

**MACROZOOBENTHOS AS AN DETERMINANT OF ECOLOGICAL STATUS  
OF THE BOSNA RIVER**

**Makrozoobentos kao determinanta ekološkog statusa rijeke Bosne**

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**Abstract**

The paper presents the distribution and diversity of macrozoobenthos composition of Bosna river up to Zenica, from 1999 to 2010. Macrozoobenthos has been chosen as an element of bioevaluation of the ecological state of running water, and according to the provisions of the Water Framework Directive. Sampling has been done by using the kick-sampling and multihabitat method, a standard for hydrobiological research. The highest diversity of macrozoobenthos has been found in samples from the sites Rimski most (36 taxa), and the lowest was at site of the Bosna river upstream from the mouth of Ljubina river and downstream of the mouth of the Zgoča river (4 taxa). According to abiotic conditions which directly affect the composition of macrozoobenthos, and using Bray-Curtis similarity, the highest degree of similarity has been found in sites which are spatially near. Taxa number and EPT taxa number were highly correlated ( $R^2 = 0,871$ ). Saprobic index and BMWP index were calculated in assessing the ecological status of the river Bosna at the study sites. The values obtained comparing EPT taxa number and BMWP index show a high correlation ( $R^2 = 0,706$ ). The composition and the distribution of the macrozoobenthos in the Bosna river are conditioned by abiotic parameters. Sites upstream of the mouth of the Ljubina river and downstream from the mouth of the Zgoča river represent the places with the highest pollution which is the result of point and diffuse sources of pollution.

**Key words:** *biotic index, BMWP index, Water Framework Directive, freshwater ecosystem*

**INTRODUCTION - Uvod**

The Bosna rivers springs out at 492 m a.s.l. with a large number of rheocrene springs at the southwestern part of Sarajevsko polje. It declines into a shallow valley, flowing shortly through Sarajevsko polje in the north-western direction, and then, it flows mainly up north until Dobož, where it flows in the north-eastern direction until its confluence with the Sava river near Bosanski Samac. The length of the Bosna river is 271 km and it is 10 to 30 m wide with the average depth of 2 meters. The part of the

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river up to the town of Zenica has a terrain of rugged landslides and narrow valleys, and when exiting Sarajevo the river is surrounded with surface quarries and pits (KACANSKI ET AL. 1980). The climate of the area up to Zenica ranges from premountain until Kakanj, where, around the mouth of the La-va river, it passes into a typical humid continental climate. The geological base in the area of the Bosna river is carbonate, with three types of rocks: permeable, highly permeable and poorly permeable rocks.

The waterbed of the Bosna river is under the high pressure from both point and diffuse sources of pollution. Activities ranging from building motorways, power plants etc. further undermine already disrupted state of this aquatic ecosystem. By running the Water Framework Directive (EU, 2000), a key goal is to achieve at least 'good' ecological state/potential until 2015 for every water body. Bosnia and Herzegovina is still implementing the provisions of this directive. Evaluation of the ecological status of water bodies is based primarily on biological quality elements with accompanying physical and hydromorphological elements. One such element is macrozoobenthos that can adequately give the assessment of river ecosystems' state. Organisms of the macrozoobenthos are an important part of the biology of freshwater ecosystems. Especially significant part is the ecology of certain taxa, and the variety of reactions to changing abiotic conditions. Because of their fast reaction to the changes of physical and chemical parameters, they give the most objective view of the ecological state in aquatic ecosystems. Macrozoobenthos species composition gives reliable information for concluding the general state of the aquatic ecosystem. They are actively included in the process of circulation of organic matter and energy flow in the aquatic ecosystems, and are consequently connected and dependent on the primary decomposers and primary producers. They are used for over 100 years for the assessment of the state of running waters (CAIRNS & PRATT, 1993). The life span in water, taxonomic diversity and susceptibility to all kinds of stresses are all reasons for their role of the leading component in the bioassessment programme (HELLAWELL, 1977; FURSE ET AL. 2006).

The main goal of this research was to determine the ecological state of the Bosna river based on the composition and distribution of macrozoobenthos with the application of different indices and determining their suitability.

The goal includes the following tasks:

- a) Determining the distribution and diversity of macrozoobenthos at the sites of the Bosna river
- b) Determining the degree of similarity/differences of ecological conditions of different sites of the Bosna river using the Bray-Curtis similarity index
- c) Determining the degree of correlation between the values of the saprobic index and BMWP index in the assessment of the ecological status of the

Bosna river, based on the macrozoobenthos composition in the samples taken from 7 sites.

