



## Fish Fauna Alterations Affect the Ecological Status in a Heavily Modified River: a Case Study of the Vacha River, Bulgaria

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**Abstract:** The Vacha River is located in South Bulgaria, being the main right tributary of the Maritsa River on the territory of Bulgaria. It flows through three big reservoirs, several small hydropower plants (HPPs) and other small weirs. The modified sector covers a significant part of the river length, contributing serious habitat and hydro-morphological alterations. Other anthropogenic pressures are negligible as the catchment is mainly mountainous, without high urbanisation rates. Fish are among the components of aquatic ecosystems defined as biological quality elements sensitive to the dam impact, especially migratory species. For assessment of the dam impact on the fish community in the Vacha River, a multihabitat fish sampling was performed at ten sites. Two standard fish-based indices regulated by the Bulgarian legislation were calculated, i.e. Bulgarian Fish-based Index (BRI) and Trout River Index (TRI). The main hydro-morphological features of the sampling sites were characterised. In contrast to the river management plan reporting “Good” ecological status, we registered “Good” status for one undisturbed (control) site as well as for one dam-affected site. TRI in two cases indicated higher status than BRI because hydro-morphological and hydrological alterations resulted to a non-type-specific fish community with an essential trout domination, even in the cyprinid river zone close to the mouth.

**Key words:** Water Framework Directive, Balkans, fish ecology, ecologic assessment, aquatic management, river fragmentation

### Introduction

Modification of the river morphology and altered water flow regime caused due to human activities are considered as hydro-morphological pressure on the freshwater ecosystems. Such activities are damming, hydropower construction, drainage schemes and water supply systems, channelization, river embankment, different barriers and locks, water transport, etc. (Freshwater information system, February 2021). The main impacts associated with dams lead to hydro-morphological and hydrological alterations reflecting on fish populations (SCHMUTZ & MOOG

2018). Fish are among the components of aquatic ecosystems defined as standard Biological Quality Elements (BQEs) for assessment of the ecological status of surface waters (EU WFD 2000, MIHOV 2010). For aquatic ecosystem assessment, most fish-based indices are associated with the sensitivity of fish communities due the interruption of the longitudinal connectivity of rivers. A significant effect of damming on fish communities has been recorded in single cases (PEHLIVANOV et al. 2018). In general, it leads to altered population structure, decline in species diversity, increase of the abundance of eurytopic and limnophilic species, population reduction

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caused by destruction of spawning sites, new opportunities for invasion of alien species and competition by non-indigenous species (WEISS et al. 2018, PIRIA et al. 2019). Unlike slowly moving species (WOLTER et al. 2015), potamodromous and diadromous fish species are highly threatened by dams disrupting the longitudinal connectivity of rivers and may consequently impede fish movements to feeding and spawning grounds (BARBAROSSA et al. 2020).

Currently, two clearly specified fish zones have been recognised by Bulgarian legislation (Ordinance № 4/20.10.2000 and amendments): salmonid and cyprinid zones with border at about 800 m a. s. l. (CHESHMEDJIEV & MARINOV 2008). A more precise fish zonation has not been developed yet. On the other hand, the current zonation does not correspond to the classical one (HUET 1949) due to certain reasons: different faunistic complexes from those inhabiting Western Europe (NOBLE et al. 2004) and higher level of endemism in the Balkan Peninsula, especially in southern areas (OIKONOMOU et al. 2014). Most specific difference represents the absence of *Thymallus thymallus* L., 1758 from the Bulgarian fish fauna (VASSILEV & PEHLIVANOV 2005).

One of the most heavily modified Bulgarian rivers is Vacha, which is artificially altered at a significant part of its length (River Management Plans, East-Aegean Basin Directory, 2016–2021). It is

located in South Bulgaria, representing main right tributary of the Maritsa River. Except damming, main alteration is also hypolimnetic cold-water release. River biota faces the challenge of three big dams: Tsankov Kamak, Vacha and Krichim, several hydropower plants (HPPs) and different weirs. Within the entire catchment, two river types are present, R3 and R5. The formed dam lakes are recognised as L13 lake-type.

