The Mayfly fauna (Insecta, Ephemeroptera) of the Plitvice Lakes National Park, Croatia

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Jean-Luc Gattolliat
Museum of Zoology Lausanne

Mladen Kučinić
University of Zagreb

Zlatko Mihaljević
University of Zagreb

Michel Sartori
Museum of Zoology, Lausanne, Swit…

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THE MAYFLY FAUNA (INSECTA, EPHEMEROPTERA) OF THE PLITVICE LAKES NATIONAL PARK, CROATIA

Marina Vilenica[1*], Jean-Luc Gattolliat[2], Marija Ivković[4], Mladen Kučinić[4], Vlatka Mičetić Stanković[5], Zlatko Mihaljević[4] & Michel Sartori[2,3]

[1]University of Zagreb, Faculty of Teacher Education, Department in Petrinja, Trg Matice hrvatske 12, 44250 Petrinja, Croatia

[2]Musée cantonal de zoologie, Palais de Rumine – Place de la Riponne 6, 1005 Lausanne, Switzerland

[3]Biozentrum Grindel und Zoologisches Museum, Universität Hamburg, Martin-Luther-King-Platz 3, D-20146 Hamburg, Germany

[4]University of Zagreb, Faculty of Science, Department of zoology, Rooseveltov trg 6, 10000 Zagreb, Croatia

[5]Croatian Natural History Museum, Demetrova 1, 10000 Zagreb, Croatia

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The mayfly fauna of Plitvice Lakes NP was investigated at 14 sampling sites representing different types of karstic freshwater habitat (springs, streams, tufa barriers and lakes). Specimens were sampled from February 2007 to February 2009 using different methods and 19 taxa were identified. Lotic habitats supported more mayfly species than lentic habitat types. The recorded species, four of which are new for the Croatian fauna, encompass 27 % of the total number of Croatian mayfly fauna. This study represents an important contribution to the knowledge of mayfly fauna of karst habitats in Croatia.

Keywords: Plitvice Lakes NP, mayfly fauna, Ephemeroptera, species richness, karst habitats, Croatia

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Fauna vodencvjetova istraživana je na 14 postaja različitih tipova krških slatkovodnih staništa (izvori, potoci, sedrene barijere i jezera) na području Nacionalnog parka Plitvička jezera. Jedinke su sakupljane različitom metodologijom od veljače 2007. do veljače 2009. Godine, prilikom čega je utvrđeno 19 svojti. Veći broj vrsta vodencvjetova zabilježen je na lotičkim staništima nego što je to bio slučaj za lentička. Zabilježene vrste, od kojih su četiri nove za faunu vodencvjetova Hrvatske, čine 27% do sada zabilježenih vrsta vodencvjetova na području Hrvatske. Ovo istraživanje predstavlja važan doprinos poznavanju faune vodencvjetova krških područja Hrvatske.

Ključne riječi: Nacionalni park Plitvička jezera, fauna vodencvjetova, raznolikost vrsta, krška staništa, Hrvatska.

* corresponding author (marina.vilenica@gmail.com)

INTRODUCTION

Mayflies are a merolimnic insect order (i.e. with aquatic larval stages and terrestrial adults) that plays a critical role in running and standing waters. They hold an important position in secondary production by being an important food source for diverse freshwater and terrestrial predators (Brittain & Sartori, 2003). In the last decades, human impact on distribution and abundance of many aquatic insects, including mayflies, is becoming more and more evident. During the 20th century, increasing industrialization, population growth, overuse of the natural resources and different types of pollution have greatly damaged many European freshwater ecosystems, equally endangering many species which inhabit them (Belančić *et al*., 2008; Brittain, 1982). Highly sensitive, confronted with alterations to their habitat, mayfly species are among the first to disappear. Therefore they are important indicators of freshwater health and widely used in biomonitoring programs all over the world (Brittain & Sartori, 2003; Elliott *et al*., 1988).

