Arch. Biol. Sci., Belgrade, 58 (1), 37-43, 2006.

SPECIES COMPOSITION, SPATIAL DISTRIBUTION AND TEMPORAL OCCURENCE OF MAYFLIES (EPHEMEROPTERA) IN THE VLASINA RIVER (SOUTHEAST SERBIA)

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Abstract - The mayfly (Ephemeroptera) fauna was studied during investigations of the Vlasina River (Serbia) conducted in 1996. Twenty-six species from 14 genera belonging to eight families were recorded. Compared to similar aquatic ecosystems in Serbia and Europe, the ephemeropteran fauna of the Vlasina River is characterized by high species diversity. Good water quality and habitat heterogeneity led to the observed richness of taxa. Based on fauna distribution, the middle reach of the river can be divided into three different segments - upper, middle, and lower. Distribution of the two dominant families, Heptageniidae and Baetidae, is emphasized. Representatives of Baetidae reach their highest density in July, while Heptageniidae were the most abundant in November. The recorded mayflies represent widely distributed European or Holarctic species.

Key words: Ephemeroptera, biogeography, running waters, Serbia.

UDC 595.734(497.11)
595.734(497.11):591.9

INTRODUCTION

The aim of this study is to present the mayfly (Ephemeroptera) community in the Vlasina River. Serbia represents a less researched area of Europe in regard to biodiversity (Vasić and Stevanović, 1995), that including of inland waters. Filipović (1979) discussed research on mayflies in Serbia up to the eighties and emphasized that they are an insufficiently studied group. Recently, data on Ephemeroptera in Serbia have been published within the framework of studies on the macrozoobenthos as a whole (Marković, 1998; Paunović *et al.* 1997) or in works concerning environmental quality (Marković, 1995; Paunović *et al.* 1999; Simić and Simić 1999). Very few authors have examined mayflies as a separate component of the aquatic ecosystem, as was done for example, by Marković and Tutundžić (1997). Mayflies of the Vlasina region were studied in relation to qualitative composition of the benthic community (Paunović *et al.* 1997) and evaluation of water quality (Paunović *et al.* 1999). The presented facts illustrate the need for detailed investigations on Ephemeroptera in Serbia.

STUDY AREA, MATERIAL, AND METHODS

The Vlasina River is situated in Southeast Serbia and belongs to the Danube basin. The river is 62 km long, flows out from the artificial Lake Vlasina (42° 42’ N, 22° 20’ E) at an altitude of 1,219 m, and joins the Southern Morava River at 226 m a. s. l. (42° 52’ N, 22° 2’ E). The Vlasina mainly flows at altitudes above 500 m. Paunović *et al.* (2003) presented the basic hydrological properties of the Vlasina River, natural and demographic characteristics of the basin area, and the distribution of sampling sites.

The investigation was performed on a 50-km long section of the watercourse with an altitude range between 930 and 250 m a.s.l.

Substrate properties were observed visually. The classification of mineral substrates by particle size was

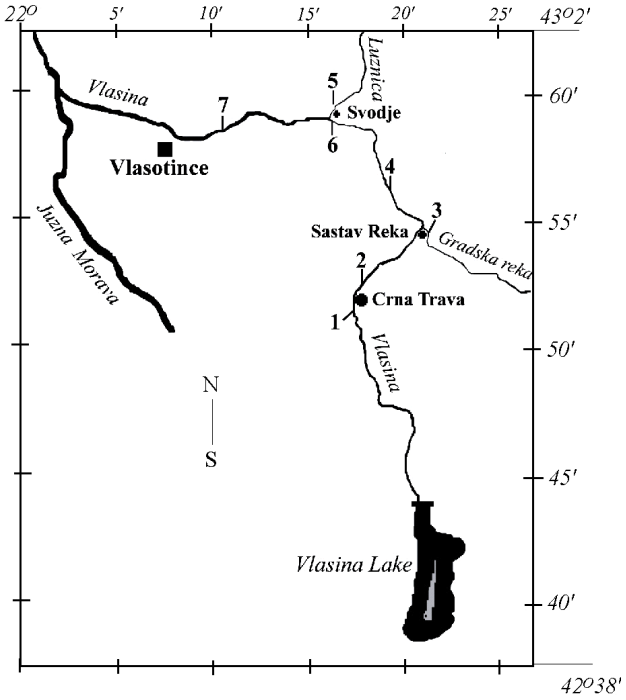

Fig. 1. Map showing the Vlasina River Basin and the location of sampling sites.

