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Influence of Environmental Variables on the Structure and Diversity of Ephemeropteran Communities: A Case Study of the Timiş River, Romania

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Abstract: We analysed, in the context of the sustainable management of rivers, the variability in the structure and diversity of ephemeropteran larvae communities in relation to the Timiş River biotope factors. Our research revealed that high diversity of the Ephemeroptera was associated with the river sectors having a heterogeneous structure where runs, pools, riffles and lithological substratum (boulders and cobbles) were present. The distribution of different species revealed that there were groups of species which inhabited different mesohabitats, created by riverbed morphodynamic and the type of substratum. The higher values of SO_4^{2-}, NO_2^-, NO_3^-, Cl^-, Cd, and conductivity in the water influenced negatively the diversity of ephemeropteran communities. The majority of the species presented in the study area thrived at low values of water nutrients and organic load. In order to preserve the diversity of Ephemeroptera in large and medium-sized Carpathian rivers, it is necessary to preserve the natural morphodynamics of river beds, to limit substratum exploitation and to control the water pollution.

Key words: Ephemeroptera, larvae communities, species composition, abundance, biotope factors, Timiş River, Romania

Introduction

Communities of larvae of the insect order Ephemeroptera (mayflies) are key components in the energy flux and matter cycling in lotic systems (Wallace, Webster 1996, Merritt *et al.* 2008). These larval communities are structured in such a way that allows maximum efficiency in using environmental resources (Ward 1992, Bauernfeind, Moog 2000, Diggins, Newman 2009, Jiang *et al.* 2011). Consequently, mayfly larvae are good indicators of the ecological status of rivers (Moog *et al.* 1997, Barbour *et al.* 1999, Bonada *et al.* 2006, Arimoro, Muller 2010, Narangarvuu *et al.* 2014).

The specific diversity and abundance of mayfly larvae communities are determined by the substratum type of the lotic habitats, water velocity, physical and chemical water characteristics (Resh *et al.* 1994, Ilmonen *et al.* 2009, Pastuchova *et al.* 2008, Narangarvuu *et al.* 2015), as well as by the available trophic resources, and predators (Vannote *et al.* 1980, Ward 1992).

The preservation of ephemeropteran communities with a similar or close to natural structure may be a good indicator of the health of the lotic ecosystems (in conformity with the EU Water Framework Directive, EU WFD 2000/60/EEC) under conditions of resources exploitation and benefiting from ecosystem services.

Our study aimed to analyse the variability in the structure and diversity of the ephemeropteran larvae communities, in relation to the biotope factors in the studied river and in the context of the sustainable management of rivers.

Study Area

The Timiş River was selected for this analysis because of its length (241 km of it run through Romania), the high variability of the biotopes along it, and the various historical and current human impacts. This river basin is the main drainage basin in the south-western part of Romania (Fig. 1), with a total basin surface area of 5795 km^2. The springs of the river are located in the eastern part of the Semenic Mountains (1135 m a.s.l.). The river is flowing through and around mountainous areas (average slope of 20 m/km), hilly areas (1.6 m/km), and lowland areas (1-0.15 m/km). At the lower boundary of the study area, the river has an average multiannual flow of 44.9 m^2/s and a specific average flow of 7.75 l/sxkmp (Costea 2013). The main human impact is from the hydro-technical structures, industry, intensive agriculture, and human settlements (Burghelea *et al.* 2013, Curtean-Bănăduc, Fărcaş 2013).

Material and Methods

The sampling was done between June and September 2012. The quantitative benthic macroinvertebrate samples were collected at 21 stations from the Timiş River. The sampling stations were located between the source of the Timiş River and the Romanian – Serbian border (Fig. 2). The samples were taken from five different microhabitats at each station in order to determine the specific diversity of the local microhabitats. Each sampling station was at least 10 m long.

The samples were collected with an 887 cm^2 surface Surber Sampler, with a 250 µm mesh net. The biological material collected was fixed in 4% formaldehyde solution and was processed in the laboratory using Olympus (150X) stereomicroscope.

A total of 3976 Ephemeroptera larvae were collected and identified at species level. The medium density (Ds) and relative abundance (A%) were used for the describing quantitatively the structure of mayfly communities. The diversity of any given community was expressed through Margalef (Krebs 1989) and Gini-Simpson indices (Jost 2007).

The assessed biotope variables were: altitude, slope, riverbed width, depth, substratum type, presence of pools, riffles, runs, and bends, as well as physical and chemical characteristics of the water: pH, conductivity, total suspended matter (MTS), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD-Cr), Cl^-, SO_4^{2-}, NO_2^-, NO_3^-, NH_4^+, and Cd.

