2.6-7.0
Sep.2022	32-14	5-0	37-14	43.8	0.0	37.8	119 (1.0)	0 (0.0)	119 (1.0)	3.7-8.5	0-0	3.2-8.5
Oct.2022	36-23	5-2	41-25	63.9	40.0	61.0	351 (2.8)	11 (0.1)	362 (2.9)	9.8-15.3	2.2-5.5	8.8-14.5
Nov.2022	38-29	4-3	42-32	76.3	75.0	76.2	395 (3.2)	11 (0.1)	406 (3.2)	10.4-13.6	2.8-3.7	9.7-12.7
Dec.2022	22-17	4-1	26-18	77.3	25.0	69.2	131 (1.0)	3 (0.0)	134 (1.1)	6.0-7.7	0.8-3.0	5.2-7.4
Jan.2023	20-13	2-2	22-15	65.0	100.0	68.2	120 (1.0)	17 (0.1)	137 (1.1)	6.0-9.2	8.5-8.5	6.2-9.1
Feb.2023	21-21	8-7	29-28	100.0	87.5	96.6	234 (1.0)	56 (0.4)	290 (2.3)	11.1-11.1	7.0-8.0	10.0-10.4
Total	322-249	57-41	379-290	77.3	71.9	76.5	9407 (75.1)	3118 (24.9)	12525 (100.0)	29.2-37.8	54.7-76.0	33.0-43.2

Total: all population of *C. kosswigi*; P: prevalence; A: mean abundance, I: mean intensity.

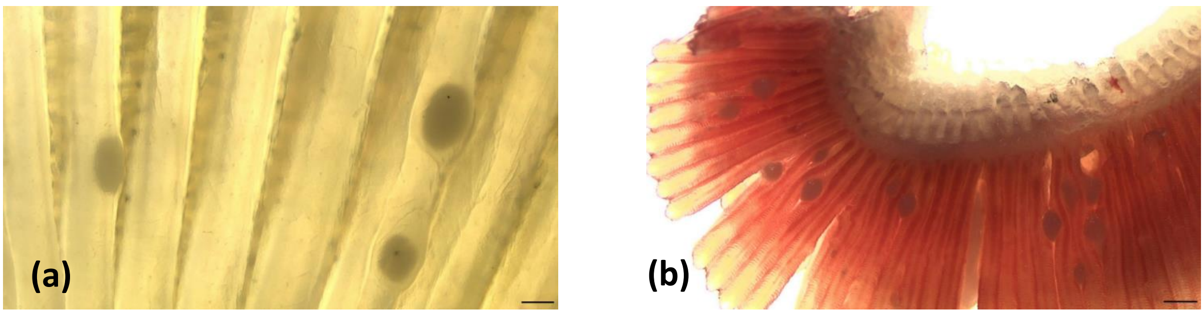

Figure 7. Glochidia in pectoral fin (a) and gill filament (b) of host *C. kosswigi*. Scale: 500 µm

Table 4. Total amount values of glochidia detected in *C. kosswigi*

	Dorsal fin	Pectoral fin	Pelvic fin	Anal fin	Caudal fin	Gill filaments
Total	238	348	314	405	189	10902
Mean±S.D.	9.9±11.9[a]	14.5±14.6[a]	13.1±13.3[a]	16.9±20.6[a]	7.9±9.6[a]	454.3±678.0[b]

*In the same column, the differences between the values indicated by the same letters were statistically insignificant (p>0.01) and the differences between the different letters were significant (p<0.01).

Table 5. Correlation coefficients between the mean intensity (I) and the condition factor of *C. kosswigi* in the Karasu River

	Parameter	Male condition factor
Male I	Pearson Correlation	-0.135
	Sig. (2-tailed)	0.914
	n	62
		Female condition factor
Female I	Pearson Correlation	-0.373
	Sig. (2-tailed)	0.757
	n	13
		Total condition factor
Total I	Pearson Correlation	-0.484
	Sig. (2-tailed)	0.678
	n	75

*Correlation is significant at the 0.05 level (2-tailed),
**Correlation is significant at the 0.01 level (2-tailed) and the other parameters were non-significant.

Discussion

The structure of fish communities living in rivers is shaped by changes in environmental factors. The biological characteristics of *C. kosswigi* (n=379) caught from the Karasu River between March 2022 and February 2023 and its relationship with the reproduction of the freshwater mussel, *U. stevenianus* were investigated.

The water quality of the river was also evaluated. In this study, the mean WT, DO, pH, salinity and EC values (18.1°C, 12.0 mg/L, 8.53, 0.31‰ and 496.0 µS/cm respectively) indicated that the habitat conditions of the river were sufficient for the survival of *C. kosswigi* and the breeding cycle of *U. stevenianus* (Geldiay and Balık, 2009; Sereflisan and Gokce, 2016).

