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THE INFLUENCE OF DAMMING ON THE DISTRIBUTION OF BROWN TROUT *SALMO TRUTTA* LINNAEUS, 1758 AND EUROPEAN GRAYLING *THYMALLUS THYMALLUS* LINNAEUS, 1758 (PISCES: SALMONIDAE) FROM SOMEȘUL CALD RIVER

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Abstract

Monitoring fish fauna in altered aquatic habitats may provide relevant information regarding the distribution, presence or absence, and dynamics of fish species. Someșul Cald River is the main tributary of Beliș-Fântânele Reservoir and Dam, build from 1970 to 1974. The presence of the dam could have affected fish fauna, especially potamodromous brown trout Salmo trutta and European grayling Thymallus thymallus because of habitat obstruction. Altitude, riverbed width, water depth, and water velocity are easy to determine aquatic environmental parameters. River altitude and riverbed width played an important role in European grayling preference regarding the auspicious environment. Correlation coefficients showed that increasing altitude is a limiting factor for European grayling (r=-6024, p<0.05). Wider riverbed is preferred by the same species (r=0.672*, p<0.05). Beliș-Fântânele Dam blocked the migration of fish and made the grayling ecological zone framed by two trout ecological zone (upstream and downstream). The distribution range on the altitude of the brown trout in Someșul Cald River was from 518.5m to 1153.5m and 577.5m to 1068.5m for the European grayling.*

Key words: *altered aquatic environment, electrofishing, endangered species, ichthyofauna.*

INTRODUCTION

Anthropic activities such as dam constructions, reservoirs, cascade dams, hydropower plants, and other hydro-technical constructions lead to major fragmentation of river systems and diversity loss (Kang et al., 2009; Danalache et al., 2017b; Jonsson et al., 2018; Kirin et al., 2019). Assessing the fish species contributes to the development of good management measures for ichthyofauna biodiversity conservation (Nicolae et al., 2018). Nilsson (2005) stated that dams have dramatically altered over half of the river systems in the world. The main habitat alteration mechanisms consist of: lotic habitats converted to lentic habitats (Martinez et al., 1994), construction of physical barriers (Watters, 1996) and constant change of water parameters regimes (pH, temperature, turbidity) (Magilligan and Nislow, 2005). Migration of fish is essential and artificial barriers limit or obstruct their movement (Danalache et al., 2017a). Also, fish species like brown trout, European grayling, Danube salmon, Black Sea trout, that are associated with fast-flowing waters tend to diminish in numbers and sometimes disappear (Jansson, 2006). Similar phenomenon is encountered on Someșul Cald River, located in Cluj County, North-Western Romania. The distribution of fish species belonging to the Salmonidae family could be affected by habitat alteration caused by damming, in this case, brown trout *Salmo trutta* and European grayling *Thymallus thymallus* (Ombredane et al., 1987). Constant survey of the fragmented river systems fish fauna will provide data to generate the appropriate evolution and distribution of fishes, and also the long term effects of dams. The present study aimed to provide an up-to-date image of the anthropic barriers from the Someșul Cald River and how habitat alteration progresses.

MATERIALS AND METHODS

Sampling site

The study was conducted from August, 2018 to September, 2018 on Someșul Cald River (Someș-Tisa catchment, North-Western Romania). The springs of Someșul Cald River are located in Bihariei-Vlădeasa Masiff near Piatra Arsă Peak (Burned Stone Peak) at 1550 m altitude and has a total length of 66.5 km (Duma, 2016). On Someșul Cald River, four dams were constructed during 1970-1974: Beliș-Fântânele Dam, Tarnița Dam, Someșul Cald Dam and Gilău Dam. At Gilău Dam, Someșul Rece River flows into Someșul Cald River and form Someșul Mic River (Figure 1).

Sampling method

Fish sampling was performed by single-pass electrofishing techniques using a SAMUS 725 MP apparatus, powered by 12V and 24 A rechargeable battery (Cocan et al., 2020). The efficiency of freshwater fish sampling by electrofishing methods is highly effective especially in streams and small rivers (Kubečka et al., 2012). Water conductivity was tested before electrofishing to adjust the output current and non-lethal frequencies (www.fao.org) using Hannah HI9828 multi-parameter (Uiuiu et al., 2020).