The values of pH, conductivity and dissolved oxygen were measured in situ with a multi-parametric device WTW 340i. The other chemical parameters were defined in the laboratory using standard methods (STAS 3069 – 87, STAS 6328 – 85, SR ISO 7890 – 1998, STAS 3048/2 – 90, STAS 3049 – 88, STAS 3002 – 85).

The substratum type (mud, sand, coarse sand, gravel, pebbles, cobbles, boulders, large boulders, and bedrock) was expressed as percentages of the transversal section surface (10 m length).

Principal Components Analysis (PCA; Pearson 1901), based on the correlation matrix, was used to study the relationship between the environmental variables and mayfly diversity. The graphical representation was constructed using the environmental variables, while the biodiversity data was used as supplementary variables, in the sense that they were represented with their relative positions against the

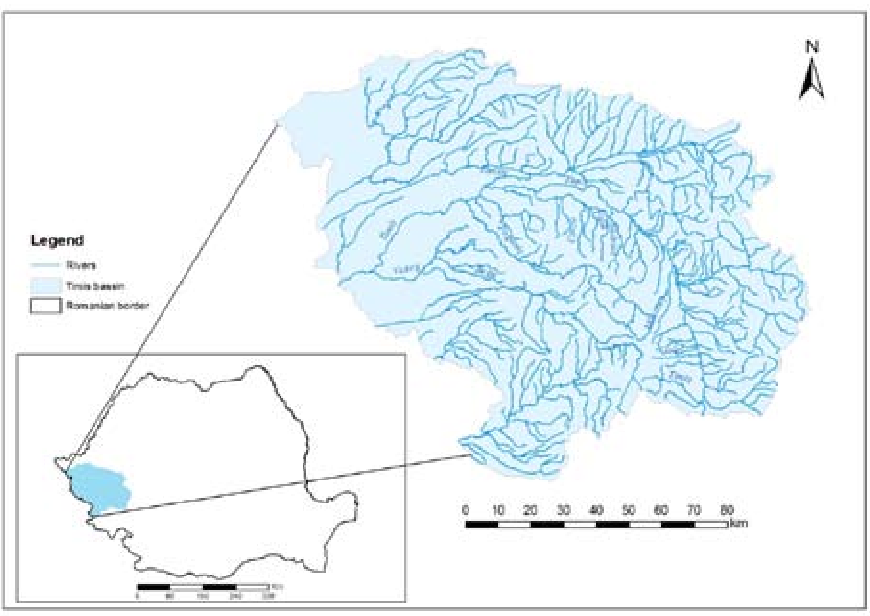

Fig. 1. Location of the Timiş River basin in Romania

correlation of the environmental variables.

Canonical Correspondence Analysis (CCA; ter Braak 1986) was used to relate each species (expressed as relative abundances) to three sets of environmental variables: chemical characteristics of water (COD-Cr, BOD_5, NO_3^-), substratum type, and presence of pools, riffles, runs and bends. Ordinations were done using Statistica v 8.0 (StatSoft 2010) for the PCA, and CANOCO v 4.5 (ter Braak, Smilauer 2002) for the CCA.

Results

We identified 15 mayfly species, belonging to 12 genera and seven families from the Timiş River. The list of the identified mayfly species from the Timiş River samples, along with specific sampling sites, follows below:

Fam. Baetidae

Baetis rhodani (Pictet, 1843) – T1, T2, T9

Baetis scambus Eaton, 1870 – T1, T8, T9

Baetis vernus Curtis, 1834 – T1, T2, T3, T4, T5, T6, T7, T8, T9, T15, T16

Cleon dipterum Linnaeus, 1761 – T8

Fam. Caenidae

Caenis macrura Stephens, 1835 – T3, T7, T9, T18, T19, T21

Fam. Ephemerellidae

Serratella ignita (Poda, 1761) – T1, T2, T4, T5, T6, T7, T8, T9, T14, T15, T18

Ephemera danica Müller, 1764 – T17, T18

Fam. Heptageniidae

Ecdyonurus dispar (Curtis, 1834) – T1, T2, T3, T4, T6, T8, T15, T20

Ecdyonurus venosus (Fabricius, 1775) – T1, T2, T3, T4, T6, T9

Epeorus sylvicola (Pictet, 1865) – T4

Heptagenia sulphurea (Müller, 1776) – T6, T7, T8, T9, T14, T15, T16, T18, T20, T21

Rhithrogena semicolorata (Curtis, 1834) – T6, T8, T9

Fam. Oligoneuriidae

Oligoneuriella rhenana (Imhoff, 1852) – T7, T8

Fam. Potamanthidae

Potamanthus luteus (Linnaeus, 1767) – T8, T9, T14, T15, T16, T17, T18, T20

Fam. Leptophlebiidae

Paraleptophlebia submarginata (Stephens, 1835) – T6, T15.