The maximum fork length (48.3 cm) and weight (1379.5 g) for *C. kosswigi* in the Lake Van basin were reported by Şen et al. (1999). However, the maximum fork length and weight for *C. kosswigi* were found in the present study as 29.2 cm and 421.8 g, respectively and these results are smaller than the previous studies except for Atıcı et al. (2021) (Table 6). In addition, the males in this study are smaller than the females, as in the studies in the basin. It is thought that the variation in fish size between regions may be caused by ecological differences such as nutrition and physicochemical (water temperature, DO, Ph, etc.) properties of the water source (Çetinkaya et al., 2005).

The *b* value used in the calculation of the length-weight relationship indicates the nutrition and therefore the optimum growth conditions of the fish (Sakar et al., 2013). The *b* values less than 3, equal to and greater than 3 show negative allometric, isometric, and positive allometric growth, respectively (Kuriakose, 2017). In the present study, the *b* values were statistically different from 3 for males and all the samples and the growth pattern for females indicated isometric growth (p>0.05), whereas for males indicated negative allometric growth (p<0.05). While Tesh (1971) reported the expected b value range between 2 and 4 for all fish species, Froese (2006) stated that the ideal *b* value should be between 2.5 and 3.5. In addition, Wootton (1992) determined that the ideal *b* value for fish is 3 or close to 3. In the present study and other studies in Table 6, *b* values were consistent with Tesh (1971), Wootton (1992), and Froose (2006).

According to Fulton's condition factor based on analysis of length-weight data, fish with high K values (>1) are known to outperform fish with lower K values (<1) (Wootton, 1992). K values ranged from 1.23 to 1.99 with a mean value of 1.53 which indicates that fish were in good condition during the study period in the river. In studies conducted with *C. kosswigi*, the mean condition factor values were found as 1.23 in Nazik Lake (Şen et al., 1999), 1.27 in Kockopru Dam Lake (Elp and Karabatak, 2007), 1.31 in Zernek Dam Lake (Şen et al., 2008), 1.45 in Karasu River (Elp and Şen, 2009), 1.28 in Cigli Stream (Şen et al., 2014) and 1.30 in Delicay Stream (Atıcı et al., 2021). It is stated that the differences in the condition factor values are caused by the biotic (such as gender, age, season, sexual maturity, and reproduction)

(Kırankaya et al., 2014; Bostancı et al., 2022) and abiotic conditions of the fishing regions (such as water temperature, food availability, and habitat type) (Bostancı et al., 2017; Yedıer, 2022), fishing periods and fishing methods (Bolger and Connolly, 1989).

The population consisted of 15.0% female and 85.0% male and the males were found dominant in the river throughout the year (χ^2=185.29, p<0.05). While the F:M ratio (0.18:1.00) in the present study is similar to that reported by Atıcı et al. (2021), females are dominant in the studies only in Kockopru Dam Lake (Elp and Karabatak, 2007) and Zernek Dam Lake (Şen et al., 2008) within the Lake Van basin (Table 6). In most species, the sex ratio is close to 1:1, but this situation may vary from species to species. It also may differ from one population to another in the same species or change from year to year in the same populations (Nikolsky, 1963). On the other hand, it is reported that in general, the hatchability of males in freshwater is higher than females, but the proportion of males gradually decreases in the upper age classes and females become dominant in the population (Yıldırım et al., 2001).

In this study, 290 fish (76.5%) were infested by glochidia in the *C. kosswigi* population (41 females and 249 males). Additionally, a total of 12525 glochidia [9407 (75.1%) from males and 3118 (24.9%) from females] were detected in *C. kosswigi* samples. While the glochidia were most densely settled on the host fish in May, it was detected at least in August (Table 3). The number of glochidia was statistically found the highest in the gill filament compared to all fins (p<0.01) and glochidia were more inclined to prefer male *C. kosswigi* as a host. Blažek and Gelnar (2006) examined the presence of Unionid glochidia (*Anodonta* and *Unio* species) in a total of 2494 specimens from 22 fish species including cyprinids, percids, and esocids. *Anodonta* glochidia were observed in 10 fish species (2 from Percidae and 8 from Cyprinidae) between March-June and October-November and *Unio* glochidia was observed in 17 fish species (1 from Percidae, 1 from Esocidae, and 15 from Cyprinidae) between April and October. *Anodonta* glochidia were predominantly found on the pectoral fins, while most of the *Unio* glochidia were found on the gills. *Anodonta* glochidia was most abundant between November and May, while *Unio* glochidia was more abundant in May and June. The highest prevalence (100.0%) for *Unio* glochidia was determined in *Abramis brama* and *Tinca tinca* in the Cyprinidae.

Kelly and Watters (2010) reported in their study that 53 (2.5%) of 2097 fish were infected with Unionid glochidia, and glochidia settled in the fins of 7 fish and the gills of 46 fish. Glochidia were detected between March and August. The month when the fish species were most contaminated was August, and the month with the least was April. In another study, Reis et al. (2014) considering 9 fish species collected in the Marateca River, glochidia of *Unio tumidiformis* was found only in *Squalius pyrenaicus* samples. 82% (n=11) of *S. pyrenaicus* had glochidia attached to their gills (density of 2 to 14 glochidia per fish).

