Fish Species Diversity From Someşul Cald River: 50 Years After Cascade Dam Constructions

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In the present study, changes in fish species composition, distribution, and diversity caused by cascade dam constructions on Someşul Cald River, Romania, were analyzed. Cascade dam constructions may act as a freshwater stressor both on short and long term. The river was divided into two sections according to the positioning of the cascade dams (T1-inferior section, respectively T2-superior section). In the T1 and T2 sections, 8 and 12 sampling stations were established, respectively. A total number of 1789 specimens grouped in 12 species and 8 families were sampled from August to September 2018. The most abundant species in both sections was *S. trutta.* The most abundant family was Salmonidae, with 66.2%. Alpha diversity (species richness) in the T2 section was higher than in T1 (T2 = 12 species vs T1 = 9 species). The Kruskal-Wallis test indicated no significant differences ($p > 0.05$) for beta diversity of T1 *vs* T2 (Sørensen coefficient). The species that contributed most to the dissimilarities between the two river sections were *T. thymallus*, *B. carpathicus*, *C. gobio,* and *S. cephalus*, their summed contribution to the dissimilarity being larger than 50%. The analyzed environmental variables influenced the distribution of some fish species. Alpha and beta diversity distribution on elevation gradient showed that stations close to reservoirs had more species (both in T1 and T2 sections) than the other stations, clearly showing that the distance from lake/reservoir is influencing species richness. The effect of dams from Someşul Cald River on fish species distribution was analyzed by comparing previous data (before 1968) to recent collected data.

Keywords: environmental degradation, freshwater stressor, habitat loss, hydroelectric facility, species richness

INTRODUCTION

The use of dams has significantly contributed to human development in many ways: flood control, energy supply, water supply for the population, industry, and agriculture (Shi et al., 2019). Freshwater demand is increasing globally, even though it represents a limited and unevenly distributed resource (Altinbilek, 2002). Along with the benefits of dams, there are also disadvantages, especially when their effects are projected on wildlife management. The concept

of clean/green energy in the case of dams is questioned by some scientists (Li et al., 2019; Laţiu et al., 2020a). Freshwater fish fauna diversity is placed under great stress by anthropogenic activities, causing important ecological alterations (Jellyman and Harding, 2012). Changes in hydrological conditions, as a consequence of dam constructions, may well cause loss of native species, loss of taxonomic distinctness, and also loss of habitat (Cutler et al., 2020). Alterations in freshwater habitats are at the leading edge of a global biodiversity crisis, sometimes causing irreversible fish species decline (Johnson et al., 2008; Kirk et al., 2020). Previous case studies and reviews have shown that dams harm biodiversity, especially of ichthyofauna (Jackson et al., 2001; Johnson et al., 2008; Arantes et al., 2019; Bănăduc et al., 2020). Natural connectivity is blocked by river fragmentation both for longitudinal and lateral dimensions limiting the transfer of energy, matter (organic and inorganic), and organisms (Pringle, 2003; Grill et al., 2015). The main cause-effect of dams is represented by riverbed fragmentation–causing migration limitations, sediment accumulation behind the dam–causing loss of structural integrity and river discharge, and alterations of downstream habitat (Agostinho et al., 2008; Zarfl et al., 2015; Moran et al., 2018). For example, fish species such as the Danube salmon (H. hucho) use river connectivity for reproduction, growth, and survival, and when spawning grounds are blocked, the existence of the species is at risk. Cascade dams (a series of impounding reservoirs built on one river) tend to cause more intense environmental impacts, such as a decrease in fish species abundance (Ganassin et al., 2021). Not only fish communities are affected by dams, but also crayfish, snails, mammals, birds, and plants, especially in mountain areas (Nilsson and Dynesius, 1994; Jansson et al., 2000; Barnett and Adams, 2021; Bohada-Murillo et al., 2021). In some cases, invasive and non-native fish species thrive in artificial lakes and reservoirs at the expense of native species (Bunn and Arthington, 2002; Mota et al., 2014).

According to FAO, there are around 1,324 large dams geo-referenced in Europe, of which 80 are found in Romania and were put to use between 1964 and 1996. Large dams are considered to have a height of more than 15 m, or a reservoir capacity of more than 3 million m^3 (height between 5 and 15 m). Based on the same database, dams and reservoirs can be sorted by purpose. Most of them have multiple purposes, as follows: water supply—40; flood control—26; hydroelectricity—63; navigation—8; recreation—6; pollution control—1; other purposes—14 and livestock and irrigation—0 (Aquastat-FAO).

In general, biodiversity conservation has multiple level effects on economy, culture, aesthetics, welfare, and sustainability (Hiddink et al., 2008). However, these effects gain more importance when genetic distinctness of populations and sub-populations, specific behavior and life history are known (Hutchings et al., 2007). Genetic differentiation leads to local endemism, which is of great importance in terms of conservation. Fish species extinction risk can be monitored by analyzing the patterns of threatening processes affecting both the long and short-term aquatic habitats (Arthington et al., 2016). Ecological integrity, especially in mountain areas, is often rendered by fish species such as European grayling (T. thymallus), bullhead (C.

gobio), and Carpathian lamprey (E. danfordi) considered indicator species (Utzinger et al., 1998; Hayes et al., 2021). Since freshwater fish species are considered more vulnerable to human activities (pollution, habitat alteration, poaching) than terrestrial and marine species, protection and conservation measures need to be applied (Basooma et al., 2020). On a global scale, the interest in dam impacts on fish fauna distribution and diversity is increasing, one of the main reasons being the magnitude of freshwater fish species decline. In Romania, the interest for this subject gained more and more interest, but it has some limitations caused by data deficiency. There are only a few qualitative studies (presence and absence based) of fish fauna before the large dams were put to use in Romania. The main source, in this case, was represented by Bănărescu's work, published in 1964, which predates all major dam constructions and is still used today as the main reference for fish species distribution at European level.

The study aimed to analyze the changes in fish species assemblage and distribuţion from Someşul Cald River, comparing qualitative data before cascade dam constructions and qualitative and quantitative data after dam constructions.

