Ecological condition of waterways and biodiversity indices with qualitative-quantitative composition of macrozoobenthos

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Enhancing Knowledge on Biodiversity and Assessing Ecological Status of the Lower Catchments of Neretva River in Bosnia and Herzegovina

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The processing of the collected samples of macroinvertebrates was performed in the laboratory of the Faculty of Teacher Education - Department of Biology, "Džemal Bijedić" University of Mostar. Processing of macroinvertebrates implies their sorting, identification and permanent storage in collections.

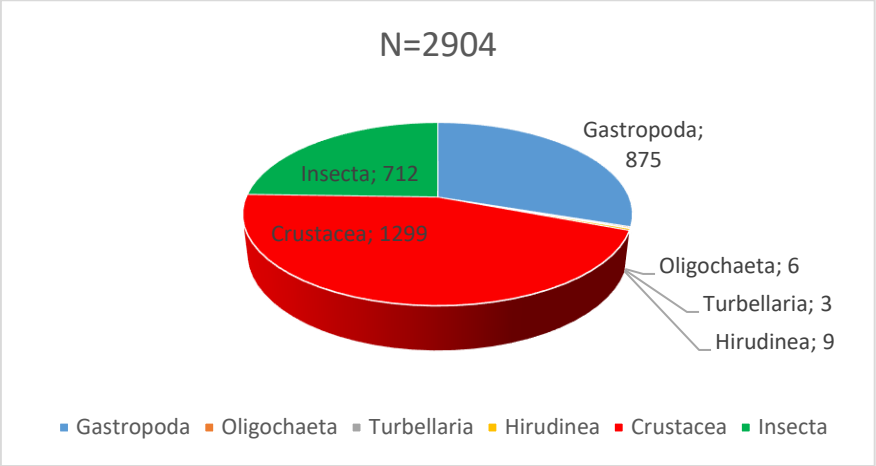
After collecting samples in the field, the material was sifted through a sieve with a mesh diameter of 500 μm, to remove sediment, and then transferred to the appropriate packaging with a label containing the name of the site and the date of sampling.

A 4% formaldehyde solution was used to fix the samples until treatment. At the end of the sampling, the materials were transported to the premises of the Faculty of Teacher Education. The material is permanently stored in 70% ethyl alcohol solution.

1. The river Buna

Macroinvertebrate sampling was performed at four sites at the Buna River. By analyzing macroinvertebrate samples in the laboratory, it was determined that a total of 2904 specimens were collected at all sites during sampling.

Table 1 presents an overall overview of all sampled species recorded on the Buna River watercourse. Most samples have been identified up to species level. The distribution of species was analysed according to taxonomic groups and the presence of six bioindicator groups is observed: Gastropoda, Oligochaeta, Turbellaria, Hirudinea, Crustacea and Insecta (Graph 1). Within the Insecta group, six orders of Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera, and Diptera are present.



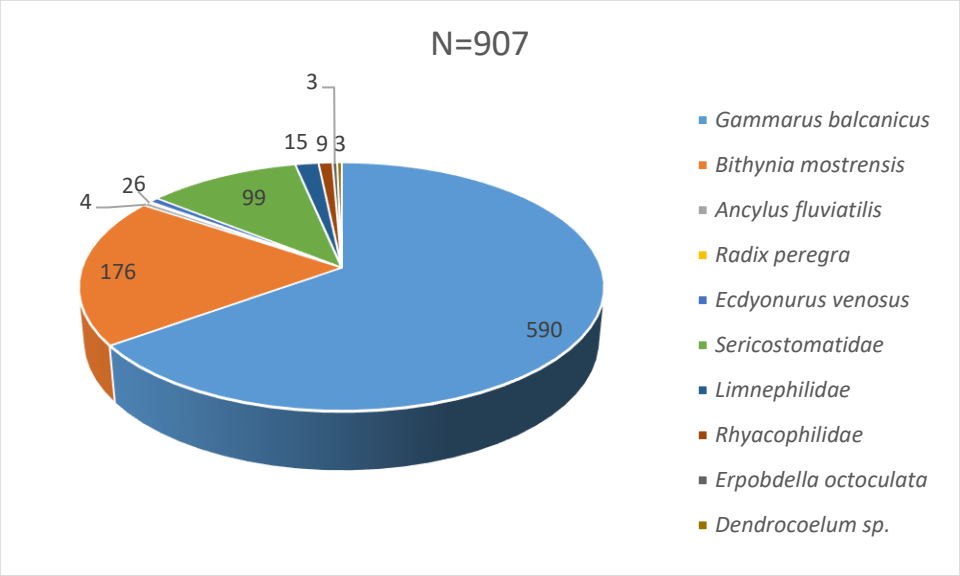
Graph 1. Taxons sampled at researched area – river Buna

The analysis of individual sites shows that the highest number of individuals was recorded at the L2 locality, a total of 907. The total number of individuals at this site is distributed across 10 taxa (Graph 2). Crustacea with the family Gammaridae and the species *Gammarus balcanicus* have the largest abudance, 590 individuals (65% of the sample).

The second largest group are Gastropods with a total of three species from three families, dominated by the family Bithynidae with the species Bithynia mostrensis (176 individuals), then the family Planorbidae with the species *Ancylus fluviatilis* (4) and the family Limnaelidae with the species *Radix peregra* (2). The taxonomic group Insecta is represented by two orders of Ephemeroptera and Trichoptera.

Ephemeroptera are represented by only one species of *Ecdyonurus venosus* (6 individuals) from the family Ephemeridae, while Trichoptera are represented by species from three families, the most numerous of which is the family Sericostomatidae (99), followed by Limnephilidae (15) and Rhiacophilidae (9).

The taxonomic group Hirudinea is represented by the species *Erpobdella octoculata* (3 individuals) belonging to the family Erpobdellidae. From Turbellaria the presence of the species Dendrocoelum sp. (3 individuals) from the family Dendrocoelidae.



