Distribution and density of Ephemeroptera and Plecoptera of the Radíkovský brook (Czech Republic) in relation to selected environmental variables

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Abstract

Approximately 11,000 specimens of 10 species of mayflies and 18 species of stoneflies have been quantitatively sampled at 9 sites of the Radíkovský brook (49° 04' 27'' N, 15° 14' 29'' E and 49° 04' 21''N, 15° 16' 30'' E, elevation of 500 – 678 m a.s.l.) in all seasons. Biogeographical aspects of species found at this relatively species-rich and undisturbed locality are discussed and their quantitative presentation is analyzed by considering some environmental variables. The stoneflies *Leuctra nigra*, *Amphinemura sulcicollis* and *L. albida* are clearly dominant in the respective taxocenosis (59.6%, 11% and 8%, respectively). Shannon-Weawer index of species diversity and Brillouin index of equitability are 1.74 and 0.53, respectively. The substrate roughness has been found the most important environmental factor explaining most of variability in the species longitudinal distribution and density. Using redundancy analysis 14 out of 16 environmental variables explain 23.1% of the variability, wheres 67.5% of 5 statistically significant environmental factors (sand and leaf litter, detritus, sand, moss, and submerged vegetation).

Keywords: Central Europe, small brook, biogeography, species composition of taxocenosis, ecology.

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Introduction

The relationships between Ephemeroptera and Plecoptera distribution and environmental variables within large catchments areas in the Czech Republic have been intensively studied (Helešic, 1995; Soldán *et al*., 1998; Zahrádková, 1999). However, despite relatively extensive knowledge on ecology of mayflies and stoneflies and long-term trends in changes of their distribution, there are very fragmentary data on distribution and seasonal changes of respective taxocenes in small brooks and respective small basins. Although this knowledge is undoubtedly necessary to clear up the whole ecological system, data are scattered within the literature. One of rare examples of complex, detailed and all-season data approach is that by Vondrejs (1958) describing benthic communities within the future water reservoir in Central Bohemia. This author recognized the importance of very small water bodies to the environment in the area studied.

The objective of this paper is to describe main factors affecting both density and distribution in a small water flow of the species belonging to Ephemeroptera and Plecoptera.

Material and Methods

The Radíkovský brook (samples taken at 49° 04' 27'' N, 15° 14' 29'' E and 49° 04' 21'' N, 15° 16' 30'' E) is situated in the Czech-Moravia Highlands and included in the Morava-Danube River basin with coordinates according to uniform grid system 6957 (Pruner and Míka, 1996). According to recent faunistic classification of aquatic insects, the Radíkovský brook belongs to the faunistic area B and faunistic district IX (Landa and Soldán, 1989). Number of hydrological order of the Radíkovský brook is 4–14–01–050, its springs area at the elevation of 678 m a.s.l. and the mouth into the Pilský pond is situated at that of 507 m a.s.l. The length of brook is 8.05 km, the catchments area 14.9 km^2, mean slope 21‰ and mean year flow at mouth 19.5 ls^{-1}.

To study vertical distribution, densities and seasonal changes of mayflies and stoneflies, 9 sites in the Radíkovský brook were sampled at elevations of 500 – 678 m a.s.l. Sites were selected in order to study maximal variability of environmental factors, primarily with respect to both substrate roughness and brook size. Surber sampler modified by Hrbáček (1985) has been used to sample the specimens quantitatively from March 1999 to January 2001. Samples were carried out once in two months, resulting in 11 samples at each of nine sites selected. One sample per site consisted of three squares (30 x 30 cm) of bottom area surveyed, corresponding to 0.27 m^2.

Sixteen environmental variables were recorded, ten of them in field: width and depth, current velocity (estimated by using cork markers), substrate roughness (i.e. sand, sand and leaf litter, detritus, moss, and submerged vegetation), water temperature, and dissolved oxygen (latter two by means of mobile oximeter, Oxi 320 WTW). Physio-chemical water characteristics, such as pH, conductivity, ammonium ions, nitrates, phosphates, and total phosphorus were analysed in laboratory.