MATERIALS AND METHODS

Study Area and Fish Species Before Cascade Dam Constructions

Someşul Rece River and Someşul Cald River form Someşul Mic River, with a length of 178 km. They are part of the Someş-Tisa River catchment (Romanian Environment Ministry, 2015). The surface of Someşul Cald River is 3,773 km^2, with a total length of 66.5 km. It springs from the Bihariei-Vlădeasa massif below the Piatra Arsă peak, Cârligatele peak (Duma, 2016) (altitude 1,550 m), and is the largest river that supports the Beliş-Fântânele Reservoir. For these reasons, Someşul Cald River is considered the mainspring of Someşul Mic. Someşul Cald River crosses a large part of the Apuseni Natural Park (**Figure 1**). From a lithological perspective, the river passes over crystalline shale, granite, and sedimentary rocks (limestone) and has an exocarst and endocarst structure. The geological structure, the geographical position, and the ecological potential make it an important area for both flora and fauna. The specialized literature in the field of geography regarding the area of this body of water describes the special quality of the substrate, the abundant precipitations, and the lack of pollution sources (Şerban et al., 2010). The arrangement of the accumulation reservoirs and dams on Someşul Cald River (Beliş-Fântânele, Tarniţa, Someşul Cald, and Gilău) started in 1968, to produce electricity, as a water supply, and for flood prevention (Petrişor, 2016). The project aimed to overcome the watershed that separates the Someşul Mic River catchment and the Arieş River Catchment. A series of adductions were built through the mountains, guiding waters such as Valea Ierii, Şoimu, Valea Calului, Negruţa, Dumitreasa, Răcătău and Someşul Rece Rivers to the Beliş-Fântânele Reservoir. The project had 2 successive stages. The first stage lasted from 1968 to 1980, when the Gilău (1972), Tarniţ;a (1973), and Beliş;-Fântânele (1976) Reservoirs were put into use. The
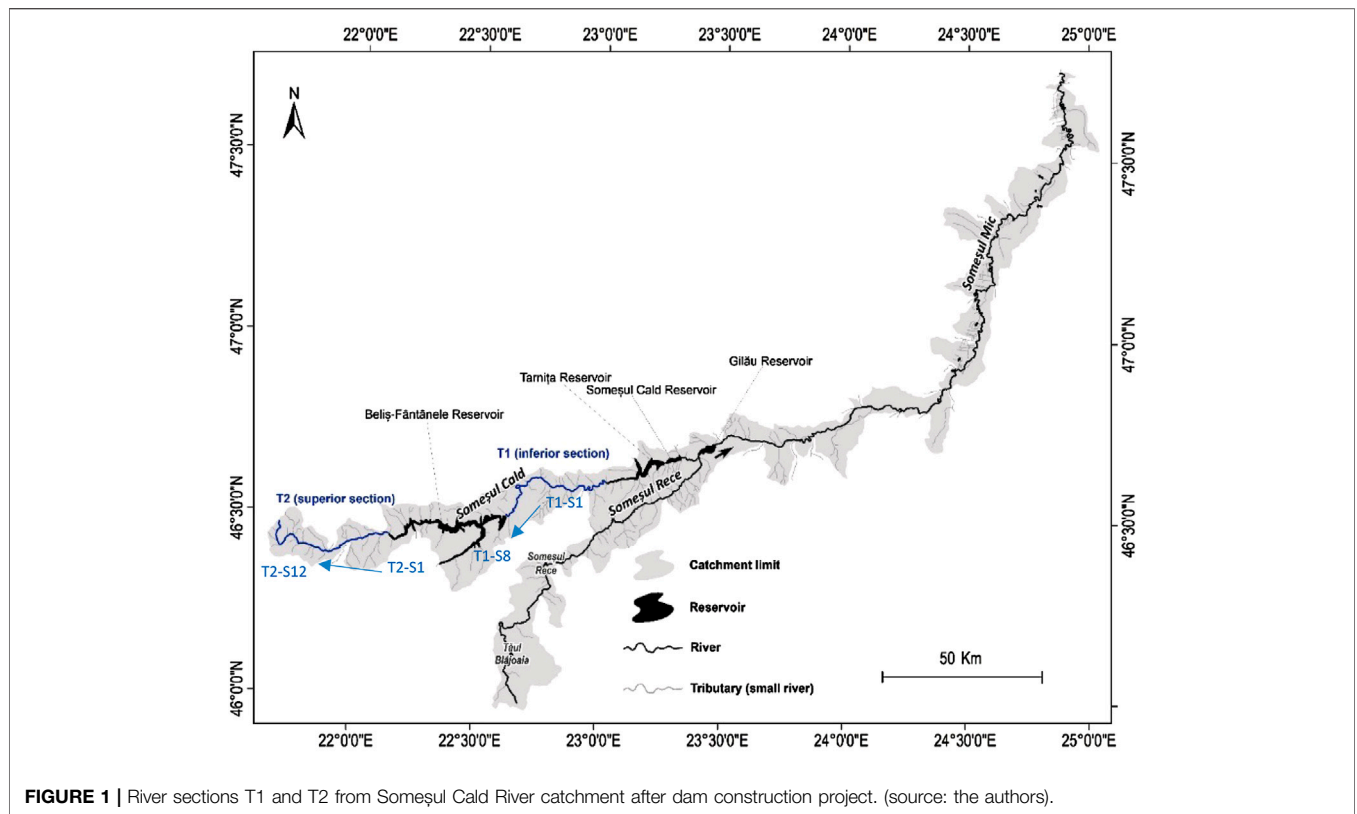
FIGURE 1 | River sections T1 and T2 from Someşul Cald River catchment after dam construction project. (source: the authors).

TABLE 1 | Fish species from Someşul Cald River mentioned before the dam construction.

Species (according to Bănărescu, 1964 [31])	Species	Observations (according to Bănărescu, 1964 [31])
	Accepted Name (2021)	
Salmo trutta fario Linnaeus, 1758	*Salmo trutta* Linnaeus, 1758	Descends downstream from Gilău
Thymallus Linnaeus, 1758	*Thymallus* Linnaeus, 1758	Descends to the confluence of Someşul Cald River and Someşul Rece River
Leuciscus cephalus Linnaeus, 1758	*Squalius cephalus* Linnaeus, 1758	Upstream of the confluence of Someşul Cald River and Someşul Rece River
Phoxinus Linnaeus, 1758	*Phoxinus* Linnaeus, 1758	On Someşul Cald and downstream to Cluj-Napoca City
Alburnoides bipunctatus Bloch, 1782	*Alburnoides bipunctatus* Bloch, 1782	Uppstream of the confluence of Someşul Cald River with Someşul Rece River
Gobio obtusirostris Valencienes, 1842	*Gobio obtusirostris* Valencienes, 1842	Upstream of Gilău–limnophilic morph
Gobio uranoscopus friči Vladykov, 1925	*Romanogobio uranoscopus* Agassiz, 1828	On Someşul Mic River up to Gilău, migrates to its tributaries
Barbus meridionalis petenyi Risso, 1826	*Barbus carpathicus* Kotlík, Tsigenopoulos, Ráb and Berrebi, 2002	Found in Someşul Cald River
Noemacheilus barbatulus Linnaeus, 1758	*Barbatula* Linnaeus, 1758	Found at the confluence of Someşul Cald River with Someşul Rece River
Cottus gobio Linnaeus, 1758	*Cottus gobio* Linnaeus, 1758	On both Someşul Cald River and Someşul Rece Rivers to their confluence

second stage consisted of the completion of the deviation's constructions and the accumulation of Someşul Cald River (1983). Currently, all catchments and reservoirs are operational. It is worth mentioning that the whole damming project was not designed with fish passes. The analyzed specialty literature is limited in the case of the studied river. Bănărescu (1964) and Bănărescu (1994) presented a qualitative analysis of fish species observed in Someşul Cald River, mentioning 10 fish species. These data are of great importance since they represent the only source describing the ichthyofauna from Someşul Cald River and a basis for the analysis of the influence of damming on fish communities (**Table 1**).

