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Research Article Araştırma Makalesi

The Effect of Anthropogenic Activities on the Fish Fauna of the Devrez Stream (Türkiye)

Devrez Çayı (Türkiye) Balık Faunası Üzerine Antropojenik Faaliyetlerin Etkisi

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Abstract: In this study, fish species diversity and protection criteria, habitat evaluation, and threat elements of the ichthyofauna of the Devrez Stream were examined monthly between April 2020 and March 2021. Eight fish taxa (7 natives, 1 non-native) belonging to four families (Cyprinidae, Gobionidae, Leuciscidae, Gobiidae) were identified. *Chondrostoma angorense* Elvira, 1987 (endemic) from the mentioned species was reported for the first time in the Devrez Stream. *Squalius* sp. (32.5%), *Chondrostoma angorense* (24.4%), *Capoeta tinca* (23.9%), and *Alburnoides freyhofi* (11.1%) were the most common and abundant species while *Pseudorasbora parva* (0.5%), *Barbus anatolicus* (1.2%), *Alburnus goekhani* (2.4%) and *Neogobius fluviatilis* (4%) were the most rarely encountered species in the stream. According to our observations, drought, agricultural irrigation, and Devrez Kızlaryolu Dam, which is under construction, were considered major threats to the fish fauna.

Keywords
- Ichthyofauna
- Endemism
- Turkiye inland fishes
- Devrez Kızlaryolu Dam

Özet: Bu çalışmada Nisan 2020 ile Mart 2021 tarihleri arasında Devrez Çayı'nın balık türü çeşitliliği ve koruma ölçütleri, habitat değerlendirmesi ve ihtiyofaunayı tehdit eden unsurlar aylık olarak incelenmiştir. Dört familyaya ait (Cyprinidae, Gobionidae, Leuciscidae, Gobiidae) sekiz balık taksonu (7'si yerli, 1'i yerli olmayan tür) tespit edilmiştir. Söz konusu türlerden *Chondrostoma angorense* Elvira, 1987 (endemik) Devrez Çayı'ndan ilk kez rapor edilmiştir. Çayda *Squalius sp.* (%32,5), *Chondrostoma angorense* (%24,4), *Capoeta tinca* (%23,9) ve *Alburnoides freyhofi* (%11,1) en yaygın türler iken, *Pseudorasbora parva* (%0,5), *Barbus anatolicus* (%1,2), *Alburnus goekhani* (%2,4) ve *Neogobius fluviatilis* (%4) en az rastlanan türlerdir. Gözlemlerimize göre kuraklık, tarımsal sulama ve yapımı devam eden Devrez Kızlaryolu Barajı balık faunası için başlıca tehditler olarak düşünülmektedir.

Anahtar kelimeler
- İhtiyofauna
- Endemizm
- Türkiye içsu balıkları
- Devrez Kızlaryolu Barajı

1. INTRODUCTION

The geographical location of Türkiye between the Asian and European continents, its location in the mid-latitude temperature and the subtropical climate zone (İyigün et al., 2013), and its different topographic structure have caused great differences in the local climate. Climatic variations affect hydrology (Burn & Hag Elnur, 2002), flora, and fauna including fish diversity (Giannetto & Innal, 2021). Türkiye has thirteen freshwater ecoregions (Abell et al., 2008) and a rich freshwater fish fauna with 409 species in inland waters, including 194 endemic species (Çiçek et al., 2018). However, Türkiye's freshwater fish fauna is threatened by various anthropogenic alterations, such as water extraction, habitat

degradation, construction of dams and HEPPs (Hydroelectric Power Plant), sand extraction from the rivers, pollution and introduction of non-native species (Fricke et al., 2007; Freyhof et al., 2014; Küçük et al., 2018).

Studies on ichthyofauna, which were initiated by Abbot (1835) for the first time, have been continuing intensifying in recent years (Fricke et al., 2007; Güçlü et al., 2013; Kuru et al., 2014; Çiçek et al., 2018; Turan et al., 2018). Although many freshwater fish faunas in Türkiye have been studied, different results might have been obtained even in studies conducted in the same place. It is thought that differences in the sampling methods and sampling times may cause these results. It is extremely important to update the fish fauna studies of water systems and take necessary precautions against the threats to protect fish biodiversity. However, few studies (İlhan & Balık, 2008; Yoğurtçuoğlu et al., 2020) have been conducted on fish fauna in the Devrez Stream. Unlike previous studies, this study is a longer-term study, and fish samples were captured regularly every month for one year. The present study aims to provide further information on the population structure of fishes, habitat evaluation, and threat elements of the Devrez Stream. The specific aims of the study were to: (i) provide taxonomic features and current assessment of fish species; (ii) identify habitat structure and threat elements and discuss protection measures; (iii) evaluate the possible effects of the Kızlaryolu Dam under construction on the river ecosystem. Investigation of the effects of human-induced factors on the fish fauna of the Devrez Stream contributes to a greater understanding of species conservation.