The aim of the present study was to assess the impact of dams on the fish community in the Vacha River. In view of the fact that the Vacha River between downstream the town of Devin and upstream the town of Krichim is not affected by other anthropogenic pressures except damming and accompanying effects, we assume that any alterations of the local fish communities should be caused by hydro-morphological pressure. The aim of the present study is to characterise the effect of the hydro-morphological alterations on the ecological state of the river as evidenced by the fish communities.

## Materials and Methods

Nine lotic (eight affected and one unaffected) and one control lentic site along the Vacha River (Fig. 1) were sampled according to CEN 14011: 2003 Standard and assessed using Bulgarian Fish-based

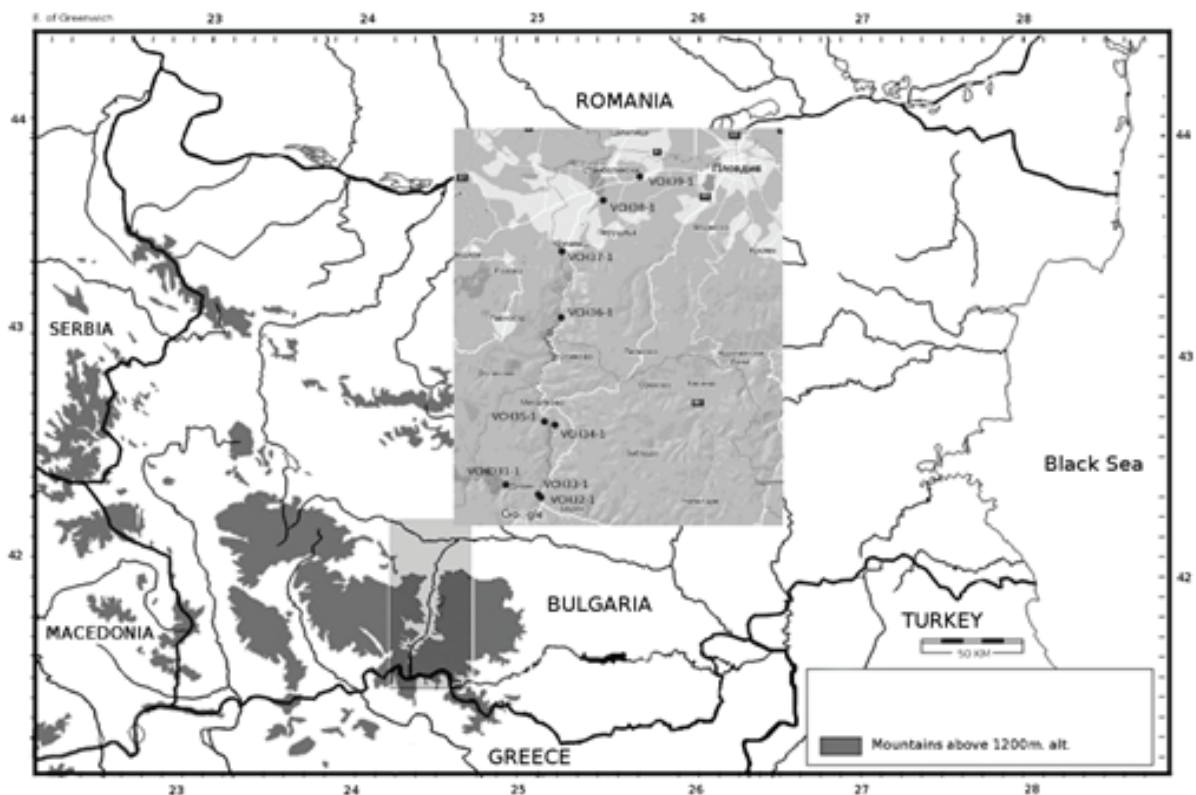


Fig. 1. Study area with sampling sites in 2019 in the Vacha River, South Bulgaria.

**Table 1.** Sampling sites arranged according to altitude and fish index values calculated from data from the 2019 sampling in the Vacha River. Legend: H = High ecological status; G = Good; M = Moderate; N.A. = Not applicable.