The program Canoco, version 4.0 (RDA, redundancy analysis) was used to evaluate distribution and density of species in relation to most of the above environmental variables (Ter Braak and Šmilauer, 1998). The gradient of the environmental factors was quite strait, so that the linear model, of species distribution dependence and environmental factors gradient, was used. The seasonal data were entered like covariats (Lepš and Šmilauer, 2000). The species data were log-transformed, as well as some those concerning environmental variables.

Only species occurring in three and more samples were considered in respective statistical analysis. Species showing "negligible" occurrence, e.i. those occurring in a single or at least two samples in this case, were not take into account in the analysis since such data could bias the results (cf. Ter Braak and Šmilauer, 1998). Only 14 environmental factors were evaluated with the program Canoco. The values of phosphates and total phosphorus were not considered because they were not detected by the instrument. Values of main environmental variables are reported in (Table 2).

Brillouin species equitability index was 0.53 and Shannon-Weaver species diversity index was 1.74 (Krebs, 1989).

Brillouin species equitability index:

$$E = \frac{H}{H_{max}}$$

$$H = \frac{1}{N} \log_2 \left(\frac{N!}{n_1! \cdot n_2! \cdot \ldots n_i!} \right)$$

$$H_{max} = \frac{1}{N} \log \left[\frac{N!}{[I!]^{S-J} [(I+1)!]^J} \right]$$

H_{max} – maximal value of Brillouin species equitability index

S – number of species in sample

N – total number of specimens in sample

$$I = \frac{N}{S}$$

$$J = [N - (S) \cdot (I)]$$

Shannon-Weaver species diversity index:

$H = -\sum Pi \ln Pi$

Pi – number of specimens of species i

Results

Approximately 11,000 specimens belonging to 10 species of the Ephemeroptera (4 families and 6 genera) (Table 1) and 18 species of the Plecoptera (6 families and 9 genera, Table 1) have been collected and identified in the Radíkovský brook from March 1999 – January 2001.

The stoneflies *Leuctra nigra* (OLIVIER, 1811), *Amphinemura sulcicollis* (STEPHENS, 1836) and *Leuctra albida* KEMPNY, 1899 were clearly dominant in the respective taxocenosis (59.6 %, 11 % and 8 %, respectively) (Fig. 1), at least the former 1-2 species can be ranged within dominant ones. Quantitative presentation of the species is reported in (Fig. 1). Although this contribution is not directed to detailed study of this question, I would like to emphasize relatively very high portion of clearly recedent species in the Radíkovský brook. Besides 3 very abundant species (*L. nigra, A. sulcicollis* and *L. albida*), there are only 8 species (5 of the Plecoptera, 3 species of the Ephemeroptera) the quantitative presentation of which reaches 1 % and more. Most of remaining representatives of these orders, i.e. 7 species of mayflies and 10 species of stoneflies belongs to clearly recedent (or, in other words, very rare) species.

Fourteen factors explain 23.1% of data variability according to redundancy analysis. The Monte Carlo Permutation Test (999 permutations) confirmed 5 statistically significant ($p > 0.05$ in all the cases) environmental factors, which are: sand and leaf litter ($F = 8.72$), detritus ($F = 6.50$), sand ($F = 2.94$), moss ($F = 1.80$), and submerged vegetation ($F = 1.80$). They represent 67.5% of 23% of the variability of the environmental factors (Fig. 2). These environmental variables were not included into following analysis due to their high correlation with current velocity. There was the p value lower than 0.05 in all other cases.

Redundancy analysis of 9 environmental variables with the exclusion of the variables characterising substrate roughness explains 13.6% of total data variability (Fig. 3). The Monte Carlo Permutation Test (999 permutations) confirms three of them, namely current velocity, average stream width, and maximal temperature statistically significant ($p > 0.05$ for all variables). The above three variables ($F = 4.64, 3.44, 1.87$, respectively) explain 70.6 % of variability exhibited by nine environmental factors.

Table 1 - Species composition and their quantitative presentation in samples taken bimonthly in the Radíkovský brook from March 1999 – January 2001. Those species, of which name abbreviation is missing, were not included in redundancy analysis (see Material and Methods for details). Abbreviations: HOL – Holarctic, EAS – Euroasian, E – European, NCE – Nort-Central European, SCE – South-Central European, CE – Central European. Data on abundance are in the Czech Republic, are reported according to modify six-grade scale modified by Friederichs (see Soldán *et al*., 1998).