2. MATERIAL AND METHODS

2.1. Study area

The Devrez Stream is located in the northern part of Anatolia within the provincial borders of Çankırı, Kastamonu, and Çorum (Figure 1) in Türkiye. This stream is an important tributary of the Kızılırmak River with a length of 186 km, a basin area of 3364 $km^{2,}$ and a flow rate of 4.081 m^3/s. The climate of the region transitions between the Black Sea and Central Anatolia land-type climates. According to 1929-2020 data, annual average temperatures vary between 9.8 ℃ and 11.3 ℃ (see https://www.mgm.gov.tr, accessed 28 January 2022). Annual total precipitation varies between 348 mm and 545 mm in the basin. The precipitation in the basin is below the Tükiye's average value. Most of the precipitation falls in the winter and spring months and the flow regime is irregular (DSI, 2014).

Flowing in the southwest-northeast direction, the Devrez Stream is located in a tectonically very active region. The North Anatolian fault line, which is Türkiye's most active fault zone, forms roughly the northern border of the Devrez Stream basin (Köle, 2016).

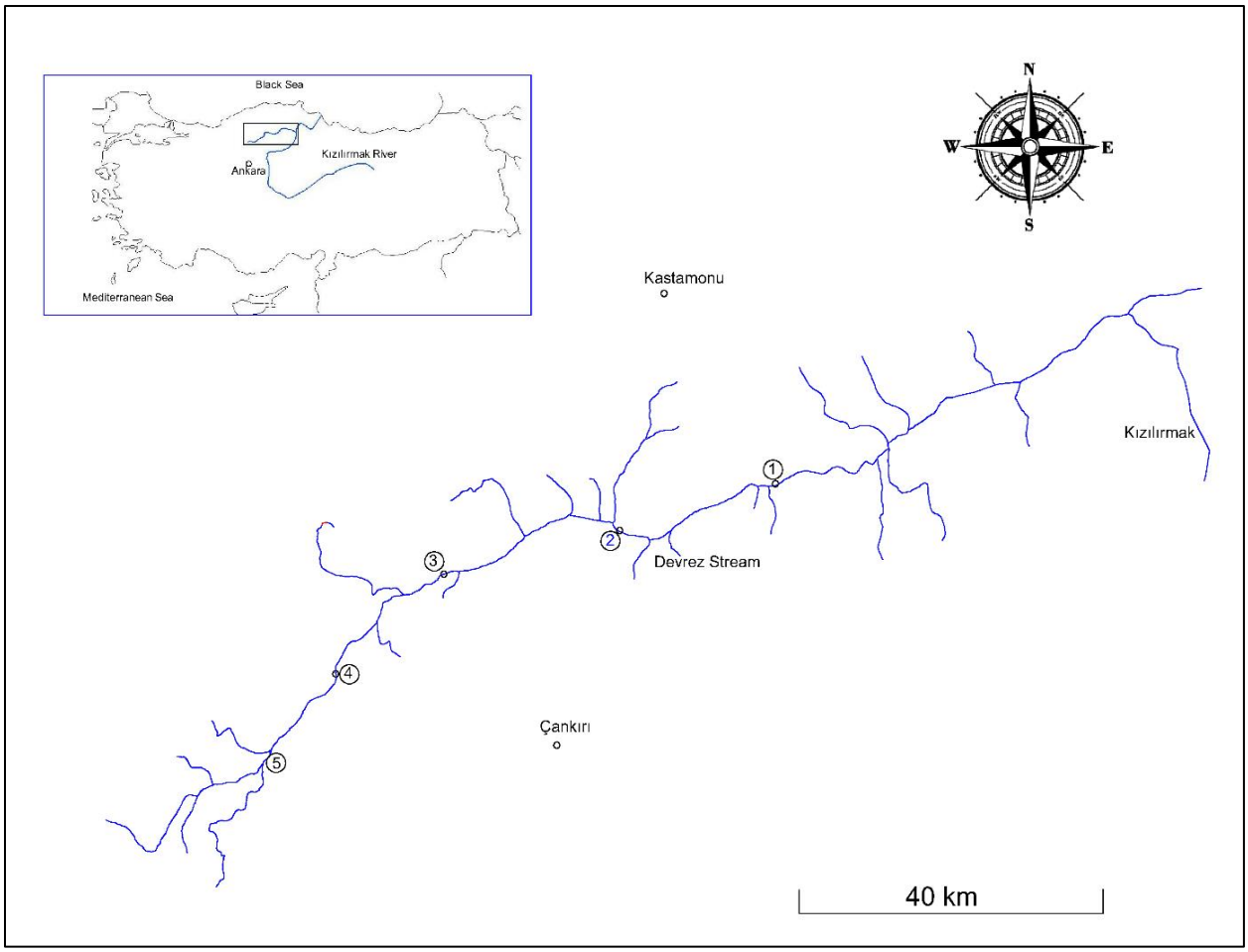

Figure 1. Devrez Stream map and sampling stations

The Devrez Stream (Figure 2), which has a stony and sandy ground, has a wide bed that creates deep ponds in places. The stream has significant importance for agricultural activities in the basin. Although Güldürcek Dam on İçin Creek, a branch of the Devrez Stream was put into operation in 1988 for drinking water and irrigation purposes, demands for irrigated agriculture in the region have been increasing. Therefore, the construction of Devrez Kızlaryolu Dam located 7 km southeast of Kurşunlu district of Çankırı province was initiated in 2017 and planned to be completed in 2023 as a second dam for purpose of water demand on both agricultural activities and energy. The height of the dam from the foundation is 91.5 meters with a reservoir volume of 114.82 hm^3, a reservoir area of 3759 km^2, and the total irrigation area of 1767 ha (DSI, 2014).

Figure 2. Devrez Stream (near Köpürlü Village)

2.2. Sampling

