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Composition and structure of benhtic macroinvertebrate communities in watercourses of Donji Vakuf

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Abstract

Zoobenthos are one of the most significant communities in aquatic habitats. Remediation of aquatic ecosystems depends on maintaining a healthy zoobenthos community. The first step in restoring aquatic ecosystems is to understand the hydrology and water quality parameters that influence zoobenthos variation. Based on field sampling of the river zoobenthos in the watercourses of Donji Vakuf, the current study used principal component analysis to identify the key habitat elements affecting zoobenthic communities. Bray-Curtis similarity was used to compare analyzed zoobenthic communities. The findings in this study demonstrate that water temperature, dissolved oxygen, total Phosphourous and total Nitrogen were the main physical and chemical water quality parameters affecting the zoobenthic populations in investegated watercourses. The highest similarity of analyzed macrozoobenthos communities was observed between Semešnica river and Sokolinski stream. All of the approaches described in this work can be used for studies on different communities, such as fish, algae, and zooplankton in aquatic ecosystems. Managers can use the techniques and findings in this report as important references to safeguard and revitalize deteriorated water ecosystems.

Keywords: *macrozoobenthos, Donji Vakuf, Bosnia and Herzegovina, physical and chemical parametars of water, PCA*

1. Introduction

Macrozoobenthos is a community of macroscopic invertebrates that inhabit the bottom area of aquatic ecosystems (Rosenberg, 1992). They size from 200 to 500 μm. The largest number of aquatic invertebrates are insects that are bound to aquatic habitats through the larval stage, and adult individuals live on land. Only a few representatives spend their entire time life in aquatic ecosystems (e.g. beetles) (Giller & Malmqvist, 1998). Their spatial distribution and composition are determined by the number of abiotic (e.g. oxygen concentration, temperature, pH, conductivity, substrate, etc.) and biotic factors (e.g. predation, interspecies and intraspecies competition) (Trichkova et al., 2013).One of the five biological elements of water quality on the basis of which is determined ecological status of surface waters is macrozoobenthos. Macrozoobenthos is an important part of the food chain and is one of the key biological quality elements in the assessment of the ecological status of streams. Due to the relatively long lifespan and limited mobility, major or minor changes in ecological conditions in the environment, such as changes in the physical properties of water (flow rate water, temperature, light), chemical properties of water (amount of nutrients, oxygen and carbon dioxide), and seasonal and daily changes in water flow regime result change in the qualitative and quantitative structure of the benthic communies. It is convenient to be used because it can be collected relatively easily with available equipment. Taxonomy of most groups is well known, determination keys are available, and many methods have been developed for data analysis. The response to different types of pollution is also known to most common species (Rosenberg & Resh, 1993).The research objectives of this paper are to analyze the composition of the macrozoobenthos community of the watercourses in Donji Vakuf minicipality and compare the composition and structure of communities and determine the spatial differences of the community macrozoobenthos of the investigated rivers. Based on qualitative and quantitative composition community of macrozoobenthos, compare abiotic factors with macrozoobenthos communities and determine their association.

Geographically, the municipality of Donji Vakuf is located in the upper reaches of the Vrbas River, in the central part of Bosnia and Herzegovina and belongs to

the Central Bosnia Canton. It is located at the intersection of the main roads Travnik - Donji Vakuf - Jajce and Travnik - Donji Vakuf - Bugojno. The length of the border is 93 km, and it borders the municipalities of Jajce, Šipovo, Kupres, Novi Travnik and Travnik. The area of the municipality of Donji Vakuf is 323.7 km^2. It is divided into 13 local communities with 64 settlements.

According to the basic physiographic conditions, in general, the Vrbas river basin is divided into three parts: 1. upper stream - from the source to Jajce, it is characterized by a steep slope and the characteristics of the mountain stream; 2. middle course - from Jajce to Banja Luka, the presence of limestone canyons with a pronounced fall of the riverbed; 3. lower course - from Banja Luka to the mouth of the Sava, where it flows through the alluvial plain, and is a typical lowland river with a small slope and meandering (Trožić-Borovac, 2015).

