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RESULTS OF INVESTIGATING THE MACROINVERTEBRATE COMMUNITY OF THE DANUBE RIVER ON THE SECTOR UPSTREAM FROM THE IRON GATE (KM 1083-1071)

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Abstract - The present work cites results of investigating aquatic macroinvertebrates of the Danube River on the sector upstream from the Iron Gate (KM 1083-1071). The investigated part is interesting from the hydrobiological standpoint above all due to differences of faunal composition in relation to higher sections that could be expected in view of differences in overall characteristics of the river. A rich macroinvertebrate community (84 taxa) was observed. The diversity of taxa is primarily a result of habitat diversity within the given stretch. Oligochaeta and Mollusca were the principal components.

Key words : Aquatic macroinvertebrates, Danube, Iron Gate, Serbia

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INTRODUCTION

The watershed of the Danube is the second largest river basin in Europe, with a size of about 800.000 km^2. The basin extends over 17 countries. Total length of the river is 2.857 km.

The Serbian reach of the Danube measures 588 km in length. Its middle section and some of its lower part constitute a 220 km-long waterway that forms a natural frontier between Serbia and Montenegro and Romania. The major part of this sector of the Danube (358 km) belongs to the Pannonian basin. The given basin has an area of 178.000 km^2 within the borders of our country. In this section, the Danube is a typical lowland river with a slope of 0.05-0.04 per thousand.

Among the most important factors affecting the nature of the Danube are regulation and damming of the river. Due to construction of a dam at km 943 on the Danube near Sip, a large artificial lake, Djerdap, was formed. The lake stretch, 100 km in length, extends from the dam to Golubac (Iron Gate). After damming of the Danube, the flow rate was slowed upstream as far as Slankamen (km 1215).

The present work treats structure of the macroinvertebrate community upstream from the Iron Gate (km 1083-1076). Due to changes in overall characteristics of the river in the area, the sector can be characterized as the border zone between two Danube types, the Pannonian Plain Danube and the Iron Gate Danube (R o b e r t *et al.* 2003). As such, it is interesting from the hydrobiological standpoint. Moreover, the sector is important as target of monitoring because significant human pressure is present in the stretch of the river on the territory of Serbia and neighboring countries.

The Danube watershed on the territory of Serbia and Montenegro has 390 protected areas of national and international importance. This part of the Danube has particular importance for the preservation of biological diversity.

The sector is directly influenced by urban waste waters from numerous settlements within the stretch, as well as by the Kostolac Power Plant. Due to the Iron Gate I dam, the Danube's flow is retarded in this section and the sedimentation rate is higher than before the damming. The Iron Gate Reservoir (including the investigated sector) therefore acts as a depository of fine sediments and

pollutans, which are adsorbed to sediments or exist in particulate form (organic micro-pollutants, heavy metals, etc.). Through water-sediment interaction, water quality may also be affected, although its extent is yet to be studied. Moreover, bioaccumulation of persistent substances may have impacts on health of the ecosystem (B T F R e p o r t, 1999).

MATERIAL AND METHODS

The study is based on bottom fauna material collected during the period 1999-2002. The investigation was performed at 15 locations along the banks of the main channel of the Danube River on the sector between km 1083 and km 1076, on an artificial channel, and in marshy ecosystems along the investigated stretch.

Samples of macroinvertebrates were taken in the period 1999-2001 on the sector from km 1083 to km 1071. The investigations involved the main course of the Danube, as well as associated pools and bogs along the stretch and Ada Čibuklija, an island that has been partially submerged since the Iron Gate I dam was built. The sampling sites are presented in Fig. 1.

Sampling sites along the main course (marked MC for main course on Fig. 1) contained habitats with domination of soft-bottom substrates (silt and fine sand deposits) as well ones on hard substrates - pebbles and boulders.