Sampling in the Devrez Stream was conducted from April 2020 to March 2021 with gill nets, cast nets, and fishing rods, and assistance was received from local fishermen. The fishes were fixed and preserved in 4% formaldehyde.

2.3. Analyses

Metric measurement was carried out with a 0.01 mm sensitive caliper and ruler. Meristic characters were counted under a stereomicroscope. The last two branched rays articulated on a single pterygiophore in dorsal and anal fins are counted as "1½ (Kottelat & Freyhof, 2007). Longitudinal scales were used since there is no linea lateral in Gobiidae family. Elvira (1997), Kottelat and Freyhof (2007), Turan et al. (2017, 2018), Özuluğ et al. (2018), Bayçelebi (2019) and Van der Laan (2021) were used for classification. The relative abundance of species was calculated via the equation of 1.

Relative abundance %= (ni/N) x100 (1)

where *ni* is the number of individuals of the species and *N* is the total number of individuals of fish caught in the river (Magurran, 1996).

The biotic and abiotic factors thought to threaten the fish were evaluated and the conservation status of fish species was provided from the IUCN Red List (International Union for Conservation of Nature and Natural Resources) (IUCN, 2022- version 2021-3).

3. RESULTS

3.1. Fish diversity and relative abundance

A total of 422 fish specimens were collected from the Devrez Stream during this study. Eight species belonging to four families Cyprinidae (2 taxa), Gobionidae (1 taxon), Leuciscidae (4 taxa), and Gobiidae (1 taxon) were identified. All species were recorded as rheophilic fishes except *Pseudorasbora parva* and *Neogobius fluviatilis* (Table 1, 2).

Table 1. Geographic information on sampling stations in the Devrez Stream

Station number	Locality	Coordinates	Altitude (m)
1	Near Aşağıdikmen Village	40°58'34"N/34°04'40"E	581
2	Near İnköyü Village	40°53'58"N/33°39'30"E	839
3	Near Kızılcaköyü Village	40°50'16"N/33°23'46"E	978
4	Near Köpürlü Village	40°46'37"N/33°17'05"E	1007
5	Near Yuva Village	40°37'02"N/33°02'08"E	1300

Table 2. Native status, IUCN, habitat guild and abundance categories of fishes sampled from the Devrez Stream (n: native; e: endemic; nn: non-native; NE: not evaluated; LC: least concern)