In the area of the municipality of Donji Vakuf, the hydrographic network of surface flows is extremely developed. The largest watercourse is the river Vrbas, which flows through the municipality a length of 31 km. The largest tributaries of the Vrbas River are: Semešnica, Prusačka, Oboračak, Sokolinska, Čehajićka rivers, Sandžački, Babin, Barički potok and Volušnica. The area of the municipality in the northeast is partly tangled with the Lašva basin and in the northwest by the Pliva basin. In addition to surface flows, very large groundwater reserves are also known (Figure 1.).

2. Material and Methods

Physico-chemical parameters were measured and macrozoobenthos was sampled in June of 2021 in watercourses of Donji Vakuf municipality at 5 sites. The field research included two sampling sites at Vrbas River and by one site at Semešnica, Sokolinski potok and Prusačka rivers (Figure 1.).

The physico-chemical parameters of water that were measured are pH value, concentration and saturration of dissolved oxygen, water temperature, electrical conductivity and total concentrations of Nitrogen and Phosphorous. Water temperature, concentration and saturration of dissolved oxygen, electrical conductivity and pH were measured by portable WTW 330 set. A cuvette test (Hach Lange method - LCK 138) was used to analyse surface water for total nitrogen and phosphorus content.

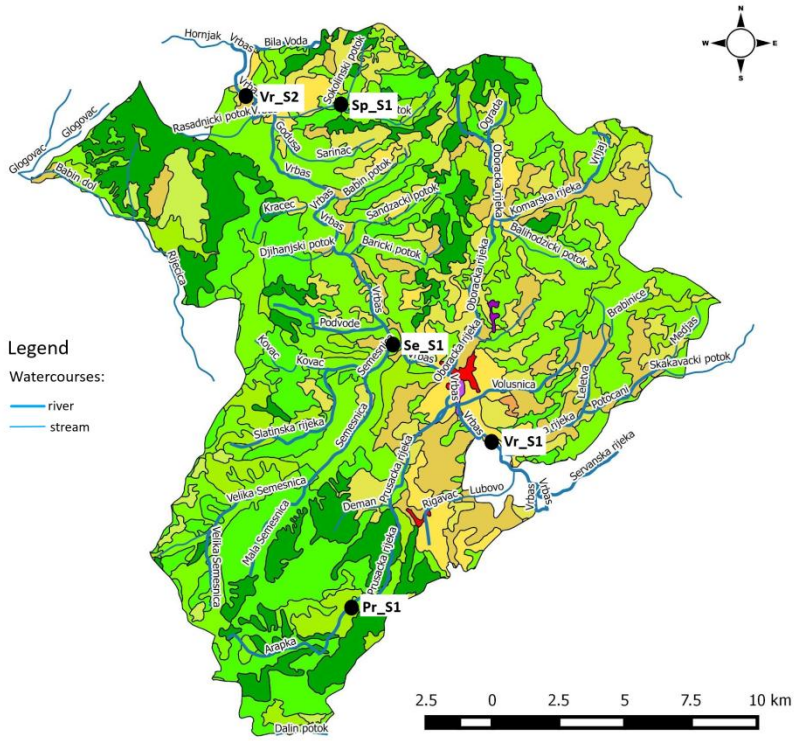

Figure 1. Study area (black circles represent sampling sites)

Macrozoobenthos was sampled by hand benthos i.e. Surber mesh, mesh size 150 µm, area 0.1 m^2. Samples were collected in June of 2021. A sampling of macrozoobenthos involved movement through water where conditions allow for this and zigzag collection of macrozoobenthos upstream along the transect. At each measuring station (location) we took ten subsamples from different microhabitats. After sampling each sample was decanted with a bucket and benthos to reduce it volume of sediment, and large stones were removed. The collected samples were placed in plastic bottles wide-mouthed and preserved with 4% formaldehyde. Inside and outside each bottle labels with station information and sampling date were placed. Isolation of macrozoobenthos from samples was first approached in the laboratory. Isolation of samples was done so that part by part of the sample was transferred to a petri dish and observed under a magnifying glass. All found individuals were separated into special vessels with 80% ethanol. After isolation, determination of each group to the smallest possible extent was performed at taxonomic levels. Determination is done using different determination keys inspecting specimens beneath the Olympus SZX10 stereozoom microscope. The keys used on the occasion

determinations were: Belifore (1983), Consiglio (1980), Nilsson (1996, 1997), Waringer & Graf (2011). All samples were preserved in 80% ethyl alcohol and stored in the zoological collection of the Faculty of Natural Sciences and Mathematics, University of Sarajevo.