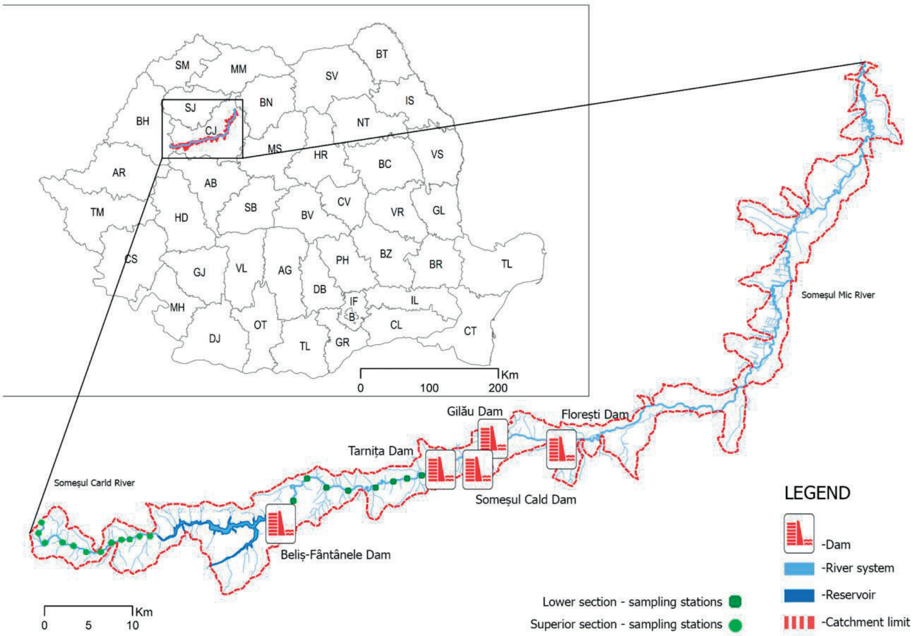

Figure 1. Someșul Cald River catchment and constructed dams

Habitat characterization

Fish sampling stations were marked using Garmin eTrex 20X GPS device. Each station's altitude, width, depth, water velocity was measured. The altitude of the stations was measured based on GPS data using Garmin BaseCamp software (ex-situ). Station riverbed width was measured with a 50m measuring tape. A total number of 5 measurements were performed inside each station (1 measurement at the lowest point of the station and 1 measurement at the highest point of the station, and 3 intermediary measurements). Water depth and water velocity were measured in the same locations as riverbed width.

Data analysis

The data was processed using MS Excel, GraphPad Prism Ver. 8. Pearson correlations were performed to highlight the "links" between the amount of fish, presence or absence of fish and river configuration.

RESULTS AND DISCUSSION

GPS coordinates and altitude of the sampling stations

The sampling stations were grouped into two sections based on the Beliș-Fântânele Dam position as follows: the *lower section* (from station 1 to station 8) positioned between Tarnița Reservoir (downstream) and Beliș-Fântânele Dam (upstream) and the *superior section* (station 9 to station 20) positioned between Beliș-Fântânele Dam and the springs of Someșul Cald River. The altitude for each sampling station was determined in two points (1 point on the downstream limit of the station and 1 point on the upstream limit of the station). In Figure 2, the mean altitude recorded values of the sampling stations are presented. The lowest altitude was recorded in station 1 (518.5 m) and the highest altitude was recorded in station 20 (1153.5 m). Beliș-Fântânele Dam is situated between stations 8 and 9. GPS coordinates of each river section with the corresponding stations are presented in Table 1.

Altitude is one of the most important factors which influence fish species richness. At low altitudes, the trophic composition is more diverse (Pouilly et al., 2006) and ecological zones for fish species can be determined. Barradas et al., in 2012, concluded that the historical and spatial distribution of fish species can help to identify the potential impact of damming.