Sampling sites on the Čibuklija Island (marked C for Čibuklija on Fig. 1), as well as ones in pool-bog ecosystems on side arms (marked SA for side arms on Fig. 1) were characterized by domination of soft-bottom substrates and a dense macrophyte community during the vegetation period (April - October). Macrophyte vegetation was mainly composed of the following species: *Potamogeton pectinatus, P. natans, P. fluitans, P. lucens, P. perfoliatus, Trapa* sp., and *Ceratophylum* sp. Pool-bog ecosystems were also characterized by the presence of *Nymphaea alba*, *Ranunculus paucistamineus*, and species belonging to the genera *Myriophyllum*, *Nymphoides*, and *Najas*.

Material was collected with a Hydraulic Polyp Grab, an FBA hand net (mesh size 950 µm), a benthological dredge (mesh size 250 µm), an Ekman-type grab (225 cm^2) and a Van Veen grab (270 cm^2) in the shore region. Animals were separated from sediment with a 200-µm sieve. The fauna stuck on the surface of rocks was collected with tweezers and, if necessary, scraped with a brush. Most of the available substrates were observed.

The samples were preserved with 4% formaldehyde. Sorting and identification were carried out using a binocular magnifier (5-50 x) and a stereomicroscope (10x10 and 10x40). The study included qualitative and quantitative analysis of the benthic community. The number of observed taxa and relative abundance are presented in order to describe the distribution of invertebrates along

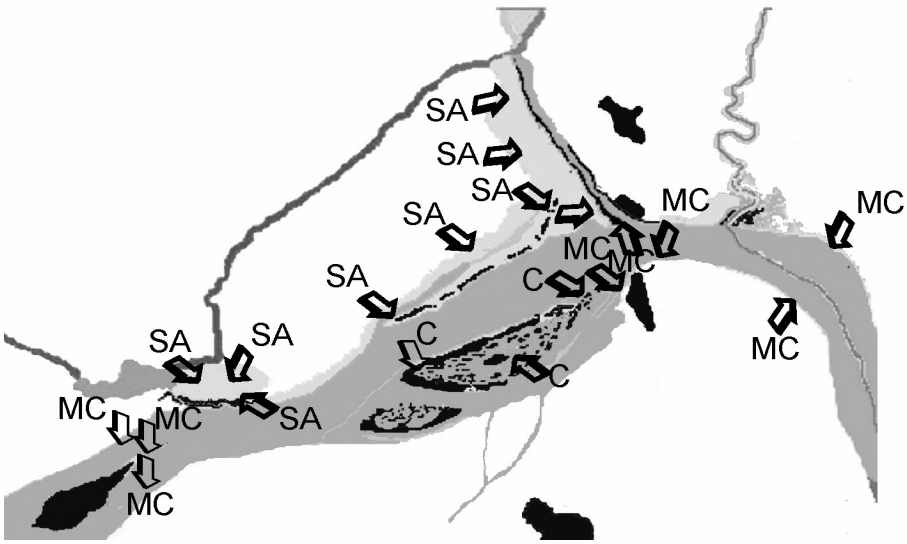

Fig. 1. Sampling sites: MC - sampling sites along the main course of the Danube; C - sampling sites on the partially submerged Čibuklija Island; SA - sampling sites on side arms of the Danube.

the sector. The relative abundance of taxa in samples or within certain habitats was expressed via the following five-step scale: 1 - present (1-2 individuals per sample); 2 - rare; 3 - frequent; 4 - common; and 5 - very common, mass occurrence. This was done to provide comparable data obtained from material collected by different sampling techniques. In the case of taxa fixed on a hard horizontal surface in relatively deep water (2-5 m), animals were collected and counted by scuba diving.

Correspondence (reciprocal averaging) analysis - CA (P i e l o u , 1984) - was carried out on an input table with 84 rows (taxa) x three columns. The input table implied data about the presence/absence of taxa at three groups of sites - sites on the main course of the Danube (MC), sites on Čibuklija Island (C), and sites on side arms in a pool-bog region (SA). This statistical technique resulted in an ordination diagram, which made it possible to analyze the relations between locations and fauna.

RESULTS

During the investigation, 84 macroinvertebrate taxa were identified, as presented in Table 1.