TABLE 2 | GPS coordinates of the sampling sites.

T1-Inferior Section	Downstream Limit	Upstream Limit
T1-S1	46°42′24.8″N 23°12′55.9″E	46°42′27.2″N 23°12′49.0″E
T1-S2	46°41′54.8″N 23°10′59.4″E	46°42′00.3″N 23°10′54.1″E
T1-S3	46°41′53.5″N 23°09′32.3″E	46°41′55.6″N 23°09′17.2″E
T1-S4	46°42′01.4″N 23°08′07.5″E	46°42′00.8″N 23°07′59.5″E
T1-S5	46°42′04.8″N 23°07′46.9″E	46°42′09.2″N 23°07′40.3″E
T1-S6	46°42′29.7″N 23°07′01.7″E	46°42′34.7″N 23°06′54.4″E
T1-S7	46°42′36.5″N 23°06′27.9″E	46°42′36.7″N 23°06′21.8″E
T1-S8	46°41′55.5″N 23°04′36.1″E	46°41′57.5″N 23°04′49.5″E
T2-Superior Section	**Downstream Limit**	**Upstream Limit**
T2-S1	46°38′46.0″N 22°52′06.7″E	46°38′47.2″N 22°51′57.1″E
T2-S2	46°38′49.1″N 22°51′50.2″E	46°38′49.9″N 22°51′37.3″E
T2-S3	46°38′50.0″N 22°51′27.4″E	46°38′47.2″N 22°51′19.6″E
T2-S4	46°38′35.3″N 22°50′34.9″E	46°38′29.9″N 22°50′13.3″E
T2-S5	46°38′25.7″N 22°49′24.5″E	46°38′22.7″N 22°49′19.4″E
T2-S6	46°38′18.1″N 22°49′03.6″E	46°38′13.0″N 22°48′45.3″E
T2-S7	46°37′57.3″N 22°48′17.0″E	46°37′48.8″N 22°48′04.8″E
T2-S8	46°37′46.2″N 22°46′24.4″E	46°37′48.8″N 22°46′19.6″E
T2-S9	46°38′05.5″N 22°45′01.3″E	46°38′06.7″N 22°44′55.9″E
T2-S10	46°38′29.1″N 22°44′04.0″E	46°38′31.9″N 22°43′59.7″E
T2-S11	46°38′39.2″N 22°43′42.7″E	46°38′38.9″N 22°43′37.0″E
T2-S12	46°38′21.4″N 22°43′08.3″E	46°38′18.6″N 22°43′07.9″E

Mapping, Sectoring, and Environmental Variables

To map the minor riverbed of Someşul Cald River, a Garmin Etrex 20X GPS device was used. The mapping was carried out in July 2018. The team progressed through the minor riverbed, along its entire length. In the first phase, the areas of interest were marked. Areas of interest were represented by structures and configurations of the riverbed with a high degree of complexity (areas with deep water, areas with sandy, stony or muddy substrate, mostly shaded areas, areas without shading, etc.).

To analyze the lotic fish fauna from Someşul Cald River, sectorization was carried out as follows: the inferior section (T1), limited downstream by the inlet of Tarniţa Reservoir and upstream by the Beliş-Fântânele Dam; the superior section (T2), limited downstream by the inlet of Beliş-Fântânele Reservoir and upstream by the springs of Someşul Cald River (**Figure 1**). In the inferior section T1, a total of 8 sampling stations (from T1-S1 to T1-S8) were analyzed, while in the superior section T2, a total of 12 stations (from T2-S1 to T2-S12) were analyzed.

The geographic starting point for the study was the Tarniţa Reservoir inlet area. The argument underlying the selection of this point results from the configuration of the Someşul Cald River. This stretch of river has a high degree of anthropization due to the successions of dams and reservoirs. To characterize the aquatic habitat and morphology of the river, altitude, width, distance from lake and depth were analyzed. Altitude and length of the limits of each sampling station were determined with a Garmin Etrex 20X GPS device (**Table 2**). Riverbed width was determined with a measuring tape (5 determinations/station, including the start and end of the station and 3 intermediary determinations). The depth of the major riverbed was determined with a 1.5 m measuring rod (5 determinations/station, including the start and end of the station and 3 intermediary determinations).

Fish Sampling

Fish sampling was performed by single-pass electrofishing techniques using a SAMUS 725 MP apparatus, powered by a 12 V and 24 A rechargeable battery (Kubečka et al., 2021). The sampling period was from August to September 2018. The efficiency of freshwater fish sampling by electrofishing methods is highly effective, especially in streams and small rivers (Dybko et al., 1998). Water conductivity was tested before electrofishing to adjust the output current at non-lethal frequencies (Barwell et al., 2015).

Data Analysis

A total of 20 sampling sites were analyzed (8 and 12 sites in T1 and T2, respectively). Alpha diversity was represented by species richness, the total number of species from each sampling site (Cheng et al., 2019). Sørensen's coefficient was used to determine beta diversity to assess the similarities or dissimilarities among neighboring sampling stations (Sørensen, 1948). Non-metric multidimensional scaling (NMDS) and analysis of similarity (ANOSIM) were used to compare fish species composition and differences in resemblances among groups of sampled sites (Runde et al., 2021). The contribution of fish species to the dissimilarity of the two river sections was determined by similarity percentage analysis (SIMPER) based on Bray-Curtis similarity (Medeiros-Leal et al., 2021). Species composition and environmental variables were analyzed by canonical correspondence analysis as a data exploration method (Carosi et al., 2015). Fish species abundance data and environmental variables (station altitude, distance from lake, mean riverbed width, mean water depth) were log (x+1) transformed. NMDS,

TABLE 3 | Altitude, width, depth, and distance from the lake in the inferior river section T1.