according to Wentworth (1922) and Verdonschot (1999): 1) fine substrate (silt-clay and very find 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) pebbles (16-34 mm); 6) cobbles (64-256 mm); and 7) boulders (>256 mm) (Fig. 1). Material for observation of the benthic fauna was taken using a Sürber net (0,1 m^2, mesh size 200 μm). In addition to 27 standard quantitative samples, 27 qualitative samples were taken (with a Sürber net at 10 to 15 spots, depending on habitat richness at the sampling site). Samples were preserved with 4% formaldehyde. Sorting and identification were carried out using a binocular magnifier (5-50 x) and a stereomicroscope (10 x 10 and 10 x 40).

Relationships between sampling sites along the main course of the river were established using an agglomerative UPGMA clustering method (Pielou, 1984). Classification of sampling sites and grouping of species based on their average abundance per site were performed using Euclidean distance as the dissimilarity measure. "Statistica 5.1 for Windows (Edition ·97)" was used for statistical processing of the data.

RESULTS AND DISCUSSION

Physical characteristics of the stream and relevant water quality parameters are presented and discussed in Paunović *et al.* (2003). Diversity of the physical habitat, high content of dissolved oxygen, the presence of moderate amounts of organic matter, and the absence of toxicants [(micro)organic pollutants and heavy metals] were reported.

With respect to substrate type, different microhabitats ("substrate habitats" – Verdonschot, 1999) were surveyed: boulders, cobbles, pebbles, coarse and fine sand, silt-clay, and silt-clay with detritus and leaf litter. The substrate at all sites mainly contained coarse material (gravel, boulders, cobbles, and pebbles) (Table 1).

A total of 126 animal taxa were identified in the Vlasina River and its main tributaries. Primarily consisting of insects (Ephemeroptera, Trichoptera, Coleoptera, Plecoptera, Diptera, and Hemiptera) and Oligochaeta (Paunović *et al.* 2003), the taxa collected also included representatives of Nematoda, Mollusca, Hirudinea and Crustacea. The greatest species richness was observed among mayflies (Ephemeroptera – 26 species, 14 genera, eight families), caddisflies (Trichoptera - 25 species, 15 genera, seven families), and oligochaetes (Oligochaeta - 26 species, 17 genera, seven families), while the other animal groups were less diverse. The mean density of meio- and macrozoobenthos varied from 1.505 (site 5) to 6.458 ind. m^{-2} (site 1).

Mayflies were one of the principal components of the benthic community and constituted from 11.71% (site 4) to 35.65% (site 5) of the mean zoobenthos density per site, i. e.. 22,66% of total collected specimens.

During the investigation, the presence of 26 species of Ephemeroptera from 14 genera belonging to eight families was established (Table 2). The recorded mayflies represent widely distributed European, trans-Palearctic or Holarctic species.

The total number of observed species is lower at sites 2, 3, 4, and 5 (11) than at site 1 (15) and sites 6 and 7 (16).

The number of species per sampling period varied between 11 (November) and 20 (July). Mean density per site varied between 283 ind. m^{-2} (site 6) and 1,238 ind.