The three species with the widest distribution in the study area were *Baetis vernus*, *Serratella ignita* and *Heptagenia sulphurea*. The species with the most restricted distribution were *Cleon dipterum, Epeorus sylvicola, Ephemera danica, Oligoneuriella rhenana* and *Paraleptophlebia submarginata*.

Ephemeropteran communities showed a high specific diversity (according to the Margalef index), and heterogeneity (according to the Gini–Simpson index) in the Timiş River sectors T6, T8, T9, T11, and T12 (Table 1). These were areas with high diversity of the specific microhabitats (diverse substratum types, presence of pools, riffles, runs, and bends), while the human impact was insignificant. The lowest diversity was recorded in sector T5 located 300 m downstream of the man-made Trei Ape Lake Dam (Table 1). The river bed was strongly modified there and the water was rich in oxidisable substances (COD-Cr = 56.66 mg/l).

The results of the PCA showed that the first two axes (eigenvalues $\lambda_1 = 4.684$, $\lambda_2 = 3.025$) cumulatively explained 64.2% of the variation of the environmental variables (Fig. 3). Axis 1 was in close relation with Cd, SO_4^{2-}, conductivity, NO_2^-, NO_3^-, Cl^-, (with loadings of 0.874, 0.897, 0.937, 0.793, 0.597, and 0.987, respectively), while axis 2 reflected the variability of pH, NH_4^+ and COD-Cr (the loadings were 0.667, -0.889, -0.825, and -0.904, respectively). These two biodiversity indices were mostly determined by the second axis, being positively correlated with the pH and negatively correlated with NH_4^+ and COD-Cr values. The variables related to Axis 1 influenced less the biodiversity values; the higher values of SO_4^{2-}, NO_2^-, NO_3^-, Cl^-, conductivity ,and Cd in the water were negatively correlated with biodiversity.

In the examined river sectors pH varied between 6.53 and 8.81, with an average of 7.72, corresponding to neutral pH levels. The conductivity which is an indicator of dissolved salts varied between 50.9 µs/cm and 446.56 µs/cm, with the highest values (>280 µs/cm) recorded in the lower reaches of the river (T19, T20, T21). The concentration of nitrates was relatively low in all of the analysed sectors and ranged between 0.675 mg/l and 3.14 mg/l. The concentration of nitrites varied between 0.001 mg/l and 0.475 mg/l; ammonium salt concentration varied between 0 mg/l and 0.3 mg/l; and chloride concentration varied between 0.141 mg/l and 18.323 mg/l. The COD-Cr values, as an indicator of oxidisable matter in the water, ranged between 2.16 mg/l and 56.66 mg/l, with the highest values recorded downstream of the Trei Ape Lake Dam (Fig. 2, station T5), as well as downstream of the Caransebeş locality (Fig.

Table 1. The structure of the ephemeropteran larvae communities within the 21 analysed river sectors along the Timiş River

Sampling station	Structure of the ephemeropteran larvae communities			Biodiversity indices Margalef (M) Gini-Simpson (1-l)
	Species	Medium number of individuals/ m²	Relative abundance A (%)	
T1	*Baetis rhodani* *Baetis scambus* *Baetis vernus* *Serratella ignita* *Ecdyonurus dispar* *Ecdyonurus venosus*	33.82 22.55 11.27 146.56 33.82 33.82	12.00 8.00 4.00 52.00 12.00 12.00	M = 3.577 1-l = 0.707
T2	*Baetis vernus* *Serratella ignita* *Ecdyonurus dispar* *Oligoneuriella rhenana*	67.64 67.64 33.82 293.12	14.63 14.63 7.32 63.41	M = 1.860 1-l = 0.563
T3	*Baetis vernus* *Caenis macrura* *Ecdyonurus venosus*	112.74 11.27 11.27	83.33 8.33 8.33	M = 1.853 1-l = 0.318
T4	*Baetis vernus* *Serratella ignita* *Epeorus sylvicola*	135.29 45.10 11.27	70.59 23.53 5.88	M = 1.625 1-l = 0.471
T5	*Serratella ignita*	631.34	100	M = 0 1-l = 0
T6	*Baetis rhodani* *Baetis vernus* *Serratella ignita* *Ecdyonurus dispar* *Ecdyonurus venosus* *Heptagenia sulphurea* *Rhithrogena semicolorata* *Paraleptophlebia submarginata*	67.64 124.01 22.55 11.27 11.27 11.27 11.27 11.27	25.00 45.83 8.33 4.17 4.17 4.17 4.17 4.17	M = 5.072 1-l = 0.743
T7	*Baetis rhodani* *Baetis vernus* *Caenis macrura* *Serratella ignita* *Heptagenia sulphurea* *Oligoneuriella rhenana*	78.92 225.48 11.27 33.82 11.27 56.37	18.92 54.05 2.70 8.11 2.70 13.51	M = 3.188 1-l = 0.664
T8	*Baetis scambus* *Baetis vernus* *Cleon dipterum* *Serratella ignita* *Ecdyonurus dispar* *Heptagenia sulphurea* *Rhithrogena semicolorata* *Oligoneuriella rhenana* *Potamanthus luteus*	78.92 56.37 11.27 135.29 124.01 11.27 11.27 338.22 11.27	10.14 7.25 1.45 17.39 15.94 1.45 1.45 43.48 1.45	M = 4.351 1-l = 0.750
T9	*Baetis rhodani* *Baetis vernus* *Caenis macrurar* *Serratella ignita* *Ecdyonurus venosus* *Rhithrogena semicolorata* *Potamanthus luteus*	11.27 56.37 56.37 124.01 11.27 11.27 45.10	3.57 17.86 17.86 39.29 3.57 3.57 14.29	M = 4.146 1-l = 0.786
T10	*Baetis vernus* *Serratella ignita* *Rhithrogena semicolorata* *Oligoneuriella rhenana* *Potamanthus luteus*	293.12 22.55 56.37 11.27 33.82	70.27 5.41 13.51 2.70 8.11	M = 2.551 1-l = 0.491