Stations from T1	T1-S1	T1-S2	T1-S3	T1-S4	T1-S5	T1-S6	T1-S7	T1-S8
Mean altitude (m)	518.5	577.5	617.5	655	696	725	732	832
Mean station width (m)	9.53	6.28	5.16	4.48	7.12	6.76	6.19	5.94
Mean water depth (cm)	55.8	24.2	26	40.6	20.4	50.2	42.2	38.2
Distance from lake (m)	1	4266.8	6881.3	9029.1	9597.1	11060.15	11908.72	15540.56

TABLE 4 | Altitude, width, depth, and distance from the lake in the superior river section T2.

Stations from T2	T2-S1	T2-S2	T2-S3	T2-S4	T2-S5	T2-S6	T2-S7	T2-S8	T2-S9	T2-S10	T2-S11	T2-S12
Mean altitude (m)	1001.5	1005.5	1008	1013.5	1019.5	1027	1040.5	1068.5	1111.5	1125	1135.5	1153.5
Mean station width (m)	24.68	20.64	14.48	18.7	15.3	13	7.11	6.22	4.37	4.47	4.3	2.34
Mean water depth (cm)	17.8	25	26.6	38	33.8	30.8	24	42	19.2	21.4	16.4	19.6
Distance from lake (m)	2454.56	2818.07	3362.54	4607.45	6267.52	6787.46	8161.85	11065.96	13105.99	14866.18	15502.08	16508.86

ANOSIM, SIMPER, and CCA analyses were conducted in PAST Software ver. 4.03 (Hammer et al., 2001; Hammer and Harper, 2006). Non-parametric Spearman correlations were determined for species richness and environmental variables (log-transformed).

RESULTS

Mapping, Sectoring, and Environmental Variables

The sampling river sections are presented in **Figure 1**. The mean altitude of the stations from T1 ranged from 518.5 to 832 m, while the mean altitude in stations from T2 ranged from 1,001.5 to 1,153.5 m (**Table 3**). Station length varied from 142 to 328 m in T1 and from 105 to 458 m in T2. The mean riverbed width of the stations varied from 4.48 to 9.53 m in T1 and from 2.34 to 24.68 m in T2. The mean water depth of the stations varied from 20.4 to 55.8 cm in T1 and from 16.4 to 42 cm in T2. Distance from

the lake in the T1 river section (distance from Tarniţa Reservoir) ranged from 1 to 15,540.56 m while in T2, ranged from 2,454.56 m to 16,508.86 m (**Table 3** and **Table 4**).

Fish Species Composition in the Someşul Cald River

The fish survey was carried out from August to September 2018 (50 years after the start of the damming project in 1968). A total number of 1789 specimens were sampled and analyzed, 761 from T1 and 1,028 specimens from T2. Nine species grouped into 7 families were found in the inferior section (Salmonidae: *Salmo trutta*, *Thymallus*; Cyprinidae: *Barbus carpathicus*, Nemacheilidae: *Barbatula*, Leuciscidae: *Phoxinus* and *Squalius cephalus*; Cobitidae: *Cobitis elongatoides*; Cottidae: *Cottus gobio*; Petromyzontidae: *Eudontomyzon danfordi*). Twelve species grouped into 8 families were found in the superior section (Salmonidae: *Salmo labrax*, *Salmo trutta,* and *Thymallus*; Cyprinidae: *Barbus carpathicus*, Nemacheilidae: *Barbatula*,
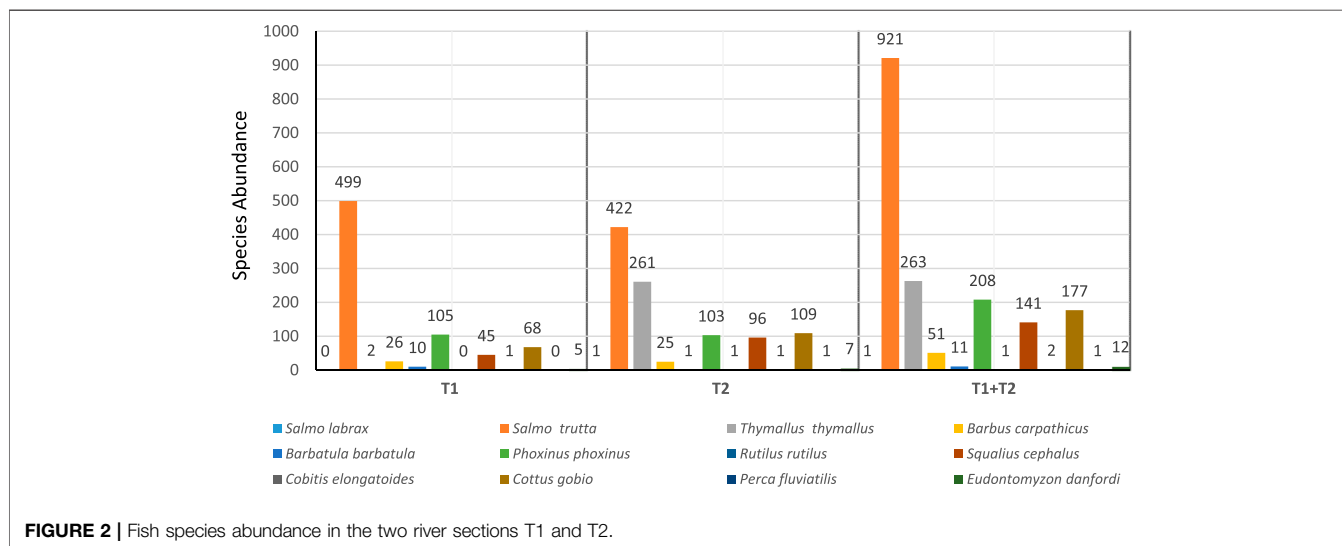