### **MATERIALS AND METHODS – *Materijal i metode***

The sampling was conducted in the period between 1999 and 2010. The research sites range from Rimski Most to downstream of the mouth of the La-va river which covers 80km of area of the river (Table 1).

Table 1. The research sites on the Bosna river

*Tabela 1. Lokaliteti istraživanja na rijeci Bosni*

<b>Site</b>	<b>Meters ASL</b>
L1 Rimski most	494
L2 Upstream from the mouth of the Miljacka river	492
L3 Upstream from the mouth of the Ljubina river	490
L4 Downstream from the city of Visoko	420
L5 Downstream from the mouth of the Zgo- a river	385
L6 Upstream from the mouth of the La-va river	350
L7 Downstream from the mouth of the La-va river	345

Sampling was carried out by using the kick-sampling methodology and the samples (360) are fixated in 4% formalin in the field and further inspection was carried out in the laboratory of the Faculty of Science, Sarajevo. Insect larvae and other collected macroinvertebrates were identified to genus or species level with the aid of pertinent literature ( REYNOLDSON, 1978; KOSEL, 1989a; 1989b; STUDEMANN AT ALL., 1992; HYNES, 1977; ILLIES, 1955; FREUDE ET ALL. 1971; WAR NGER & GRAF, 1997; BRUND N, 1983).

Data on qualitative and quantitative composition were used for the assessment of the saprobic index by Pantle-Buck, 1955 and BMWP index (KAZANCI ET AL. 2013). The values obtained were used to analyze the correlation between the two applied indexes.

Hierarchical clustering of the zoobenthos communities was done using Bray-Curtis similarity distance (BRAY & CURTIS, 1957). Within which is a group average linkage method used for forming clusters or groups of most similar samples. The ecological statistical package PRIMER 5 was used.

Correlation analysis suggests that one factor changes similarly to another. The analysis of the parameters was carried out according to the general model of simple linear regression:

$$\hat{y}_i = a + b x_i$$

Statistical analysis was done using MS Excel (PAPIC, 2012).

### RESULTS - *Rezultati*

Based on the analysis of qualitative and quantitative macrozoobenthos composition of the Bosna river from Rimski Most to downstream of the mouth of the La-va river, the greatest diversity of 36 taxa was found in the samples from the site of Rimski most (Graph 1). The lowest diversity was found in the samples from the site upstream from the mouth of the Ljubina river (12 taxa). Higher number of taxa is registered in the samples from the site upstream from the mouth of the La-va river (26 taxa) and downstream from the mouth of the La-va river (25 taxa).



Figure 1. The number of taxa in the composition of macrozoobenthos of the Bosna river from Rimski Most to downstream of the mouth of the La-va river

*Grafikon 1. Broj taksa u sastavu makrozoobentosa rijeke Bosne od Rimskog mosta do nizvodno od ušća Lašve*

A high correlation ( $R^2 = 0,871$ ) between the total number of taxa in the composition of macrozoobenthos (Graph 2) and the number of EPT taxa (Ephemeroptera, Plecoptera and Trichoptera). With increasing the total number of taxa, the increase in number of taxa of EPT groups was noted. The site Rimski Most stands out with the highest number of taxa ó 36. furthermore, 50% of them are the species from the 3 groups (EPT groups). The lowest number was noted in the samples from the site upstream from Ljubina (4) and downstream from Zgo-ca (4).