Graph 2. Distribution of taxa sampled at L2

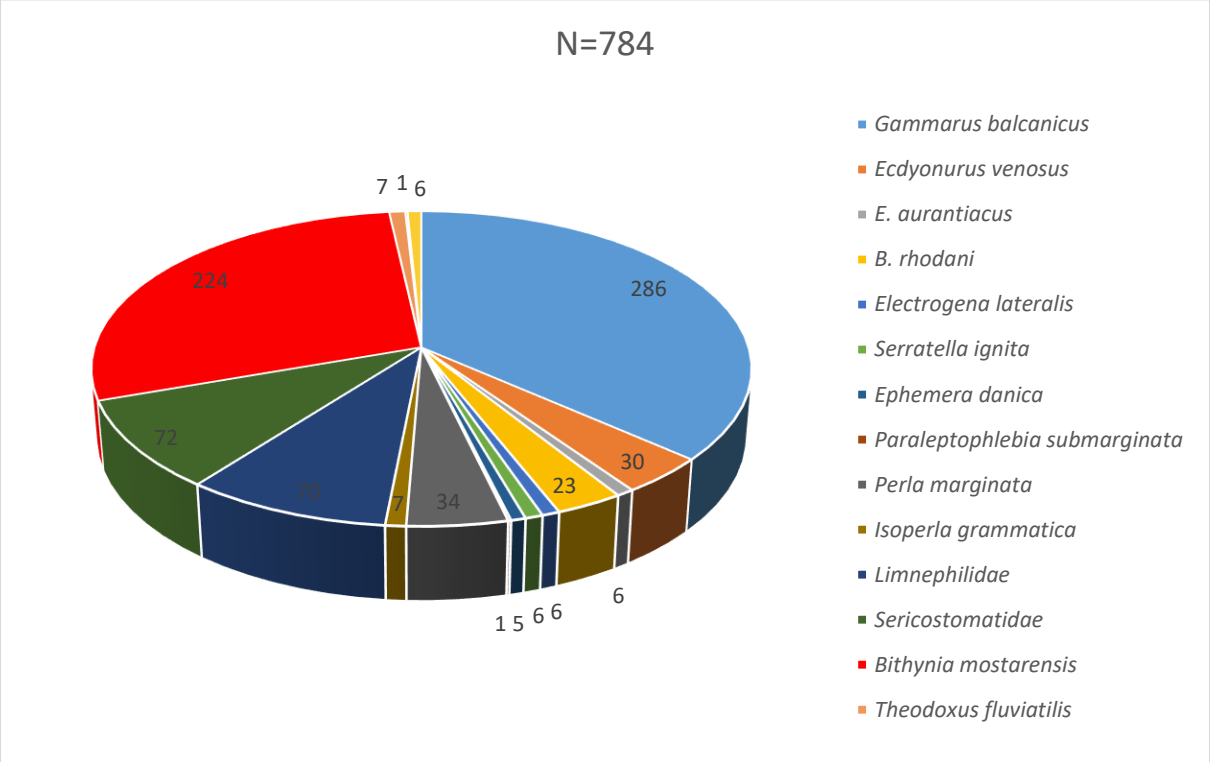
The second largest site is L3 (delta of the river Bunica) with a total of 784 individuals, which are distributed in 16 taxa (Graph 3). Therefore, the greatest diversity of species in the sample was recorded at this site. Also, Crustacea with the species *Gammarus balcanicus* (286 individuals) from the family Gammaridae has the largest abundance at this locality. From the taxonomic group Insecta, the following orders are represented: Ephemeroptera, Plecoptera, Trichoptera and Odonata.

Ephemeroptera are represented by seven species that are distributed in five families: Heptagenidae, Ephemeridae, Ephemeriliidae, Baetidae and Leptophlebiidae. Most individuals belong to the genus Ecdyonurus (Ephemeridae) 36 individuals. Two species of *Ecdyonurus venosus* (30 individuals) and *E. aurantiacus* (6) are present from the mentioned genus. Next in number is the genus Baetis (Baetidae) with the species *B. rhodani* (23). With six individuals

each, the species *Electrogena lateralis* (Heptagenidae) and *Serratella ignita* (Ephemeriliidae) are present. *Ephemera danica* (Ephemeridae) is represented by 5 individuals.

The family Leptophlebiidae is represented by one individual of the species *Paraleptophlebia submarginata*. Two families from the order Plecoptera are present: Perlidae with the species *Perla marginata* (34 individuals) and Perlodidae with the species *Isoperla grammatica* (7). The order Trichoptera is interspersed with representatives of two families, Limnephilidae (70) and Sericostomatidae (72).

Taxonomic group Gastropoda was represented by two families, namely Bithynidae with the species *Bithynia mostarensis* (224) and Neritidae with the species *Theodoxus fluviatilis* (7). The Odonata group is represented by only one species and one present individual of the family Calopterygidae, *Calopteryx splendens*.



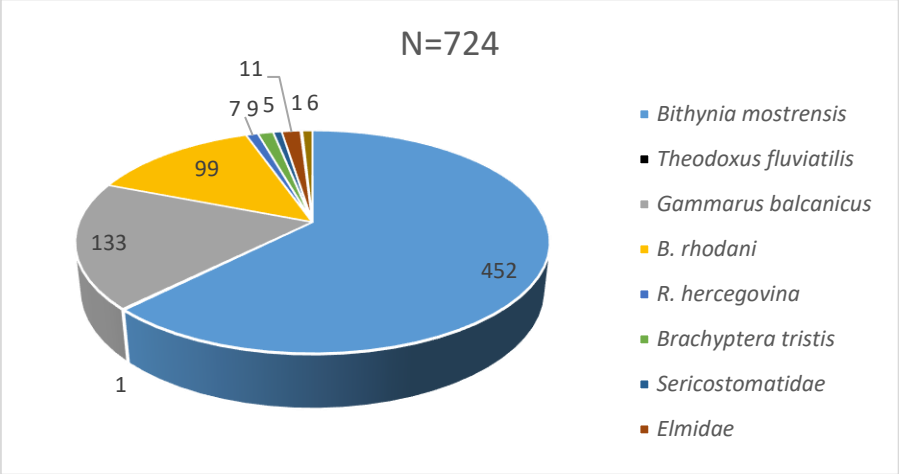
Graph 3. Distribution of taxons sampled at L3

The third locality in terms of the number of individuals in the sample is L1 (source), with a total of 724 individuals, which are distributed in 10 taxa (Graph 4). Unlike the previous two sites (L2 and L3) where the species *Gammarus balcanicus* had the highest abudance, Gastropodi are the most common in this locality, with the dominant species *Bithynia mostarensis* from the family Bithyniidae (452 individuals or 62.4% of the sample).

