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TROPHIC RELATIONS BETWEEN MACROINVERTEBRATES IN THE VLASINA RIVER (SERBIA)

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Abstract - The aim of the study presented was to define trophic relationships within the benthic community according to functional feeding groups (FFG) in the Vlasina River (Southeast Serbia), with an attempt to use those results to describe the watercourse. In an investigation performed during 1996, a total of 125 macrozoobenthic taxa were identified, 95 of which were included in FFG analyses. Although the investigated part of the river, in its physical and chemical characteristics, as well as characteristics of the benthofauna, generally corresponds to what could be expected, certain variations of faunal composition were observed along the river. Two groups of sites were separated by FFG analysis - sites on the upper section of the river and on a tributary (the Gradska River) comprised one group, while the remaining sites made up the other.

Key words: Stream ecosystem, benthic invertebrates, functional feeding groups, bioindication, watercourse characterization

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INTRODUCTION

Changes in food availability play an important role in distribution of functional groups along a watercourse, as well as in seasonal changes of the biocenosis (Allan, 1995). The relations among functional groups are often more important for community description than taxonomic status of organisms. Classification according to functional groups provides a further perspective that can be combined with the other community attributes to ensure better understanding of the match between habitat and aquatic fauna (Towsend *et al.,* 1997). The river continuum concept (Vannote *et al.,* 1980), i. e., the nature of trophic relationships, implies that the macroinvertebrate community should follow a predictable pattern along the watercourse. Regularities of community distribution can thus be used as a trait for watercourse description.

The aim of this work is to give a picture of the watercourse using the pattern of trophic relationships among benthic macroinvertebrates. Functional groups have been found to be useful for characterization of river reaches (Palmer *et al.,* 1996). Feeding roles, incorporated in functional analysis, can play an important part in biomonitoring (Charvet *et al.,* 1998). The thropic structure of a stream ecosystem can be indirectly evaluated on the basis of FFG. Accordingly, the aim of this paper was to establish trophic relationships within the "benthic community". Regardless of the complexity of food relationships, habitat, and age-specific variations, this generalization is reasonable in view of the advantage of observing the trophic aspect of an ecosystem in terms of groups with similar food requirements. The ecological importance of such an approach was underlined by Cummins (1973) and confirmed by Allan (1995).

MATERIAL AND METHODS

The Vlasina River is a medium-sized watercourse that belongs to the watershed of the Danube. The river is 62 km long. It flows out from the Vlasina Reservoir (42° 42' N, 22° 20' E) at an altitude of 1,219 m and runs through Southeast Serbia. The Vlasina joins the Southern Morava River (42° 52' N, 22° 2' E) at an altitude some 1,000 m lower. The watercourse mainly flows at altitudes over 500 m. Total area of the watershed of the Vlasina is

830 km^2, about 80% of it belonging to forest ecosystems. Thirty three settlements with more than 12,700 inhabitants are associated with the river's watershed. The Vlasina receives water from 70 permanent and ephemeral tributaries. The absolute minimum water discharge was recorded in 1950 and comprised 0.996 m^3 s^{-1}, while the maximum value was 130 m^3 s^{-1} prior to 1988, when a historical maximum water discharge of 1,200 m^3 s^{-1} was registered (PHIB, 1995). These data point to an occasional torrential nature of the Vlasina and its tributaries. In 1996 water discharge per km^2 (average values in dm^3 s^{-1} km^{-2}) of these rivers was above average, to judge from analysis of hydrological data for the watershed of the southern Morava River (D u t i n a *et al.,* 1999).

According to previous investigations, the chemical quality of the water of Vlasina River and its tributaries can be classified as good (belonging to the category of second class, i.e., within the category defined as suitable for water supply; P H I B , 1995). It was underlined that the Crna Trava settlement and the tributaries Gradska Reka and Lužnica contribute to pollution of the river section examined. Diversity of the physical habitat, high content of dissolved oxygen, the presence of moderate amounts of organic matter, and the absence of toxicants in the form of (micro)organic pollutants and heavy metals were reported.

The Vlasina River is not a typical model for river investigations from source to mouth (S i m i ć , 1995; P a u n o v i ć , 2001) because its initial section differs from the source part of a typical lotic system (V a n n o t e *et al.,* 1980; A l l a n , 1995). The Vlasina flows out of a reservoir and in its initial section it passes through a mildly inclined terrain with dominant peat bog vegetation (over the first 7 km of the water course).