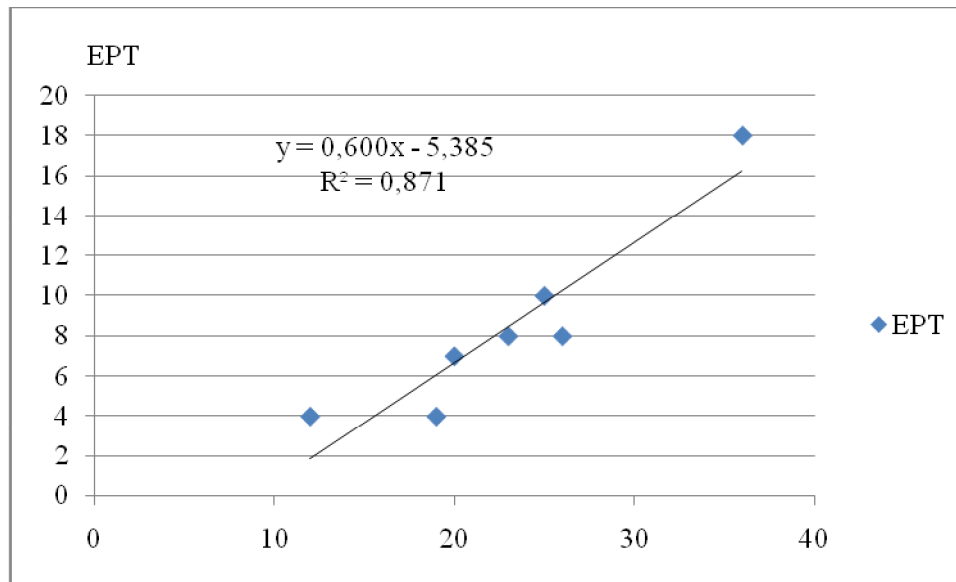


Figure 2. Total taxa number (UBT) correlation in the macrozoobenthos composition of the sites on the Bosna river and EPT taxa

Grafikon 2. Prikaz korelacije ukupnog broja taksa (UBT) u sastavu makrozoobentosa lokaliteta na rijeci Bosni i EPT taksa

#### **Similarity/dissimilarity index Bray-Curtis, 1957**

According to the degree of similarity, 3 groups stand out (Fig. 1) and the sites upstream from the mouth of the Miljacka river, upstream from the mouth of the Ljubina river and downstream from the mouth of the Zgo- a river make one group. The highest degree of similarity is within the composition of macrozoobenthos of the following sites: upstream from the mouth of the La-va river, downstream from the mouth of the La-va river and downstream from the mouth of the Zgo- a river. They represent the second group of sites. The site Rimski Most shows the highest degree of dissimilarity compared to all other sites and represents the third group. All sites within one group are territorialaly close which affected the obtained results.

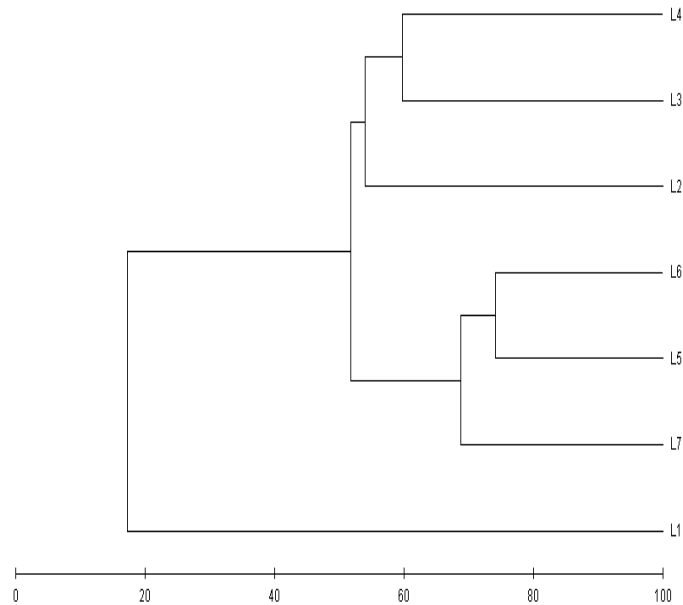


Figure 3. The values of Bray-Curtis index (group average linkage) for the macrozoobenthos composition in the samples from the sites of the Bosna river during the period between 1999 and 2010

*Slika 3. Vrijednosti Bray-Curtis-ovog indeksa (povezivanje po prosjeku grupa) za sastav makrozoobentosa u uzorcima na lokalitetima rijeke Bosne tokom 1999 – 2010. godine*

### ***Saprobic index and BMWP index***

The application of the saprobic index for the assessment of water quality of the Bosna river at the sites researched has determined that the value varies from 1.68 at Rimski Most up to 2.85 at the site upstream from the mouth of the Ljubina river (table 2). The only site that stands out for its ecologically good state is the site at Rimski Most, while the impact of waste water pollution and other sources was registered at other sites. The values of BMWP index varied from 129 at Rimski Most which points to a preserved habitat, up to 41 at the site upstream from the mouth of the Ljubina river which indicates the intensified impact and place of the greatest pollution. Both indices point to sites with increased stress for aquatic ecosystem of the Bosna river.