Order/Species	Abbreviation	Chorology	Abundance in the Czech Republic	Sampling date										
				1999					2000					2001
				03-13	05-08	07-17	09-23	11-12	03-10	05-12	07-13	09-23	11-01	01-27
Ephemeroptera														
Ameletus inopinatus EATON, 1887		NCE	3	0	0	1	0	0	0	0	0	0	0	0
Baetis rhodani PICTET, 1843-1845	Bae-rho	EAS	6	0	0	0	0	1	0	0	0	0	22	22
Baetis vernus CURTIS, 1834	Bae-ver	EAS	6	0	0	230	52	0	0	0	9	22	0	0
Cloeon dipterum (LINNÉ, 1761)	Clo-dip	HOL	6	0	0	0	11	0	1	1	0	16	0	0
Leptophlebia marginata (LINNÉ, 1767)	Lep-mar	HOL	4	3	2	0	0	2	0	0	0	0	17	1
Leptophlebia vespertina (LINNÉ, 1758)	Lep-ves	NCE	3	87	94	0	0	130	43	167	0	16	0	0
Paraleptophlebia submarginata (STEPHENS, 1835)	Par-sub	E	4 - 5	0	0	0	203	0	0	0	0	29	1	0
Siphlonurus aestivalis (EATON, 1903)		E	3	0	0	1	0	0	0	0	0	0	0	0
Siphlonurus armatus (EATON, 1870)		NCE	1	0	0	1	0	0	0	0	0	0	0	0
Siphlonurus lacustris (EATON, 1870)		EAS	3	0	0	1	0	0	0	0	0	0	0	0
Plecoptera														
Amphinemura sulcicollis (STEPHENS, 1836)	Apm-sul	E	5	188	186	3	188	89	22	28	0	106	196	200
Brachyptera seticornis (KLAPÁLEK, 1902)	Bra-set	SCE	4	13	0	0	0	0	6	0	0	0	2	30
Capnia bifrons (NEWMAN, 1839)	Cap-bif	EAS	2	2	0	0	0	1	10	0	0	0	0	7
Isoperla oxylepis (DESPAX, 1936)	Iso-oxy	E	6	0	0	1	1	0	0	0	0	0	0	4
Leuctra albida KEMPNY, 1899	Leu-alb	SCE	6	0	0	16	193	86	0	0	0	320	245	0
Leuctra autumnalis AUBERT, 1948		CE	5	0	0	0	0	1	0	0	0	0	0	0
Leuctra digitata KEMPNY, 1899	Leu-dig	HOL	3	57	1	0	0	0	24	0	0	0	0	353
Leuctra nigra (OLIVIER, 1811)	Leu-nig	E	6	545	408	317	620	997	254	613	443	642	789	455
Leuctra teriolensis KEMPNY, 1900	Leu-ter	CE	4	0	5	0	0	0	0	0	0	0	0	0
Nemoura cinerea (RETZIUS, 1873)	Nem-cin	EAS	6	1	11	0	0	0	3	19	0	0	1	0
Nemoura flexuosa AUBERT, 1949		EAS	5	0	0	0	0	0	0	0	0	0	0	1
Nemoura marginata PICTET, 1835	Nem-mar	SCE	1	0	6	0	0	1	0	0	0	2	0	11
Nemurella pictetii KLAPÁLEK, 1900	Nem-pic	EAS	6	60	41	11	20	11	9	10	0	12	0	0
Protonemura auberti ILLIES, 1954	Pro-aub	SCE	5	0	32	0	0	1	0	13	0	0	0	0
Protonemura intricata (RIS, 1902)	Pro-int	SCE	5	0	31	0	0	0	0	20	0	0	0	10
Protonemura lateralis (PICTET, 1835)	Pro-lat	SCE	4	0	0	1	0	22	0	0	0	26	17	0
Protonemura meyeri (PICTET, 1841)	Pro-mey	E	6	44	0	0	0	0	1	0	0	0	0	0
Siphonoperla torrentium (PICTET, 1841)	Siper-th	E	3	0	0	0	0	0	1	1	0	0	1	0
Total number of species				10	11	11	8	12	11	9	2	10	10	11

Table 2 - Values of main environmental variables measured and their range in the Radíkovský brook from March 1999 – January 2001.