Table 1. Continued

Sampling station	Structure of the ephemeropteran larvae communities			Biodiversity indices Margalef (M) Gini-Simpson (1-l)
	Species	Medium number of individuals/ m²	Relative abundance A (%)	
T11	*Baetis scambus* *Baetis vernus* *Caenis macrura* *Serratella ignita* *Ecdyonurus dispar* *Ecdyonurus venosus* *Heptagenia sulphurea* *Rhithrogena semicolorata* *Oligoneuriella rhenana* *Potamanthus luteus*	236.75 112.74 22.55 45.10 11.27 45.10 11.27 33.82 22.55 22.55	42.00 20.00 4.00 8.00 2.00 8.00 2.00 6.00 4.00 4.00	M = 5.297 1-l = 0.777
T12	*Baetis scambus* *Baetis vernus* *Caenis macrura* *Serratella ignita* *Ecdyonurus dispar* *Heptagenia sulphurea* *Rhithrogena semicolorata* *Oligoneuriella rhenana* *Potamanthus luteus*	33.82 293.12 11.27 67.64 22.55 22.55 11.27 33.82 90.19	5.77 50.00 1.92 11.54 3.85 3.85 1.92 5.77 15.38	M = 4.662 1-l = 0.716
T13	*Baetis scambus* *Baetis vernus* *Caenis macrura* *Ephemera danica* *Rhithrogena semicolorata* *Oligoneuriella rhenana* *Potamanthus luteus*	45.10 293.12 22.55 67.64 78.92 90.19 22.55	7.27 47.27 3.64 10.91 12.73 14.55 3.64	M = 3.448 1-l = 0.733
T14	*Baetis scambus* *Baetis vernus* *Heptagenia sulphurea* *Potamanthus luteus*	90.19 529.88 67.64 33.82	12.50 73.44 9.38 4.69	M = 1.661 1-l = 0.441
T15	*Baetis vernus* *Serratella ignita* *Ecdyonurus dispar* *Heptagenia sulphurea* *Potamanthus luteus*	1533.26 11.27 22.55 1984.22 552.42	37.60 0.27 0.55 48.35 13.46	M = 1.562 1-l = 0.61
T16	*Baetis verus* *Heptagenia sulphurea* *Potamanthus luteus*	22.55 1679.82 315.67	1.12 83.24 15.64	M = 0.888 1-l = 0.284
T17	*Ephemera danica* *Potamanthus luteus*	56.37 33.82	62.5 37.5	M = 1.107 1-l = 0.536
T18	*Caenis macrura* *Serratella ignita* *Ephemera danica* *Heptagenia sulphurea* *Potamanthus luteus*	169.11 22.55 11.27 11.27 1059.75	13.27 1.77 0.88 0.88 83.19	M = 1.948 1-l = 0.293
T19	*Baetis verus* *Caenis macrura*	33.82 101.47	25.00 75.00	M = 0.927 1-l = 0.409
T20	*Baetis verus* *Ecdyonurus dispar* *Heptagenia sulphurea* *Potamanthus luteus*	33.82 56.37 45.10 22.55	21.43 35.71 28.57 14.29	M = 2.618 1-l = 0.780
T21	*Baetis verus* *Caenis macrura*	22.55 191.66	10.53 89.47	M = 0.782 1-l = 0.199