Table 1. GPS coordinates of the sampling stations

River section	Station	Downstream point	Upstream point
Lower section	1	N46° 42.413' E23° 12.932'	N46° 42.454' E23° 12.816'
	2	N46° 41.914' E23° 10.990'	N46° 42.005' E23° 10.902'
	3	N46° 41.892' E23° 09.538'	N46° 41.926' E23° 09.286'
	4	N46° 42.023' E23° 08.125'	N46° 42.013' E23° 07.991'
	5	N46° 42.080' E23° 07.781'	N46° 42.153' E23° 07.672'
	6	N46° 42.495' E23° 07.029'	N46° 42.578' E23° 06.906'
	7	N46° 42.609' E23° 06.465'	N46° 42.612' E23° 06.363'
	8	N46° 41.925' E23° 04.602'	N46° 41.959' E23° 04.825'
Superior section	9	N46° 38.766' E22° 52.112'	N46° 38.787' E22° 51.952'
	10	N46° 38.818' E22° 51.837'	N46° 38.832' E22° 51.622'
	11	N46° 38.834' E22° 51.457'	N46° 38.786' E22° 51.326'
	12	N46° 38.589' E22° 50.581'	N46° 38.498' E22° 50.221'
	13	N46° 38.429' E22° 49.409'	N46° 38.378' E22° 49.323'
	14	N46° 38.301' E22° 49.060'	N46° 38.216' E22° 48.755'
	15	N46° 37.955' E22° 48.284'	N46° 37.814' E22° 48.080'
	16	N46° 37.770' E22° 46.407'	N46° 37.813' E22° 46.327'
	17	N46° 38.092' E22° 45.022'	N46° 38.112' E22° 44.932'
	18	N46° 38.485' E22° 44.067'	N46° 38.532' E22° 43.995'
	19	N46° 38.653' E22° 43.712'	N46° 38.649' E22° 43.616'
	20	N46° 38.356' E22° 43.138'	N46° 38.310' E22° 43.131'

Based on altitude, brown trout is present in both sections of the river and in all the sampled stations. European grayling is also present in both sections of the river but in small numbers in the lower section. The highest point where European grayling was signalled was station 16 at the altitude of 1068.5 m. In this case, we can stipulate its limit of habitat based on altitude. The ecological zone of trout is above/upstream the grayling zone. The influence of damming clearly changed the distribution based on the altitude of the two species. The ecological zone of the grayling is "framed" by two ecological trout zones: one downstream the Beliș-Fântânele Dam and the second one upstream station 16. In an unaltered habitat, the grayling ecological zone is below (downstream) the trout zone (Aarts and Nienhuis, 2003; Lasne et al., 2007).

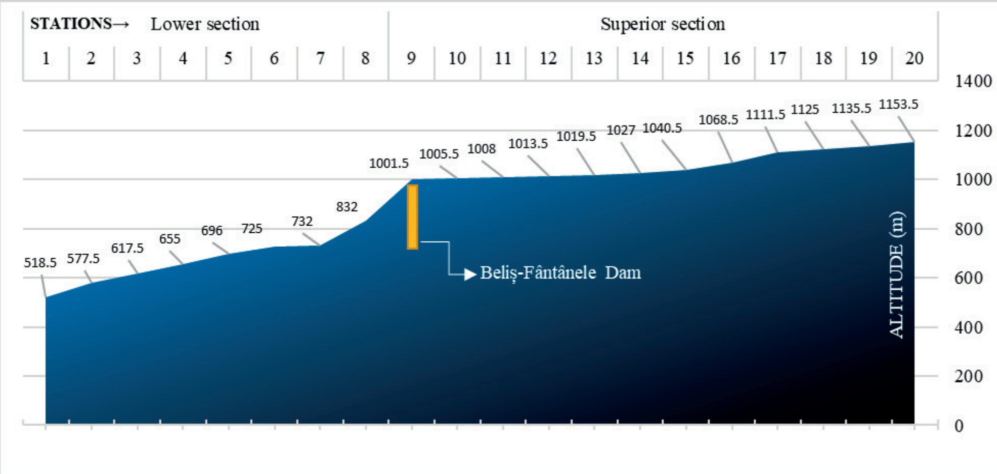

Figure 2. The altitude of sampling stations

Water depth

Water depth in the lower section of Someșul Cald River ranged from 20.4 cm (station 5) to 55.8 cm (station 1). The mean value of water depth was 37.2 cm. In the superior section of the river, water depth ranged from 11.9 (station 17) cm to 42 cm (station 16) (Figure 3).