Table 2. Values of the saprobic and BMWP indices for the composition of macrozoobenthos at the researched sites of the Bosna river

*Tabela 2. Vrijednosti saprobnog i BMWP indeksa za sastav makrozoobentosa na istraživanim lokalitetima rijeke Bosne*

Localities	BMWP index		Saprobic index - SI	
	value	category	value	category
Bosna-Rimski most	129	I	1,68	I-II
Upstream from the mouth of the Miljacka river	96	II	2,17	II
Upstream from the mouth of the Ljubina river	41	III	2,85	III
Downstream from the city of Visoko	93	II	2,26	II
Downstream from the mouth of the Zgo- a river	49	III	2,39	II-III
Upstream from the mouth of the La-va river	92	II	2,23	II
Downstream from the mouth of the La-va river	114	I	2,30	II

The representation and distribution of the families of the macrozoobenthos with a tolerable value (ARMITAGE ET AL.1983, HELLAWEL, 1986) can be seen in table 3, as well as a great diversity of snails present in large abundances of populations in the samples of benthos at the site upstream from the mouth of the La-va river. The high density of oligocheta and insects of the family Chironomidae was found in most sites, while the greatest number of oligocheta is noted upstream from the mouth of the Miljacka river (2270 individuals). A greater number, as well as the diversity of leeches (Hirudinea) has been noted and they are present in the samples from all sites. 14 families from the EPT groups (Ephemeroptera, Plecoptera i Trichoptera) have been noted and they are mostly present in the samples from the site Rimski Most (Baetidae, Heptagenidae, Ephemerellidae, Siphonuridae, Perlodidae, Leuctridae, Limnephilidae, Odontoceridae, Leptoceridae i Sericostomatidae).

Table 3. the distribution of the families of macrozoobenthos by the sites of the Bosna river and tolerable values for taxa

Tabela 3. Distribucija familija makrozoobentosa po lokalitetima rijeke Bosne i tolerantne vrijednosti za takse

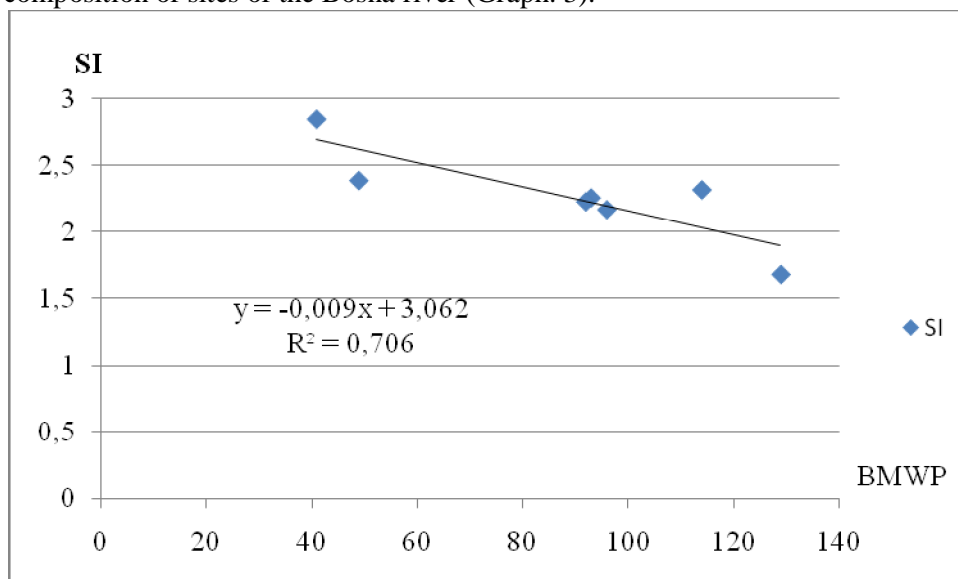
Tolerable value	TAXON	Bosna at Rimski Most site	Upstream from the mouth of the Miljacka	Upstream from the mouth of the Ljubina	Upstream from the mouth of the Visoko	Downstream from the city of Zgo-e	Bosna after mouth of the La-va	Bosna Upstream from the mouth of the La-va	After the mouth of the La-va
5	Planaridae	+							
5	Dugesiiidae				+	+			
6	Ancyliidae	+	+		+				+
3	Melanopsidae				+	+	+		+
3	Bythinidae	+							
3	Planorbidae						+		
3	Lymnaeidae	+							
6	Neritidae					+	+		+
3	Valvatidae	+							
6	Viviparidae		+	+					
3	Sphaeriidae		+				+		+
6	Unionidae		+						
	<b>OLIGOCAHET</b>								
1	<b>A</b>	+	+	+	+	+	+		+
3	Erpobdellidae	+	+	+	+	+	+		+
3	Glossiphoniidae		+	+	+	+	+		+
6	Gammaridae	+	+						+
3	Asellidae	+	+		+				
4	Baetidae	+		+	+	+	+		+
4	Caenidae				+		+		
10	Leptophlebiidae				+				
7	Ephemerellidae	+	+		+		+		+
8	Heptageniidae	+	+						+
10	Siphonuridae	+	+						
9	Perlodidae	+	+		+		+		+
9	Leuctridae	+			+				
7	Limnephilidae	+	+	+					+
10	Goeridae								+