Seven sampling sites were chosen along a 50-km-long section of the river; five were on the main stream and the reminder on its major tributaries (the Gradska and Lužnica Rivers) just before entering the Vlasina (Fig.1). The altitude of sampling sites ranged between 930 and 250 m. a.s.l. The samples were collected during May, July, September, and November of 1996.

Substrate properties were observed visually. Mineral substrates were classified by particle size according to V e r d o n s c h o t (1999) as follows: 1) fine substrate (silt-clay and very fine sand; grains not visually perceptible; <0.125 mm); 2) fine sand (grains visually perceptible; 0.125-0.5 mm); 3) coarse sand (0.5-2 mm); 4) gravel (2-16 mm); 5) pebble (16-34 mm); 6) cobble (64-256 mm); and 7) boulder (>256 mm).

The samples for analyses of physical and chemical characteristics of the water and biological materials were collected simultaneously. Collecting of the benthic fauna was performed using a Sürber net (0.1 m^2). 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). After identification, macroinvertebrates were classified into four functional groups (shredders, collectors, scrapers, and predators) according to C u m m i n s (1973), C u m m i n s and K l u g (1979), and P e r r y and D a v i d (1987), as well as in the light of discussions of oligochaete feeding ecology (C h e k a n o v s k a y a , 1962; T i m m , 1980, 1987). The functional feeding group (FFG) ratio was analyzed in relation to sampling site and period, with notation of the percentage composition of each group. Relationships between the analyzed sites were derived from the obtained distance matrix using the complete linkage clustering method (P i e l o u , 1984).

Processing of samples for analyses of physical and chemical water quality parameters was performed applying standard limnological methodology (A P H A , 1980).

RESULTS

During 1996, the flow rate of the Vlasina at location 7 ranged from 0.33 to 1.08 m s^{-1}.

With respect to substrate type and current, some habitat heterogeneity was in evidence from site to site, but a similar biotope composition was observed at all sampling stations.

The estimated participation of substrate types of different sampling sites is presented in Table 1.

Table 2 shows the range of selected water-quality parameters in the Vlasina River and its main tributaries.

A total of 131 macroinvertebrate taxa were found (Table 3). Primarily consisting of insects (Ephemeroptera, Trichoptera, Coleoptera, Plecoptera, Diptera, and Hemiptera) and oligochaetes (Oligochaeta), the taxa collected also included representatives of Nematoda, Mollusca, Hirudinea, and Crustacea. The greatest species

Table 1. Estimated participation of substrate types (%) at sampling sites (sampling sites correspond to Fig. 1)

substrate	fine substrate	fine sand	coarse sand	gravel	pebble	cobble	boulder	detritus cover
Site 1	2	3	7	15	20	23	30	2
Site 2	1	3	9	17	25	25	20	4
Site 3	3	2	17	25	24	18	11	6
Site 4	3	7	12	12	28	28	10	17
Site 5	1	3	15	23	30	18	10	9
Site 6	2	3	15	11	32	29	8	19
Site 7	25	11	7	10	21	20	6	20

richness was recorded among oligochaetes (Oligochaeta), mayflies (Ephemeroptera), and caddisflies (Trichoptera), while other groups were less diverse. Species that are typical of highland streams predominated. Twenty-seven taxa were typical rheophilous species, while the others were rheotolerant forms, euryvalent species, or ones adapted to specific habitats.

One hundred and nineteen taxa from the total of 131 observed macroinvertebrate taxa were included in functional analyses based on their preference for a particular food resource (Table 3).

Table 2. Selected water quality parameters in the Vlasina river and its two main tributaries - the Gradska River and the Lužnica.