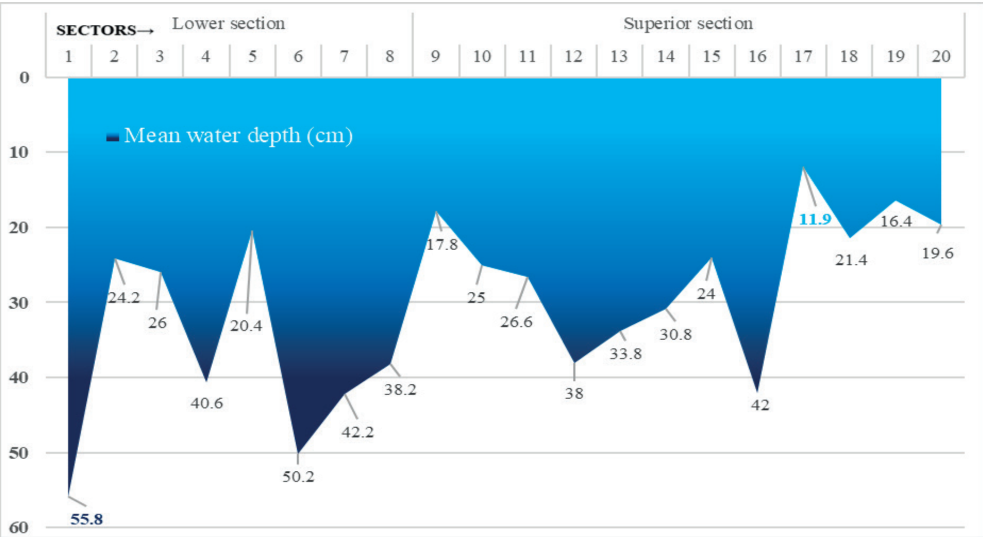

Figure 3. Mean water depth of the sampling stations

The mean value of water depth was 25.6 cm. The coefficient of variation (CV%) was highly similar for the two sections: 34.14% for the lower section and 35.47% for the superior section. In this case, water depth did not influence the presence or absence of both species. Large specimens of European grayling prefer deeper water than small specimens (Mallet et al., 2000) but in this case, in the deeper pools from the lower section of the river, we did not encounter any specimen. The two specimens caught in the lower section were caught in stations 2 and 3 where the mean water depth was 24.2 cm respectively 26 cm. The highest number of brown trout *Salmo trutta* was caught in station 4 (lower section) and station 12 (superior section). The mean water depth in both cases was similar (40.6 cm and 38 cm). Water depth is not related to the number of specimens but rather for their size, a fact confirmed by Vismara et al. (2001) who stated that adult brown trout prefer deeper water than smaller specimens.

Water width

Water width in the lower section of the Someșul Cald River ranged from 4.48 m (station 4) to 9.53 m (station 1). The mean value of the water width was 6.433 m. In the superior section of the river, water width ranged from 2.348 m (station 20) to 24.68 m (station 9). The mean value of water depth was 11.30 m. The coefficient of variation (CV%) was 23.45% for the lower section and 66.26% for the superior section. The alteration of the habitat can be best visualized in Figure 4.

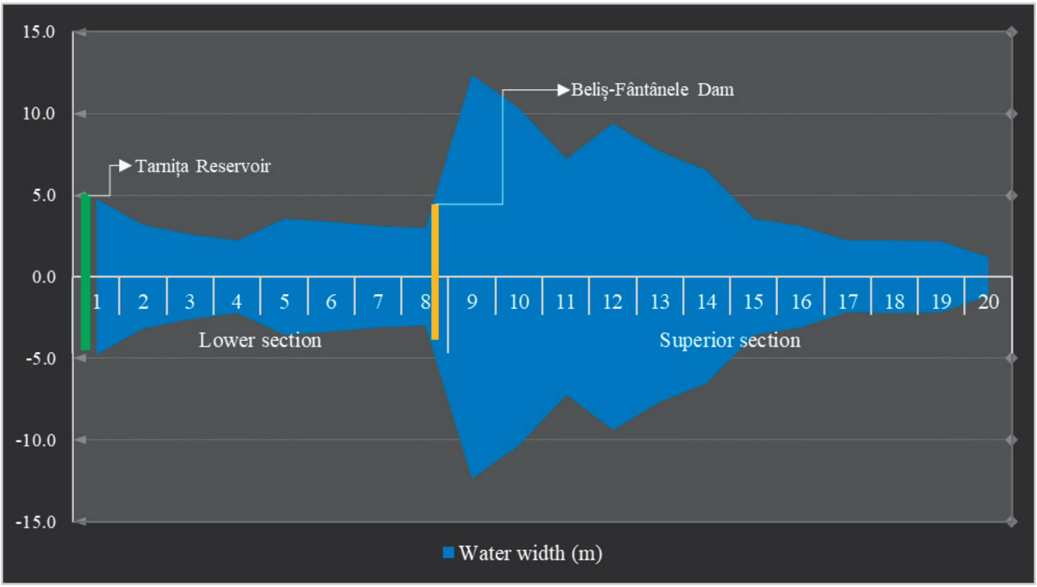

Figure 4. Mean water width of the sampling stations

Water width is constantly increasing from station 20 to station 9, where the Beliș-Fântânele Dam is positioned. Downstream of station 9, and implicitly the Beliș-Fântânele Dam the width of the river is much narrower. Fish migration is stopped by the dam and also the habitat continuity is altered. In figure 4 can be observed as a similarity in the lower section and the superior section of the river.