Species	# of fish	Station number	Native status	IUCN	Habitat guild	Abundance category
CYPRINIDAE						
Barbus anatolicus Turan, Kaya, Geiger and Freyhof, 2018	5	1,3,4	n, e	NE	Lotic	Unknown
Capoeta tinca (Heckel, 1843)	101	1,2,3,4,5	n, e	LC	Lotic	Decreasing
GOBIONIDAE						
Pseudorasbora parva (Temminck and Schlegel, 1846)	2	5	nn	LC	Lotic/ lentic	Unknown
LEUCISCIDAE						
Alburnoides freyhofi Turan, Kaya, Bayçelebi, Bektaş and Ekmekçi, 2017	47	2,3,4,5	n, e	NE	Lotic	Unknown
Alburnus goekhani Özuluğ, Geiger and Freyhof, 2018	10	2,4,5	n, e	NE	Lotic	Unknown
Squalius sp.	137	1,2,3,4,5	n	LC	Lotic	Unknown
Chondrostoma angorense Elvira, 1987	103	2,3,4,5	n, e	LC	Lotic	Decreasing
GOBIIDAE						
Neogobius fluviatilis (Pallas, 1814)	17	1,3,4,5	n	LC	Lotic/lentic/ marine	Unknown

The distribution of fish species in terms of percentage and number of fish caught during this study is presented in Figure 3. The most dominant family was Leuciscidae with four species. One non-native species (*P. parva*) and five endemic species (*B. anatolicus*, *C. tinca*, *A. freyhofi*, *A. goekhani* and *C. angorense*) were recorded. *Squalius* sp. (32.5%), *C. angorense* (24.4%), and *C. tinca* (23.9%) were the most common and abundant species in the Devrez Stream. The most rarely encountered species were *P. parva* (0.5%), *B. anatolicus* (1.2%), *A. goekhani* (2.4%), *N. fluviatilis* (4%) and *A. freyhofi* (11.1%). *P. parva* was caught from only one station while *C. tinca* and *Squalius* sp. specimens were caught from all sampling stations.