Environmental variable	mean	minimum	maximum
Stream depth [m]	0.19	0.04	0.6
Stream width [m]	1.22	0.25	2.5
Current velocity [$m.s^{-1}$]	0.29	0.01	0.83
Temperature [^{o} C]	8.36	0.8	14.2
Dissolved oxygen [$mg.l^{-1}$]	10.40	8.3	13.9
pH	5.63	4.34	6.69
Conductivity [$mS.m^{-1}$]	9.90	6.1	11.6
Ammonium ions [$mg.l^{-1}$]	0.21	0	0.95
Nitrates [$mg.l^{-1}$]	5.59	0.4	11.6

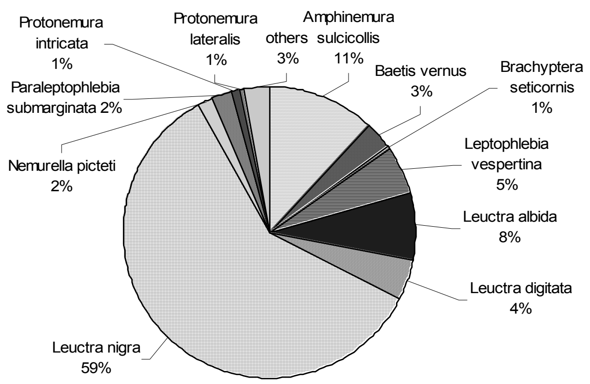

Fig. 1 - Quantitative species composition of mayfly and stonefly taxocenosis in the Radíkovský brook (cumulative data from March 1999 – January 2001). Eleven species included, those with quantitative presentation below 1 % summarized (cf. list of species found in Table 1).

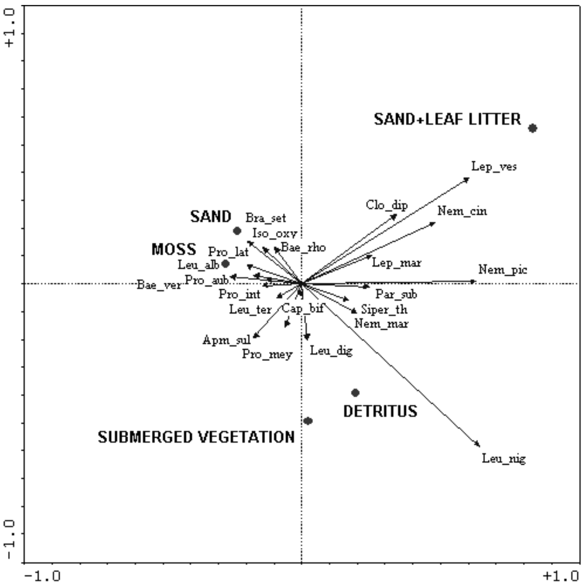

Fig. 2 - RDA (redundancy analysis) of species distribution in relation to substrate roughness. See Table 1 for species name abbreviations.

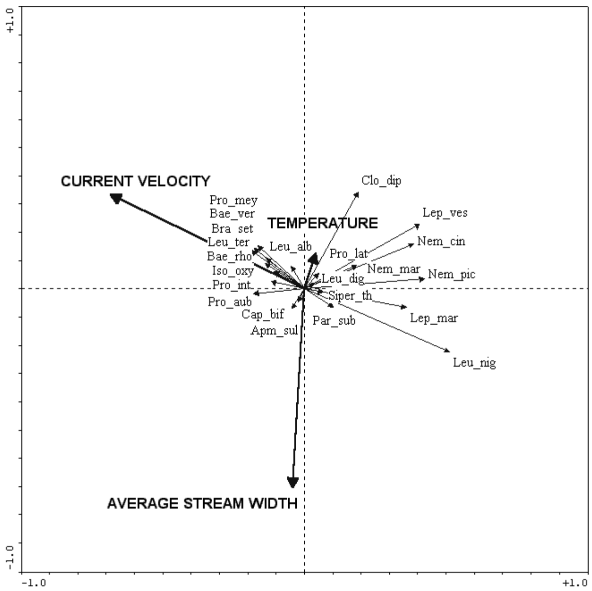

Fig. 3 - RDA (redundancy analysis) of species distribution in relation to current velocity, average stream width and maximal water temperature. See Table 1 for species name abbreviations.