Another representative of Gastropod in this locality is the family Neritidae with the species *Theodoxus fluviatilis*, which is represented by one individual. The Crustacea taxonomic group is in second place with 133 individuals. All individuals belong to the family Gammaridae and the species *Gammarus balcanicus*. The Insecta group in this locality includes 132 individuals arranged in the following orders: Ephemeroptera, Plecoptera, Trichoptera, Coleoptera and Diptera.

The order Ephemeroptera is present with two families Baetidae and Heptageniidae. Baetidae are represented by the genus Baetis and the species *B. rhodani* (99 units), while Heptageniidae are represented by the genus Rhithrogena and the species *R. hercegovina* (7 units). The order Plecoptera is represented by one species from the family Taeniopterygidae, *Brachyptera tristis* (9 individuals).

The family Sericostomatidae (5 individuals) is present from the order Trichoptera. Order Coleoptera with representatives of the family Elmidae (11 individuals) and order Diptera with one representative of the family Chironomidae. The Hirudinea group is represented by 6 individuals from the family Erpobdelidae belonging to the species *Erpobdela octoculata*.



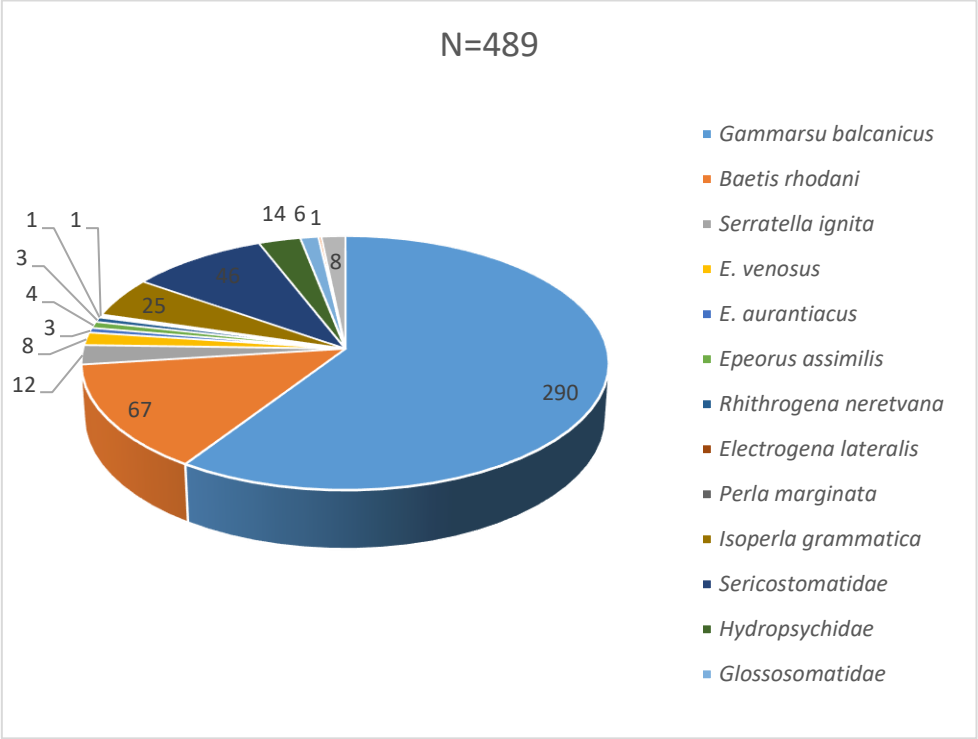
Graph 4. Distribution of taxons sampled at L1

The fourth site in terms of the number of individuals in the sample is also the last site on the watercourse of the river Buna L4 (Buna canals), with a total of 489 individuals. However, although the smallest number of individuals was sampled here, this site is one of the most diverse in terms of the number of taxa, ie. others in that category. Individuals at this site of 489 of them are distributed in 15 taxa (Graph 5).

Crustacea with the family Gammaridae and the species *Gammarus balcanicus* (290 individuals or 59% of the sample) have the highest abundance. The Insecta group has a total of 190

individuals arranged in three orders: Ephemeroptera, Plecoptera and Trichoptera. The most numerous species of Ephemeroptera is *Baetis rhodani* from the family Baetidae with a total of 67 individuals, followed by *Serratella ignita* from the family Ephemeriliidae with 12 individuals.

The genus Ecdyonurus from the family Ephemeridae is represented by two species *E. venosus* (8) and *E. aurantiacus* (3). The family Heptagenidae is interspersed with the species *Epeorus assimilis* (4), *Rhithrogena neretvana* (3) and *Electrogena lateralis* (1). The order Plecoptera is represented by two families Perlidae and Perlodidae. From the family Perlidae, one individual is present, and the representative of the family Perlodidae is the species *Isoperla grammatica* (25 individuals). The order Trichoptera includes representatives of three families, namely Sericostomatidae (46), Hydropsychidae (14) and Glossosomatidae (6).