Mayfly fauna of Croatia is still poorly known. The published data are generally only parts of diverse limnological researches (e.g. Filipović, 1976; Matoničkin & Pavletić, 1961, 1963, 1967; Matoničkin, 1959, 1987; Habdija & Primc, 1987; Habdija *et al*., 1994, 2000, 2004; Žganec, 2005) in which mayflies were investigated as a component of the macro invertebrate fauna. Thus these studies were focused on mayfly larval stages. Although some other aquatic insects in the Plitvice Lakes NP have already been investigated (e.g. Previšić *et al*., 2007; Popijač & Sivec, 2009; Ivković *et al*., 2010, 2012; Šemnički *et al*., 2011), until now and as mentioned above, mayflies were mainly investigated as a component of diverse biocoenological researches into lakes and streams (e.g. Kostić-Brnek & Brnek-Kostić, 1965, 1974; Matoničkin, 1959, 1987; Matoničkin & Pavletić, 1963, 1967; Matoničkin *et al*., 1971; Pavletić & Matoničkin, 1972). Additionally, two dissertations for BSc degrees (Juroš, 1992; Slavikovski, 2006) were conducted on the mayflies of the Park. Juroš (1992) recorded 18 mayfly species while in the more recent study done by Slavikovski (2006), 20 species were registered. Most of the publications do not cite which identification tools were used thus the accurateness of the identifications is questionable. We therefore ignored all the unpublished and unreliable data of the previous researches.

The main objective of our study is to document mayfly species richness of the Plitvice Lakes National Park using different sampling methods.

Study area

Plitvice Lakes National Park is located in the karst region of the Dinarid Mountains in Croatia. The Plitvice Lakes system comprises 16 oligotrophic, dimictic and fluvial lakes divided by tufa barriers. The streams Bijela rijeka and Crna rijeka form the Matica River, which is the main surface-water supplier of the lakes. The area is rich in habitat types of the karst system (Stilinović & Božičević, 1998) and well known for its high endemism, especially in freshwater (Bănărescu, 2004). Plitvice Lakes National Park was placed under the protection of UNESCO as a world natural heritage site in 1979 (Stilinović & Božičević, 1998).

MATERIALS AND METHODS

Mayflies of the Plitvice Lakes NP were studied from February 2007 until February 2009 at 14 sampling sites representing different types of karstic freshwater habitats: springs, streams, tufa barriers and lakes (Fig. 1).

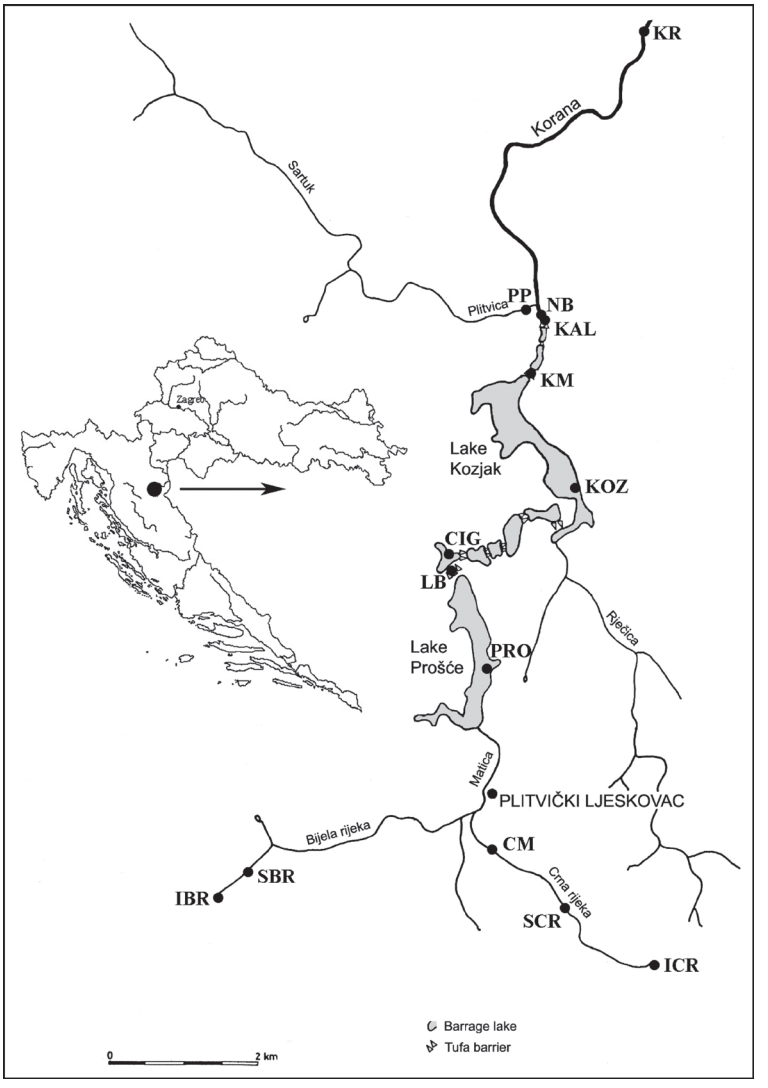

Fig. 1. Map of the researched area. Plitvice lakes NP.
Legend: Sampling sites: IBR – Spring of Bijela rijeka, SBR – Upper reach of Bijela rijeka, ICR – Spring of Crna rijeka, SCR – Upper reach of Crna rijeka, CM – Middle reach of Crna rijeka, KR – Korana River, PP – Plitvica Stream, KM – Kozjak – Milanovac Tufa barrier, LB – Labudovac Tufa barrier, NB – Novakovića Brod Tufa barrier, PRO – Lake Prošće, KAL – Lake Kaluđerovac, CIG – Lake Ciginovac, KOZ – Lake Kozjak.