Code	River type	Site	Alt. (m)	Quality	Total abundance (ind./ha)	Species (number)	BRI	TRI	Latitude	Longitude
VCHD31-1	R3	above Devin	741	Referent	714	1	0.76 G	28 H	41.74310	24.37613
VCH32-1	R3	near Devin	701	Affected	47	1	0.51 M	22 M	41.73132	24.42204
VCH33-1	R3	near Devin	685	Affected	550	2	0.45 M	23 M	41.73222	24.42148
VCH34-1	R3	Tsankov Kamak Dam	589	Affected	2582	3	0.47 M	28 H	41.82996	24.44429
VCH35-1	R3	Tsankov Kamak Dam/HPS	554	Affected	204	3	0.60 G	30 H	41.84719	24.41921
VDAM	R3 modified to L13	Vacha Dam tail	542	Dam control	125	7	0.45 M	N.A.	41.86417	24.41634
VCH36-1	R3	Krichim Dam	307	Affected	426	3	0.47 M	20 M	41.99752	24.47876
VCH37-1	R3	Krichim Dam/HPS	244	Affected	113	2	0.45 M	18 M	42.03674	24.46834
VCH38-1	R5	above Kadievo HPP	180	Affected	178	3	0.49 M	24 M	42.11995	24.55641
VCH39-1	R5	below Kadievo HPP	172	Affected	622	4	0.45 M	N.A.	42.13850	24.60299

Index (BRI) (BELKINOVA et al. 2013) in accordance to the Ministry of Environment and Water (MOEW) Ordinance H-4/2012 (including subsequent amendments). Trout River Index (TRI) was calculated for the sites when applicable (where trout was present) (PEHLIVANOV et al. 2012). BRI was also calculated for the dam control site in the ecotone zone of the dam lake (accepted the heavily modified river sector near the inflow). Currently, according to the national legislation, there is not proposed a methodology of assessment of the ecological status of standing waters in Bulgaria (MOEW Ordinance H-4/2012 and amendments). Results have been compared in terms of abundance, species composition and indicative values of the fish communities in order to establish their heterogeneity by cluster analysis, Simpson's similarity index and Spearman's correlation. Statistical analysis was performed according to HAMMER et al. (2001).

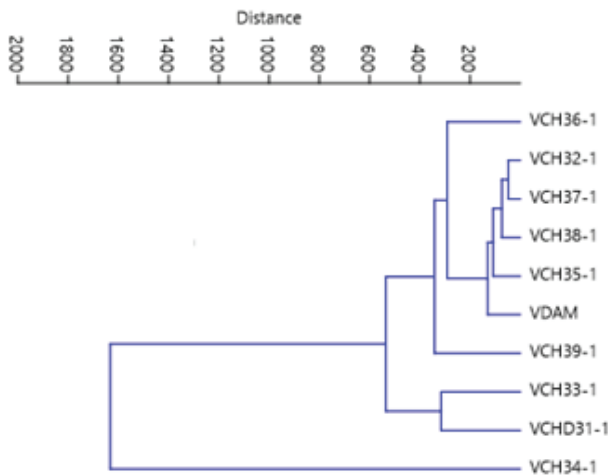
## Results

BRI was calculated for all ten sampling sites, and TRI was for measured for two of them as trout was absent in the majority of sites positioned below the natural trout zone (Table 1). Most of the affected sites were assessed as being in "Moderate" ecological status; only three of them (except the referent one) were assessed in "Good" status. In two cases, TRI indicated a better ecological status than BRI. Spearman's correlation between both indices was insignificant ( $r=0.096$ ). The highest total fish abundance was found at the affected site VCH 34-1, in which the less tolerant native species *Barbus cyclolepis* Heckel, 1837 predominates.

As it can be tracked out from a cluster analysis, there is no clear association of the sampling sites depending on their altitude or site quality (referent/dam/affected) (Fig. 2). Simpson's index showed similarity of the most of the sampled sites, except the site in the dam lake (VDAM) and that one situated most downstream (VCH39-1) based on the species composition (Table 2). This is clearly connected with the predomination of *Salmo* sp. and *B. cyclolepis* in most samples.

## Discussion

The natural distribution of the fish fauna along the river continuum in Bulgaria does not follow the pattern described by HUET (1949) due to above-mentioned reasons. Moreover, a fish zonation relevant to this part of the Balkan Peninsula has not been developed. The adopted division to "trout zone"



**Fig. 2.** Cluster analysis according to the total fish abundance in the ten sampling sites along the Vacha River, South Bulgaria, during 2019.

**Table 2.** Simpson’s Similarity Index based on the species composition of the sampling sites in the Vacha River in 2019.