Benaissa et al. (2019) observed 677 glochidia of *Unio foucauldianus* in 164 individual fish between March and June 2017. The infestations in the two rivers were different, with fish from the N'Fis River (453 glochidia) having more infestations than fish from the Laabid River (224 glochidia). *Labeobarbus maroccanus* and *Luciobarbus magniatlantis* were the most infested species for the Laabid River (4.26 glochidia per fish) and the N'Fis River (11.48 glochidia per fish), respectively. Glochidial invasion peaked at the beginning of May for the Laabid River and at the end of May for the N'Fis River. Schneider et al. (2019) examined the presence of *U. crassus* glochidia in the gills of *Phoxinus phoxinus* (n=140) and *Cottus gobio* (n=150). Glochidia occurred in approximately 63% of the fish gills examined, following the seasonal breeding pattern of mussels with a delay of 1-2 weeks. There was an increase of up to 66 glochidia per fish when the water temperature in the river was 15°C. Mean rates of glochidia were significantly higher in *P. phoxinus* (8.6 glochidia per fish) than in *C. gobio* (4.8 glochidia per fish).

As seen in these studies, Unionid glochidia mostly prefer members of the Cypriniformes order and their gills as a host. When studies with related species are evaluated, it is assumed that unionids need relatively long-term stable physicochemical conditions in the stream substrate (McRae et al., 2004; Geist, 2010). Environmental factors such as water depth, water temperature, and habitat composition with adult mussel density and host factors such as abundance, seasonal migrations, behavior, endemic distributions, and immune response affect the success of glochidia (Rogers and Dimock 2003; Strayer 2008). McMahon

Table 6. Length-weight relationships of *Capoeta* sp. in the Lake Van basin

Locality	Species*	Sex	n	F:M	Length min-max	Weight min-max	*a*	*b*	r^2	Reference
Nazik Lake	*C. capoeta*	F+M	603	0.77:1.00	1.9-48.3	0.1-1379.5	0.01349	2.960	0.993	Şen et al., 1999
Kockopru Dam Lake	*C. capoeta*	F+M	1234	1.43:1.00	3.2-39.8	0.4-755.6	0.01262	2.999	0.998	Elp and Karabatak, 2007
Zernek Dam Lake	*C. capoeta*	F+M	586	1.72:1.00	4-41	0.7-1060.4	0.0137	2.992	0.990	Şen et al., 2008
Karasu Stream	*C. capoeta*	F+M	427	0.85:1.00	4-37.5	0.7-676.2	0.0129	3.039	0.989	Elp and Şen, 2009
Cigli Stream	*C. capoeta*	F+M	535	0.33:1.00	3.8-33.2	0.8-432.3	0.0170	2.887	0.985	Şen et al., 2014
Delicay Stream	*C. kosswigi*	F+M	309	0.15:1.00	3.7-26.1	0.6-227.4	0.01435	2.952	0.996	Atıcı et al., 2021
Karasu River	*C. kosswigi*	F+M	43	0.27:1.00	9.2-37.9	11.3-779.4	0.0137	3.056	0.994	Atıcı and Kankaya, 2022

*In binomial nomenclature, *C. capoeta* was used as the synonym of *C. kosswigi*.

(1991) emphasized that in water with a low pH level, the calcium concentration is also low and that low calcium levels cause shell dissolution in mussels. It has also been determined that some Unionid species can survive at pH 4.7 (min. level) and can reproduce and grow at pH values between 5.6 and 8.3 (McMahon (1991). pH did not fluctuate much during the present study in the Karasu River. Furthermore, previous studies have reported that eutrophic conditions positively affect the growth of freshwater mussels. Arter (1989) reported that *Unio tumidus* living in more eutrophic waters grow faster.

Conclusion

This study representing the biological characteristics of *C. kosswigi* in the Karasu River showed that the population was in good condition despite having an allometric growth pattern. A low number of female *C. kosswigi* was found in the Karasu River during the sampling period and a significant male *C. kosswigi* dominance was detected in the river. On the other hand, *C. kosswigi* was found to be a suitable host for *U. stevenianus*. The fact that *U. stevenianus* prefers the male *C. kosswigi* in the river may be related to the presence of female *C. kosswigi* with a low population in the river. During our study, it was observed that the river was under threat from pollution and other reported adverse factors such as sand pits and sand extraction activities. It should not be overlooked that these negative factors in the river may adversely affect the breeding regions of both species and thus their extinction. Therefore, monitoring programs should be established in the river and measures should be taken for the conservation of both endemic species.

Ethical Statement

Final report of the research Project detailed above was approved by Van Yuzuncu Yil University Animal and Research Local Ethics Committee in the session held on 29.12.2022 (decision number 2022/13-14).

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Author Contribution

A.A.A.: Conceptualization, Visualization, Writing - Original Draft, Data Curation; E.K.: Investigation, Writing - Review & Editing

Conflict of Interest

The authors declare that they have no conflicts of interest.

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