According to their altitudes, lotic habitats were classified into three categories.

1) Upper streams were Crna rijeka and Bijela Rijeka. Different sections of their flow were sampled: spring of Bijela rijeka (720 m), upper reach of Bijela rijeka (716 m), spring of Crna rijeka (675 m), upper reach of Crna rijeka (670 m) and middle reach of Crna rijeka (665 m).

2) Three tufa barriers, situated between upper and lower streams, were: the Labudovac Tufa barrier (630 m), Kozjak-Milanovac Tufa barrier (545 m) and Novakovića Brod Tufa barrier (505 m).
3) Finally, Plitvica Stream (555 m) and River Korana (390 m). were classified as downstream sites.

Diverse microhabitats were sampled and processed. Substrate categories at each sampling site were defined based on AQEM river sampling guidelines (AQEM consortium, 2002). Additionally, accessible microhabitats were sampled at the four lakes: Prošće, Kaluđerovac, Ciginovac and Kozjak.

Mayfly larvae were sampled once every month from February 2007 until March 2008 together with other macroinvertebrates, using a Surber sampler (0.0625 m^2 area and 0.5 mm mesh size). At the site middle reach of Crna rijeka and in the lakes, macroinvertebrates were sampled using a D-frame hand net and 0.5 mm mesh size. All the samples were conserved in 80% ethanol.

Adults were collected from February 2007 until February 2009 using four sided emergence pyramidal traps with a base of 45×45 cm and height of 50 cm. At nine sites (spring of Bijela rijeka, upper reach of Bijela rijeka, spring of Crna rijeka, upper reach of Crna rijeka, Labudovac tufa barrier, Kozjak-Milanovac tufa barrier, Novakovića Brod Tufa barrier, Plitvica Stream and River Korana), traps were fastened to the streambed to allow the free movement of larvae in and out of the sampling area. On each of these sites six traps were placed in diverse microhabitats. At the sites middle reach of Crna rijeka, Lake Prošće, Lake Kaluđerovac, Lake Ciginovac and Lake Kozjak floating pyramidal emergence traps (surface area 80×80 cm and height of 80 cm) were used. All together 3 traps were installed on each of these sites. On the top of each pyramidal trap was a container filled with preservative (2% formaldehyde with detergent). During the winter months, with the aim of lowering the freezing point, ethanol was added. All the collected specimens were preserved in 80% ethanol. During the study, the mayfly specimens were collected from each trap once every month.

Additionally, flying adults were occasionally captured using an entomological net.

The collected material (larvae and adults) was identified in the lab using a stereomicroscope (Leica M 295 C) and a microscope (Olympus BX51). Species identification was done using Müller-Liebenau (1969), Elliott & Humpesch (1983), Elliott *et al*. (1988), Engblom (1996), Studemann *et al*. (1992), Bauernfeind & Humpesch (2001), Macadam & Bennett (2010), Malzacher (1984) and Haybach (1999).

Data were statistically analyzed using the PRIMER 6 software package (Clarke & Warwick, 2001). Species diversity, uniformity of studied sites and similarity between sites with respect to the mayfly composition and abundance were determined by the Shannon-Weaver (Shannon & Weaver, 1949) and Simpson indices (Simpson, 1949). For estimation of similarity and differences among mayfly composition of the sites NMDS analysis was used. Similarity among the sites was determined using the Bray-Curtis similarity index (Bray & Curtis, 1957).

RESULTS

During the study, 17 293 mayfly specimens (13 609 larvae and 3 684 adults, Tab. 1) were captured and identified. Very young or damaged specimens were identified up to the family or genus level (5 438 specimens). In total, 19 taxa, belonging to 14 genera and

Tab. 1. Number of captured mayfly specimens, number of species (S), Shannon-Weaver (H') and Simpson (1-Lambda') diversity indices for the studied localities in Plitvice Lakes NP. Abbreviations of the sampling sites are given in Fig. 1.