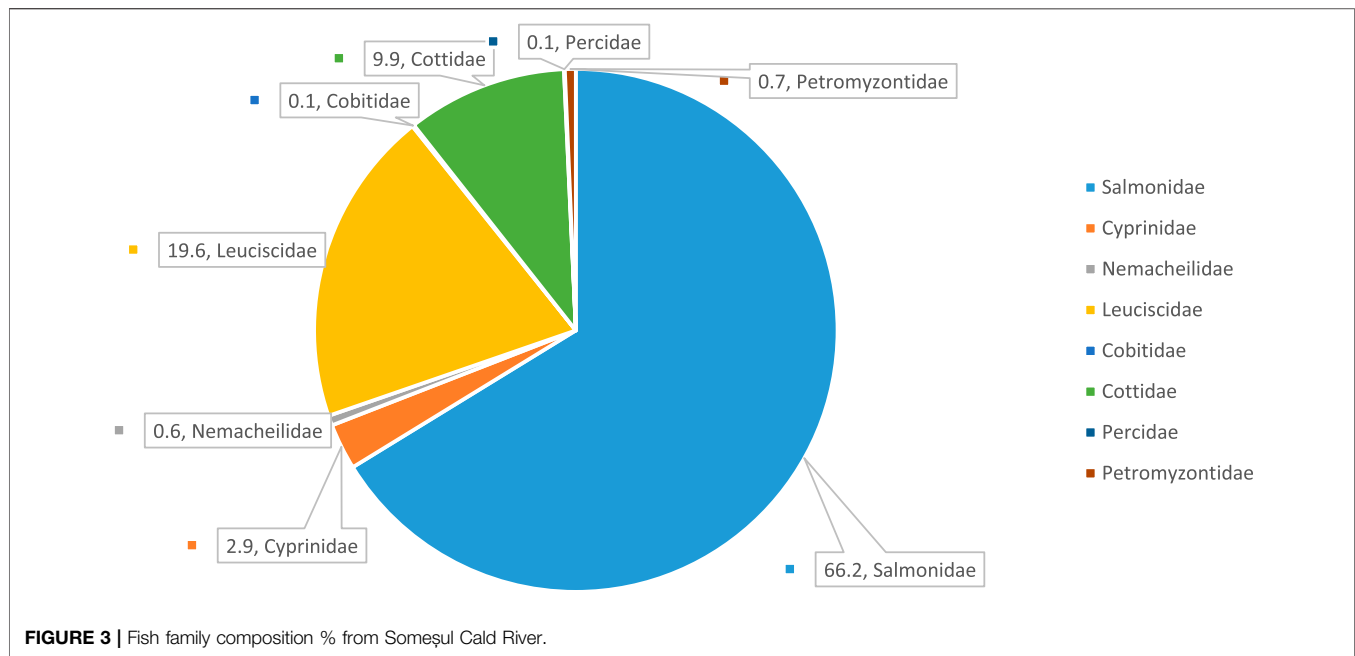**FIGURE 2 |** Fish species abundance in the two river sections T1 and T2.

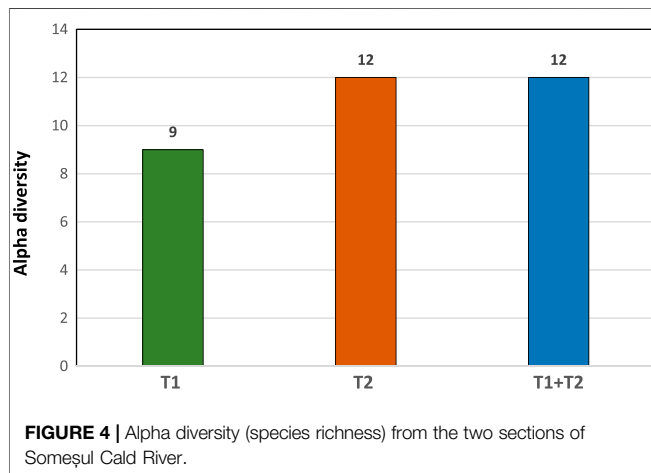**FIGURE 3 |** Fish family composition % from Someşul Cald River.

FIGURE 4 | Alpha diversity (species richness) from the two sections of Someşul Cald River.

Leuciscidae: *Phoxinus, Rutilus,* and *Squalius cephalus*; Cobitidae: *Cobitis elongatoides*; Cottidae: *Cottus gobio*; Percidae: *Perca fluviatilis*; Petromyzontidae: *Eudontomyzon danfordi*) (**Figure 2**).

Identification and validation of fish species were performed using meristic character analysis for all the specimens in the study. In the case of *B. carpathicus*, identification in the field is difficult, and the species distribution based on specialty literature was used to validate the species' presence (Kottelat and Freyhof, 2007; Antal et al., 2016). For the identification and validation of *S. labrax*, non-overlapping meristic characters to *S. trutta* were used (Laţiu et al., 2020b).

Overall, Salmonidae and Leuciscidae families were the richest (3 genera for each family were identified). Of the total number of observed specimens, 66.2% were represented by Salmonidae fish species. Overall, species from Leuciscidae family represented 19.6%, followed by Cottidae (9.9%), Cyprinidae (2.9%),

Petromyzontidae (0.7%), Nemacheilidae (0.6%), Percidae (0.1%) and Cobitidae (0.1%) (**Figure 3**).

Diversity and Distribution Patterns of Fish Species

Alpha diversity varied in the two river sections of the Someşul Cald River. The inferior section T1 had 9 species, while the superior section T2 had 12 species. It can be noticed that the global alpha diversity (T1+T2) is equal to the alpha diversity of T2 (**Figure 4**). In terms of species composition, the differences are caused by *S. labrax, R. rutilus* and *Perca fluviatilis* found only in the superior river section T2.

Beta diversity determined by Sørensen's coefficient ranged from 0.29 to 1 in the T1 section and from 0.67 to 1 in the T2 section (similarity between neighboring stations) (**Figure 5**). The determined overall beta diversity (T1 *vs* T2) was 0.86, suggesting a high degree of similarity between the two river sections. Beta diversity between neighboring stations inside each river section showed less variation in T2 than in the T1 section (Coefficient of variation: T2 = 14.72% vs T1 = 32.94%). Beta diversity values were tested using a t-test to compare the mean values of the T1 and T2 sections. The results showed that there is no significant difference between the two sections ($p = 0.2047$, $t = 1.322$) in terms of means for beta diversity.