Parameter	Vlasina	Gradska River	Lužnica
pH	6.9-8.5	7.5-7.7	8-8.5
O_2 (mg l^{-1})	8.80-12.50	9.50-11.40	6.10-9.90
% O_2	82-125	87-118	59-97
BOD_5 (mg l^{-1})	0.20-3.44	1.50-11.13	1.60-2.30
COD (mg l^{-1})	1.50-4.70	2.20-5.00	1.40-1.70
$N\text{-}NH_4^+$ (mg l^{-1})	<0.05-0.12	0.08-0.12	<0.05-0.29
$N\text{-}NO_3^-$ (mg l^{-1})	<0.1-0.68	0.23-0.68	0.53-0.90
$P\text{-}PO_4$ (mg l^{-1})	<0.01-0.86	0.03-0.82	0.02-0.60
Orthophosphate (mg l^{-1})	<0.01-0.47	0.02-0.49	<0.01-0.36
Total hardness (°dH)	1.08-13.10	3.70-4.48	9.80-13.10
Conductivity (µS cm^{-1})	94-258	103-123	352-375
Dissolved matter (mg l^{-1})	68-178	79-122	264-300
CO_3^{-2} (mg l^{-1})	0-18	0-6	0-36
Fe^{3+} (mg l^{-1})	0.05-0.70	0.26-1.10	0.05-0.50
Mg (mg l^{-1})	2.34-17.00	6.998-8.5	5.78-29.14
Mn (mg l^{-1})	<0.001-0.09	<0.001-0.12	<0.05
Cl^- (mg l^{-1})	4.00-8.00	4.00-5.00	6.00-10.00
SO_4^{-2} (mg l^{-1})	2.7-22.74	4.30-16.02	11.20-30.10

As can be seen from Table 4, scrapers and collectors were the principal components of the community. The mean percentage of collectors and shredders increased down the watercourse, while that of scrapers declined in the same direction. The pattern of FFG distribution indicates gradual changes in food availability and a nuanced transition of the watercourse.

In terms of mean density per site, predators were best represented at sites 4 and 6.

Relationships between sites based on average percentage participation of FFG per site [ind. m^{-2}] were analyzed using the complete linkage clustering method (P i e l o u , 1984). The result are presented in Fig. 2. Two groups of sites were separated - sites on the upper section of the river (1, 2, and 4; altitude up to 500 m) together with site 3 on a tributary (the Gradska River) comprised one group, while sites 6, 7, and 5 made up the other. Extrapolation of the results of cluster analyses (Fig. 2) underline the differences between two reaches of the river.

The patterns of FFG distribution in relation to sampling period (Table 5) showed that the percentage of collectors and shredders rises from May to September and then declines in November. The maximum density of these groups in September can be attributed to intensive defoliation in that period, which provides plenty of food for shredders. At the same time, decomposition of allochthonous matter provides a feeding substratum for collectors, fiterers, and sediment feeders.

Table 3. Invertebrates recorded in the Vlasina, Gradska, and Lužnica Rivers; their trophic categories; sampling sites correspond to Fig. 1; Abbreviations: FFG) Functional fidings group; *SC*) scraper; *CO*) collector; *SH*) shreeder; *PR*) predator.