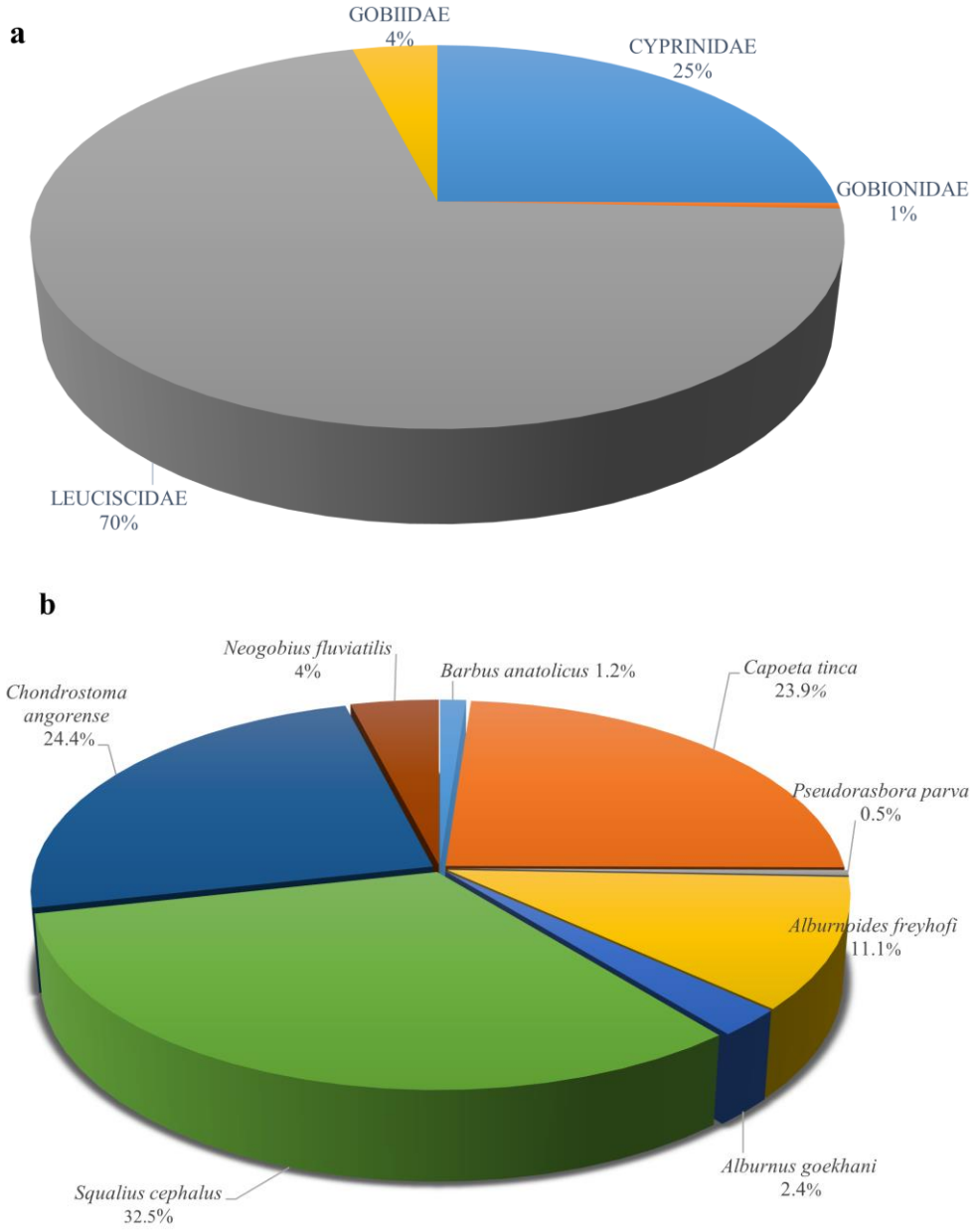

Figure 3. % distribution of families (a) and species (b)

The photos of *B. anatolicus*, *C. tinca*, *P. parva*, *A. freyhofi*, *A. goekhani*, *Squalius* sp., *C. angorense*, and *N. fluviatilis* samples are presented in Figures 4, 5. The number of species captured monthly is shown in Table 3.

Figure 4. Fishes of the Devrez Stream. **a,** *Barbus anatolicus* (SL: 147 mm) **b,** *Capoeta tinca* (SL: 165 mm) **c,** *Pseudorasbora parva* (SL: 77 mm) (fixed material) **d,** *Alburnoides freyhofi* (SL: 83 mm) **e,** *Alburnus goekhani* (SL: 100 mm). Fishes represented as "a, b, d, e" were captured from station 4, "c" was from station 5.