Table 2. Water physical and chemical characteristics of the Timiş River

Physical and chemical variables	Minimum	Maximum	Median	Mean	Standard Deviation
pH	6.53	8.81	7.72	7.741	0.506
Conductivity (µs/cm)	50.9	446.56	146.86	179.054	103.385
MTS (mg/l)	3.8	402	5.66	30.686	95.796
DO (mg/l)	4.36	8.89	5.32	6.375	1.856
COD-Cr (mg/l)	2.16	56.66	9.13	11.618	12.155
BOD_5 (mg/l)	0.713	1.44	1	1.03	0.216
NO_2^- (mg/l)	0.001	0.475	0.021	0.1	0.144
NO_3^- (mg/l)	0.675	3.14	1.67	1.651	0.614
NH_4^+ (mg/l)	0	0.3	0.025	0.059	0.079
SO_4^{2-} (mg/l)	9.23	68.83	22.7	25.779	16.318
Cl^- (mg/l)	0.141	18.323	2.623	4.305	4.798
Cd (mg/l)	0	0.029	0	0.005	0.01

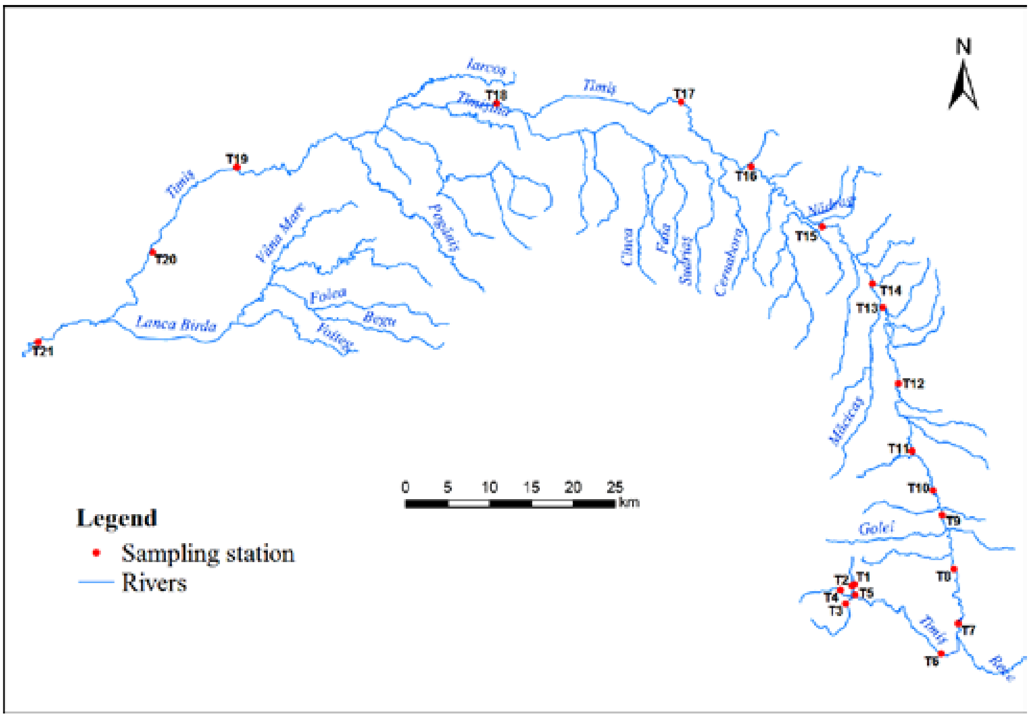

Fig. 2. Location of the sampling stations at the the Timiş River: T1; T2; T3 – N 45°12'290" E 22°08'007" 870 m; T4 – N 45°13'163" E 22°07'426" 846 m; T5 – N 45°12'875" E 22°08'847" 802 m; T6 – N 45°09'299" E 22°16'838" 420 m; T7 – N 45°11'264" E 22°18'308" 354 m; T8 – N 45°14'768" E 22°17'745" 296 m; T9 – N 45°18'220" E 22°16'516" 265 m; T10 – N 45°19'770" E 22°15'610" 250 m; T11 – N 45°22'255" E 22°13'553" 219 m; T12 – N 45°26'569" E 22°12'111" 175 m; T13 – N 45°31'456" E 22°10'413" 174 m; T14 – N 45°32'939" E 22°09'401" 158 m; T15 – N 45°36'476" E 22°04'608" 142 m; T16 – N 45°40'182" E 21°57'885" 117 m; T17 – N 45°44'181" E 21°51'222" 116 m ; T18 – N 45°43'590" E 21°34'262" 83 m; T19 – N 45°38'734" E 21°10'696" 83 m; T20 – N 45°33'000" E 21°03'033" 75 m; T21 – N 45°26'859" E 20°53'309" 74 m

2, station T12). The BOD_5 values ranged between 0.713 mg/l and 1.44 mg/l (Table 2). Cadmium was present in very low quantities in four sectors of the river (Table 2.). These sectors were of quality class I for surface water according to the regulation for the classification of surface waters applied in Romania.