A cluster comparison of the composition and structure of macrozoobenthos between rivers was performed. The matrix contains the values of the Bray - Curtis similarity index calculated from logarithmically transformed densities of individuals of individual taxa of all samples. Analyzes were done using the computer package Primer 6.0 (Clarke and Gorley 2006, Clarke and Warwick 2010).

3. Results and Discussion

During the study, water temperature ranged from 10.1 °C to 12.7 °C (Table 1.). The lowest water temperature value of 10,1 °C was measured at the Sokolinski potok, and the highest of 12,5 °C was measured at site 2 in Vrbas River. The concentration of dissolved oxygen did not appreciably vary at all sampling sites. Oxygen concentration ranged from 10,2 to 12,6 mg/l at investegated sites. Oxygen saturation at all sites did not fall below 98% (Fig. 4). The lowest measured conductivity of water was at Vrbas River (Vr_S1) and the highest at Prusačka River (Pr_S1). Values of pH ranged from 7,5 at Vr_S2 site to 8,4 at Semešnica River. The lowest and the highest values of total nitrogen and total phosphorus content were at the same sampling sites. The lowest values were at Sokolinski potok and the highest at Vrbas River sampling site 2.

The macrozoobenthos in the watercourses of Donji Vakuf has a comparatively high degree of variety. A total of 343 animals were collected during field sampling. There were 22 distinct macroinvertebrate taxa identified (Figure 2.). Samples of macroinvertebrates were taken from a variety of microhabitats, including moss, submerged plants, fine sand, fine pebbles, and algae that covered the cobbles.

At sampling site Vr_S1 a total of 40 speciements were collected in 6 different taxa. The lowest number of taxa and individuals were registered at this site. Unlike this site, at second sampling locality on the Vrbas River, 17 different taxa were recorded with total of 98 individuals. The biggest abundance at this site had Ephemeroptera with 54 individuals. Macrozoobenthos communities in other investegated rivers were similar. In samples collected from Prusačka River there were total of 92 specimens and 7 different taxa. The most abundant taxa are *Gammarus fossarum* with 53 individuals. High numbers of individuals were

recorded in Ephemeroptera and Trichoptera. The most abundant species in Semešnica River was *G. fossarum*. Specimens collected from this river belong to 10 different taxa. Collected benthic macroinvertebrates from the river Sokolinski potok belong to 9 taxa. Equal abundance is recoded for *G. fossarum* and *Baetis sp*. Other recorded taxa were less abundant.