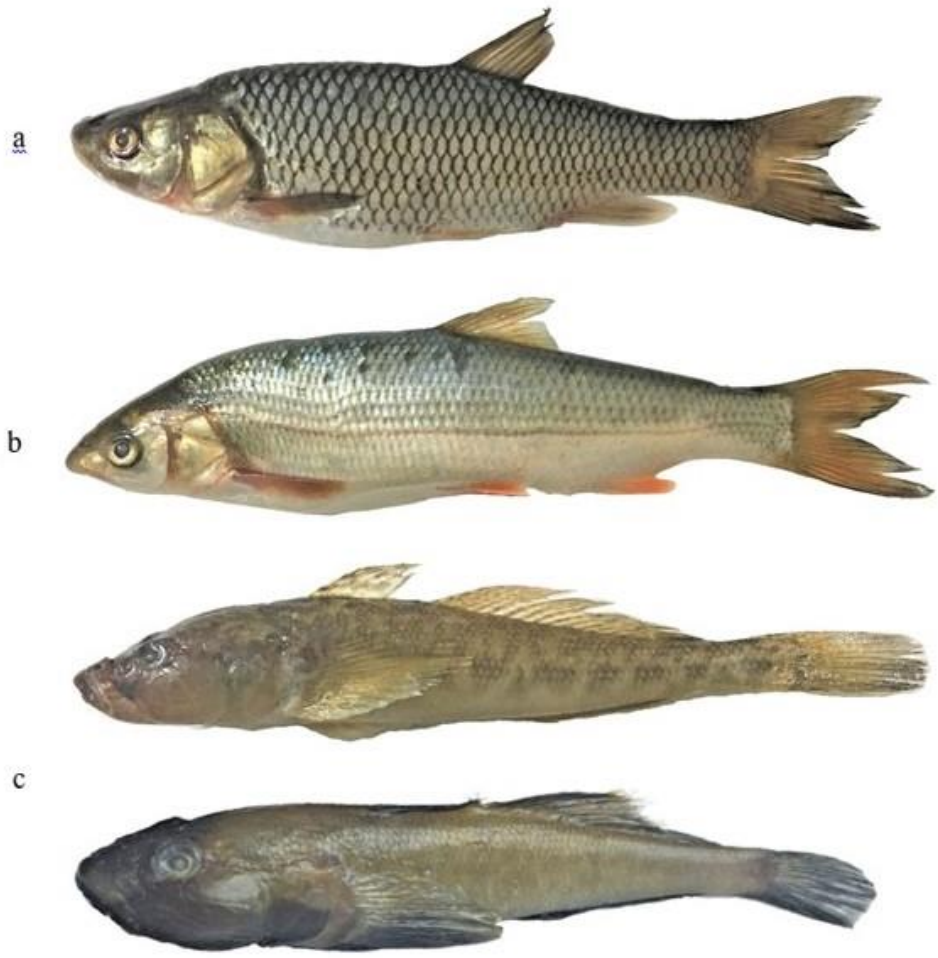

Figure 5. a, *Squalius* sp. (SL: 185 mm) **b,** *Chondrostoma angorense* (SL: 203 mm) **c,** *Neogobius fluviatilis* (SL: 106 mm) (above); a male individual with a black body in the breeding season (SL: 95 mm). Fishes represented as "a, b, c" were captured from station 4.

3.2. Vegetation

Devrez Stream was characterized by low turbidity, relatively shallow, and high abundance of emergent and submerged aquatic macrophytes e.g., *Potamogeton* sp., *Typha* sp., *Juncus* sp., *Scirpus* sp., *Ranunculus* sp. There were also *Mentha* sp., *Equisetum* sp., *Rubus* sp., *Fraxinus* sp., *Salix* sp., *Verbascum* sp., and *Urtica* sp. in the study area. Although sand and silt predominate in low-slope areas, gravel-cobble substrates form the stream bed in most areas (see Figure 2).

3.3. Human impacts

The construction of the Devrez Kızlaryolu Dam is considered the biggest threat to the stream ecosystem as it will change the stream structure and flow regime. In addition to this, there are villages and agricultural activities along the Devrez Stream basin. These parts of the stream are affected by domestic waste and agricultural aids such as pesticides and fertilizer. Agricultural irrigation together with drought causes a decrease in the amount of stream water in the summer months. Some local people engage in amateur fishing in the different parts of the stream, commonly by using gill nets and cast nets. The most preferred and caught fishes by inhabitants are *Squalius* sp., *C. tinca*, *C. angorense*, and *B. anatolicus*.

Table 3. Number of examined fishes and capture date in the Devrez Stream

		CYPRINIDAE		**GOBIONIDAE**	**LEUCISCIDAE**			
		B. anatolicus	***C. tinca***	***P. parva***	***A. freyhofi***	***A. goekhani***	***Squalius* sp.**	***C. angoren***
Capture date and examined number of specimens	April 2020	-	7	-	9	-	20	8
	May 2020	1	6	2	17	7	12	7
	June 2020	-	4	-	6	3	9	1
	July 2020	1	8	-	-	-	1	11
	August 2020	1	9	-	1	-	8	10
	September 2020	2	12	-	7	-	13	9
	October 2020	-	14	-	3	-	12	8
	November 2020	-	11	-	-	-	15	10
	December 2020	-	5	-	-	-	8	8
	January 2021		8	-	-	-	15	10
	February 2021	-	11	-	4	-	13	12
	March 2021	-	6	-	-	-	11	9
SL (min-max) mm		**143-191**	**101-336**	**75-87**	**68-92**	**93-113**	**85-353**	**94-205**

4. DISCUSSION

Five out of eight fish species, *B. anatolicus, C. tinca, A. freyhofi, A. goekhani* and *C. angorense,* found in the Devrez Stream are endemic and the protection of these species is extremely important in terms of Türkiye's biodiversity. All the fishes caught in the Devrez Stream were native except *P. parva* which had spread rapidly in Türkiye's inland waters (Ekmekçi & Kırankaya, 2006). *P. parva* is considered a threat, especially for endemic species (İnnal, 2012) due to its high success in reproduction, growth, competition with other species, and transmission of parasites and new diseases that have not been seen before in the environment (Gozlan et al., 2005; Gürbüz, 2018; Özcan & Tarkan, 2019). Although its current population is low in the Devrez Stream according to our observations, *P. parva* might be a threat to endemic fishes in the future. Therefore, *P. parva* population should be monitored periodically for the sustainability of the stream ecosystem.