Graph 5. Distribution of taxons at L4

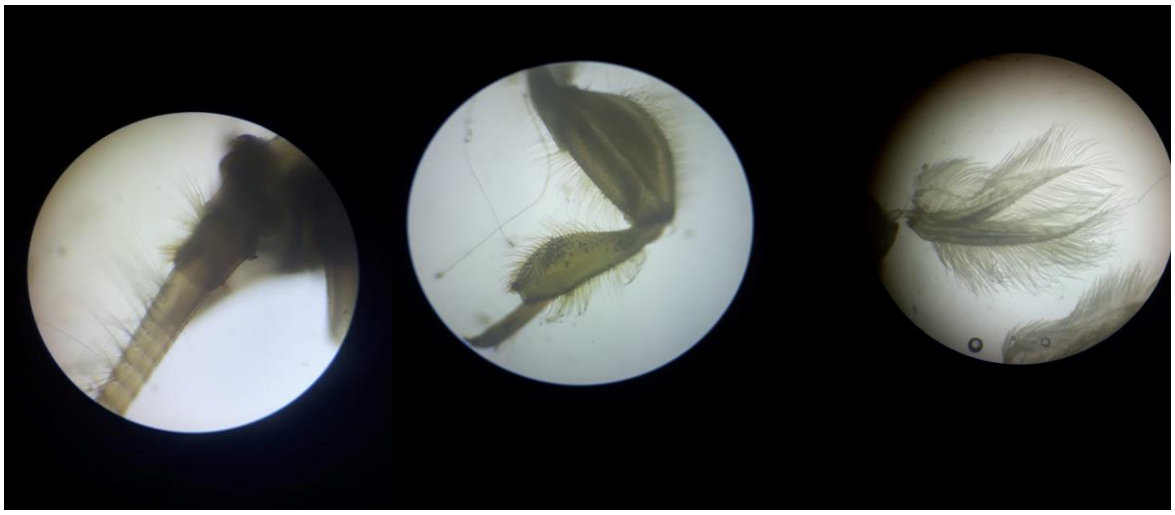
Gastropods (snails) were recorded with four families: Planorbidae, Neritidae, Bithynidae, and Limnaeidae. From the family Planorbidae, one species of *Ancylus fluviatilis* was sampled, four individuals on L2 and one individual on L1. A representative of the Neritidae family is *Theodoxus fluviatilis*, also sampled at two sites, L1 one individual and L3 seven individuals.

The indicator value of this family is 6, which means that it is an excellent indicator of water quality. The family Bithynidae with the species *Bithynia mostarensis* is the most numerous

with a total of 860 specimens sampled at all localities. However, their highest prevalence was on L1 with 452 individuals (52.55%), and the lowest was recorded on L4, eight individuals. The last family of snails to be sampled is the family Limnaeidae with the species *Radix peregra*. Individuals of this species (two) were sampled at L2.

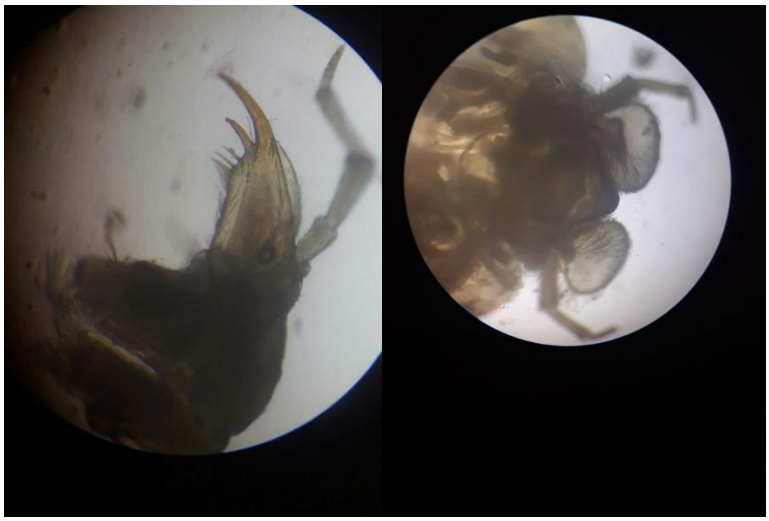
a b c

Photo 1. *Gammarus balcanicus* (a – *G. balcanicus*; b – anterior legs (100x); c – auditory apparatus (100x)) (photo E. Hodžić)



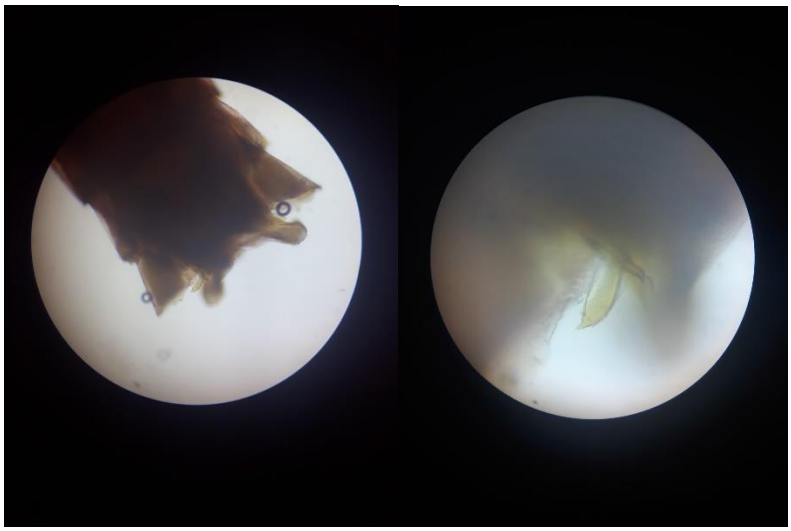
a b c

Photo 2. *Ephemera danica* (a – antenna base (100x¸b – extremity (100x); c – breathing apparatus (100x)) (photo E. Hodžić)



a – *I. grammatica* b – *P. marginata*

Photo 3. Determination of individual Plecoptera (a – maxila (100x); b – auditory apparatus (100x) (photo E. Hodžić)



a b

Photo 4. *Rhithrogena hercegovina* (a – tintilator (40x); b – tintilator (100x))

(photo E. Hodžić)