The mean width of stations from 2 to 8 (lower section) is almost identical to the mean width of stations from 14 to 20 (superior section) (2 to 8= 5.99m vs. 14 to 20= 5.97m). The number of brown trout specimens in stations from 2 to 8 is 483 and in stations from 14 to 20 is 312.

In the case of European grayling, in stations from 2 to 8 two specimens were caught and in stations from 14 to 20, 35 specimens were caught. In the superior section (stations 9 to 13) the total number of European graylings is higher than the number of brown trout (181 vs. 119).

In the same stations, the mean width of the river is 18.76 m, 3 times wider than the stations interval 2 to 8 and 14 to 20.

Water velocity

The mean recorded velocity in the lower section of the river was highly similar to the velocity recorded in the superior section (0.335 m/s vs. 0.363 m/s). The smallest value for the lower section was 0.14 m/s (station 1) and the highest value was 0.44 m/s (station 5). The superior section of the river showed more homogenous water velocity. The smallest value was recorded in station 16 (0.3 m/s) and the highest values were recorded in sectors 10 and 19 (0.42 m/s) (Figure 5).

Both brown trout and European grayling have great swimming capacity and their presence can be influenced by water velocity. For spawning, they use slow flow habitats (10-30 cm/s). The data presented in Figure 5 may indicate spawning sites since velocity is one of the most important variables together with substrate composition (Fukuda et al., 2013).

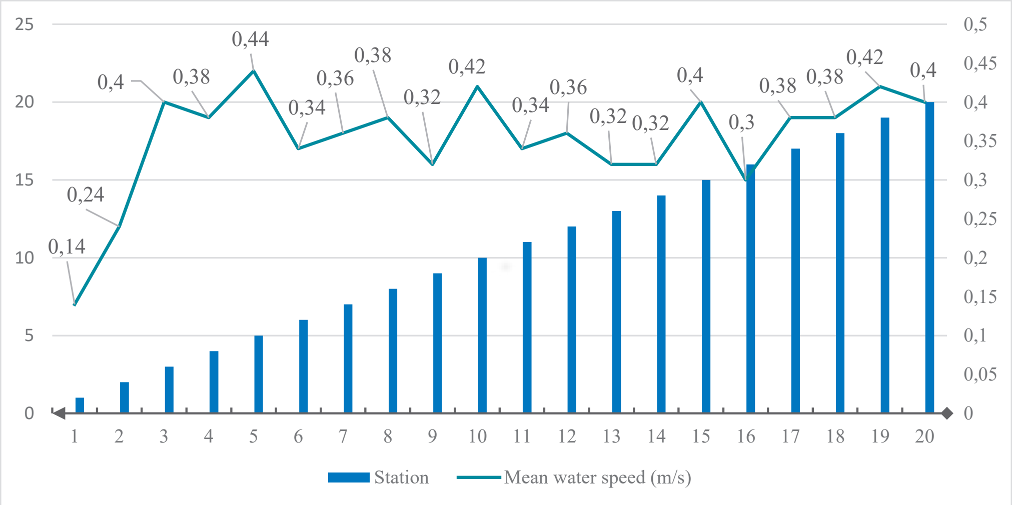

Figure 5. Mean water velocity of the sampling stations

Fish samples

A total number of 1235 fishes were caught from the Someșul Cald River of which 938 brown trout Salmo trutta specimens (488 in the lower section and 450 in the superior section) and 297 European Grayling Thymallus thymallus (2 in the lower section and 295 in the superior section) (Figure 6).

Brown trout represented 75.95% of the total number of fish caught and European grayling represented 24.05%. In the lower section of the river, brown trout represented 99.59% and European grayling represented 0.41%. A different situation was noticed in the case of the superior section of the river, where brown trout represented 60.40% and European grayling represented 39.60%. The largest number of brown trout specimens were caught in the lower section of the river in station 4 (174 specimens) while the smallest number was caught in the superior section in station 20 (1 specimen). In terms of numbers, in station 12 from the superior section of the river, 104 European grayling specimens were caught and the species was missing in stations: 1, 4, 5, 6, 7, 8 (lower section) and 17, 18, 19 and 20 (superior section).