TAXA **SITE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**FFG**
NEMATODA								
1. Nematoda spp.	+	+	+	+			+	
GASTROPODA								
2. *Ancylus fluviatilis* Müll.	+	+	+					*SC*
BIVALVIA								
3. *Sphaerium corneum* L.	+	+						*CO*
OLIGOCHAETA								
4. *Haplotaxis gordioides* Hart.	+							*CO*
5. *Enchitraeus albidus* Henl.		+		+	+			*CO*
6. *Proppapus volki* Mich.				+		+		*CO*
7. *Mesenchitraeus* (*Analycus*) sp.			+					*CO*
8. Enchytraeidae spp.	+	+	+	+	+	+	+	*CO*
9. *Nais alpina* Sper.				+				*CO*
10. *N. barbata* Müll.			+		+			*CO*
11. *N. behningi* Mich.			+					*CO*
12. *N. bretcheri* Mich.	+	+	+					*CO*
13. *N. communis* Pig.	+	+	+	+	+		+	*CO*
14. *N. elinguis* Müll.		+	+			+	+	*CO*
15. *N. pseudobtusa* Pig.	+	+	+		+	+	+	*CO*
16. *N. simplex* Pig.		+	+	+	+		+	*CO*
17. *Homochaeta naidina* Brets.				+		+		*CO*
18. *Paranais frici* Hr.							+	*CO*
19. *Pristina bilobata* Brets.	+							*CO*
20. *P. foreli* Pig.			+					*CO*
21. *P. menoni* Aiy.		+						*CO*
22. *P. rosea* Pig.	+		+			+	+	*CO*
23. *Limnodrilus hoffmeisteri* Clap.	+	+		+	+	+	+	*CO*
24. *Tubifex tubifex* Müll.		+		+	+	+	+	*CO*
25. *Peloscolex velutinus* Gr.	+							*CO*
26. *Psammoryetides albicola* Mich.						+	+	*CO*
27. *Eiseniella tetraedra* Savi.	+	+		+	+			*CO*
28. *Microscolex* sp.	+	+						*CO*
29. *Lumbriculus variegatus* Müll.	+	+	+	+		+		*CO*
AMPHIPODA								
30. *Gammarus* (*Rivulogammarus*) *balcanicus* Sch.	+	+	+	+	+		+	*CO*
HYDRACARINA								
31. Acarina spp.	+	+	+	+	+	+	+	
32. Hydrobatinae spp.				+				
INSECTA								
EPHEMEROPTERA								
33. *Baetis alpinus* (Pict.)		+		+	+		+	*CO*
34. *B. rhodani* Pict.	+	+	+	+	+	+	+	*CO*
35. *B. fuscatus* L.	+	+	+	+	+	+	+	*CO*
36. *B. niger* L.	+				+	+		*CO*
37. *B. vernus* Curt.							+	*CO*
38. *B. lutheri* Müll. & Libb.				+				*CO*
39. *Baetis* sp.		+		+	+		+	*CO*
40. *Oligoneuriella rhenana* Imh.			+	+	+	+	+	*CO*
41. *Ecdyonurus venosus* group	+	+	+		+	+	+	*SC*
42. *E. dispar* (Curt.)						+		*SC*
43. *Ecdyonurus* sp.	+	+	+		+	+	+	*SC*
44. *Rhitrogena semicolorata* Group	+	+	+	+	+	+	+	*SC*
45. *Electrogena lateralis* (Curt.)	+	+	+	+		+	+	*SC*

Table 3. Continued.

TAXA	**SITE**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**FFG**
46.	*Heptagenia lateralis* Gran.	+	+	+	+		+	+	*SC*
47.	*H. sulphurea* Müll.	+	+		+		+		*SC*
48.	*Habroleptoides confusa* Sar. et Jac.							+	*CO*
49.	*H. modesta* Hag.							+	*CO*
50.	*Habrophlebia fusca* Curt.					+	+	+	*CO*
51.	*Paraleptophlebia cincta* Retz.	+							*CO*
52.	*P. submarginata* Steph.	+	+					+	*CO*
53.	*Paraleptophlebia* sp.	+							*CO*
54.	*Potamanthus luteus* L.						+	+	
55.	*Ephemera danica* Müll.	+	+				+		*CO*
56.	*E. glaucops* Pict.	+							*CO*
57.	*E. lineata Etn.*	+							*CO*
58.	*Seratella ignita* (Pod.)	+	+	+	+	+	+	+	*CO*
59.	*Ephemerella mucronata* (Bent.)	+	+	+	+	+	+	+	*CO*
60.	*E. notata* Etn.	+	+	+	+	+	+	+	*CO*
61.	*Caenis* gr. *macrura* Steph.			+	+	+		+	*CO*
62.	*C. horaria* L.			+					*CO*
63.	*C. robusta* Etn.			+					*CO*
64.	*Caenis* sp.			+		+	+	+	*CO*
ODONATA									
65.	*Gomphus* sp.			+			+	+	*PR*
PLECOPTERA									
66.	*Isoperla grammtica* (Pod.)	+	+	+	+		+	+	*PR*
67.	*Perlodes microcephala* Pict.			+					*PR*
68.	*Perlodes* sp.				+				*PR*
69.	*Leuctra hippopus* Kmp.	+	+	+	+	+	+	+	*SH*
70.	*L. nigra* (Ol.)		+			+			*SH*
71.	*Nemoura cinerea* Retz.	+	+		+				*SH*
72.	*Nemoura* sp.	+						+	*SH*
73.	*Amphinemoura sulcicolis* Steph.	+	+	+					*SH*
74.	*Nemurella picteti* Klp.		+						*SH*
75.	*Protonemura mayeri* Pict.	+	+						*SH*
76.	*Perla bipunctata* Pict.	+	+	+	+			+	*PR*
77.	*Dinocras cephalotes* (Curt.)	+		+		+			*PR*
78.	*Taeniopterix nebulosa* L.							+	*PR*
79.	*Taeniopterix* sp.							+	*PR*
TRICHOPTERA									
80.	*Brachicentrus* sp.				+		+	+	*PR*
81.	*Oligoplectrum maculatum* Four.	+	+				+	+	*PR*
82.	*Glossosoma boltoni* Curt.	+	+	+			+	+	*SC*
83.	*Hydropsyche angustipennis* Curt.	+	+	+	+	+	+	+	*CO*
84.	*H. instabilis* Curt.	+	+	+	+	+	+	+	*CO*
85.	*H. pellucida* Curt.			+		+		+	*CO*
86.	*Hydropsyche* sp.	+		+		+		+	*CO*
87.	*Hydroptila* sp.	+				+			*CO*
88.	*Limnephilus flavicornis* Fabr.		+						*SH*
89.	*L. bipunctatus* Curt.				+				*SH*
90.	*Limnephilus* sp.	+	+	+	+			+	*SH*
91.	*Potamophylax stellatus* Curt.		+		+				*SH*
92.	*Potamophylax* sp.		+						*SH*
93.	*Odontocerum albicorne* Scop.	+	+	+	+				*SC*
94.	*Philopotamus montanus* Don.	+	+	+		+	+		*CO*
95.	*Polycentropus flavomaculatus* Pict.	+	+	+	+	+	+	+	*PR*
96.	*Polycentropus* sp.		+				+		*PR*
97.	*Plectrocnemia conspersa* Curt.	+	+	+	+	+	+	+	*PR*
98.	*Rhyacophila dorsalis* Curt.	+	+	+	+				*PR*
99.	*R. fasciata* Hag.				+	+			*PR*
100.	*R. nubila* Zett.	+	+		+		+	+	*PR*
101.	*Rhyacophila* sp.	+	+	+					*PR*