Table 1. Qualitative-quantitative composition of zoobenthos on the Buna river

Zoobenthos	**L1**		**L2**		**L3**		**L4**	
	Br.	%	Br.	%	Br.	%	Br.	%
GASTROPODA								
Ancylus fluviatilis			4	0,4%			1	0,2%
Theodoxus fluviatilis	1	0,14%			7	0,9%		
Bithynia mostarensis	452	62,4%	176	19,4%	224	28,6%	8	1,6%
Radix peregra			2	0,2%				
OLIGOCHAETA								
					6	0,8%		
TURBELLARIA								
Dendrocoelum sp.			3	0,3%				
HIRUDINEA								
Erpobdella octoculata	6	0,8%	3	0,3%				
CRUSTACEA								
Gammarus balcanicus	133	18,4%	590	65%	286	36,5%	290	59,3%
INSECTA								
Ephemeroptera								
Electrogena lateralis					6	0,8%	1	0,2%
Ecdyonurus venosus			6	0,7%	30	3,8%	8	1,6%
E. aurantiacus					6	0,8%	3	0,6%
Rhithrogena hercegovina	7	1%						
Rhithrogena neretvana							3	0,6%
Ephemera danica					5	0,6%		
Epeorus assimilis							4	0,8%
Serratealla ignita					6	0,8%	12	2,4%
Baetis rhodani	99	13,7%			23	2,9%	67	13,7%
Paraleptophlebia submarginata					1	0,13%		
Plecoptera								
Brachyptera tristis	9	1,3%						
Perla marginata					34	4,3%	1	0,2%
Isoperla grammatica					7	0,9%	25	5,1%
Trichoptera								
Limnephilidae			15	1,6%	70	8,9%		
Sericostomatidae	5	0,7%	99	10,9%	72	9,2%	46	9,4%
Glossosomatidae							6	1,2%
Rhyacophilidae			9	1%				
Hydropsychidae							14	2,9%
Odonata								
Calopteryx splendens					1	0,1%		
Coleoptera								
Elmidae	11	1,5%						
Diptera								
Chironomidae	1	0,14%						
Σ number of individuals	724	100%	907	100%	784	100%	489	100%
Σ number of taxa	10		10		16		15	

The next indicator group is Oligochaeta. With the available equipment and keys, it could be determined that these individuals belong to the Oligochaeta group. However, this indicator group carries a minimum number of environmental points, so it can be said that it is a poor indicator of water quality.

Turbellaria are represented by *Dendrocoelum sp*. which belongs to the family Dendrocoelidae. Three units on L2 were found. They carry 5 indicator points, so it can be said that they are a good indicator of the quality of watercourses. Leeches (Hirudinea) were found in zoobenthos samples in the upper part of the watercourse at localities L1 and L2. They are represented by one species from the family Erpobdellidae, *Erpobdella octoculata*. Six units were sampled on L1 and three units on L2. In general, leeches inhabit localities with a lot of organic waste, which they use as their main food source. Therefore, it carries small indicator points (3 points), and they are a rather weak indicator of the quality of watercourses.

The group of crustaceans (Crustacea) is interspersed with the family Gammaridae and one species *Gammarus balcanicus.* A total of 1299 units were sampled, with distribution at all localities. Almost half of the 590 units (45.4%) were caused by L2. Shrimp appear in clean waters of a higher degree of quality. Shrimp of the genus Gammarus, inhabit sandy sediment and clear water with a longer and moderate flow. Dissolved oxygen, nitrites and reactive phosphorus are the limiting factors in the distribution of Gammaridae.

The next indicator class is Insecta, which is represented by six orders: Ephemeroptera, Plecoptera, Trichoptera, Odonata, Coleoptera and Diptera.

Due to the high concentration of dissolved oxygen at all sites, it shows that they like clean and oxygen-saturated water. Based on indicator points 6, which are carried by the family Gammaridae, it can be said that they are a good indicator of watercourse quality.

Water flowers (Ephemeroptere) have been recorded with five families: Heptageniidae, Ephemeridae, Ephemerillidae, Baetidae and Leptophlebidae. There are four species from the family Heptagenidae. The most common species from this family is *Electrogena lateralis* with seven individuals, which were found on L3 (6) and one on L1. The genus Rhithrogena is represented by two species *R. herzegovina* (7 units) and *R. neretvana* (3 units).

For the mentioned genus, it is stated in the literature (Tomka and Rasch, 1993) that most of its species inhabit the Alps. In BiH, three genera have been described on the Neretva watercourse. The indicator value of the family Heptagenidae 10, shows that it is an excellent indicator, and species of this genus inhabit clean waters. These species live in streams with a lot of underwater

vegetation, which is why they are marked as detritus, and belong to the group of weak swimmers, they feed on plants and algae, while some are even predators.

In a paper published in 1985, Tanasijević discovered two new species of this genus, *R. hercegovina* and *R. neretvana*. All units of the species *R. herzegovina* were found on L1, which is an interesting fact. Tanasijevic then found this species at the same locality, and no data on the discovery of this species have been recorded since then. Thus, *R. herzegovina* was found at the source of the Buna after a long period of time. Also, all individuals of *R. neretvana* were found at one site in the area of the Buna canals. The next species from this family is *Epeorus assimilis* from the genus Epeorus. It was sampled at L4 with four individuals. The family Ephemeridae is represented by three species from the two genera Ecdyonurus and Ephemera.

The species *Ecdyonurus venosus* is the most numerous with 44 individuals distributed at L2, L3 and L4. It is most numerous at L3 with 30 individuals. The next species of this genus is E. *aurantiacus,* present on L3 with six individuals and at L4 with three individuals. *Ephemera danica* was sampled only at L3 with five individuals. In general, all species from the family Ephemeridae are good indicators of watercourse quality, which is indicated by the indicator value of 10. The family Ephemerillidae is present with the species *Serratella ignita*, which was sampled at localities L3 six individuals and L4 12 individuals. It is a good indicator of the quality of watercourses with regard to the indicator value of 7. The family Leptophlebidae is present with one species of *Paraleptophlebia submarginata* in locality L3. The species *Baetis rhodani,* from the family Baetidae, is represented by 189 individuals.

The individuals were distributed at sites L1, L3 and L4. At the L1 site, more than 52% of individuals of this species were sampled. *B. rhodani* is the only species of aquatic flower that occurs in waters at the transition from β-mesosaprobic to α-mesosaprobic water. This species can be said to be a weak indicator of water quality because it lives mostly in waters with a lot of organic waste and is not a reliable indicator due to its wide ecological valence in relation to most ecological factors.

Plecoptera (stonecrops) were recorded with three families: Taeniopterygidae, Perlidae and Perlodidae. They are sensitive to water pollution and their presence guarantees the purity of the water. They require water saturated with oxygen to survive. They are good water quality indicators and serve as a food source for mountain stream fish. The family Taeniopterygidae is represented at site L1 with the species *Brachyptera tristis.* Nine individuals were sampled. The most numerous family of rockfish on the Buna river is the Perlidae family, with the species

Perla marginata. A total of 35 individuals were sampled, represented in the lower course of the river, at sites L3 (34 individuals) and L4 one individual. *P. marginata* is a good indicator of water quality, with indicator value of 10. *Isoperla grammatica* as a representative of the family Perlodidae is also a good indicator of watercourse quality.