The CCA, which relates the species to NO_3^-, COD-Cr and BOD_5 variables, showed that the first two axes (eigenvalues $\lambda_1 = 0.464$, $\lambda_2 = 0.239$) cumulatively explained 85.4% of the total variance (Fig. 4). COD-Cr and BOD_5 loaded strongly on the first axis, while the NO_3^- concentration was positively related with the second axis. The majority of the mayfly species were negatively correlated with both axes,

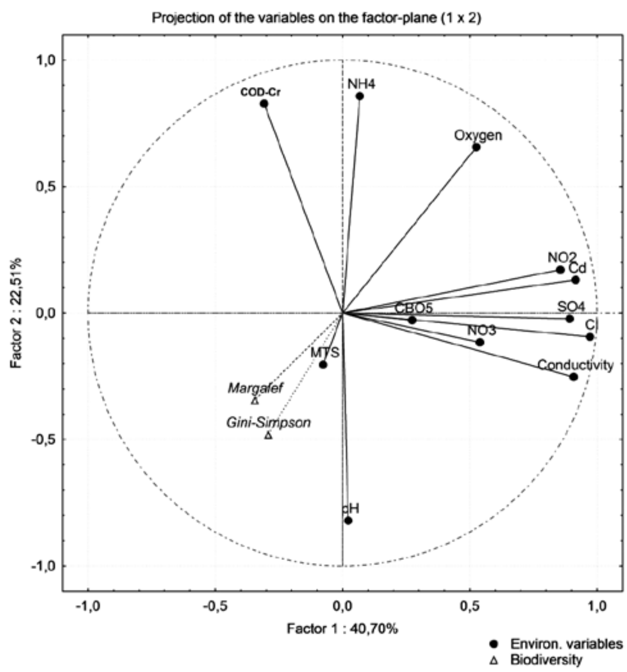

Fig. 3. PCA ordination of biodiversity values and environmental variables (COD-Cr – chemical oxygen demand, CBO_5 – biochemical oxygen demand, NO_3^- – nitrates, NO_2^- –nitrites; NH_4^+ – ammonia, SO_4^{2-} – sulphates; Cd – Cadmium, Cl^- – clorine, MTS – total matters in suspension)

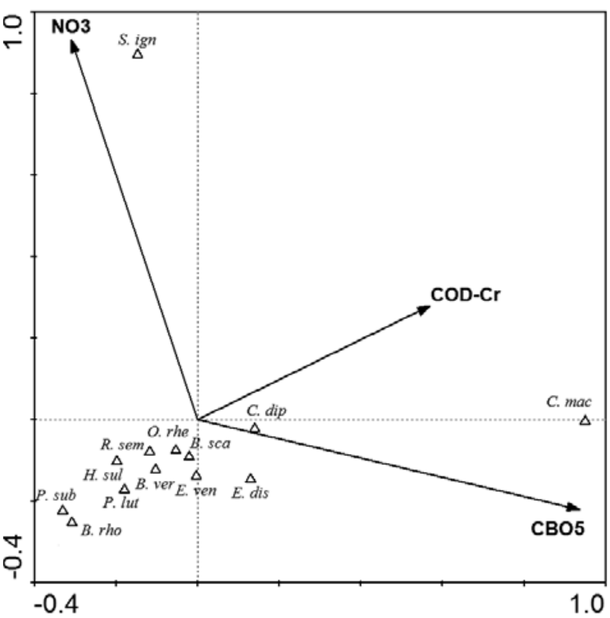

Fig. 4. CCA biplot of species and water physical and chemical variables (COD-Cr – chemical oxygen demand, CBO_5 – biochemical oxygen demand, NO_3^- – nitrates; *B. rho – Baet rho*, *B. sca – Baet sca*, *B. ver – Baet ver*, *C. dip – Cleo dip*, *C. mac – Caen macr*, *S. ign – Serr ign*, *E. dis – Ecdy dis*, *E. ven – Ecdy ven*, *E. syl – Epeo syl*, *H. sul – Hept sul*, *R. sem – Rhit sem*, *O. rhe – Olig rhe*, *P. lut – Pota lut*, *P. sub – Para sub*)