Table 3. Continued.

TAXA	SITE	1	2	3	4	5	6	7	FFG
102.	*Silo palipes* Fabr.	+		+	+	+		+	*PR*
103.	Leptoceridae spp.	+		+	+	+			*SH*
104.	*Sericostoma personatum* K. & Sp.					+			*SC*
105.	*Psychomya pulsila* Fabr.				+				*CO*
COLEOPTERA									
106.	Gyrinidae spp.				+	+	+	+	*PR*
107.	*Elmis* sp_1.	+	+	+	+	+	+	+	*SC*
108.	*Elmis* sp_2.		+					+	*SC*
109.	*Elmis* sp_3.	+	+	+	+	+	+	+	*SC*
110.	*Elmis* sp_4	+	+	+	+	+	+	+	*SC*
111.	*Limnius* sp.	+	+	+	+	+	+	+	*SC*
112.	Coleoptera spp.	+	+	+	+	+	+	+	
113.	*Enicocerus* sp.				+				
HEMIPTERA									
114.	Heteroptera spp.		+	+	+	+		+	
DIPTERA									
115.	Chironomidae spp.								
116.	*Atherix ibis* F.		+		+				*PR*
117.	*Dicranota* sp.	+	+	+	+	+		+	*PR*
118.	*Antocha* sp.		+	+	+	+	+	+	*CO*
119.	*Pedicia* sp.		+						*PR*
120.	*Tabanus* sp.		+		+	+	+	+	*SC*
121.	*Tipula* sp	+					+	+	*SH*
122.	Tipulidae	+	+	+	+	+	+		*SH*
123.	*Wiedemannia oedorum* Vaill.	+	+	+	+	+	+	+	
124.	*Hemerodromia unilineata* Zett.		+					+	*PR*
125.	Blephaceridae spp.		+	+	+				
126.	Ceratopogonidae spp.	+	+	+		+			*CO*
127.	*Simulium* sp.			+					*CO*
128.	*Wilhelmia lineata* Mg.		+						*CO*
129.	*Twinnia hydroides* Nov.							+	
130.	Simulidae spp.	+	+	+	+	+		+	*CO*
131.	Psychodidae spp.		+						