Study Site/ N of specimens & Diversity indices	N (larvae)	N (adults)	S	H'(loge)	1-Lambda'
IBR	364	265	4	1,235	0,747
ICR	526	8	4	1,323	0,771
SBR	2070	365	5	1,412	0,774
SCR	1224	492	7	1,707	0,829
CM	580	311	11	2,291	0,917
KR	322	1136	9	1,989	0,878
PP	2961	943	12	2,333	0,913
NB	465	66	10	2,108	0,898
LB	531	32	7	1,851	0,871
KM	60	30	5	1,45	0,816
KOZ	17	1	4	1,317	0,86
CIG	324	0	4	1,358	0,786
KAL	28	3	4	1,299	0,821
PRO	4137	32	6	1,669	0,825
Σ	**13609**	**3684**			
	17293				

7 families were recorded. Four species are new records for the Croatian mayfly fauna. (Tab. 3). Some of the species were captured only in larval stage, some only as adults, and thus our results indicated the benefits of combining different sampling methods in order to get the most accurate data about the mayfly fauna (Tab. 2).

Lotic habitats supported more mayfly species than lentic sites (Tab. 4). The highest number of species (12) and the highest Shannon - Weaver diversity index was recorded for the study site Plitvica Stream (Fig. 3) while middle reach of Crna rijeka had the highest Simpson index. On the other hand, spring of Bijela rijeka, spring of Crna rijeka and three of the four researched lakes (Kozjak, Ciginovac, Kaluđerovac) had the fewest mayfly species (4) (Tab. 1).

Compared to the other three sampled lakes, Lake Prošće had a very high abundance of mayflies (with 3 565 collected specimens) and a high diversity (6 mayfly species). Additionally, it had the highest number of captured mayfly specimens of all investigated sites (Tab. 3, Tab. 1).

Ephemera danica was the most common species (present in 11 of the 14 sites) while *Caenis horaria* was the most abundant (with 3 391 collected specimens). *Electrogena lateralis* was recorded with the lowest number of specimens (only one) (Tab. 3).

Tab. 2. Mayfly taxa recorded in Plitvice Lakes NP using various sampling methods. Legend: *New species recorded for the Croatian mayfly fauna.

Species / Life cycle stage	Larvae	Adults (traps)	Adults (entomological net)
Alainites muticus (Linnaeus, 1758)	+	+	
Baetis alpinus gr.	+	+	
Baetis rhodani (Pictet, 1843)	+	+	+
Centroptilum luteolum (Muller, 1776)	+	+	+
Procloeon pennulatum (Eaton, 1870)	+	+	
Caenis sp.	+		
Caenis horaria (Linnaeus, 1758)*	+		
Seratella ignita (Poda, 1761)	+	+	
Torleya major (Klapalek, 1905)	+		
Ephemera danica Muller, 1764	+	+	+
Ecdyonurus submontanus Landa 1969*	+		
Rhithrogena semicolorata gr.		+	
Leptophlebiidae juv.	+	+	
Habrophlebia lauta Eaton, 1884	+	+	+
Leptophlebia vespertina (Linnaeus, 1758)*	+		+
Paraleptophlebia submarginata (Stephens, 1835)	+	+	+
Paraleptophlebia werneri Ulmer, 1920*	+	+	
Siphlonurus croaticus Ulmer, 1920	+		+

NMDS analysis (Fig. 2) revealed similarities and differences in mayfly fauna composition between the study sites: upper streams (springs and upper reaches of Crna rijeka and Bijela rijeka) are clustered together. Springs and upper reach of Bijela rijeka are grouped together with the highest similarity of 80%. Downstream sites (Plitvica Stream and River Korana) are clustered together with 60% and with 40% similarity with tufa-barriers.

DISCUSSION

In this study, 19 mayfly taxa were recorded. Fifteen were identified to the species level and two to the species group. No accurate identification of the specimens of the *Rhithrogena semicolorata* species-group and *Baetis alpinus* species-group based on morphological characteristics was possible. Two taxa, in very low numbers, were represented in rather early (not identifiable) instars or in a damaged state and accordingly one was identified to the family and one to the genus level.

Currently, 62 mayfly species are recorded for Croatia (Vilenica *et al.*, in preparation), thus the number of 17 taxa identified to species-level during this study represents 27% of the hitherto known total species number.

Tab. 3. Mayfly species and their abundance at the researched sampling sites in Plitvice Lakes NP. Abbreviations of the sampling sites are given in Fig. 1.