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5	Hydropsychidae		+	+	+	+	+	+	
10	Leptoceridae						+		
10	Odontoceridae	+							
10	Sericostomatidae	+						+	
5	Dytiscidae	+							
5	Eminthidae;	+	+						
2	Chironomidae	+	+	+	+	+	+	+	
5	Limoniidae	+		+	+	+	+	+	
5	Simuliidae			+	+		+	+	
4	Tabanidae				+		+		
5	Tipulidae	+			+			+	
6	Gomphidae		+			+	+	+	
6	Cordulegastridae						+		
5	Calopterygidae					+	+		
<b>Total</b>	<b>BMWP</b>		<b>129</b>	<b>96</b>	<b>41</b>	<b>93</b>	<b>49</b>	<b>92</b>	<b>114</b>

By calculating the correlation, a close connection ( $R^2 = 0,706$ ) was noted between BMWP values and values of saprobic index for the macrozoobenthos composition of sites of the Bosna river (Graph. 3).



Graph 3. Correlation between the values of Saprobic index (SI) and BMWP index for the composition of macrozoobenthos of samples at sites of the Bosna river

*Grafik 3. Korelacija između vrijednosti saprobnog indeksa (SI) i BMWP indeksa za sastav makrozoobentosa uzoraka na lokalitetima rijeke Bosne*

## **DISCUSSION - *Diskusija***

The use of different elements in the assessment of the status of aquatic ecosystems dates over a century, but since the year 2000 with the establishment of Water Framework Directive, the construction of unified system has begun. However, it is open for adaptations in respective countries. Basic provisions are aimed at finding ways of establishing aquatic ecosystems of good status / potential, and consequently carrying out monitoring which will give an objective view of thze status. Countries in the region are already at the end of these provisions, particularly EU countries, especially Slovenia (URBANIC, 2012).

Macrozoobenthos, with its taxonomic composition and autecology of certain species, is one of the most important biological elements of teh provision of ecological state/potential of aquatic ecosystems.

There is a lot of data about the composition and distribution of macrozoobenthos in the waters of BiH, but there is still not enough published literature data about this component. In the composition of macrozoobenthos of the Bosna river, a great diversity of eurivalent taxa (Oligochaeta, Chironomidae, Hirudinea, Gastropoda) stand out. They dominate the macrozoobenthos composition (ЉENK, 1956, KA ANSKI & RATKOVI , 1983, JERKOVI ET ALL.1987, TROŽI -BOROVAC, 2002). According to the results presented, the sites of confluence of waste waters had higher degree of degradation. At the site of the Bosna river upstream from the Ljubina river anegativ influence of the mouth of the Miljacka river can be seen, where the lowest number of taxa of macroinvertebrates was registered in the samples, and the values of both indices point to pollution and changed ecological conditions. The second site is after the mouth of the Zgo– a river which, receives all waste waters of Kakanj and that is consequently reflected in a low biodiversity, muddy sediment and water odour. Saprobic index has been used in our country for more than 50 years for the water quality assessment, but the use of biotic indices, primarily of BMWP index, was determined by the regulation by the country authorities. Comparison of values of these two indices indicated a high degree of correlation, confirming its applicability. For BiH it is necessary to modify the saprobic and tolerable values according to the ecological circumstances because that will largely eliminate the drawbacks of their application. The Bosna River requires far more extensive analysis due to conducting intense negative activities. The area of the Bosna river at the site Rimski Most suffers a greater antropogenic pressure, which likely reflects on overall state of this river downstream. Management of ecosystems is possible only with ecosytemic approach which will include all the elements relevant to functioning and undisturbed energy flow and organic matter circulation.