VCH32-1	VCH33-1	VCH34-1	VCH35-1	VCH36-1	VCH37-1	VCH38-1	VCH39-1	VDAM	Code
1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	VCHD31-1
	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	VCH32-1
		1.00	1.00	1.00	0.50	1.00	0.50	0.00	VCH33-1
			1.00	1.00	1.00	1.00	0.33	0.00	VCH34-1
				1.00	1.00	1.00	0.33	0.00	VCH35-1
					1.00	1.00	0.33	0.00	VCH36-1
						1.00	0.00	0.00	VCH37-1
							0.33	0.00	VCH38-1
								0.14	VCH39-1

and “cyprinid zone” for Bulgarian rivers (MOEW Ordinance №4/20.10.2000 and amendments; see also CHESHMEDJIEV & MARINOV 2008) is beyond accuracy. Therefore, the assessments are often based on a solid portion of the expert judgement. For this purpose, a specific fish zonation has been proposed for the Vacha River (Table 3).

**Our data demonstrate:**

- (1) Presence of rheophilic, migratory, sensitive cyprinids (*Vimba melanops* Heckel, 1837; *Chondrostoma vardarensis* Karaman, 1928) in the Vacha Reservoir at 542 m a. s. l. and their absence from all other lotic sites;
- (2) Some native (e.g. *Rhodeus amarus* Bloch, 1782, *Perca fluviatilis* L., 1758) and two alien species

**Table 3.** Fish zonation of the Vacha River against that of the normal river continuum (R3 and R5 types – still not standardised).

Altitude (m a. s. l.)	Normal continuum	Registered zones
Above 800	trout zone	trout zone
800-550	transitional zone 1	transitional zone 1
550-200	rheophilic cyprinid zone	transitional zone 1
200-150	transitional zone 2	transitional zone 1
150 – estuary	transitional zone 2 or lower course cyprinid zone	altered transitional zone 2 + aliens

(*Lepomis gibbosus* L., 1857 and *Pseudorasbora parva* Temminck & Schlegel, 1846) appearing near the mouth as typical inhabitants of the lower cyprinid zone.

The attributed guilds of the European fish species as used to calculate the European Fish Index (EFI) are presented in Table 2 of Annex IV of the manual (BREINE et al. 2004). The first trout zone is accepted according to CHESHMEDJIEV & MARINOV (2008). The next fish zones were determined based on the species found at the given altitude, e.g. the native rheophilic cyprinids are present at 542 m a. s. l.

The River Management Plan (2016–2021) of the East-Aegean River Basin Directorate (EARBD) reported the ecological status of the Vacha River and dams as “Good” based on the Biological Quality Elements. However, only 30 % of the sampling sites in 2019 confirmed the good state. Dams modify hydro-morphological and hydrological conditions in the Vacha River, which led to a non-typical fish community with essential domination of *Salmo* sp., even in the cyprinid zone close to the mouth. The improvements of biological characteristics of trout populations, which are due to connectivity restorations, are well known (BIRNIE-GAUVIN et al. 2018). A similar situation has also been recorded from the middle course of the Ogosta River (downstream the Ogosta Reservoir, Bulgaria) at 150 m a. s. l. (KAZAKOV et al. 2022). Our results (Table 1) correspond to those of POUILLY et al. (2006), which noted that the trophic composition is more diverse at lower altitudes; in our case, the Spearman’s correlation value, connecting altitude and species diversity, is -0.67. The results of cluster analysis (Fig. 2) opposed to the statement by POUILLY et al. (2006) showing loose connection between the altitude and the total abundance. These observations point out the disconnection between the total abundance and the species diversity (Table 1). The peculiar ab-

sence of the relatively tolerant *Squalius orpheus* Kottelat & Economidis, 2006 from almost all samples is also an indication for the deterioration of the local fish community. In general, the “Good” status alternates to “Moderate”, without smooth transition from one to other (see index values in Table 1). Moreover, TRI is higher for an affected site in one case if compared to the referent site. The supreme domination of the trout and the secondary domination of the barbel on other species at 569 m a. s. l. as well as taking into account the river typology, it can be concluded that the normal fish zonation as a basis for the ecological integrity (AARTS & NIENHUIS 2003) is disturbed and reflects the heterogeneous ecological status.

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