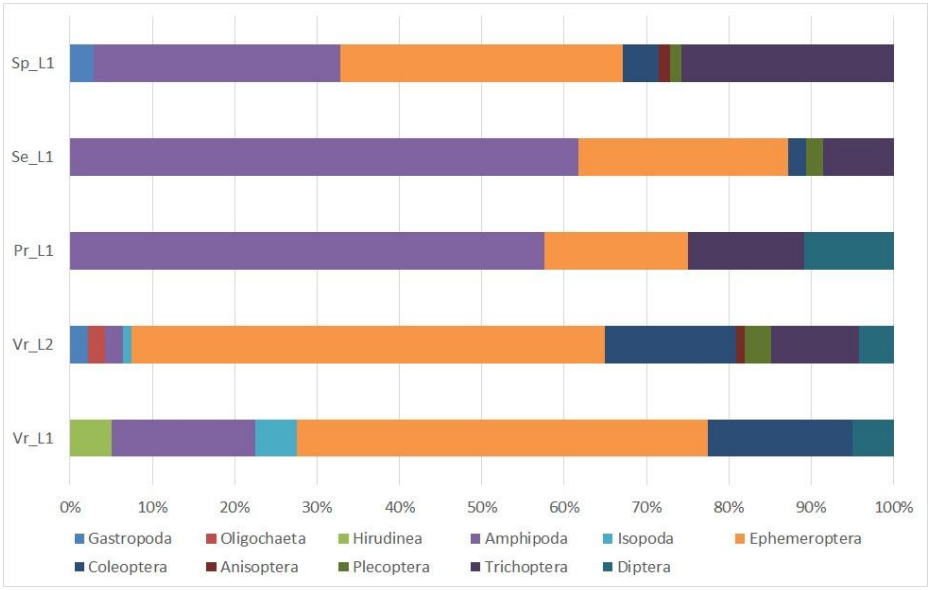

Figure 2. Relative abundance (%) of all major taxa macroinvertebrates in river communities. Vr_S1 – Vrbas river site 1, Vr_S2 – Vrbas river site 2, Pr_S1 – Prusačka river site 1, Se_S1 – Semešnica site 1, Sp_S1 – Sokolinski stream site 1

Each species occupies a distinct niche, the scope of which is in part determined by how well the organisms adapt to their surroundings. However, one or more key habitat characteristics frequently have a significant impact on an organism's ability to survive. Analysis of the primary zoobenthos habitat factors is crucial for their protection (Zhao, Pan, Wang, Shao, Sun & Zhang, 2020).

Pearson correlation matrix shows a significant correlation between TP and TP with WT, also TP and TN are significantly correlated (Table 2). DO is negatively correlated with WT and TN. NT is not significantly correlated with any of the tested variables. The strongest correlation number of taxa has with TN, and it is negatively correlated with altitude and concentration of dissolved oxygen (Table 2; Figure 3A).

Analyzed variables at all investigated sites show that Semešnica and Sokolinski stream have the most similar ecological conditions. Prusačka river, and two

sites at River Vrbas have uniqe ecological conditions for development of zoobenthos communities (Figure 3B). Among analyzed physical and chemical parameters of water in this study water temperature, dissolved oxygen, total Phosphourous and total Nitrogen had relative significance in distribution of species. Water temperature has high influence in distribution of alpine aquatic organisms (Barnes, 2017). According to Carter, Resh & Hannaford (2017), a stream's width and depth, flow rate, water temperature, and meteorological conditions can all be used to construct a reasonable stream study. Conductivity is frequently taken into account when measuring the quality of water, such as pH. According to Mahboob et al. (2014), a decrese in pH at high river discharges may cause metal complexes to be released into the river and streams, which could be hazardous to the ecosystem's zoobenthos. Similar conclusions on the impacts of physical and chemical parameters of water on zoobenthos have been made by numerous other researchers (Sponseller, Benfield & Valett, 2001; Zhao et al., 2015).