The most common and abundant species is *Squalius* sp. (32.5%) in the Devrez Stream. *Squalius* sp. distributed in the Kızılırmak and Yeşilırmak basins is considered to be a possible new species, because morphologically different from other *Squalius* species in the nearby basins (Bayçelebi, 2019). Therefore, further studies are needed to elucidate the *Squalius* sp. Although *C. tinca* and *C. angorense* are listed as the least concern (LC) in IUCN Red List (IUCN, 2022), their abundance category is decreasing. Fortunately, the relative abundance of these species compared to other species in the stream is not found low in the present study. As the native species, *Barbus anatolicus* (1.2%), *Alburnus goekhani* (2.4%) and *Neogobius fluviatilis* (4%) were the most rarely encountered species in the stream. Since they are recently described species (Turan et al., 2018, 2017; Özuluğ et al., 2018) conservation status evaluations for *B. anatolicus, A. freyhofi* and *A. goekhani* are lacking. Further detailed research is needed to indicate current population trends for fish species in the Devrez Stream.

İlhan and Balık (2008) identified 30 fish species and two subspecies in the Western Black Sea region. In their study, the Devrez Stream was one of the sampling locations in which seven fish species were identified as *Alburnoides bipunctatus*, *Barbus tauricus escherichii*, *Capoeta baliki*, *Capoeta sieboldii*, *Alburnus escherichii*, *Leuciscus cephalus*, *Nemacheilus angorae*. Freshwater fish diversity in the Anatolian Midwestern Black Sea basin was studied by Yoğurtçuoğlu et al. (2020). In their study, 13 species (*Rhodeus amarus, Barbus anatolicus, Capoeta tinca, Neogobius fluviatilis, Pseudorasbora parva, Alburnoides freyhofi, Alburnus derjugini, Alburnus escherichii, Alburnus goekhani, Squalius* sp., *Oxynoemacheilus angorae, Oxynoemacheilus samanticus, Oxynoemacheilus seyhanensis)* were determined in the Devrez Stream. *A. bipunctatus*, previously reported by İlhan and Balık (2008), is understood to be the valid species as *A. freyhofi*.

İlhan and Balık (2008) reported *Barbus tauricus escherichii* (valid as *Luciobarbus escherichii)* in the Devrez Stream. It is thought that *L. escherichii* was not encountered in this study due to some restrictions such as using only gill nets, cast nets, and fishing rods in fishing. *Barbus anatolicus* was recognized in the present study, being recently recognised as a valid species (Turan et al., 2018). *B. anatolicus* inhabited only in Kızılırmak drainage while all records of *B. tauricus* were from small coastal rivers flowing into Black Sea (Turan et al., 2018; Yoğurtçuoğlu et al., 2020).

İlhan and Balık (2008) also found *Capoeta baliki* and *Capoeta sieboldi* in their study in the Devrez Stream. In this study, different from the findings of İlhan and Balık (2008), *Capoeta tinca* was determined. Meanwhile, recent studies show that *Capoeta baliki* was a junior synonym of *C. tinca* (Özdemir, 2015; Bektaş et al., 2019). Comparing the findings of present study with previous studies, *Chondrostoma angorense* was reported for the first time from the Devrez Stream. These differences might be due to differences in sampling locations, fishing tools, and low flow rates especially in summer months due to drought and agricultural irrigation.

Devrez Stream has significant importance for agricultural activities including rice farming, which requires much water in the region. According to the water samples taken from Devrez Stream, the irrigation water was determined as class C2S1. Devrez Stream has suitable irrigation conditions for all types of soil and plant species since it contains moderate salt and trace amounts of sodium having 450-

600 micromhos/cm electrical conductivity and SAR (sodium adsorption rate) values between 0.33-1.63 (DSI, 2014). However, chemical fertilizers and pesticides used especially in rice farming and domestic wastes may leak into the soil and groundwater and cause toxic effects on fishes and other ecosystem elements in the basin in the long term.