DISCUSSION

A total of 131 macroinvertebrate taxa were found (Table 3). Species that are typical of medium-sized highland streams in the region (Paunović *et al.*,1997, 2003; Paunović, 2001) predominated among the macroinvertebrates recorded during our investigation of the Vlasina River and its main tributaries. Due to habitat heterogeneity (Simić, 1995; Paunović, 2001; Paunović *et al.*, 2003) and good water quality (PHIB, 1995; Simić, 1995; Martinović-Vitanović *et al.*, 1995, 1998; Paunović *et al.*, 1998, 1999), a diversified invertebrate community composed of species having different ecological requirements (Paunović, 2001; Pau-

Table 4. Breakdown of FFG (%) in relation to sampling site (sampling sites correspond to Fig. 1)

Location	Predators	Shreeders	Scrapers	Collectors
1	3.62	6.80	40.55	49.03
2	3.95	5.50	57.50	33.05
3	2.84	6.38	48.58	42.20
4	9.25	5.63	40.28	44.85
5	2.36	11.82	32.86	52.96
6	9.54	8.09	30.71	51.66
7	4.15	20.25	17.20	58.39

Table 5. Breakdown of FFG (%) in relation to sampling period.

Period	Collectors	Predators	Scrapers	Shreeders
May	43.26	6.51	45.89	4.34
July	49.15	3.15	38.48	9.22
September	50.78	4.43	32.98	11.82
November	35.08	8.06	50.69	6.17

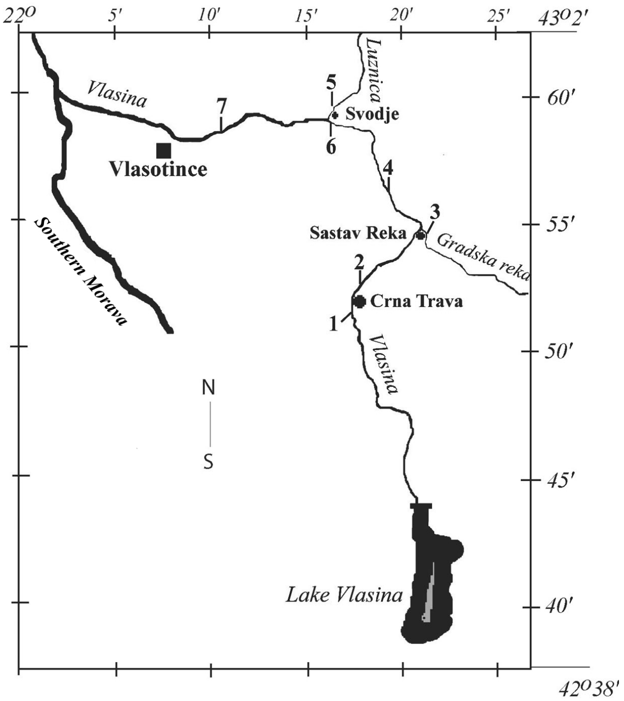

Fig. 1. Sampling sites.

n o v i ć *et al.,* 2003) was found. Oxygen content in the water, which can be an essential factor limiting the distribution of aquatic invertebrates in streams (A l l a n , 1995) is high (Table 2). This was also indicated by previous studies (P H I B , 1995; M a r t i n o v i ć - V i t a n o v i ć *et al.,* 1995, 1998). The presence of a moderate amount of organic matter (Table 2) is another reason for species richness, which was also reported previosly, (M a r t i n o v i ć - V i t a n o v i ć *et al.,* 1995, 1998; P a u n o v i ć *et al.,* 1998, 1999, 2003).

In order to underline the favorable environmental conditions for aquatic fauna, it is relevant to mention that according previous studies (P H I B , 1995, M a r t i n o v i ć - V i t a n o v i ć *et al.,* 1995, 1998; P a u n o v i ć *et al.,* 1998, 1999), heavy metals (As, Cd, Cr, Ni, Pb, Hg, Zn) and (micro)organic pollutants [organochlorine and organophosphate insecticides, triazine herbicides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs)] are not present in the Vlasina River.

We attempted to describe the Vlasina River by observing trophic aspects of the ecosystem in relation to groups with similar food requirements (FFG).

The following information can be worked out by observing the FFG ratio alone:

- According to the food resources - invertebrates - stream size relationship (A l l a n , 1995), all sampling places corresponded to mid-order sites.