The order Trichoptera was represented with five families. Due to the lack of keys for determining Trichoptera, they are determined to the family level. The family Limnephilidae is present at two sites, L2 15 individuals and L3 70 individuals. The indicator value of the family is 7, which means that it is a pretty good indicator of the quality of watercourses. The family Sericostomatidae is the most numerous with 222 individuals present across all sites. It is an excellent indicator of the quality of watercourses with an indicator value of 10.

Glossosomatidae are present in the lower course of the river at the site of the Buna canals with six individuals. Their indicator value is 8. Rhyacophilidae were sampled only at site L2 with nine individuals. Their indicator value is 7. Hydropsichidae are present in the lower course of the river in the area of the Buna canals with 14 individuals. They are a good indicator of the quality of watercourses with an indicator value of 5 points.

The order Odonata is present with the family Calopterygidae and the species *Calopteryx splendens.* One individual of this species was found at site L3. It is an excellent indicator of the quality of watercourses, with an indicator value of 8.

Diptetra are a large group of insects, which are very difficult to determine to lower systematic categories, so the determination of these individuals was performed to the level of the family. One individual belonging to the family Chironomidae at the source of the river Buna was sampled. In general, Chironomidae are poor indicators of watercourse quality with an indicator value of 2. A representative of Coleoptera is the family Elmidae with 11 individuals sampled at L4. They are a good indicator of the quality of watercourses. Their indicator value is 5.

Analyzing the results of the qualitative-quantitative composition of macroinvertebrates, it can be said that the samples are very diverse. Of the total of 28 taxa sampled, more than 2/3 (72%) belong to the Insect class. It is known that members of this class are very good indicators of watercourse quality, primarily species from the orders Ephemeroptera, Plecoptera and Trichoptera. Analysis of numerousness of individuals indicates that the first three sites are quite uniform, with L2 being the most numerous with 907 individuals.

At the site of the Buna canals, at the delta, the fewest individuals were sampled. This can be attributed to specific conditions that prevail in this part of the watercourse. Benthic

macroinvertebrates are bound to the bottom of river bed, so their survival directly depends on the water flow rate. The water flow is the highest at this site, due to the fact that it is located at the confluence of the river Buna and the river Neretva. This locality is one of the most diverse with 15 taxa.

The analysis of the BMWP index of watercourse quality revealed that the sites L1 and L2, which are located in the upper part of the Buna river watercourse, have a lower ecological status in contrast to the lower part of the watercourse. The results obtained from these sites (L1 - 59 and L2 - 57) correspond to the status of moderate ecological aspect. The highest BMWP index (102) was calculated at the L3 (Bunica) site, which corresponds to a high ecological status. At the site L4 (estuary), the obtained result is (76), which belongs to the category of good ecological status.

Interestingly, only three species from three different groups were sampled at all sites. The first of these species is *Bithynia mostarensis* from the Gastropoda group, with 860 individuals. The largest distribution was recorded at the L1 site (452 individuals), and the smallest at L4 (8 individuals). This species is not a reliable and good indicator because it can live in watercourses loaded with organic waste, which is indicated by its indicator value 3. The next species is also the most numerous, belonging to the group of shrimp *Gammarus balcanicus* from the family Gammaridae. Most of them were sampled at L2 (590), and the least at source L1 (133). Their number is 1299 individuals. They are very good indicators of watercourse quality.

The third species belongs to the family Sericostomatida from the order Trichoptera. Its number is 222 individuals and they are excellent indicators of watercourse quality. Most of them were sampled at L2 (99), and the least at source L1 (5 individuals).

2. The river Jasenica

Sampling macrozoobenthos on the river Jasenica was done at one site, in the upper part of the river. The lower part of the river, during the summer, dries up completely. The reason for that is the operation of the reversible hydroelectric power plant Mostarsko Blato, which captures the waters of the river Jasenica. Its operation does not respect the legal obligation to maintain the biological minimum water flow in the riverbed, with complete drying of watercourses at longer intervals. With this work, HPP Mostarsko blato prevents the survival of aquatic organisms.Sample analysis revealed a relatively small number of macrozoobenthos species in the Jasenica River.

Table 3. Qualitative-quantitative composition of zoobenthos at the Jasenica river

Jasenica **zoobenthos**	**Number of individuals**
GASTROPODA	
Bithynia mostarensis	588
HIRUDINEA	
Erpobdella octocualta	3
CRUSTACEA	
Gammarus balcanicus	62
INSECTA	
Ephemeroptera	
Ecdyonurus venosus	7
Serratealla ignita	3
Baetis rhodani	7
Plecoptera	
Isoperla grammatica	3
Trichoptera	
Limnephilidae	1
Sericostomatidae	13
Hydropsychidae	1
Σ number of individuals	689
Σ number of taxa	10

The most numerous is the representative of Gastropoda, the species *Bithynia mostarensis* with 588 individuals, crustaceans Crustacea are represented by the family Gammaridae and one species *Gammarus balcanicus* with 62 individuals. The group of aquatic insects Ephemeroptera is represented by three species: *Ecdyonurus venosus* (7 individuals); *Serratealla ignita* (3 individuals) and the species *Baetis rhodani* (7 individuals). The group of Trichoptera is represented by three families: Limnephilidae (one individual), family Sericostomatidae (13 individuals) and family Hydropsychidae (one individual). These data indicate existence of a significant negative anthropogenic impact on the watercourse.

3. The River Bunica

The Bunica River is a tributary of the Buna River and in recent years there has been expansion and uncontrolled construction of residential buildings on its banks. The sampling site was located near the source of the river Bunica, which is a protected area (category of natural monuments). However, a large number of private houses were built on this site.

The analysis of the samples revealed a relatively small number of macrozoobenthos species in the Bunica River.