The Kruskal–Wallis test showed that the alpha diversity in sampled stations of section T1 did not show significant variation ($p > 0.05$), while the opposite was determined for stations from the T2 section ($p < 0.05$). In the case of beta diversity, the Kruskal–Wallis test showed no significant variations ($p > 0.05$). Based on ANOSIM analysis, no significant evidence of differences in fish species between the two river sections was found ($R = 0.1362$, $p = 0.069$). Based on NMDS (T1 stress =
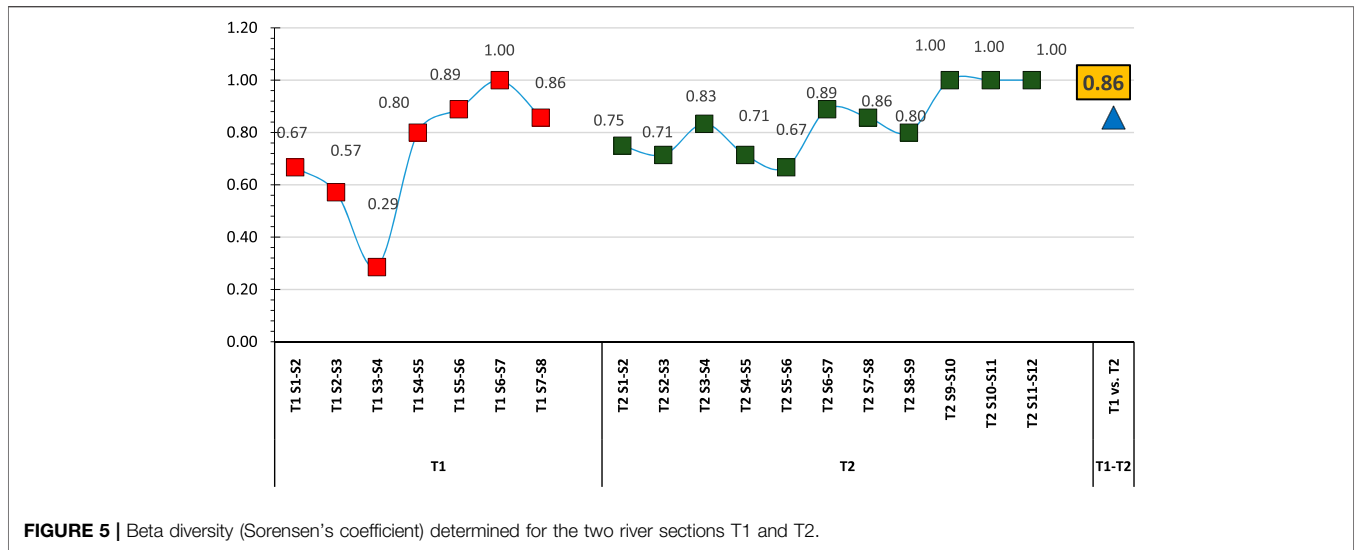
FIGURE 5 | Beta diversity (Sorensen's coefficient) determined for the two river sections T1 and T2.
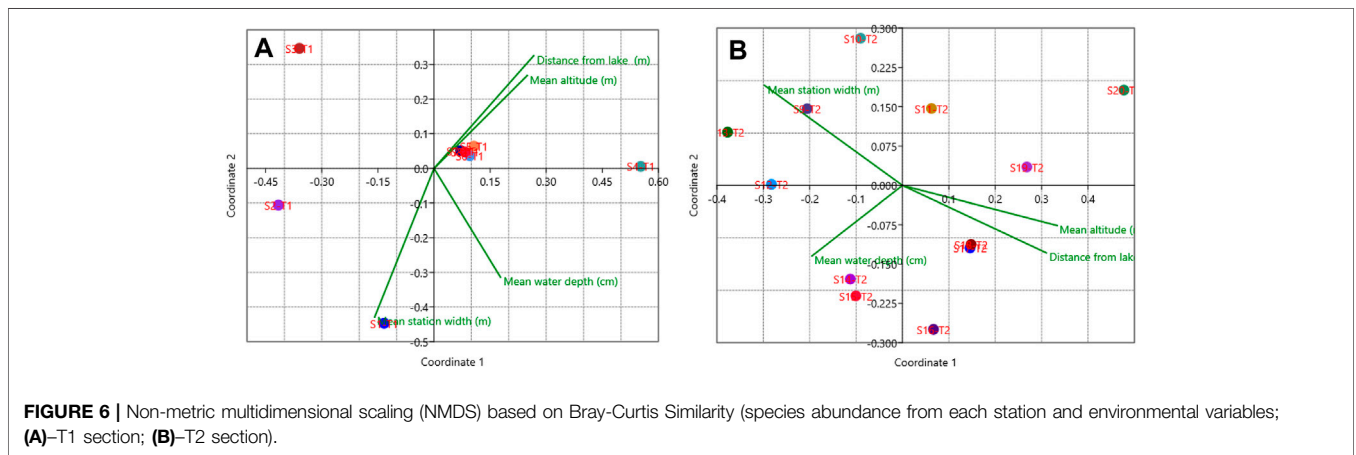

FIGURE 6 | Non-metric multidimensional scaling (NMDS) based on Bray-Curtis Similarity (species abundance from each station and environmental variables; **(A)**–T1 section; **(B)**–T2 section).

0.0644 and T2 stress = 0.146), fish species composition displayed different distribution patterns in the two river sections (**Figure 6**).

SIMPER showed that *T. thymallus* (contributed 15.78%), *B. carpathicus* (contributed 14.06%), *C. gobio* (contributed 13.1%), and *S. cephalus* (contributed 14.49%) contributed with more than 50% to the dissimilarity of the two sampled river sections. The species that contributed most to the similarity of both the T1 and T2 river sections was *S. trutta*.

Fish Species and Environmental Variables

The direct gradient analysis represented by environmental variables in the sampled sites and fish species' presence or absence was determined by Canonical Correspondance Analysis (CCA). A total of 4 environmental variables were included in the study (altitude, water depth, station width, and distance from the lake). For the inferior river section T1, 67.24% was explained by axis 1 and 24.91% by axis 2. A similar situation was observed in the case of the superior river section T2, where 66.55% was explained by axis 1 and 27.37% was explained by axis 2. Environmental variables influenced the distribution of some fish species. In both T1 and T2 sections, the

mean altitude influenced the distribution of *C. gobio*, the species being better represented at higher altitudes. Mean water (station) width influenced *C. elongatoides* and *E. danfordi* distribution in T1 river section. The same environmental variable influenced the distribution of *E. danfordi* and *T. thymallus* in T2. Mean water depth in T1 section did not influence fish species distribution, while in T2 section, the distribution of *B. barbatula, P. fluviatilis, E. danfordi* and *T. thymallus* was influenced by this environmental variable. Distance from lake influenced the distribution of *S. trutta* in both T1 and T2 sections, the species being better represented in terms of numbers in stations more distant from the lake/reservoir. (**Figures 7A,B**). Even when CCA is used as an exploratory method, applied on data that is not normally distributed, it may show patterns of habitat preferences in some fish species.