- We found scrapers to be one of the principal components at all sampling sites. The periphyton is an important food source for some invertebrates, particularly in shallow streams with minimal shading (A l l a n , 1995). The domination of scrapers indicates that the periphyton was productive along the watercourse. This assertion is supported by previous studies. The phytoperiphyton of the Vlasina river is composed of moss (S i m i ć , 1995) and algae. Diatoms are dominant both qualitatively and quantitatively, while *Chlorophyceae* and *Cyanophyceae* are also abundant (M a r t i n o v i ć - V i t a n o v i ć *et al.,* 1995, 1998; P a u n o v i ć *et al.,* 1997, 1998, 1999).

- Gradual changes in food availability and a nuanced transition of the watercourse were indicated by increase in mean percentage of collectors and shredders and decrease in the mean percentage of scrapers along the watercourse. The increase in abundance of collectors was in correlation with the intensification of sedimentation that was observed along the watercourse. Increase in the mean participation of shredders along the watercourse may be connected with the fact that some reaches of the Vlasina river situated between sites 2 and 6 (Fig. 1) are characterized by the presence of forest down to the very edge of the watercourse, while forests are more or less far from the water line along other sectors of the Vlasina (P a u n o v i ć , 2001). Forests are a source of leaf litter, which plays an important role in stream food webs. The relation of shredders to leaf litter has been extensively discussed, and they are typically most abundant where there is a strong interaction between the stream and the riparian zone (V a n n o t e *et al.,* 1980; A l l a n 1995; D e - l o n g and B r u s v e n , 1998).

- Two groups of sites were separated when the complete linkage clustering method was used to analyze relations between sampling sites on the basis of average percentage participation of FFG per site (Fig. 2). Sampling sites on the upper section of the river (1, 2, and 4; altitude up to 500 m) together with site 3 on a tributary (the Gradska River) comprised one group, while sites 6, 7, and 5 made up the other. The participation of FFG at different sampling sites is presented in Table 4, from which it can be seen that noticeable differences exist between the two groups of sites in the guise of significantly higher abundance of collectors and shredders and lower density of scrappers at sites 5, 6, and 7 in relation to others. At sites on the upper sector (Fig. 2), scrapers and collectors were represented for the most part equally (with certain fluctuations), while at sites on the lower sector (sites 5, 6, and 7) collectors became the principal group. In the light of the FFG relationships observed on the Vlasina River, it can be asserted that the amount of collectors corresponds to the typical shift discussed in the river continuum concept (Vannote *et al.,* 1980). Vannote *et al.* (1980) predicted an increase of fine particulate organic matter (FPOM) downstream, such increase being reflected in rising density of collectors-filterers.

- FFG data, particularly the abundance of shredders (Table 4) observed in our study, suggest that the Vlasina is an agriculturally less impacted stream. According to Dance and Hynes (1980) and Delong and Brusven (1998), shredders are rare in impacted streams.

The river continuum concept (Vannote *et al.,* 1980) and stream trophic theory (Cummins and Klug, 1979) postulate that the abundance of functional feeding groups should change seasonally, primarily in response to increased availability of particulate organic matter. Our observations of the FFG ratio in relation to sampling period (Table 5) showed that the percentage of collectors and shredders increases from May to September and then declines in November. The greater density of those organisms was caused by increased accessibility of allochthonous plant matter during the warmer period of the year. Annual vegetation activity leads to an increase in the amount of plant debris entering the aquatic food web through microbial processing (Allan, 1995). The

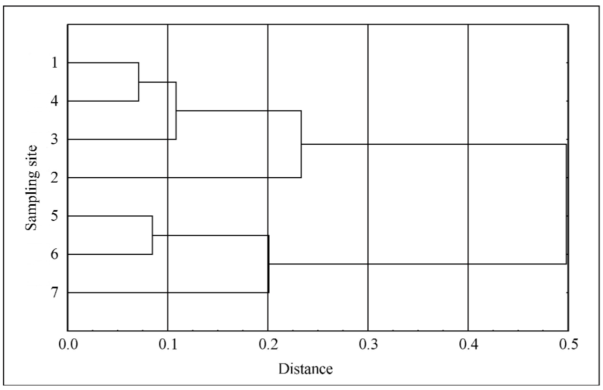

Fig. 2. Relationships between analyzed sites based on average percentage participation of FFG per site [ind. m^{-2}] using the complete linkage clustering method (Pielou, 1984)