Taxa/Study site	IBR	SBR	ICR	SCR	CM	KR	PP	KM	LB	NB	PRO	KAL	CIG	KOZ	Σ
Alainites muticus (Linnaeus, 1758)	1	1	0	0	2	218	189	0	0	4	0	0	0	0	415
Baetis alpinus gr.	31	84	92	102	19	15	276	0	87	77	0	0	0	0	783
Baetis rhodani (Pictet, 1843)	112	319	62	84	130	113	127	40	24	0	0	0	0	0	1011
Centroptilum luteolum (Muller, 1776)	0	0	0	0	0	545	688	2	28	59	207	13	37	1	1580
Procloeon pennulatum (Eaton, 1870)	0	0	0	0	0	1	2	0	0	2	0	0	0	0	5
Caenis sp. juv.	0	0	5	0	2	0	0	0	0	0	0	0	0	0	7
Caenis horaria (Linnaeus, 1758)	0	0	0	0	0	0	0	0	36	4	3104	7	232	8	3391
Seratella ignita (Poda, 1761)	0	0	0	0	25	126	1177	1	0	1	0	0	0	0	1330
Torleya major (Klapalek, 1905)	0	0	0	0	0	1	0	0	0	36	0	0	0	0	37
Ephemera danica Muller, 1764	0	0	0	1	13	89	240	25	244	183	17	8	19	4	843
Ecdyonurus submontanus Landa, 1969	0	0	0	3	52	0	0	0	0	0	0	0	0	0	55
Electrogena lateralis (Curtis, 1834)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Rhithrogena semicolorata gr.	105	516	195	635	96	0	2	0	0	0	0	0	0	0	1549
Leptophlebiidae juv.	0	0	0	0	0	0	0	0	0	0	0	1	0	4	5
Habrophlebia lauta Eaton, 1884	0	0	0	4	278	0	130	0	0	0	29	0	0	0	441
Leptophlebia vespertina (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	205	0	27	0	232
Paraleptophlebia submarginata (Stephens, 1835)	0	5	0	0	42	2	23	6	42	25	0	0	0	0	145
Paraleptophlebia werneri Ulmer, 1920	0	0	0	0	0	0	2	0	0	0	3	0	0	0	5
Siphlonurus croaticus Ulmer, 1920	0	0	0	3	5	0	11	0	1	0	0	0	0	0	20
Σ	249	925	354	832	664	1110	2867	74	462	392	3565	29	315	17	11855

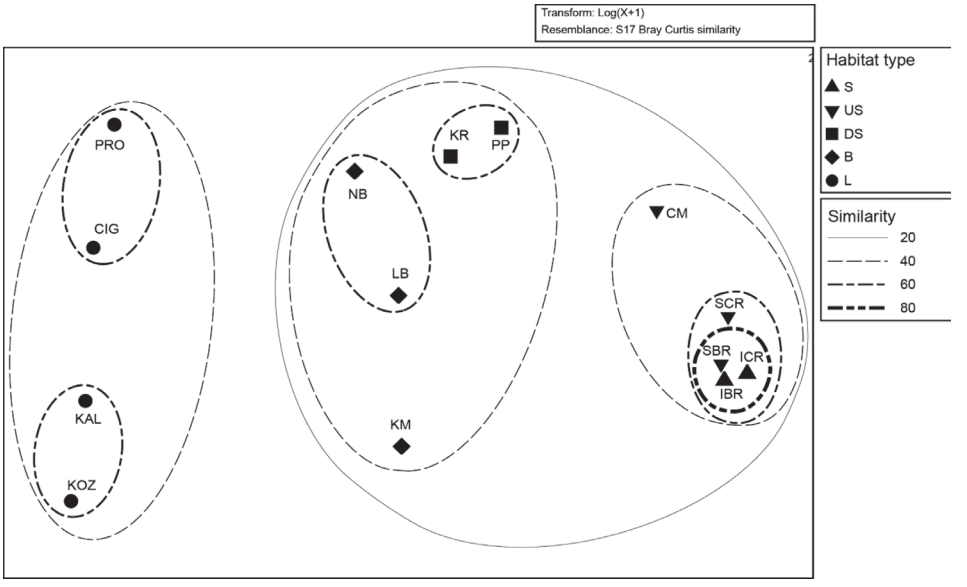

Fig. 2. NMDS analysis of the researched localities in Plitvice Lakes NP based on the mayfly fauna composition. Abbreviations of the sampling sites are given in Fig. 1.
Habitat type legend: S = spring; US = upper streams; DS = lower streams; B = tufa barriers; L = lakes.