The greatest taxa richness was observed among Oligochaeta (25 species) and molluscs (22 species), the latter group including 13 species of snails (Gastropoda) and nine species of shells (Bivalvia). Aquatic worms (Oligochaeta) and molluscs were also the principal components of the community in regard to relative abundance. Other benthic groups were less diverse and frequent in the samples. Some animals were observed with considerable relative abundance at particular sampling sites.

Within the principal benthic group (Oligochaeta), the following species adapted to a high organic load (M o o g, 1995) were dominant: *Tubifex tubifex, Limnodrilus hoffmeisteri, L. claparedeianus, L. udekemianus,* and *L. profundicola* (Oligochaeta). Freshwater mussels (*Synanodonta woodiana, Anodonta complanata, A. anatina, Unio pictorum,* and *U. tumidus*) were found to be frequent inhabitants of silt-dominated habitats.

A diverse phytophilous fauna was observed on aquatic vegetation. Representatives of Naididae (Oligochaeta), Gastropoda, Amphipoda, Chironomidae (Diptera), and Odonata were typical inhabitants of aquatic vegetation. Among these groups, *Dikerogammarus villosus* (Amphipoda); *Theodoxus danubialis, T. fluviatilis, and Fagotia acicularis* (Gastropoda); *Pyrhossoma nymphula* (Odonata); and representatives of Chironomidae (Diptera) were the most frequent.

Habitats on hard substrates were observed near the settlement of Ram (right bank, km 1076-1071). This sector is interesting due to the presence of species that were not observed at other investigated sites: *A. holanri* and *Plumatella* sp. The given habitats are also characterized by dense populations of *T. fluviatilis* and *T. danubialis.*

The introduced, invasive species *S. woodiana, C. fluminea, H. invalida,* and *B. sowerbyi* were frequently found within the investigated area.

Figure 2 shows the position of groups of habitats (squares) among the species (arrows) that mostly influenced the habitats (three groups of sites - sites on the main course of the Danube, MC; sites on Čibuklija Island, C; and sites on side arms in a pool-bog region, SA) obtained by correspondence analyses. The position of groups of habitats is mainly determined by species specialized for a particular habitat type. Thus, *H. stagnalis* (Hirudinea); *H. invalida* (Polychaeta); *L. profundicola* (Oligochaeta); *A. lacustris, F. acicularis, B. tentaculata, V. naticina, V. piscinalis, L. peregra,* and *A. hollandri* (Gastropoda); and *Cleon* sp. (Ephemeroptera) were found only in habitats on the main course (taxon group 1 - TG1 on Fig. 2).

Sampling sites on side arms are characterized by the following taxa that were not observed at other sites: *G. concolor* (Hirudinea); *P. hammoniensis, N. communis, N. pseudobtusa, N. eluinguis, P. frici, V commata, S. josinae, C. diaphanus, Chaetogaster* sp., *A. pluriseta, D. obtusa,* and *U. uncinata* (Oligochaeta, Aelosomatidae and Enchitraeidae); *L. stagnalis* (Gastropoda); *S. woodiana, A. anatina, P. complanata, U. tumidus,* and *U. pictorum* (Bivalvia); *L. benedety* (Crustacea, Mysidae); Hydracarina; *C. agilis, C. plumosus,* Tanypodinae, and *Chaoborus* sp. (Insecta, Diptera); Collembola (Insecta), *C. horaria, E. ignita, P. luteus,* and *E. virgo* (Insecta, Ephemeroptera); *Notonecta glaucops* (Insecta, Hemiptera); *P. nymphula* (Insecta, Odonata); *Laccophylus* sp. (Insecta, Coleoptera) (taxon group 2 - TG2 on Fig. 2). Most of the observed species within TG2 are phytophilous taxa - animals adapted to habitats with dense aquatic vegetation. Taxon group 3 (taxon group 3 - TG3 on Fig. 2) is represented by the other species (not

Table 1. Relative abundance of macroinvertebrates in relation to habitat groups: UD - undetermined species among the group (species belonging to group, but not belonging to other taxa listed within the group; the abbreviations of sampling site groups correspond to those on Fig. 1).