Table 4. Qualitative-quantitative composition of zoobenthos in river Bunica

Bunica zoobenthos	**Number of individuals**
GASTROPODA	
Bithynia mostarensis	*23*
CRUSTACEA	
Gammarus balcanicus	26400
INSECTA	
Ephemeroptera	
Electrogena lateralis	14
Ecdyonurus venosus	8
Serratealla ignita	55
Baetis rhodani	83
Paraleptophlebia submarginata	5
Plecoptera	
Isoperla grammatica	3
Trichoptera	
Limnephilidae	1
Sericostomatidae	15
Glossosomatidae	2
Hydropsychidae	25
Odonata	
Calopteryx splendens	4
Σ broj jedinki	26634
Σ broj taksona	13

Gastropods are represented by the species *Bithynia mostarensis* with 23 individuals. The most numerous group, as well as the species in the whole sample, are Crustacea crabs with the species *Gammarus balcanicus* 26400 individuals. This represents the largest presence of a species in all investigated watercourses. The group of aquatic insects Ephemeroptera is represented by five species: *Electrogena lateralis* (14 individuals) *Ecdyonurus venosus* (8 individuals); *Serratealla ignita* (55 individuals1), *Baetis rhodani* species (83 individuals) and *Paraleptophlebia submarginata* species (5 individuals). The group of Trichoptera is represented by four families: Limnephilidae (one individual), family Sericostomatidae (15 individuals), family Glossosomatidae (two individuals) and family Hydropsychidae (25 individuals).

4. The River Bregava

The river Bregava is a tributary of the river Nereva. The sampling site was located downstream of the mini hydropower plant Do, which uses about one third of the waters of the river Bregava for its work. The MHPP was constructed without the consent of the local community and a valid environmental impact study, which are the legal obligation of the investor.

The sample analysis revealed a relatively small number of macrozoobenthos species in the Bregava River.

Table 5. Qualitative-quantitative composition of zoobenthos on the Bregava river watercourse

Bregava zoobenthos	**Number of individuals**
CRUSTACEA	
Gammarus balcanicus	24
Austropotramobius pallipes	30
INSECTA	
Ephemeroptera	
Electrogena lateralis	6
Ecdyonurus venosus	5
Serratealla ignita	1
Baetis rhodani	17
Plecoptera	
Perla marginata	24
Isoperla grammatica	1
Trichoptera	
Limnephilidae	51
Sericostomatidae	2
Glossosomatidae	46
Rhyacophilidae	13
Hydropsychidae	2
Σ broj jedinki	**222**
Σ broj taksona	**13**

Crustacea crabs are present with two species: the species *Gammarus balcanicus* (24 individuals) and the species *Austropotramobius pallipes* (30 individuals). The river Bregava is the only habitat in which the white-legged crab *Austropotamobius pallipes* was found, and in the earlier literature the presence in all tributaries of the Neretva is mentioned. The group of aquatic insects Ephemeroptera is represented by four species: *Electrogena lateralis* (6 individuals) *Ecdyonurus venosus* (5 individuals); *Serratealla ignita* (1 individual), and the species *Baetis rhodani* (17 individuals). The group of Trichoptera is represented by five families: Limnephilidae (51 individuals), family Sericostomatidae (2 individuals), family Glossosomatidae (46 individuals), family Rhyacophilidae (13 individuals) and family Hydropsychidae (2 individuals).

6. The River Trebižat

The river Trebižat is a tributary of the river Nereva. The macrozoobenthos sampling site is located downstream from the mouth of the tributary Studenčica. The ecosystem of the river Trebižat is negatively affected by the operation of the hydroelectric power plant Peć Mlini, then intensive agriculture and irrigation, as well as fish farming, and this includes the problem of pollution with municipal wastewater. The river Trebižat flows through an area of exceptional ecological value, there are protected areas such as the travertine formation around the Kravica waterfall. Although there have been many negative anthropogenic impacts on the Trebizat River in recent years, especially from hydropower and irrigation exploitation, uncontrolled urbanization and tourism, analysis of aquatic organisms, river ecology and river morphology still shows high biodiversity, despite high levels of threat.

Table 5. Qualitative-quantitative composition of zoobenthos on the Trebižat river watercours

Trebižat zoobenthos	**Number of individuals**
GASTROPODA	
Theodoxus fluviatilis	2
Bithynia mostarensis	10
Radix peregra	1
OLIGOCHAETA	4
CRUSTACEA	
Gammarus balcanicus	*19*
Palaemonetes antennarius	44
INSECTA	
Ephemeroptera	
Electrogena lateralis	1
Serratealla ignita	*2*
Baetis rhodani	4
Cloen simile	4
Plecoptera	
Perla marginata	2

Isoperla grammatica	1
Trichoptera	
Limnephilidae	11
Sericostomatidae	3
Odonata	
Calopteryx splendens	3
Libellula depressa	5
Σ broj jedinki	116
Σ broj taksona	7

Gastropod snails are represented by three species: the species *Theodoxus fluviatilis* (two individuals), the species *Bithynia mostarensis* with 10 individuals, and the species *Radix peregra* (one individual). Crustaceans are represented by the family Gammaridae and one species *Gammarus balcanicus* with 19 individuals, as well as the family Decapoda and the species *Palaemonetes antennarius* with 44 individuals. According to the available literature, the finding of the species *Palaemonetes antennarius* is the first finding of this species in Bosnia and Herzegovina. The group of aquatic insects Ephemeroptera is represented by 4 species: *Electrogena lateralis* (1 individual); *Serratealla ignita* (2 individuals), *Baetis rhodani* species (4 individuals) and *Cloen simile* species (4 individuals). The group of Trichoptera is represented by two families: Limnephilidae (11 individuals) and the family Sericostomatidae (3 individuals). Odonates are represented by two species of *Calopteryx splendens* (3 individuals) and the species *Libellula depressa* (5 individuals).

7. Comparative assessment of macrozoobenthos biodiversity in the rivers Buna, Bunica, Jesenica, Bregava and Trebizat using the Shannon-Wiener index

The analysis and assessment of the biodiversity of the studied macrozoobenthos communities was done using the Shannon-Wiener index, which determines diversity in the community. It is best to compare different samples, because it is relatively independent of the sample size.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where pi represents the ratio of the number of taxa and, and the total number of all species (R). Higher values of the Shannon index indicate a higher number of species compared to the number of individuals in the observed community.