## **CONCLUSIONS - Zaključci**

At seven sites of the Bosna river during the period from 1999 to 2010, a great diversity in macrozoobenthos composition has been determined with the emphasis on the site of Rimski Most. A relatively high relation between the total number of macroinvertebrate taxa and the number of EPT group has been determined, which indicates that a high diversity reflects auspicious existence. By comparing the values of the saprobic index with BMWP index, a high correlation is noted which points to the objectivity of the application of these two indices in the evaluation of the ecological status of our countries running waters. Macrozoobenthos, in combination with hydromorphological parameters, finding the adequate index, can objectively point to the ecological state of the stream of the Bosna river.

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## SAŽETAK

Rijeka Bosna je u prošlosti bila istraživana sa aspekta stupnja degradacije i analize abiotskih i biotskih parametara (KAMANSKI ET AL. 1980, JERKOVIĆ ET AL. 1987, TROŽIĆ - BOROVIĆ, 2002). Dosadašnji podaci ukazivali su na prisutno i permanentno zagađenje prisutnih tačkastih i difuznih izvora. U vrijeme aplikacije odredbi Okvirne direktive o vodama i na području Bosne i Hercegovine, veće rijeke, kao što je rijeka Bosna, predstavljaju poseban problem. Materijal za rad predstavlja sintezu dosadašnjih podataka (1999-2010 god.) o kvalitativno-kvantitativnom sastavu makrozoobentosa rijeke Bosne na sedam lokaliteta (Rimski most do nizvodno od ušća Lašve). Ukupno je analizom obuhvaćeno 390 uzoraka. Metodologija uzorkovanja je multi-habitat ali nije zahvatila sredinu korita uslijed velike dubine.

Primjenjeni su saprobni indeks (PANTLE & BUCK, 1955) i BMWP indeks, a kao podloga za utvrđivanje korelacije u ocjeni ekološkog stanja istraživanih dijelova vodotoka rijeke Bosne.

U analizi je primjenjen Bray-Curtis indeks sličnosti ili različitosti za uzorke makrozoobentosa.

Rezultati rada ukazuju na najveću u raznovrsnost u sastavu makrozoobentosa na lokalitetu Rimski most (36 takse), a najmanja na lokalitetu Bosne uzvodno od ušća Ljubine (12 taksa). Najveća i najmanja skupina Ephemeroptera, Plecoptera i Trichoptera (EPT) konstatovano je tako i u uzorcima na lokalitetu Rimski most (18) što ovaj lokalitet i prema primjeni klastera Bray-Curtis izdvaja od svih ostalih lokaliteta. Po sličnim abiotičkim uvjetima i sastavu makrozoobentosa grupisani su lokaliteti koji su prostorno bliski. Najveći i stupanj sličnosti pokazuju uzorci rijeke Bosne na lokalitetu poslije ušća Zgošće, uzvodno od ušća Lašve i nizvodno od ušća Lašve).

Primjenjeni indeksi u ocjeni ekološkog stanja rijeke Bosne, a na osnovu sastava makrozoobentosa, pokazuju veliku povezanost ( $R^2 = 0,706$ ).

Za oba indeksa se mora istaknuti, da svojim vrijednostima ukazuju na dva mjesta pojačanog zagađenja. Rijeka Bosna poslije ušća Miljacke (lokalitet uzvodno od ušća Ljubine) predstavlja mjesto najvećeg stresa za ovaj akvatični ekosistem, koji narušava ekološke prilike, a takav status se zadržava ili pogoršava do samog ušća u rijeku Savu. Drugi lokalitet pojačanog zagađenja ali manjeg intenziteta je na lokalitetu Bosne poslije ušća Zgošće. Manja revitalizacija abiotskih prilika rezultat je pojačanog protoka i proširenja korita na lokalitetu Bosne nizvodno od Visokog. Ovakve abiotske prilike i utok pritoka sa većim stupnjem kvaliteta vode (Ribnica, Lašva, Krivaja) rezultiraju povećanje raznovrsnosti makrozoobentosa. BMWP indeks ima veliku vrijednost za uzorke makrozoobentosa Bosne poslije ušća Lašve, što je posljedica direktnog utoka rijeke Lašve i drifta organizama. Rijeka Bosna zahtijeva poseban metodološki pristup u analizi sastava hidrobionata, na osnovu kojih se i objektivnije može ukazati na najadekvatniji pristup upravljanju.

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Dobiveni rezultati ipak potvrđuju potrebu primjene vi-e indeksa u ocjeni ekološkog stanja tekućica, ali i neophodnost usklađivanja dosadašnjih podataka o sastavu makrozoobentosa i dopuna podataka sa podacima istavog presjeka korita rijeke.