Taxa Habitat groups	MC	C	PB	Taxa Habitat groups	MC	C	PB
COELENTERATA				*Amphimelandria hollandri*	3		
Hydra sp.	1		1	Bivalvia			
BRYOZOA				*Synanodonta woodiana*			3
Plumatella sp.	3			*Anodonta anatina*			1
NEMATODA UD	3	1	2	*Pseudanodonta complanata*			1
TURBELLARIA				*Sphaerium rivicola*	1	1	
Polycelis tenuis	1			*Corbicula fluminea*	3		
ANNELIDA				*Dreissena polymorpha*	5	1	2
Polychaeta				*Unio tumidus*			1
Hypania invalida	1			*U. pictorum*			1
Hirudinea				CRUSTACEA			
Helobdella stagnalis	2			Isopoda			
Erpobdella octoculata	1		1	*Asellus aquaticus*	3		1
Piscicola geometra		1		*Jaera* sp.	2		
Glossiphonia complanata	1		1	Amphipoda			
G. concolor			1	*Corophyum curvispinum*	5		3
Oligochaeta				*Corophyum* sp.	2		
Eisenniella tetraedra	1		2	*Gammarus* sp.	5		
Branchiura sowerbyi	2	2	2	*Dikerogammarus villosus*	2		3
Tubifex tubifex	2	4	3	*D. hemobaphes*	1		1
Limnodrilus hoffmeisteri	3	5	5	*Pontogammarus obesus*	1		1
L. udekemianus	3			Mysidae			
L claparedianus	3	5	2	*Paramysis lacustris*	4		
L. profundicola	3			*Limnomyssis benedety*			5
P. hammoniensis			2	ACARINA			
Nais communis			2	Hydracarina			1
N. pseudoobtusa			1	INSECTA			
N. elinguis			1	Diptera			
Paranais frici			1	Chironomidae UD	4	3	3
Ophidonais serpentina	1		1	*Chironomus agilis*			1
Vejdovskyella commata			1	*Chironomus gr. plumosus*			2
Specarira josinae			1	Tanypodinae			1
Stylaria lacustris	2		1	Ceratopogonidae		2	1
Chaetogaster diaphanus			1	Chaoboridae			
Chaetogaster sp.			1	*Chaoborus* sp.			2
Aulodrilus pluriseta			1	Simulidae UD	1		
Dero obtusa			2	Trichoptera			
Psammryectes allbicola	2	2	2	*Hydropsyche bulgaricomonorum*	3	1	1
Isochaetes michaelseni	1		1	Collembolla UD			1
Uncinais uncinata			1	Ephemeroptera			
Enchytraeidae UD			1	*Caenis horaria*			1
Aelosomatidae UD			1	*Ephemerella ignita*		1	
MOLLUSCA				*Potamanthus luteus*		1	
Gastropoda				*Ephoron virgo*			1
Acroloxus lacustris	2			Cloeon sp.	1		
Bithynia tentaculata	1			Hemiptera			
Fagotia acicularis	1			*Notonecta glaucops*		3	
Valvata naticina	1			Odonata			
V. piscinalis	1			*Pyrrhosoma nymphula*			2
Viviparus viviparus	2	2	2	*Gomphus flavipes*	2		1
Litoglyphus naticoides		2	2	*Calopterix splendens*	1		
Limnea peregra	2			*Onycogomphus forcipatus*	1		
L. stagnalis			2	Coleoptera (larvae)			
Theodoxus danubialis	1		2	*Laccophylus* sp.			1
T. fluviatilis	3		2				

included within TG1 and TG2) listed in Table 1, except for *Plumatella* sp., which was observed only in samples collected at Ada Čibuklija. We note that TG3 is mostly composed of ubiquitous species that contribute to faunistic similarity of the observed groups of sampling sites.