Table 6. Diversity index in the community of macroinvertebrates of the river Buna

Buna zoobenthos	Count of species unit	Shannon Index Variable Name	Shannon Index Calculation
Ancylus fluviatilis	5	=n1	-0.01106405
Theodoxus fluviatilis	8	=n2	-0.016392822
Bithynia mostarensis	852	=n3	-0.360513563
Radix peregra	2	=n4	-0.005063928
Oligocheata	6	=n5	-0.012895833
Dendrocoelum sp.	3	=n6	-0.007172208
Gammarus balcanicus	1299	=n7	-0.358826993
Electrogena lateralis	7	=n8	-0.014669292
Ecdyonurus venosus	44	=n9	-0.064034116
E. aurantiacus	9	=n10	-0.018072699
Rhithrogena hercegovina	7	=n11	-0.014669292
Rhithrogena neretvana	3	=n12	-0.007172208
Ephemera danica	5	=n13	-0.01106405
Epeorus assimilis	4	=n14	-0.009162133
Serratealla ignita	18	=n15	-0.031799648

Baetis rhodani	179	=n16	-0.173016492
Paraleptophlebia submarginata	1	=n17	-0.002773395
Brachyptera tristis	9	=n18	-0.018072699
Perla marginata	35	=n19	-0.053726007
Isoperla grammatica	32	=n20	-0.050119733
Limnephilidae	85	=n21	-0.104207585
Sericostomatidae	216	=n22	-0.194643557
Glossosomatidae	6	=n23	-0.012895833
Rhyacophilidae	9	=n24	-0.018072699
Hydropsychidae	14	=n25	-0.025958557
Calopteryx splendens	1	=n26	-0.002773395
Elmidae	11	=n27	-0.021320002
Chironomidae	1	=n28	-0.002773395
SUM:	2871		**1.622926186**

Table 7. Diversity indices in macroinvertbrate community of river Trebižat

Trebižat zoobenthos	Count of species unit	Shannon Index Variable Name	Shannon Index Calculation
Theodoxus fluviatilis	2	=n1	-0.070007638
Bithynia mostarensis	10	=n2	-0.211293543
Radix peregra	1	=n3	-0.040979226
Oligocheata	4	=n4	-0.116113649
Gammarus balcanicus	19	=n5	-0.296326492
Palaemonetes antennarius	44	=n6	-0.36770366
Electrogena lateralis	1	=n7	-0.040979226
Serratealla ignita	2	=n8	-0.070007638
Baetis rhodani	4	=n9	-0.116113649
Cloen simile	4	=n10	-0.116113649
Perla marginata	2	=n11	-0.070007638
Isoperla grammatica	1	=n12	-0.040979226
Limnephilidae	11	=n13	-0.223384863
Sericostomatidae	3	=n14	-0.094525291

Zoobenthos Jasenica	Count of species unit	Shannon Index Variable Name	Shannon Index Calculation
Bithynia mostarensis	558	=n1	-0.170787124
Erpobdella octocualta	3	=n2	-0.023671824
Gammarus balcanicus	62	=n3	-0.216694669
Ecdyonurus venosus	7	=n4	-0.046626006
Serratealla ignita	3	=n5	-0.023671824
Baetis rhodani	7	=n6	-0.046626006
Isoperla grammatica	3	=n7	-0.023671824
Limnephilidae	1	=n8	-0.009485111
Sericostomatidae	44	=n9	-0.175683994
Hydropsychidae	1	=n10	-0.009485111
SUM:	689	=n11	**0.746403492**
Calopteryx splendens	3	=n15	-0.094525291
Libellula depressa	5	=n16	-0.135523805
SUM:	116	=n17	**2.104584483**

Table 8. Diversity indices in macroinvertbrate community of river Jasenica

Table 9. Diversity indices in macroinvertbrate community of river Bregava

Zoobenthos Bregava	Count of species unit	Shannon Index Variable Name	Shannon Index Calculation
Gammarus balcanicus	24	=n1	-0.240499843
Austropotamobius pallipes	30	=n2	-0.27047027
Electrogena lateralis	6	=n3	-0.097592376
Ecdyonurus venosus	5	=n4	-0.085433321
Serratealla ignita	1	=n5	-0.024336385
Baetis rhodani	17	=n6	-0.19676076
Perla marginata	24	=n7	-0.240499843
Isoperla grammatica	1	=n8	-0.024336385
Limnephilidae	51	=n9	-0.337898375
Sericostomatidae	2	=n10	-0.0424282
Glossosomatidae	46	=n11	-0.326151601

Rhyacophilidae	13	=n12	-0.166173263
Hydropsychidae	2	=n13	-0.0424282
SUM:	222	=n14	**2.095008821**

Table 10. Diversity indices in macroinvertbrate community of river Bunica

Zoobenthos Bunica	Count of species unit	Shannon Index Variable Name	Shannon Index Calculation
Bithynia mostarensis	23	=n1	-0.006091925
Gammarus balcanicus	26400	=n2	-0.008747054
Electrogena lateralis	14	=n3	-0.003969078
Ecdyonurus venosus	8	=n4	-0.002436135
Serratealla ignita	55	=n5	-0.012767274
Baetis rhodani	83	=n6	-0.01798459
Paraleptophlebia submarginata	5	=n7	-0.001610818
Isoperla grammatica	3	=n8	-0.001024029
Limnephilidae	1	=n9	-0.000382592
Sericostomatidae	15	=n10	-0.004213727
Glossosomatidae	2	=n11	-0.000713133
Hydropsychidae	25	=12	-0.006543392
SUM:	26634	=13	**0.066483748**

Table 11. A comparative review of the Shannon index of macrozoobenthos diversity for researched rivers

Researched river	Shannon Index Value
Trebižat	**2.104**
Buna	**1.622**
Bunica	**0.066**
Bregava	**2.095**
Jasenica	**0.746**

Based on the calculation of the Shannon Index, it can be concluded that the highest degree of macrozoobenthos diversity has the river Trebizat (2,104), then the river Bregava (2,095), followed by the river Buna (1,622), the river Jasenica (0,746) and finally the river Bunica which has an index value of only 0.066 (the cause of such a small index requires special consideration of all biotic and abiotic factors in the ecosystem of the Bunica River).