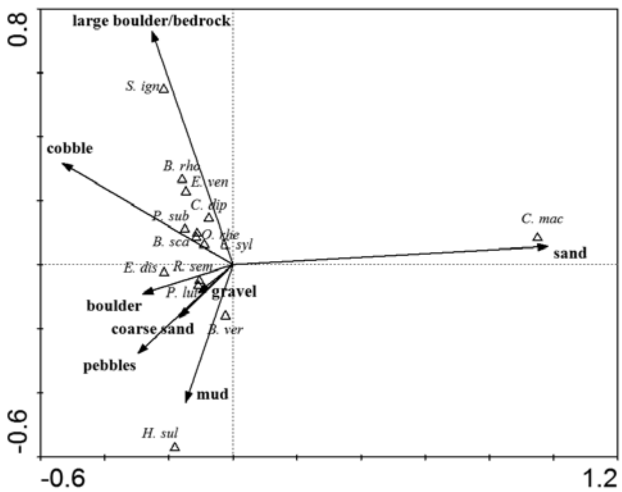

Fig. 5. CCA biplot of species and substrate variables (*B. rho – Baët rho*, *B. sca – Baet scam*, *B. ver – Baet ver*, *C. dip – Cleo dip*, *C. mac – Caen macr*, *S. ign – Serr ign*, *E. dis – Ecdy dis*, *E. ven – Ecdy ven*, *E. syl – Epeo syl*, *H. sul – Hept sul*, *R. sem – Rhit sem*, *O. rhe – Olig rhe*, *P. lut – Pota lut*, *P. sub – Para sub*)

which means that they were thriving at low values of water nutrients and organic load. Some exceptions were *Caenis macrura*, which was also present in the river sectors with higher COD-Cr and BOD_5 values, and *S. ignita*, which occurred in habitats with higher NO_3^- concentrations.

The results of the CCA showed that the first two axes (eigenvalues $\lambda_1 = 0.661$, $\lambda_2 = 0.469$) cumulatively explained 53.8% of the total variance of the relationship between species and substratum variables (Fig. 5). The first axis was positively correlated with sand and negatively correlated with cobble and boulder, while the second axis was positively correlated with large boulders/ bedrock and negatively correlated with mud. Coarse sand and pebbles loaded equally on both axes, being negatively correlated with both of them. The majority of the mayfly species preferred lithological substrata (cobbles, boulders, large boulders/ bedrock) with the exceptions of *C. macrura* and *H. sulphurea*, which favoured the presence of sand and mud, respectively.

The first two axes of the CCA, relating species to the characteristics of the riverbed (eigenvalues $\lambda_1 = 0.592$, $\lambda_2 = 0.402$), cumulatively explained 80.0% of the total variance (Fig. 6). The presence of bends was positively correlated, while runs were negatively correlated with the first axis. The presence of pools loaded strongly and positively on the second axis. Riffles were equally and negatively determined by both axes. The majority of the species were positively correlated to the second axis and negatively – to the first axis, which meant that the species preferred

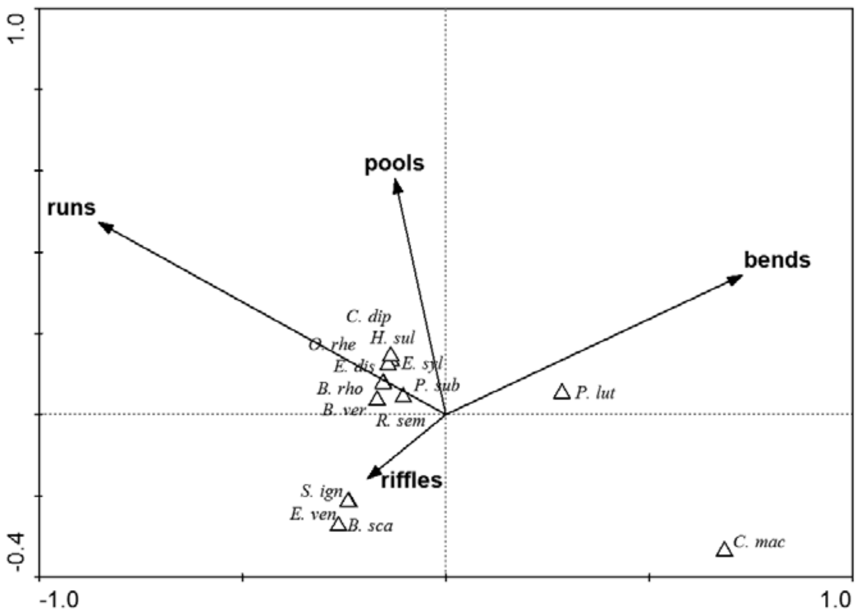

Fig. 6. CCA biplot of species and hydro-morphological variables (*B. rho – Baet rho*, *B. sca – Baet sca*, *B. ver – Baet ver*, *C. dip – Cleo dip*, *C. mac – Caen mac*, *S. ign – Serr ign*, *E. dis – Ecdy dis*, *E. ven – Ecdy ven*, *E. syl – Epeo syl*, *H. sul – Hept sul*, *R. sem – Rhit sem*, *O. rhe – Olig rhe*, *P. lut – Pota lut*, *P. sub – Para sub*)