Correlations of fish and habitat parameters

Pearson correlations were performed to characterize the relationship between the aquatic environment (in its current state) and the distribution of the two salmonid fish species under the present conditions (Figures 7 and 8). The brown trout was present in all the analyzed stations and it appears that altitude, water width, water depth and water velocity do not affect its distribution and all the correlations were not statistically significant (for $p<0.05$). The correlation coefficient was weak and moderate in the case of brown trout. In biological terms, this may be explained by the plasticity of the species which adapts very well to different new environments with different morphology (Valiente et al., 2010; L'Abée-Lund and Vøllestad, 2017). The presence of European grayling is affected by two major parameters: altitude and water width (Table 2).

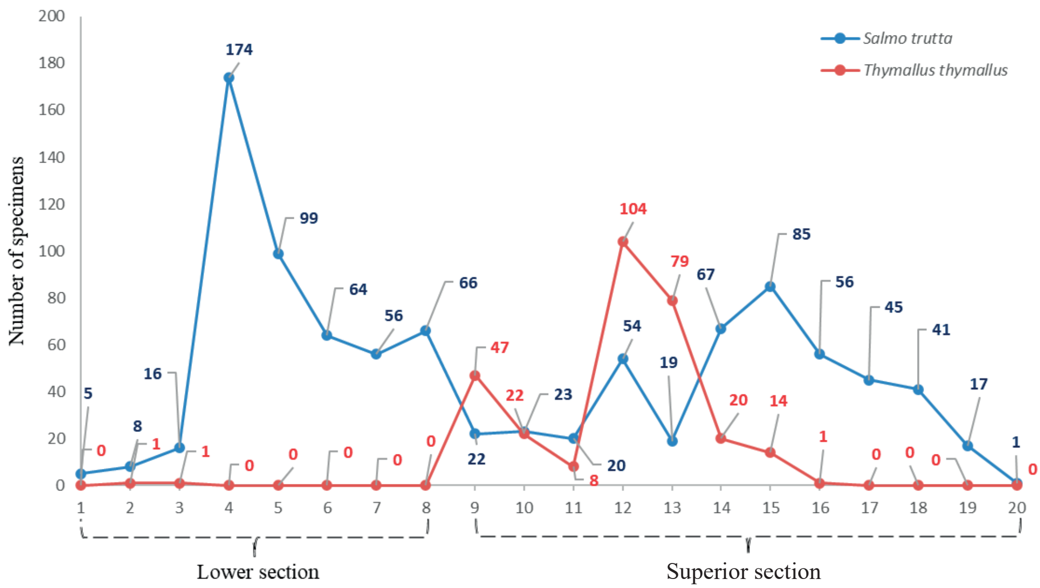

Figure 6. Brown trout and European Grayling specimens from the two sections of the river

Table 2. Correlation of species (*Salmo trutta* and *Thymallus thymallus*) with habitat parameters (*significant for p<0.05)

		Altitude (m)		**Width (m)**		**Depth (cm)**		**Velocity (m/s)**	
River Section	Species	r	p-value	R	p-value	r	p-value	r	p-value
L	*Salmo trutta*	0.4031	0.3221^{ns}	-0.5089	0.1978^{ns}	-0.01672	0.9687^{ns}	0.5756	0.1354^{ns}
S		-0.2268	0.4784^{ns}	-0.0980	0.7617^{ns}	0.34	0.2796^{ns}	-0.1756	0.5851^{ns}
L+S		-0.1959	0.4078^{ns}	-0.2165	0.3592^{ns}	0.2239	0.3426^{ns}	0.3178	0.1721^{ns}
L	*Thymallus thymallus*	-0.448	0.2656^{ns}	-0.2917	0.4832^{ns}	-0.588	0.1253^{ns}	-0.09463	0.8236^{ns}
S		**-0.6024**	**0.0382^{*}**	**0.672**	**0.0167^{*}**	0.4806	0.1137^{ns}	-0.3193	0.3116^{ns}
L+S		0.2799	0.2320^{ns}	**0.7181**	**0.0004^{***}**	0.0432	0.8565^{ns}	-0.04945	0.8360^{ns}

Legend: L-lower section; S-superior section; L+S-both sections, r-correlation coefficient; p-statistical significance.