DISCUSSION

The sampling program revealed the presence of a rich macroinvertebrate community with 84 identified taxa, which is more than indicated by results of investigation of higher upper sections (Jakovčev, 1987, 1988; Djukić and Karaman, 1994) and the downstream stretch (Djukić and Karaman, 1994; Simić *et al.* 1997; Simić and Simić, 2004). Bearing in mind that some taxa (Nematoda, Chironomidae, Ceratopogonidae, Simulidae) were not identified to species level, the total number of taxa is certainly higher.

The taxa diversity results primarily from the presence of different habitat types - soft-bottom habitats (areas with domination of mud, fine sand and sand), habitats on hard substrates (gravel, stones and boulders), and ones with aquatic macrophytes and woody debris. Differences in macrophyte density and species composition additionally contribute to habitat complexity and, consequently, to the diversity of macroinvertebrate taxa.

Another aspect that contributes to the observed diversity of macroinvertebrates is the fact that investigated sector is in a zone of changes in overall characteristics of the river - the sector can be characterized as the border zone between two Danube types, the Pannonian Plain Danube and the Iron Gate Danube (Robert *et al.* 2003). Within the observed stretch, the influence of both the downstream sector and the higher zone is evident in the faunistic composition of macroinvertebrates. Thus, some species that were not observed in the higher stretch, but were observed downstream (Berneth *et al.* 2002), were found during our investigation. An example of this is *A. hollandri* (Gastropoda). Further, considerable relative abundance of *T. danubialis* and *T. fluviatilis* (Gastropoda) was observed in the present study. That is characteristic of the Iron Gate Danube.

We observed the macroinvertebrate fauna typical of

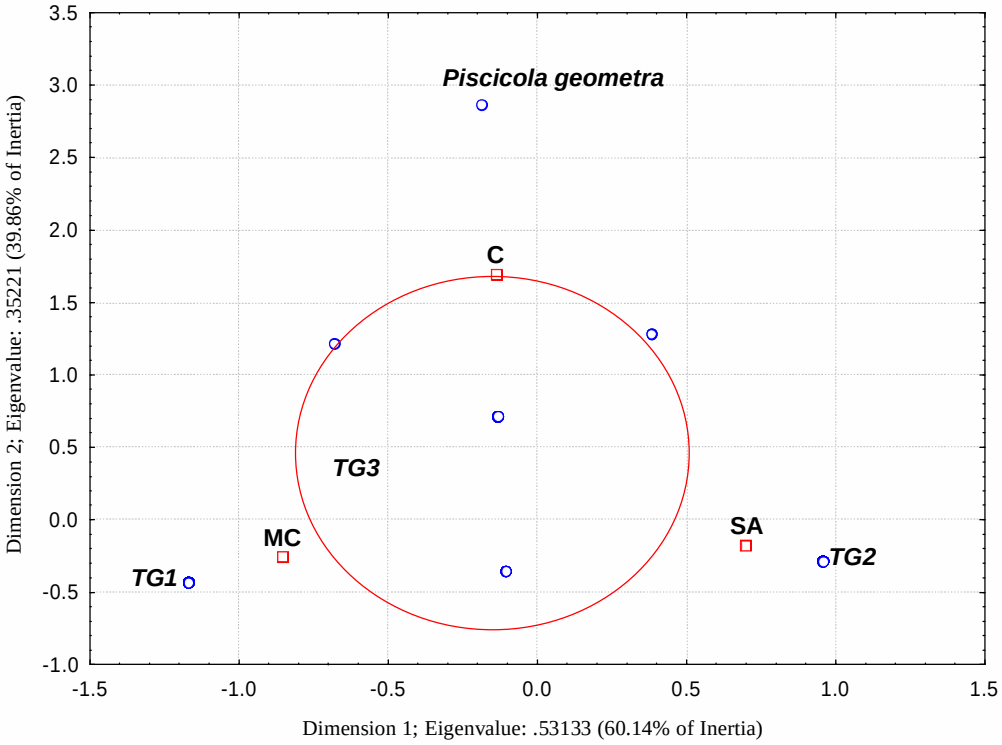

Figure 2. Results of correspondence analyses - input table with 84 rows (presence/absence of taxa within sampling site groups) x 3 columns (sampling site groups). Legend: The abbreviations of sampling site groups correspond to those on Fig. 1; TG1, TG2 and TG3 - taxon groups 1, 2 and 3, respectively (explanation in the text).