Alpha and Beta Diversity Patterns on an Elevation Gradient

In terms of species richness (alpha diversity), a species distribution pattern can be observed in both T1 and T2 river
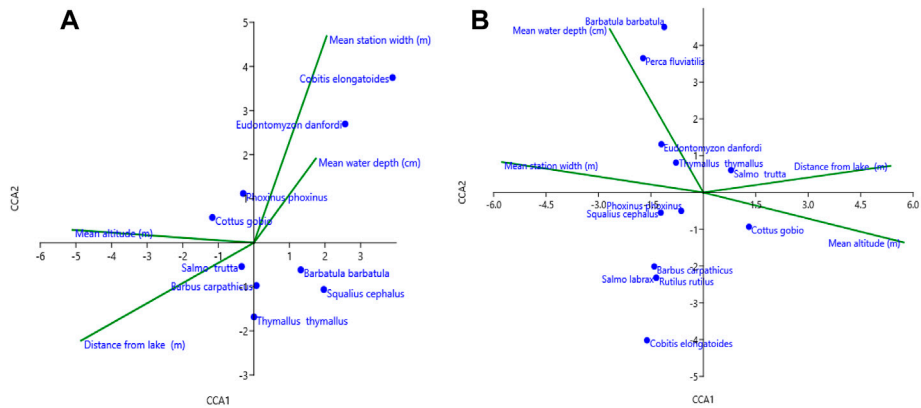
FIGURE 7 | Canonical Correspondence Analysis (CCA): relationship of fish species and environmental variables for T1 **(A)** and T2 **(B)** river sections (used as exploratory method).
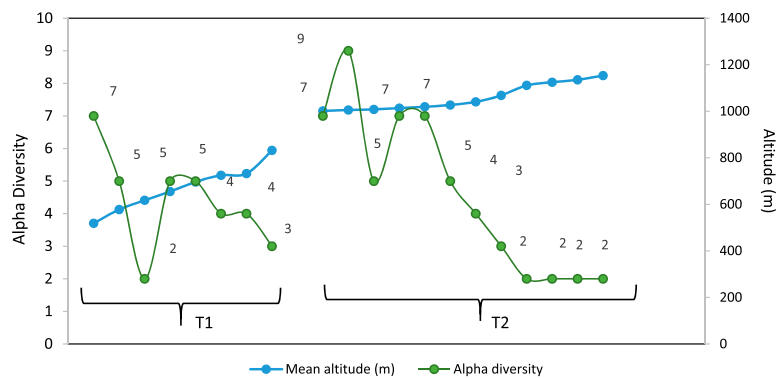

FIGURE 8 | Variations of alpha diversity in the T1 and T2 river sections.
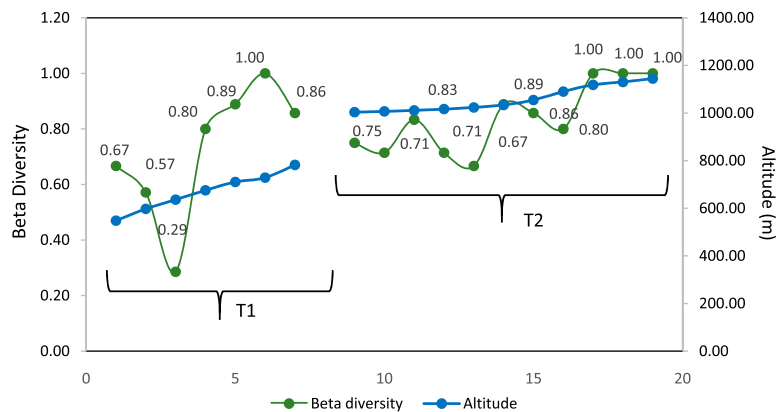

FIGURE 9 | Variations of beta diversity in the T1 and T2 river sections.

sections. The inferior stations from each river section had more species in both cases compared to the superior stations (stations T1-S1, T1-S2, and T2-S1 and T2-S2). In this case, increased alpha diversity is to be associated with the distance from the lake rather than elevation. The stations mentioned above make the connection of the river with Tarniţa and Beliș-Fântânele

TABLE 5 | Spearman correlations of alpha diversity and environmental variables.

Alpha Diversity *vs* EV	Alpha *vs* Mean Altitude (m)		Alpha *vs* Mean Station Width (m)		Alpha *vs* Mean Water Depth (cm)		Alpha *vs* Distance from the lake(m)	
River section	T1	T2	T1	T2	T1	T2	T1	T2
r	−0.577	−0.9231	0.5647	0.9591	0.1596	0.4526	−0.577	−0.9231
P (two-tailed)	0.1423	<0.0001	0.1494	<0.0001	0.7101	0.1401	0.1423	<0.0001
P-value summary	ns	****	ns	****	ns	Ns	ns	****
Significant? (alpha = 0.05)	No	Yes	No	Yes	No	No	No	Yes
Number of XY Pairs	8	12	8	12	8	12	8	12

Reservoirs. In general, alpha diversity showed a monotonic decrease when altitude is increased (**Figure 8**). The determined beta diversity showed that neighboring superior stations from both river sections were more homogenous (T1 S5-S6, T1 S6-S7, T1 S7-S8, T2 S9-S10, T2 S10-S11, and T2 S11-S12), beta diversity ranging from 0.86 to 1 in T1, and 1 in T2 (**Figure 9**). The superior river section T2 had more species than the inferior section T1 (12 *vs* 9).

Spearman correlations between alpha diversity and environmental variables showed different patterns in the 2 analyzed river sections. Moderate negative correlations of alpha diversity and mean altitude were determined for T1 (r = -0.577, *p* = 0.1423), while very strong negative correlations were determined for T2 (r = -0.9231, *p* < 0.0001). In the case of alpha diversity and station width, correlations were moderate and positive for T1 (r = 0.5647, *p* = 0.1494) and strong and positive for T2 (r = 0.9591, *p* < 0.0001). Alpha diversity and mean water depth for both river sections were weak and positively correlated (T1: r = 0.1596, *p* = 0.7101 respectively T2: r = 0.4526, *p* = 0.1401). Alpha diversity and distance from lake showed moderate and negative correlations in T1 section (r = -0.577, *p* = 0.1423) and very strong and negative correlations in T2 section (r = -0.9231, *p* < 0.0001) (**Table 5**).