A strong negative correlation can be observed (r=-0.6024) in the case of European grayling and altitude, meaning that the number of fish decreases when altitude increases. An almost identical situation is encountered in the case of European grayling and water width (r=0.672). The strong and positive correlation between European grayling and river width was observed only for the superior section of the river. The presence of the Beliş-Fântânele Dam had two negative side effects: first, the dam is blocking the European grayling upstream and downstream migration and second, it is genetically isolating the upstream existing population (Curtean-Bănăduc and Bănăduc, 2016). Petru Bănărescu (1964) mentioned that European grayling was found in Someşul Cald River, at the confluence of Someşul Cald River and Someșul Rece River and downstream, in Someșul Mic River (formed by Someșul Cald River and Someșul Rece River) close to Florești Village and Cluj-Napoca, Cluj County. The species was not signalled in the last 20 years in Someșul Mic River.

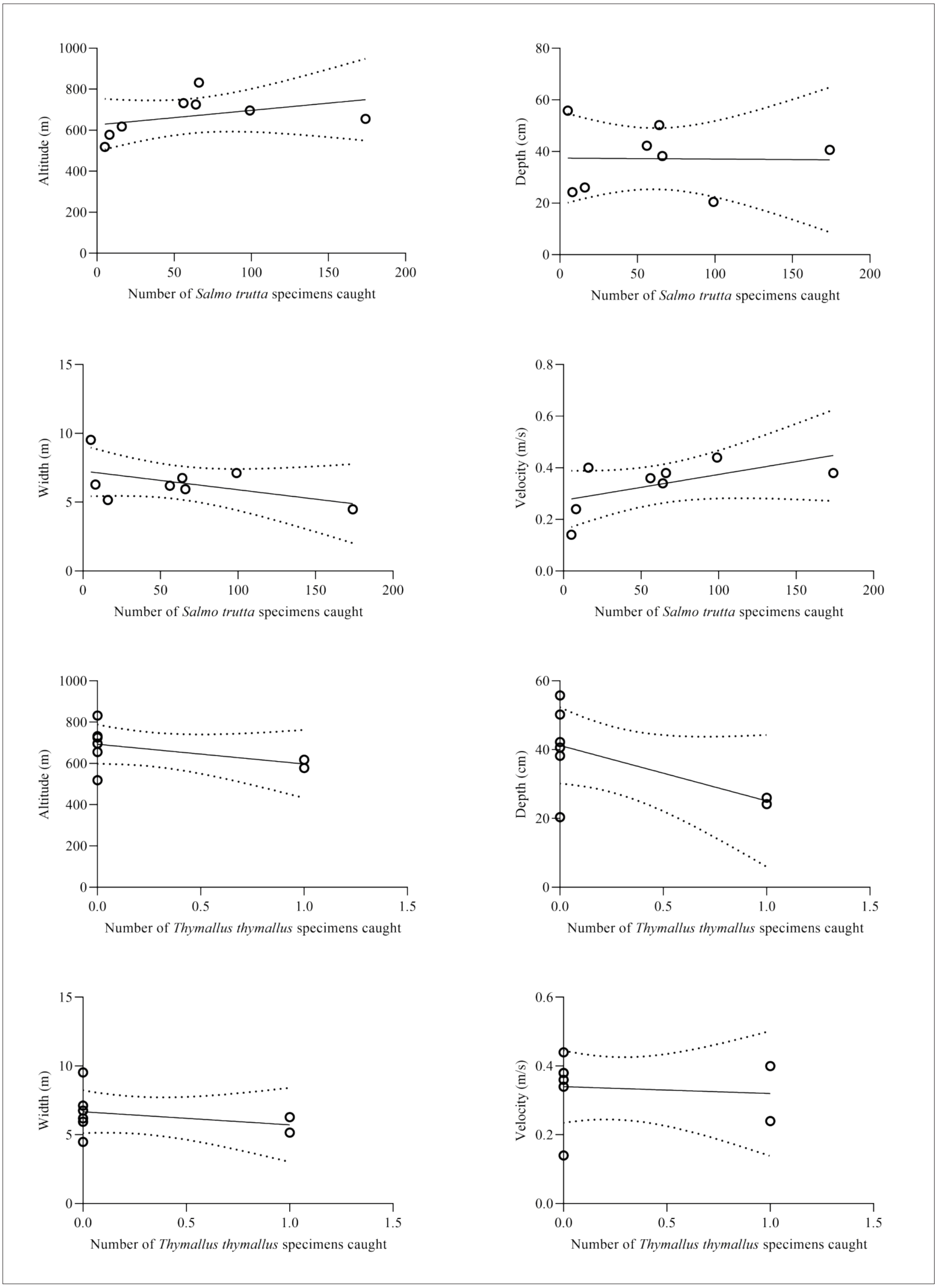

Figure 7. Correlations and 95% confidence intervals between fish number and aquatic habitat parameters - The lower section of Someșul Cald River