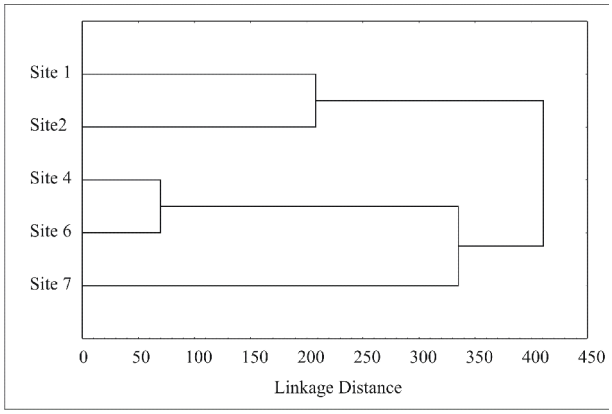

Fig. 2. Relationships between sites on the main course of the Vlasina River based on average species abundance per location [ind. m^{-2}] using an agglomerate UPGMA clustering method (P i e l o u , 1984).

m^{-2} (site 7) (Table 2). Mean abundance per sampling period oscillated between 184 ind. m^{-2} (May) and 1.504 ind. m^{-2} (July). The high density of Ephemeroptera in July was largely determined by high density of nymphs belonging to the family Baetidae, with mean abundance 980 ind. m^{-2}. Small nymphal instars constitute a significant share of individuals belonging to the family Baetidae (27,38% of total abundance of the family recorded in July). In July, *Ecdyonurus* sp. *Ephemerella ignita*, *Ephemerella* sp., *Paraleptophlebia submarginata*, and *Ecdyonurus* sp. were also abundant. In September, the high density of earlier instars of *Baetis* spp. reappeared. High population densities of species belonging to the *Rhithrogena semicolorata* group and *Electrogena lateralis* (Heptageniidae) were recorded in November. In this period, earlier instars belonging to the family Heptageniidae were also abundant.

Representatives of Baetidae and Heptageniidae were the principal components of the mayfly community in the Vlasina River. The mean density of Baetidae at different sampling sites varied between 36.99% (site 2) and 70.51% (site 5) of the all mayflies, while their density by season ranged from 28.68% (May) to 65.15% (July). The mean density of Heptageniidae per site varied between 14.16% (site 6) and 33.33% (site 1) of all mayflies, while their density by season ranged from 9.21% (June) to 59.83% (November). Representatives of Baetidae reached maximum of its density at sites 3, 4, 5, and 6, while Heptageniidae were best represented at sites 1 and 2. Decline of abundance is especially notable for dominant taxa among the family Heptageniidae – species belonging to the *R. semicolorata* group. Caenidae reached maximum density at site 7, as did Leptophlebiidae.

Based on average species abundance per site (for sites along the main course), three different segments of the investigated part of the river can be separated (Fig. 2) - upper (sites 1 and 2), middle (sites 4 and 6) and lower (site 7).

Mayflies were one of the principal components of the benthic community with respect to species richness and abundance. The high percentage participation of mayflies in the total density of macroinvertebrates, as well as constant diversity along the river, reflect the situation typical of the middle sector of rivers in general (V a n n o t e *et al.* 1980; A l l a n 1995).

Compared to similar aquatic ecosystems in Serbia (F i l i p o v i ć 1976, 1979) and Europe (I k o n o m o v , 1960; R u s s e v and J a n e v a , 1983; M i l l e t t and L a r n e r , 1988), the mayfly fauna of the Vlasina River

Table 1. Evaluated participation of substrate habitats (%) at sampling sites

substrate	fine substrate	fine sand	coarse sand	gravel	pebbles	cobbles	boulders	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

Table 2. Mayflies of the Vlasina River and main tributaries. Abreviations: juv = early larval stages that could not be identified; fr = fragments, damaged individuals that could not be identified; + = taxa observed in qualitative samples only.