Compared to the number of recorded mayfly species in the Plitvice Lakes NP, studies on other aquatic insect groups like stoneflies (Popijač & Sivec, 2009; Popijač & Sivec, 2011) and caddisflies (Previšić *et al*., 2010; Šemnički *et al*., 2012) revealed greater number of species, 31 and 81 respectively. The mayfly fauna of karst freshwater ecosystems is still generally poorly known and relatively systematic and reliable research in Croatia is still in its beginnings. Study on the mayfly fauna conducted in the lowland karst rivers in neighbouring Slovenia (Hrovat *et al*., 2009) showed similar results to ours: 26 taxa (20 species) were recorded.

During our research, the highest number of species (12) and the highest Shannon - Weaver diversity index were recorded for the site Plitvica Stream. Since one of the species, *Serratella ignita,* highly dominated in the abundance at this site (Tab. 3), the Simpson index was not the highest; the highest was at the site middle reach of Crna Rijeka. For this site, the number of recorded species was also high (11) but with the highest evenness in the abundance of each species (Tab. 1).

On the other hand, the springs (spring of Bijela rijeka, spring of Crna rijeka) and three of the four researched lakes (Kaluđerovac, Kozjak, Ciginovac) had the lowest number of mayfly species (Tab. 1). The species richness according to the four main habitat types is presented in Tab. 4. It is obvious that most of the mayfly species prefer lotic habitats which have a greater variety of microhabitats and these are less diversified in spring areas and lentic habitats. Our data confirmed the results of many previous studies (see in: Bauernfeind & Soldán, 2012; Bauernfeind & Humpesch, 2001; Elliott *et al*., 1988; Berner & Pescador, 1988).

Although the species diversity in still water habitats is generally poor, some limnophilic taxa (Schmedtje & Colling, 1996 in Bauernfeind & Soldán, 2012) can be very

Tab. 4. Mayfly species recorded in different types of freshwater karst habitat in Plitvice Lakes NP.

Taxa/Habitat	Springs	Streams		Tufa barriers	Lakes
		upper streams	lower streams		
Alainites muticus (Linnaeus, 1758)	1	1	1	1	0
Baetis alpinus gr.	1	1	1	1	0
Baetis rhodani (Pictet, 1843)	1	1	1	1	0
Centroptilum luteolum (Muller, 1776)	0	0	1	1	1
Procloeon pennulatum (Eaton, 1870)	0	0	1	1	0
Caenis sp. juv.	1	1	0	0	0
Caenis horaria (Linnaeus, 1758)	0	0	0	1	1
Seratella ignita (Poda, 1761)	0	1	1	1	0
Torleya major (Klapalek, 1905)	0	0	1	1	0
Ephemera danica Muller, 1764	0	1	1	1	1
Ecdyonurus submontanus Landa, 1969	0	1	0	0	0
Electrogena lateralis (Curtis, 1834)	0	0	0	1	0
Rhithrogena semicolorata gr.	1	1	1	0	0
Habrophlebia lauta Eaton, 1884	0	1	1	0	1
Leptophlebia vespertina (Linnaeus, 1758)	0	0	0	0	1
Paraleptophlebia submarginata (Stephens, 1835)	0	1	1	1	0
Paraleptophlebia werneri Ulmer, 1920	0	0	1	0	1
Siphlonurus croaticus Ulmer, 1920	0	1	1	1	0
Number of species	5	11	13	12	6

abundant. Compared to the other three sampled lakes, Lake Prošće had very high abundance of captured mayfly specimens and a rather high number of mayfly species. In fact, it had the greatest abundance of captured mayfly specimens of all the investigated sites. Most of the specimens were captured in the larval stage and consisted of the species *C. horaria* (Tab. 1, Tab. 3).

The lowest number of captured mayfly specimens was recorded from the Kozjak-Milanovac tufa barrier as well as from the Lake Kozjak and Lake Kaluđerovac. Most of the mayfly species feed mainly on detritus, periphyton and aquatic vegetation (Brittain, 1982; Engblom, 1996; Elliott & Humpesch, 1983). The reason for such a low number of specimens recorded for the Kozjak-Milanovac tufa barrier and for such a big difference in mayfly abundance between the lakes might be due to the availability of nutrients. Tufa barriers are situated between the lakes and are natural lake outlet habitats. The amount of organic matter decreases downstream along this lake system due to the accumulation of the particles at the barrier's substrates. Obelić *et al*. (2005) recorded that the organic matter content in the lake sediments differs between the highest lake, Lake

Fig. 3. Plitvica Stream (Plitvice Lakes NP). (Photo: M. Ivković).