The use of the Devrez Stream for irrigation purposes causes a decrease in the amount of water, especially in summer. Although dams and HEPPs change flow regimes (Fricke et al., 2007, Freyhof et al., 2014, Ablak-Gürbüz & Bonner, 2020) that play a primary role in riverine systems (Boavida et al., 2020), irrigated agriculture and domestic supply in the basin create water demand that requires the development of infrastructure such as dams (Zeiringer et al., 2018). Therefore, Devrez Kızlaryolu Dam construction was started in 2017 to support agricultural activities and energy production with a reservoir volume of 114.82 hm^3. While approximately half of this amount (61.67 hm^3) will be used for irrigation purposes, the amount reserved for aquatic organisms in Devrez Stream is only 8.07 hm^3 (DSI 2014). According to Acreman and Ferguson (2010), the critical abstraction level for rivers is 20%, except least sensitive rivers where 30% abstraction is allowed for the lowest level of protection. The abstraction in the Devrez Stream will be even more than 30%. Meanwhile, the planned environmental flow rate (0.26 m^3/s) of the Devrez Stream is far below the current flow rate (4.081 m^3/s).

Although the Devrez Stream might be classified as in good condition due to its ecological status (Acreman and Ferguson, 2010), changes in the flow regime disrupt river ecosystems through alteration of physical habitat and sediment supply. The flow regime is a significant factor that affects fish distribution and community structure (Osmundson et al., 2002). Even though Devrez Kızlaryolu Dam is thought to be economical as it will irrigate 15,989 ha of gross agricultural area and generate 5 MW of electricity per year (DSİ, 2014), the environmental flow rate to be released is crucial to protect aquatic life. Thus, once the Kızlaryolu Dam is operational, it should release the appropriate environmental flow to maintain the ecological status of the stream.

Dam construction also might be a threat, especially for fish species adapted to live in lotic systems since dams converted lotic environments to lentic habitats. In this study, all species were recorded as rheophilic fishes which prefer or live in swift and clear flowing water except *P. parva* and *N. fluviatilis*. Fortunately, despite being rheophilic, *C. tinca* and *Squalius cephalus* can also be found in some large lakes in Türkiye (Becer & Sarı, 2017). Yet, *S. cephalus* is potamodromous and needs to undertake spawning migrations to inflowing streams (Kottelat & Freyhof, 2007).

It is thought that when the Kızlaryolu Dam starts to hold water, these rheophilic fishes may lose their habitats. Many endemic fish species especially those that adapt to lotic systems in Anatolia are affected by similar situations (Fricke et al., 2007). According to Osmundson et al. (2002) Colorado pikeminnow populations endemic to the Colorado River Basin were extirpated in the lower sub-basin by the 1970s due to extensive dam construction during the 1930s to 1960s. Similarly, *Luciobarbus escherichii* which prefers flowing water is now less common due to the dams and HEPPs built on the Kızılırmak River (Çiçek et al., 2016). Although İlhan and Balık (2008) caught *L. escherichii* in the Devrez Stream at 40° 56' 27" N 33° 53' 52" E coordinates, it was not found in this study. Although the construction of the dam has not been completed yet, the fact that the species diversity is lower than in previous studies may be due to the geographical features and topographic structure of the river basin as well as the difference in the sampling method. The protection of the Devrez Stream, which has a high rate of endemic and native fishes, is important for the maintenance of its biodiversity.

Continuous turbidity occurring during the construction of the HEPP and dam, mixing of cement and other additives into the water, and structures that block the movement of aquatic organisms have also adversely affected aquatic life in the river. As a result of the decrease or even disappearance of the current, the benthic structure will also change, and the benthos adapted to the flowing water may largely disappear in the sections with stagnant water. Due to the drought, which is frequently seen in the summer, the water decrease in the Devrez Stream will become permanent with the construction of the dam.

5. CONCLUSION

Conservation of endemic species living in the Devrez Stream (62.5%) is of great importance in terms of Türkiye's fish biodiversity. Devrez Kızlaryolu Dam, which is under construction is thought to impose the greatest threat to fish in the Devrez Stream since the amount reserved volume of water for aquatic organisms is considered insufficient. It is crucial to determine the appropriate environmental flow rate for the stream structure to protect aquatic life. Moreover, as a non-native species, *P. parva* might be a threat to endemic fishes in the future, although its current population in the Devrez Stream is low. Therefore, the stream ecosystem should be monitored periodically for the sustainability of endemic and native fish species. This study will contribute to the monitoring and conservation strategies of the fish fauna of the Devrez Stream in the future.

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CONFLICT OF INTEREST

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

This article was written by a single author.

ETHICAL STATEMENTS

Ethics committee certificate was not requested since experimental animals were not used in the study and sampling was made in the form of dead fish from the fishermen.

DATA AVAILABILITY STATEMENT

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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