Taxa Sampling site	1	2	3	4	5	6	7
Baetidae	**460**	**455**	**367**	**223**	**688**	**168**	**490**
1. *Baetis rhodani* (Pictet, 1843)	220	228	300	33	150	15	213
2. *B. fuscatus* (L., 1761)	18	23	10	45	148	78	108
3. *B. niger* (L., 1761)	3				8	3	
4. *B. vernus* Curtis, 1834							3
5. *B. lutheri* Müller-Liebenau, 1967				5			
6. *Baetis alpinus* (Pictet, 1843)		50		5	8		45
Baetis sp. (juv)	200	138	53	90	365	73	115
Baetis sp. (fr)			3	40			
Baetidae (juv + fr)	20	18		5	10		8
Caenidae	**3**		**27**	**8**	**5**	**10**	**88**
7. *Caenis horaria* (L., 1758)			3				
8. *C. macrura* Stephens, 1836			3	8	3		75
9. *C. robusta* Eaton, 1884			7				
Caenis sp. (fr)	3		13		3	8	13
Heptageniidae	**315**	**380**	**110**	**93**	**215**	**40**	**230**
10. *Ecdyonurus venosus* group	18	45	7		25	13	183
11. *Ecdyonurus dispar* (Curtis, 1834)						+	
12. *Rhithrogena semicolorata* group	248	280	47	53	8	13	40
Rhitrogena sp. (juv)			37				
13. *Electrogena lateralis* (Curtis, 1834)	20	35	3	3		13	8
14. *Heptagenia sulphurea* (Müller, 1776)	20	15		33		3	
Heptagenia sp. (fr)				3			
Heptagenidae (juv)	1	5	17	3	3		
Ephemeridae	**13**	**3**				**8**	
15. *Ephemera danica* Müller, 1764	5	3				8	
16. *E. lineata* Eaton, 1870	8						
Ephemerellidae	**70**	**318**	**77**	**35**	**55**	**40**	**108**
17. *Seratella ignita* (Poda, 1761)	65	140	33	18	40	13	75
18. Ephemerella mucronata (Bengtsson, 1908)	5	13	20	18	15	13	23
19. *E. notata* (Eaton, 1887)						5	2
Ephemerella sp. (fr)		165	23			10	8
Leptophlebiidae	**68**	**5**			**5**	**8**	**195**
20. *Habroleptoides confusa* Sartori et Jacob, 1986							8
21. *Habrophlebia fusca* (Curtis, 1834)					5	8	18
22. *Paraleptophlebia cincta* (Retzius, 1783)	10						
23. *P. submarginata* (Stephens, 1836)	43	5					170
24. *Paraleptophlebia* sp.	15						
Leptophlebidae (juv + fr)							
Oligoneuriidae			**3**	**5**	**5**	**10**	**13**
25. *Oligoneuriella rhenana* (Imhoff, 1852)			3	5	5	10	13
Potamanthidae						**3**	**15**
26. *Potamanthus luteus* (L., 1767)						3	15
unidentified taxa (juv + fr)	**18**	**70**	**27**		**3**		**100**
Total density	**945**	**123**	**61**	**363**	**976**	**283**	**1238**

was characterized by high species richness. A high content of dissolved oxygen, the presence of moderate amounts of organic matter and the absence of toxicants [(micro)-organic pollutants and heavy metals], under conditions of physical habitat diversity (Paunović *et al.* 2003), led to the observed diversity. Poof and Ward (1990) emphasized that rivers with greater heterogeneity of physical properties are characterized by greater biodiversity in relation to those with more uniform habitats.

A diverse mayfly community was recorded at all sampling stations (11-16 taxa per site). This seems to be related to the fact that a similar, heterogeneous biotope was observed at all sites (Paunović *et al.* 2003).

Dominance of rheophylic mayflies, especially representatives of Baetidae and Heptageniidae, was to be expected, considering the type of watercourse type investigated. The mayfly fauna of the Vlasina River was characterized by community composition typical of middle sectors of the rivers in Serbia (Filipović, 1976). Among the principal mayfly families, Baetidae and Heptageniidae, species that are usually numerous in the macrozoobenthos of streams in Serbia (Filipović, 1976) – *Baetis rhodani* and species of the *R. semicolorata* group were also dominant in the Vlasina River.

Although the investigated part of the river in physical and chemical characteristics as well as the fauna observed generally corresponds to the middle sectors of streams, slight changes were observed in the distribution of fauna along its course. The characteristic shifts of fauna distribution that were observed in investigation of 25 rivers in Serbia (Filipović, 1976), were also recorded on the Vlasina River. Representatives of Baetidae reached maximum density at sites 3, 4, 5, and 6 (lower segment and tributaries), while Heptageniidae were best represented at sites 1 and 2 (upper seegment).