maximum density of shredders in September can be attributed to intensive defoliation in that period (Paunović, 2001), which provides plenty of food for shredders. Up to 80% of allochthonous inputs from throughfall and bank runoff enter European streams during the few weeks in autumn when leaf abscission occurs (Dudgeon and Bretscho, 1996). Higher abundance of shredders in autumn in relation to other periods demonstrates the linkage of life cycle timing to seasonal changes in food aviability (Allan, 1995). At the same tame decomposition of allochthonous matter provides feeding substratum for collectors, filterers, and sediment feeders (Allan, 1995), and this leads to rising density of collectors from May to September. The presumption that the abundance of scrapers is related to algal abundance is questionable due to the fact that scrapers can use alternative food sources during low algal abundance (Delong and Brusven, 1998).

The values of the FFG ratio obtained in the present investigation resulted in conclusions comparable to those reached in other studies (Simić, 1995; Paunović *et al.,* 1997; Paunović, 2001; Paunović and Jakovčev, 2002). Mayflies (Ephemeroptera), together with aquatic worms (Oligochaeta) and caddisflies (Trichoptera), are the principal benthic groups in the Vlasina River (Simić, 1995; Paunović *et al.,* 1997, 2003; Paunović, 2001; Paunović and Jakovčev, 2002). According to these findings and data indicating relatively constant diversity and density of mayflies (Paunović, 2001), the Vlasina River has qualities that correspond to medium-sized watercourses (Allan, 1995) as is also indicated by the result of FFG analyses.

Previous classification of sites along the Vlasina River on the basis of mean abundance of taxa and physical and chemical parameters of water quality (Paunović, 2001) using the complete linkage (CL) clustering method with Euclidean distance as the dissimilarity measure (Pielou, 1984) and correspondence analyses (Pielou, 1984) showed that three sectors of the river can be separated - upper reaches (sites 1 and 2), middle section (sites 4 and 6) and downstream section (site 7). Certain differences of watercourse division using FFG and other attributes (Paunović, 2001; Paunović and Jakovčev, 2002) can result from different classifications of organisms in relation to food supply (Cummins, 1973), as well as from differences in the real ratio of available food.

The ecological importance of using food relationships in combination with other attributes for aquatic ecosystem description has been clearly established (Allan, 1995; Charvet *et al.,* 1998). Classification of macroinvertebrates into EFG requires limited taxonomic precision, since collected organisms are for the most part identified only to the family or genus. Bearing in mind the difficulty of analyzing a watercourse in terms of species composition (which involves a complex process of identification) and the high costs of chemical analysis, use of the FFG ratio as the only parameter to delineate a watercourse is reasonable within the framework of a limited investigation. This approach is useful for preliminary investigations preparatory to extensive subsequent research or for quick survey of river habitat quality. The fact that FFG observation has been included in a number of seriously designed official protocols concerning bioassesment (Barbour *et al*., 1999) indicates that the given approach can be useful in combination with other monitoring procedures. Charvet *et al.* (1998) demonstrated the advantages of a functional approach that includes feeding relations over the traditional approach to monitoring. They stressed that the functional approach is clearly superior to the physico-chemical approach in discriminating between sampling sites. The functional approach also permits better discrimination between sites than that obtained by commonly used biomonitoring procedures, and the technique demands a less strenuous sampling effort compared with other biomonitoring approaches (Charvet *et al.,* 1998).

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ТРОФИЧКИ ОДНОСИ МАКРОИНВЕРТЕБРАТА У РЕЦИ ВЛАСИНИ (СРБИЈА)

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Циљ нам је да овим радом прикажемо трофичке односе у заједници макроинвертебрата према функционалним групама у исхрани (ФГИ) у реци Власини (југо-источна Србија) и те резултате употребимо за описивање водотока. У оквиру истраживања обављених током 1996. године, од укупно 125 идентификованих таксона макрозообентоса, 95 таксона коришћено је у ФГИ анализи. Иако истраживани део реке, са његовим физичким и хемијским карактристикама, као и карактеристикама бентофауне уопште, одговара средњем току река, истраживане су фине промене у дистрибуцији бентофауне дуж тока. Издвојиле су се две групе локалитета према ФФГ анализи – груписали су се локалитети горњег сектора реке као и притока Градска река, док су остали локалитети формирали другу групу.