Discussion

Taking into account that approximately up to 15-20 species of Ephemeroptera and Plecoptera are usually involved in mayfly and stonefly taxocenosis in Central European localities (Soldán *et al.*, 1989), the Radíkovský brook with 18 species of Plecoptera and 10 species of Ephemeroptera seems to represent an exception. This is worth stressing that there is a relevant high portion of rare species in the Radíkovský brook (Tab.1). Besides 3 very abundant species (*Leuctra nigra*, *Amphinemura sulcicollis* and *Leuctra albida*), there are only 8 species (5 of the Plecoptera, 3 species of the Ephemeropttera) the quantitative presentation of which reaches 1% and more. Most of remaining representatives of these orders, i.e. 7 species of mayflies and 10 species of stoneflies belong to a very rare species.

From the biogeografical point of view, most species are of the arboreal faunistic origin, except for some oreotundral elements (North-Central European *Leptophlebia vespertina* (LINNÉ, 1758), *Ameletus inopinatus* EATON, 1887, *Siphlonurus armatus* (EATON, 1870) and Holarctic *Leuctra digitata* KEMPNY, 1899) and other species show a very large distributional area, like *Cloeon dipterum* (LINNÉ, 1761). From the chorological point of view, the species are Eurasian (7 species, see Table 1 for details), South-Central or Submediterranean (6 species) and widely spread in Europe (6 species). There are only two species worth of our attention, namely very rare and vulnerable *S. armatus* and susceptible and not abundant *Leuctra teriolensis* KEMPNY, 1900. Moreover, the latter is recorded from respective faunistic district (IX) of the Czech Republic for the firs time (cf. Soldán *et al.*, 1998). From biodiversity protection and conservation management point of view, altogether 5 species found in the Radíkovský brook are important. In addition to vulnerable *S. armatus* and susceptible *L. teriolensis*, Soldán *et al.* (1998, see this monograph also for the criteria distinguishing these individual categories) consider *Isoperla oxylepis* (DESPAX, 1936) and *Siphonoperla torrentium* (PICTET, 1841) susceptible species, and *Capnia bifrons* (NEWMAN, 1839) a representative of the Low Risk category.

According to the very first redundancy analysis five environmental factors are statistically significant (sand and leaf litter, detritus, sand, moss, and submerged vegetation). All these factors determine the substrate type (roughness) so that we can state that this is the most important factor explaining most of variability within the species/density distribution.

The ordination diagram (Fig. 2) refers to dominant *L. nigra* very clearly responding to the type of substrate (detritus). Similarly, relationships of species distribution to current velocity and other variables (Fig. 3) indicate strongly negative correlation between *L. nigra* occurrence and current velocity. Naturally, this confirms a very strong indirect correlation between current velocity and detritus substrate.

Microhabitat preferences of three analyzed species do not fully correspondent with food preferences described e.g. by Moog (1995). The allegedly shredder *C. bifrons* occurred on sand and detritus, the allegedly collector stoneflies *L. albida* and *L. teriolensis* highly prefered moss substrates and *L. teriolonsis* frequently occurred on submerged vegetation as well.

Helešic (1995) described stonefly taxocene relations on environmental factors within the whole catchments area in the Czech Republic. Contrary to his conclusion, *Nemurella pictetii* KLAPÁLEK, 1900 prefered low current velocity places in the Radíkovský brook. Two species (*Nemoura cinerea* (RETZIUS, 1873) and *Nemoura marginata* PICTET, 1835) are suggested by Helešic (1995) to be tolerant to oscillating water temperatures. However, according to my observation, these species highly positively responded to water temperature in the Radíkovský brook

Besides the environmental variables affecting stonefly taxocenosis in the Czech Republic discussed by Helešic (1995), two (current velocity and temperature) were statistically significant in biotopes of the Radíkovský brook. Of these, maximal water temperature is also mentioned by Zahrádková (1999) and Soldán *et al.* (1998) to affect both the species density and variability within whole river catchments area in the Czech Republic.

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