Prošće and the lowest, Lake Kaluđerovac, in the range from 30% to 4.4% respectively. Our results confirm that the upper lake sustains a richer and more abundant population of Ephemeroptera.

Additionally, a very low number of specimens was recorded in the floating emergence traps that were installed in the lakes researched (Tab. 1). Thus they turned out to be a not very efficient sampling method since part of the emerging specimens would probably crawl under the trap and emerge somewhere else on the water surface.

The species *Ephemera danica* inhabits sandy or gravel beds in the rhithral part of rivers and streams as well as on the shores of oligotrophic lakes (Bauernfeind & Soldán, 2012) and was therefore recorded at most of the study sites.

On the other hand, *Electrogena lateralis* was recorded at a single site and with a single specimen caught in the emergence trap. As its usual microhabitats are submerged roots and rotten logs in a slow current (Bauernfeind & Soldán, 2012), this species was underrepresented in our study probably because this microhabitat was not sampled. Also, it is possible that this species was mainly present in the material of juvenile larvae identified only to the family level. Our results indicate therefore the usefulness of combining different sampling methods in order to get the most accurate data about mayfly fauna (Tab. 2).

Another species that might be present at more sampling sites but was probably found only in rather early (not identifiable) larval instars is *Ecdyonurus submontanus*, recorded from a single stream (Upper and Middle reach of Crna Rijeka). Its known European distribution is quite scattered. Larvae are usually rarely found in the limestone areas and preferably inhabit stony brooks and streams in submontane wooded highlands (Bauernfeind & Soldán, 2012).

Several species recorded in our study have been classified as threatened or endangered taxa in the Red Lists of some countries in Europe, such as Switzerland (Wagner & Sartori, 2012) and Germany (Malzacher *et al*., 1998). *Leptophlebia vespertina* (in Switzerland) and *Paraleptophlebia werneri* (in Germany) are listed as critically endangered species while *Procloeon pennulatum* and *Torleya major* are listed as vulnerable in the Red List of Swiss mayflies. *P. pennulatum*, *T. major* and *P. werneri* are species with a patchy distribution all over Europe. Larvae have frequently been recorded from lentic habitats but may also inhabit brooks and rivers (Bauernfeind & Soldán, 2012) which was the case in our study.

Records of *L. vespertina* in the study area indicate the southern border of its (presently known) Central European distribution. Larvae of both *Leptophlebia* species inhabit slow-flowing, slightly acidic rivers, streams and frequently lakes (Bauernfeind & Soldán, 2012). In our study, *L. vespertina* was recorded in two of the four investigated karst lakes (Lake Prošće and Lake Ciginovac) both in larval and adult stages. Considering the literature data about the ecological preferences of *L. vespertina* and *E. submontanus,* our records from this karst river system might be interesting for further investigations into the ecology of these species.

Of all the countries in the Balkan Peninsula, only Bulgaria has an established Red List of mayflies (Russev, 1992). The list has not been updated for more than twenty years and may be rather optimistic, thus none of our recorded species were listed among the threatened or potentially threatened mayflies in Bulgaria.

Our records of the species *E. submontanus, L. vespertina*, *P. werneri* and *C. horaria* in the freshwater habitats of the Plitvice lakes NP are new for the Croatian mayfly fauna.

According to the mayfly species composition and their abundance at each sampling site, NMDS analysis revealed the following characteristics (Fig. 2). Although the mayfly species diversity is generally quite poor in lentic habitats, some taxa can be very abundant. Due to their species composition consisting of taxa of lentic (e.g. *C. horaria*) or wide range (e.g. *C. luteolum*, *E. danica*) habitat type preferences (Bauernfeind & Soldán, 2012), the investigated lakes are **not** distant from any other study site. *Leptophlebia vespertina* prefers slow flowing or still water habitats and was recorded only in the lakes. Also, taxa included in the *Rhithrogena semicolorata* group inhabit only running water habitats and so were absent in the lakes.

Due to the presence of the three common mayfly species, *Baetis rhodani*, *B. alpinus* group and *Rhithrogena semicolorata* group, Upper streams (springs and upper reaches of Crna rijeka and Bijela rijeka) clustered together. Springs and upper reaches of Bijela rijeka are grouped together with the highest similarity of 80%. Upper and middle reaches of Crna Rijeka have a greater number of mayfly species, thus the similarity with other upper stream sites is smaller: 60% and 40% respectively. Due to the presence and abundance of the *B. rhodani, B. alpinus* group, *C. luteolum, E. danica* and *P. submarginata*, the lower reaches of streams (Stream Plitvica and River Korana) are grouped together with 60% and together with tufa-barriers with a similarity of 40%.