DISCUSSION

Quantitative studies on fish species distribution before and after cascade dam construction were not conducted for Someşul Cald River. The only data available was published by Bănărescu (1964), being a qualitative study before cascade dam constructions, where 10 fish species were mentioned (*Salmo trutta, Thymallus, Squalius cephalus, Phoxinus, Alburnoides bipunctatus, Gobio obtusirostris, Romanogobio uranoscopus, Barbus carpathicus, Barbatula, Cottus gobio*), grouped into 6 families (Salmonidae, Leuciscidae, Gobionidae, Cyprinidae, Nemacheilidae and Cottidae). In terms of species distribution, there are differences between "before cascade dam construction" and "after cascade dam construction". Species such as *A. bipunctatus, G. obtusirostris,* and *R. uranoscopus* were reported only before dam constructions, while species such as *C. elongatoides, R. rutilus, S. labrax,* and *P. fluviatilis* were reported after dam constructions, in this study. Voicu and Merten (2014) mentioned that longitudinal connectivity was also highly affected by hydro-technical facilities downstream of our study area, and habitat restoration is necessary. Other species

(*C. nasus, B. carpathicus*) that live below the trout and grayling ecological zones may be affected in the long term due to longitudinal fragmentation. Yujun et al. (2010) noticed that when migration routes are cut off, changes in fish species composition may occur, with some species being threatened while others may disappear. Species from the *Thymallus* genus are affected worldwide by hydro-constructions. Studies show that the habitat of the Arctic grayling *T. arcticus* is restricted due to dam constructions and habitat management should be analyzed according to "the new fragmented distribution" (Clarke et al., 2007). Assessments on species sensitivity to hydropower constructions are well known, but too few measures are taken for protection purposes (Weiss et al., 2018). Dispersal by the current-mediated drift of fish larvae is another issue influencing migration (upstream-downstream migration) (Zitek et al., 2004; Lechner et al., 2014).

Brown trout *S. trutta* was observed in all stations, at all altitudes, ranging from 2 specimens (T2-S12) to 174 specimens (T1-S4). Since it is well distributed along the elevation gradient, we can assess that the species has high plasticity in terms of habitat, a characteristic also observed by other authors (Ayllón et al., 2010). In some countries, the species is viewed as a possible invader due to its capacity to adapt to new environments (Budy and Gaeta, 2017). The observed altitude range distribution of *S. trutta* in Someşul Cald River was from 518.5 to 1,153.5 m. The Black Sea trout *S. labrax* is a rare species in both Romanian fresh and saltwater. Further analysis of its distribution has to be performed. The habitat of European grayling *T. thymallus* is limited not only in Romania, but also in Europe due to genetic drift and limited migration. In some cases, grayling populations should be treated as separate units for conservation plans (Swatdipong et al., 2009). The present population of the species in the studied river has a limited distribution range in terms of altitude (1,001.5 m–1,068.5 m) compared to the 1960s, when it was found from Beliş to the confluence with the Someşul Rece River (Bănărescu et al., 1999). The small number of specimens from the T1 river section suggests that the river stretch connecting Tarniţa Reservoir and Beliş-Fântânele Dam is not a suitable habitat for the species. The stone loach *B. barbatula* is a bottom-dwelling fish species inhabiting shallow depositional habitats. The presence of macrophytes is another habitat element prefered by the species (Santoul et al., 2005). In our case, the small number of specimens and the small number of sites where it was observed may be attributed to an unsuitable habitat. At higher altitudes, depositional habitats are limited (T2 river section), and a

similar situation can be found in river stretches connecting cascade dams (T1 river section limited downstream by Tarniţa Reservoir and upstream by Beliş-Fântânele Dam). Carpathian barbel *B. carpathicus* occurs usually in the Northern and Central parts of the Carpathian mountains (Konopiński et al., 2013). The species was recently described as an individual species, in the past being referred to as *B. meridionalis* or *Barbus petenyi*. Further studies are needed to have more insights into the species ecology. It can be noticed that the species tends to cluster in particular areas of the river (T1-S4 and T2-S2). The Eurasian minnow *P. phoxinus* is a gregarious species with a wide area of distribution in Europe and Asia. In terms of habitat preferences, it is found in cold, well-oxygenated streams, rivers, and lakes (Vucić et al., 2018). In our study, the species was observed in both river sections and almost all the stations from altitudes ranging from 518.5 to 1,068.5 m. The European chub *S. cephalus* specimens found in Someşul Cald River showed a similar distribution pattern in both river sections T1 and T2. It was found in both river sections in the first 4 and 5 stations upstream of the reservoirs. This may suggest that the species' presence is influenced by the distance from the lake/reservoir. The presence of *Cobitis elongatoides* in both river sections is rather accidental. Previous studies did not mention the species in this river, also our observations are limited to only 2 specimens, one in each river section. The bullhead *C. gobio* is considered to be an indicator species for habitat integrity and quality (Gosselin et al., 2010). In the present study, the species showed a clear distribution based on elevation gradient. It was observed from altitudes ranging from 696 to 1,153.5 m (from T1-S5 to T2-S12). The roach *R. rutilus* is found in a large number of habitats, especially in lowland areas. It prefers nutrient-rich water bodies, so its presence in the superior section of the studied river is spontaneous and conditioned by the spawning season. It is found in large numbers in Beliş-Fântânele Reservoir, migrating upstream between July to August. The spawning season of the roach is in general from April to May, similar to the European chub (May to June), but at higher altitudes, it can be observed until late in the summer (June to August) (Şaşi, 2004; Nõges and Järvet, 2005). The Carpathian lamprey *E. danfordi* is usually found in the trout, grayling, and sometimes barbel ecological zones. Slow water with silt and mud substrate is essential for the species to thrive, especially for larvae development (Curtean-Bănăduc et al., 2015). The species' presence in Someşul Cald River can be associated with the sampling stations close to reservoirs (T1-S1, T1-S2, T2-S2, T2-S4, and T2-S6). In general, these areas are richer in depositional matter than areas closer to the spring. The presence of the perch

P. fluviatilis in Someşul Cald River is spontaneous and mainly caused by its migration from Beliş-Fântânele Reservoir, which cannot be associated with spawning season, but rather with accidental migration. It is found in large numbers in both reservoirs (Tarniţa and Beliş-Fântânele).

In terms of alpha diversity, more species are found in both river sections in the stations closer to the reservoirs. Beta diversity shows heterogeneity in fish species assemblages in the same areas where alpha diversity is high. On the other hand, it can be noticed that more homogeneity is found in the upper stations of both river sections.

This study presented the qualitative and quantitative status of fish species from Someşul Cald River, under the influence of cascade dam construction. The presence of new species and the absence of previously reported species may be a consequence of habitat alteration. The populations of *T. thymallus, C. gobio,* and *E. danfordi* are fragile in the studied water body and habitat protection is required, while the *S. trutta* population is well distributed in all river sections and stockings with this species are not recommended (Aquastat, 2018).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

The animal study was reviewed and approved by the Ethics Committee of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca (No. 143/2019).

AUTHOR CONTRIBUTIONS

CL: writing, editing, methodology, fieldwork and review. TP: data curation, fieldwork, language editing. GM: data curation, fieldwork, substantial correction. PU: writing, editing, fieldwork and review. RC: fieldwork, review and visualization, M-CM-L: writing, fieldwork review and visualization, A-SN: writing, map editing, CC: data analysis, review and visualization. VM: methodology, and DC: methodology and supervision.

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