Representatives of the families Baetidae and Heptageniidae were dominant within the community of mayflies. The results of agglomerate UPGMA clustering analyses (Pielou, 1984) on mean species density per site indicate that the river's middle course can be divided into different segments – upper (site 1 and 2), middle (site 4 and 6) and lower (site 7). Those findings are linked with alteration of ecological factors that influence fauna distribution (Vannote *et al.* 1980). Millett and Learner (1998) observed specific Ephemeroptera and Plecoptera species assemblages in the Usk River system in Wales in relation to several environmental variables and showed that there is strong relation between species distribution and distance related variables. Among chemical variables, phosphate concentration is stressed as the factor exerting the strongest influence on distribution of the fauna. As the concentration of phosphate was stable along the Vlasina River, it could be assumed that the distribution of Ephemeroptera along the river is determined mostly by physical factors. The gradual slight changes in substrate characteristics, together with other environmental variables, contributed to the observed spatial pattern of fauna distribution.

With respect to species composition and abundance, July differs from the other investigated periods. The greatest density of the mayfly community, with dominance of representatives of Baetidae, was then observed. The gratest number of species (19) and higest mean density per sampling period (1.504 ind. m^{-2}) were also observeed in July.

A temporal shift of the dominant groups (Baetidae and Heptageniidae) was observed during the sampling period. While Baetidae reached their maximum density in July, Heptageniidae were most abundant in November. A temporal pattern in the density of Baetidae similar to that observed in the Vlasina River has been reported previously. Wright (1992) indicated that densities of Baetidae recorded in June in Bagnor Brook (Berkshire, England) almost always exceeded those in December of the same year (with one exception). Moreover, after observing densities of Baetidae in relation to water discharge, he suggested that Baetidae occur in higher densities under conditions of average or above average discharge. As water discharge of the Vlasina River was above average in 1996 (Paunović *et al.* 2003), we assume that the hydrological conditions were then favorable for Baetidae.

The recorded mayflies represent widely distributed European or Holarctic species. Biogeographical studies show that the majority of mayflies reported from Serbia are species that are widely distributed in Europe (Filipović, 1979). Migration of the fauna during glacial and interglacial periods, together with geographical location and relief characteristics, determined the presence of widely distributed species and species of different origin. The Vlasina River basin is situated in an area where two large mountain massifs - the Balkan and the Rhodope

mountain systems – approach each other. The river constitutes the boundary between the Danube River basin (northern region of the Euro-Mediterranean division) and the Aegean eastern part of the Balkans (southern region of the Euro-Mediterranean division). According to I l l i e s (1978), the Vlasina region belongs to hydrofaunistic region 7 (the eastern Balkans), but it lies near the edge of region 5 (the Dinaric, western Balkans).

Acknowledgement: This work was supported by the Ministry of Science and Environment Protection. We owe special acknowledgement to Prof. Dr Peter Zwick for useful suggestions concerning organization of the manuscript.

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СПЕЦИЈСКИ САСТАВ, ПРОСТОРНИ РАСПОРЕД И ВРЕМЕНСКА ДИНАМИКА EPHEMEROPTERA У РЕЦИ ВЛАСИНИ (ЈУГОИСТОЧНА СРБИЈА)

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Разноврсност ефемероптера проучавана је у реци Власини (Србија) током 1996. године. Двадесет шест врста из четрнаест родова утврђено је током ове обимне студије. У поређењу са сличним акватичним екосистемима у Србији и Европи, фауна ефемероптера из реке Власине карактерише се високом разноликошћу врста. Добар квалитет воде и разноврсност станишта условљавају и уочено богатство таксона. Средишњи део реке може се поделити у три сегмента - горњи, средњи и доњи. Сагледана је дистрибуција представника две доминантне породице Heptageniidae и Baetidae. Представници баетида достижу највећу густину током јула, а хептагенида у новембру. Утврђене врсте ефемероптера представљају европске или холарктичке елементе.