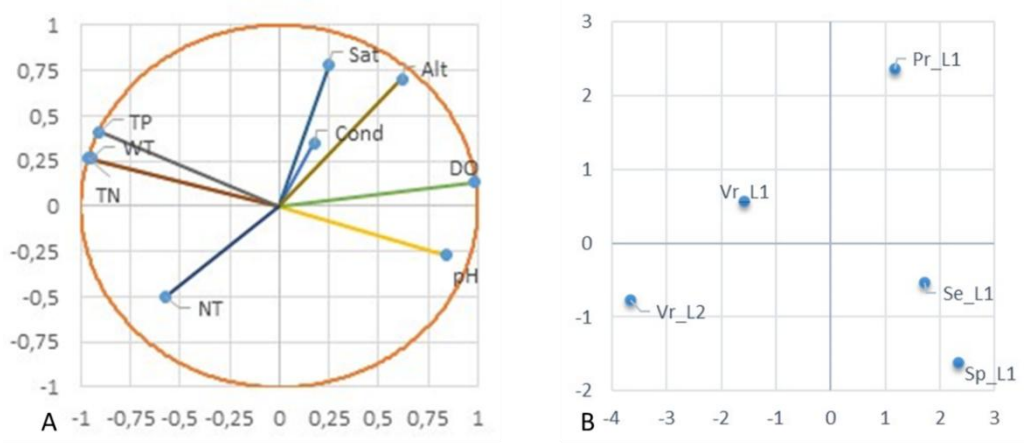

Figure 3. Principal component analysis on the normalized physical, chemical, and biological values: A) Correlation circle. B) Observations chart; WT – water temperature, pH – values of pH, Cond – conductivity, DO – dissolved O2, Sat – saturation of O2, TN – total nitrogen, TP – total phosphorous, NT – number of taxa. Vr_L1 – Vrbas River site 1, Vr_L2 – Vrbas River site 2, Pr_L1 – Prusačka river site 1, Se_L1 – Semešnica site 1, Sp_L1 – Sokolinski stream site 1

One of the aims of the paper is to analyze the composition of the macrozoobenthos communities of the rivers in area of Donji Vakuf and compare the composition and structure of communities and determine spatial differences in the composition and community structure of macrozoobenthos of the investigated rivers. To compare the composition of communities macrozoobenthos between rivers, we used cluster similarity analysis for each river separately.

Cluster similarity analysis leads to the conclusion that there is a significant difference in composition and structure of macrozoobenthos between the investigated rivers. But there is a lot of similarities in the composition of macrozoobenthos between Semešnica and Sokolinski potok rivers (Figure 4.). This could be because similar ecological conditions in these two rivers, as mentioned before.

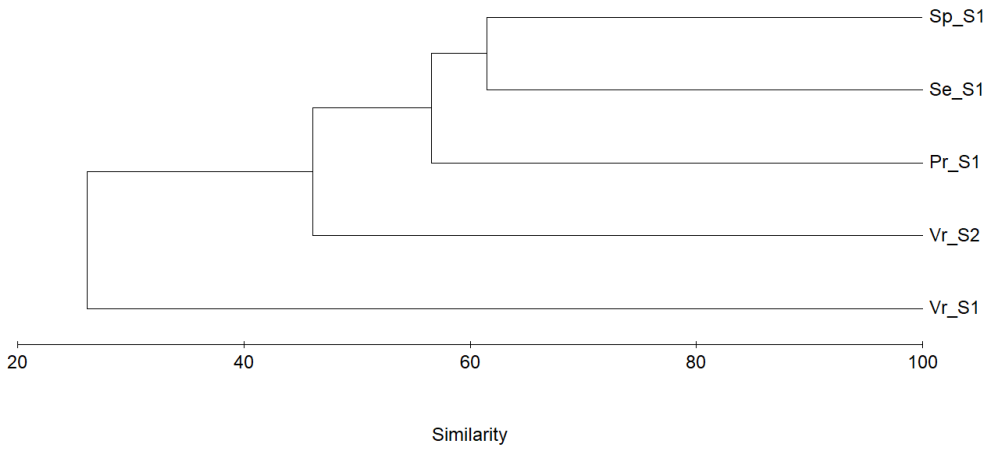

Figure 4. Similarity of species composition between sampling sites by cluster analysis based on matrix similarity of Bray-Curtis: Vr_S1 – Vrbas River site 1, Vr_S2 – Vrbas River site 2, Pr_S1 – Prusačka river site 1, Se_S1 – Semešnica site 1, Sp_S1 – Sokolinski stream site 1

4. Conclusions

Based on the data of benthic fauna in watercourses of Donji Vakuf, this study used PCA method to study the main environmental factors (hydrological and water quality factors) affecting benthic fauna. Four main environmental factors were obtained by PCA sequencing, among which the physical parameters of water quality were pH and water temperature, and the chemical parameters were total Nitrogen and total Phosphorous. Based on cluster similarity analysis Sokolinski stream and Semešnica river have similar benthic fauna.

The techniques utilized in this research can serve as a guide for managers looking to safeguard and repair of deteriorated aquatic habitats. However, monitoring of water ecosystems must be done over an extended period of time since there is a short-term inevitability of ambiguity. Future studies might include additional aquatic communities like fish and algae.

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