large lowland rivers. Oligochaetes and molluscs were the principal components of the community in regard to number of identified species, as well as in regard to relative abundance. That was expected in view of the watercourse type. Similar community structure was observed in previous investigations of the Danube River in Serbia (Jakovčev, 1987, 1988; Djukić and Karaman, 1994; Arambašić, 1994; Simić *et. al.* 1997; Simić and Simić, 2004). In potamon-type rivers in Serbia and neighboring regions, molluscs and oligochaetes are typically the most diverse and abundant groups.

Correspondence analyses (Fig. 2) showed differences in macroinvertebrate fauna composition among sampling sites along the main course of the Danube (MC) and those selected on side arms (SA). They are indicated by dimension 1 (60% of variability). Sites located on Čibuklija Island (C) are situated in the central position of the ordination graph in relation to dimension 1. Deviation in central position of the C group of sites in relation to dimension 2 is primarily a consequence of finding of *P. geometra* (Hirudinea) at related sites. The given species is not typical of a certain habitat type, so variation of the C group of sites with respect to dimension 2 can be disregarded. Positioning of site group C in the central part of the diagram showed that faunistic composition of related sites has a transitional character between the fauna observed at main course sites (MC) and that observed on side arms (SA). This finding can be attributed to the presence of the environmental conditions observed at main course sites (soft-bottom, hard bottom, flowing sections) and those observed on side arms (dense macrophyte vegetation, standing water sectors, detritus).

The position of groups of sampling sites on the correspondence analysis ordination diagram is determined by three groups of species (Fig. 2).

It should be underlined that the introduced, invasive species *S. woodiana*, *C. fluminea*, *H. invalida*, and *B. sowerbyi* were frequently found within the investigated area. The mentioned species were also found in previous investigations of the Danube (Djukić and Karaman, 1994; Simić *et. al*. 1997; Berneth *et. al*. 2002) and its main tributaries (Csanyi, 2002; Paunović, 2004). Due to the significant threat to health of the aquatic ecosystem as documented by Mack *et al.* (2000), populations of invasive alien species should be intensively observed in order to design protective measures.

CONCLUSIONS

A rich macroinvertebrate (84 taxa) community was observed within the investigated sector.

Taxon richness can be attributed to habitat diversity, as well as to the position of the investigated part at the border between two Danube types.

We observed the macroinvertebrate fauna typical of large lowland rivers, with domination of oligochaetes and molluscs.

Three groups of sites were determined according the faunistic structure of macroinvertebrates using correspondence analyses - sites along the main course (MC on Figs. 1 and 2), sites on side arms (SA on Figs. 1 and 2), and sites on Čibuklija Island (C on Figs.1 and 2).

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РЕЗУЛТАТИ ИСТРАЖИВАЊА ЗАЈЕДНИЦЕ МАКРОИНВЕРТЕБРАТА ДУНАВА У СЕКТОРУ УЗВОДНО ОД ЂЕРДАПА (1083 - 1071 КМ)

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Циљ рада је да се прикажу резултати истраживања водених макроинвертебрата у сектору узводно од Ђердапа (1083-1071 km). Истраживано подручје интересантно је за хидробиолошка истраживања, пре свега, због промена у структури фауне у односу на горњи део тока, што је и очекивано ако се узму у обзир промене општих карактеристика реке у сектору. Забележено је разноврсно насеље макроинвертебрата (84 таксона). Разноврсност фауне последица је, пре свега, диверзитета станишта у оквиру истраживаног подручја. Групе Oligochaeta и Mollusca биле су најзначајније компоненте проучаване заједнице макроинвертебрата.