the river sectors with heterogeneous structure where both runs and pools were present. *Potamanthus luteus* was positively influenced by the presence of river bends and *C. macrura* was negatively affected by the presence of runs, with preferring lower water velocity. Riffles were a favourable factor for *Serratella ignita*, *Baetis scambus* and *Ecdyonurus venosus*.

Discussion

The composition and diversity of ephemeropteran communities are conditioned by the physical, chemical and biological factors of the environment (Doisy, Rabeni 2001, Barquin, Death 2004, Atobatele *et al.* 2005, Arimoro, Muller 2010).

The presence of adequate mesohabitat structures is one of the most important factors that determine the occurrence and distribution of ephemeropteran species (Hall *et al.* 2006, Svitok 2006, Bauernfeind, Moog 2000, Beisel *et al.* 2000, Minshall 1984).

Our research confirmed the fact that high diversity of Ephemeroptera was associated with river sectors with heterogeneous structures (where runs, pools and riffles were present), and with lithological substratum (boulders and cobbles). The most commonly found species in the reference zone preferred river sectors where both runs and pools were present, and with a lithological substratum. Some species, such as *Potamanthus luteus* and *Ephemera danica,* were positively correlated to the presence of river bends. *Caenis macrura* and *Ephemera danica* preferred sand, while *Heptagenia sulphurea* had preference for mud.

The studies of Lock, Goethals (2011, 2013) in Flanders (Belgium) and Găldean (1992) in Romania reported that mayfly communities are better represented in river sectors with a well-developed river structure, higher values of sinuosity and steeper slopes. In our case study the river sectors with these natural characteristics were obviously linked to high diversity of mayfly communities in the upper part of the river (especially at T11, and also at T6, T8 and T9). When hydro-technical works (mainly dams and embankments) changed the natural characteristics of the river, the mayfly communities were rather scarce, like in T5, T15, T17, T19 and T21 sectors. (Table 1, Fig. 2)

The tolerance of mayfly species to NO_2^- and NO_3^- pollution was demonstrated experimentally by Beketov (2004). Based on observational data regarding rivers in South-western Siberia, the author revealed that the high concentrations of ammonium, nitrites and nitrates corresponded to the reduction in species richness and diversity of mayflies.

Similarly, we found that higher values of NO_2^-, NO_3^- and also of SO_4^{2-}, Cl^-, conductivity and Cd in the water influenced negatively the specific diversity and heterogeneity of the mayfly communities. The majority of the mayfly species recorded in this study area thrives in waters with low values of nutrients and organic load, this finding being in conformity with some studies in different rivers (Roy *et al.* 2003, Novotny *et al.* 2005, Wang *et al.* 2007, Yuan 2010). The exceptions were tolerant species, such as *Caenis macrura*, which were also present in river sectors with higher COD-Cr and BOD_5 values, and *Serratella ignita*, which was associated with higher NO_3^- concentrations. The last species populations can live in biotopes where other mayfly species cannot survive.

Conclusions

This study highlights the fact that the structure of ephemeropteran larvae communities are mainly determined by a variety of factors, such as the substratum type, presence of pools, riffles, runs and bends, and the chemical characteristics of the water – COD-Cr, BOD_5, SO_4^{2-}, NO_2^-, NO_3^-, Cl^-, Cd, and conductivity.

Therefore, in order to preserve the diversity of the ephemeropteran communities in the large and medium-sized Carpathian rivers it is necessary to maintain the natural morphodynamics of the river bed, to limit substratum exploitation and to control water pollution.

The diversity of mayfly communities could be a reliable indicator of the ecological integrity of this type of rivers. Therefore, the proper habitat management, which keeps typical natural structures of those communities, and ensures the maintenance of the biodiversity indices values within favourable ecological limits, may be the goal for all similar rivers. It is also recommended that the restoration activities in these rivers should be based on an approach, which considers the biodiversity-biotope relationships.

Achieving an optimum balance between the negative effects of the human activities (pollution, hydro-technical works, mineral river bed overexploitation, etc.) and the relevant protective measures with regard to the Timiş River may improve significantly the ecologic integrity of this lotic system.

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