Besides the differences in the physical and chemical characteristics of the water (Ivković *et al*., 2010; 2012), upper and lower streams differed in the composition of their microhabitats. In the upper streams these consisted mainly of gravel, sand and moss while in lower streams and tufa barriers habitats consisting of granulated tufa with detritus and silt mostly dominated. Most of the mayfly species larvae prefer lotic habitats where they inhabit microhabitats that are different depending on the longitudinal gra-

dient (Elliott *et al*., 1988; Bauernfeind & Humpesch, 2001). Our results obtained from the mayfly fauna are in accordance with data obtained from physico-chemical analyses of the water (Ivković *et al*., 2010; 2012), and thus confirm the value of Ephemeroptera as indicator organisms for the aquatic environment.

In conclusion, this study represents an important contribution to the knowledge of mayfly fauna of karst freshwater habitats in Croatia as well of the whole Dinaric karst. Future work will include species identification of taxa listed here under *Rhithrogena semicolorata* species-group and *Baetis hysic* species-group. Additionally, mayfly species in the area of Plitvice lakes NP will be studied in connection with their preferences concerning microhabitat and hysic-chemical parameters. As some of the recorded species, like *L. Vespertina* and *E. Submontanus*, are not typical for the karst freshwater environment, their ecological requirements will be investigated in more details in the future.

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SAŽETAK

Fauna vodencvjetova (Insecta, Ephemeroptera) Nacionalnog parka Plitvička jezera

M. Vilenica, J.-L. Gattolliat, M. Ivković, M. Kučinić, V. Mičetić Stanković, Z. Mihaljević & M. Sartori

Vodencvjetovi (Ephemeroptera) su red kukaca koji na svom životnom putu povezuju vodena i kopnena staništa. Kako kao ličinke žive i kreću se u vodenom okolišu, a nakon emergencije u adulta u kopnenom, izvrstan su izvor hrane čitavom nizu slatkovodnih i kopnenih predatorskih vrsta te važna karika u prijenosu energije između vodenih i kopnenih staništa. Zbog široke rasprostranjenosti, važnosti u akvatičkim hranidbenim mrežama, kompleksnog životnog ciklusa, osjetljivost mnogih vrsta na različita onečišćenja te specifičnih ekoloških zahtjeva, njihova prisutnost i raznolikost vrsta široko se koriste kao indikatori kvalitete vode. Fauna vodencvjetova balkanskog poluotoka pa tako i Hrvatske, vrlo je slabo istražena.

U vremenskom razdoblju od veljače 2007. do veljače 2009. godine fauna vodencvjetova istraživana je na 14 postaja različitih tipova krških slatkovodnih staništa (izvori, potoci, sedrene barijere i jezera) na području Nacionalnog parka Plitvička jezera prilikom čega je zabilježeno 19 svojti. Zabilježene vrste čine 27% do sada poznatih vrsta vodencvjetova za faunu Hrvatske. Među zabilježenim vrstama vodencvjetova, četiri su nove za faunu Hrvatske. Veći broj vrsta zabilježen je na tekućim nego na stajaćim slatkovodnim staništima.

Za statističku obradu podataka korišteni su Shannon-Weaverov i Simpsonov indeks raznolikosti te NMDS analiza.

Najveća raznolikost vrsta vodencvjetova zabilježena je na potoku Plitvica i srednjem toku Crne rijeke dok su izvori i tri od četiri istraživana jezera imali najmanji broj vrsta. Vrsta *Ephemera danica*, koja naseljava široki raspon stanišnih tipova zabilježena je na najvećem broju istraživanih postaja. S druge strane, *Electrogena lateralis*, vrsta koja preferira specifično mikrostanište, zabilježena je s najmanjim brojem jedinki i na samo jednoj postaji. Vrsta *Caenis horaria* zabilježena je s najvećim brojem jedinki. Prema sastavu zajednica vodencvjetova odvojila su se lotička od lentičkih staništa. Među lotičkim staništima došlo je potom do odvajanja gornjih i donjih potoka. Ovo istraživanje predstavlja značajan doprinos poznavanju faune vodencvjetova krških područja Dinarida te postavlja osnovu za buduća faunistička i ekološka istraživanja pojedinih vrsta.