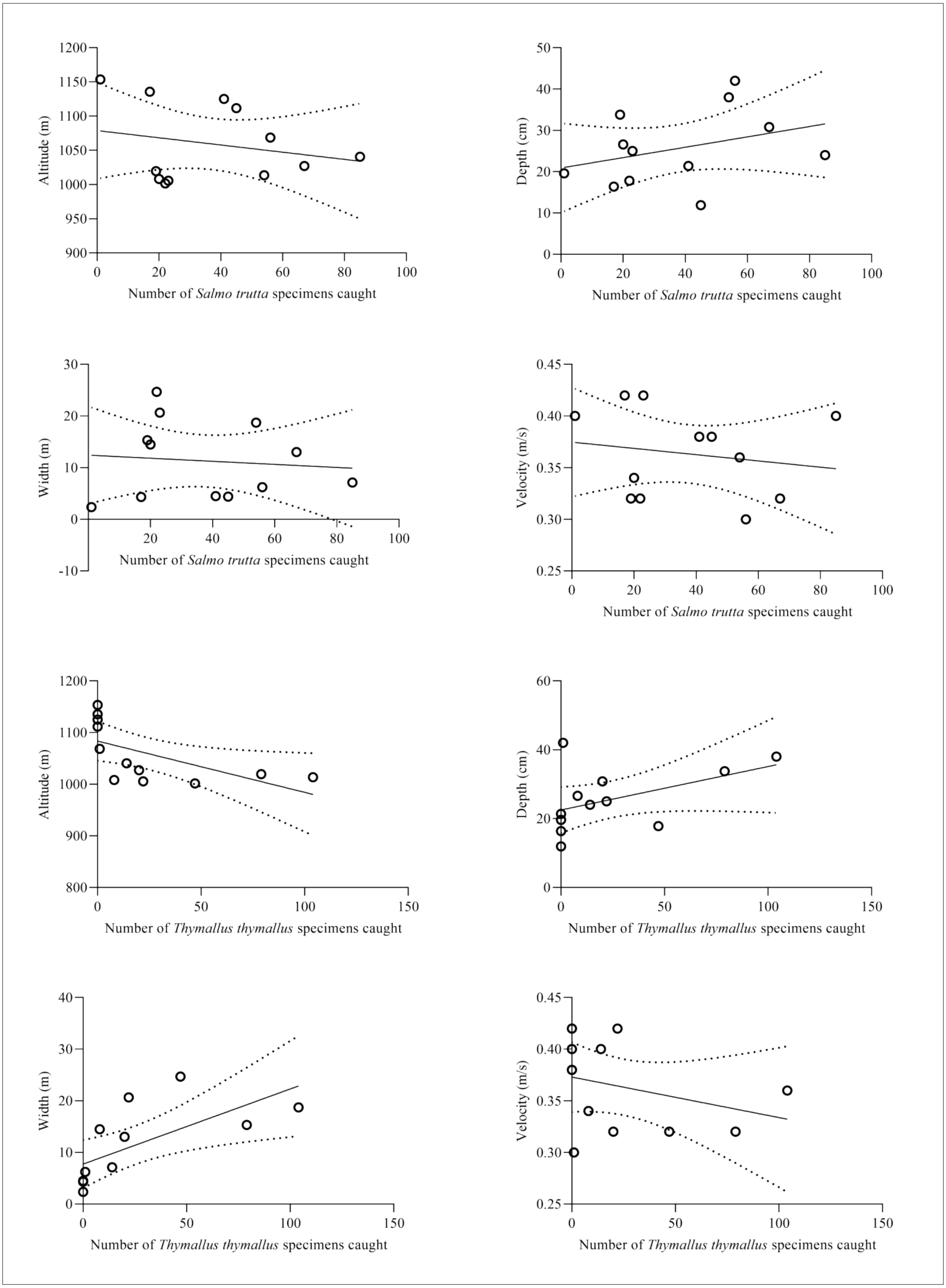

Figure 8. Correlations and 95% confidence intervals between fish number and aquatic habitat parameters -Superior section of Someșul Cald River

CONCLUSIONS

Brown trout (*Salmo trutta*) and European grayling (*Thymallus thymallus*) distribution is affected by the damming from the Someșul Cald River.

Someșul Cald River configuration is altered by the cascade dammings and as a consequence, fish ecological zones are abnormal. There is also the risk of genetic drift for the European grayling population located in the superior section of the river.

Riverbed width and altitude also influence the distribution of the studied species.

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