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Macroinvertebrate assemblages in conditions of low-discharge streams of the Cerová vrchovina highland in Slovakia

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Abstract

Macroinvertebrate communities at 16 sites in Cerová vrchovina highland were sampled in 2000–2001 to analyze the influence of environmental factors on community structure with emphasis on Ephemeroptera, Plecoptera and Trichoptera (EPT). The extreme hydrological conditions of this area determine the macroinvertebrate community structure. Totally, 16 Ephemeroptera, 8 Plecoptera and 36 Trichoptera taxa were found. Predators of the families Perlidae, Perlodidae and Chloroperlidae (Plecoptera) were absent. The record of *Protonemura aestiva* is the second one in Slovakia. Ephemeroptera were represented mainly by rheophilous taxa. A rare lowland species *Baetis tracheatus* was found, known previously just from West Slovakia. Trichoptera were mainly represented by submontane rheophilous taxa. Species preferring low currents or backwaters from the family Limnephilidae were also recorded. Altitude and dissolved oxygen content were found to be the most important environmental variables determining the EPT community structure. Six types of streams were distinguished by the results of multivariate analysis, taxonomic composition and metric values. They belong to two main types: (1) EPT communities of the natural streams and (2) EPT communities of disturbed streams, where two types of stressor were identified–organic pollution and low discharge. A similarity between EPT communities of organically polluted streams and streams with very low flow was discovered. Values of biotic indices decreased in summer. The most diversified communities were found in the spring during higher water levels and better oxygen conditions.

Keywords: Ephemeroptera; Plecoptera; Trichoptera; Organic pollution; Intermittent streams; Biotic indices

Introduction

The Cerová vrchovina highland covers a small part of south-central Slovakia, and partly belongs to an official protected area. Small shallow streams of this region have so far not been attractive to hydrobiologists. Hydrological conditions of this area lead to low discharges and partial dessication of some streams in summer, causing specific conditions for the macroinvertebrate community development.

Streams with comparable conditions can be found in southern spurs of the Little Carpathians in Slovakia, where low discharges and larger water level fluctuations are typical. Several works of Krno & Hullová (1988) and Krno (1984, 1986, 2003b) have described the macroinvertebrate communities of these kind of streams. Krno & Hullová (1988) stated that the fourth-order streams resembled the second-order streams in terms of the River Continuum Concept (Vannote, Minshall, Cummins, Sedell, & Cushing 1980) due to the low discharges

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and large water-level fluctuations. The Plecoptera communities showed limited taxa richness (Krno 1984, 1986, 2003b).

The significance of stream discharge and temperature for the structure of stream habitats and communities has been widely confirmed, but the role of low discharges and drought is more difficult to decipher. Benthic invertebrates respond in different ways to in-stream changes of flow (Wood, Hannah, Agnew, & Petts 2001).

This study analyses a macroinvertebrate community survey for 16 streams in the Cerová vrchovina highland in South Slovakia, considering the extreme hydrological conditions linked with the seasonal low-flow period typical for some streams in this area. The aim of this study is to describe the communities of Ephemeroptera, Plecoptera and Trichoptera (EPT) of streams in the Cerová vrchovina highland: to analyze the relation between environmental factors and EPT communities, to select the factors determining the EPT community composition and to classify different types of EPT communities according their composition. Principally, two types of streams were studied: streams situated in the protected area Cerová vrchovina, where no strong anthropogenic pressure was detected and streams which suffer from human influences (agriculture, urban settlements).

Study area

The volcanic highland Cerová vrchovina lies in south-central Slovakia and belongs to the West Carpathians. The 16 selected streams from this area belong to the catchments of two rivers – Slaná and Ipel' (Fig. 1). Study sites 1, 5, 6, 7, 10, 11, 12, 13, 14, 15 are situated in the protected area Cerová vrchovina. The other sites (2, 3, 4, 8, 9, 16) suffer from human influences (agriculture, urban settlements). Small width, depth and low discharges are characteristic for all streams studied (Table 1).

Materials and methods

The samples from the selected sites were taken in spring (March), summer (June, July) and autumn (September) 2000–2001. A circular net with 0.2 mm mesh size was used, and organisms were collected by disturbing the substratum by kicking for about 5 min. Material was fixed with formalin. In summer, physical parameters – pH, conductivity, dissolved oxygen content (DOC) and oxygen saturation (DO %) were measured. During every sampling occasion, the depth and width of the stream were measured in the field.

Samples were sorted in the laboratory and organisms were identified. EPT were identified to the lowest possible level (usually species level); other groups were identified to the family level in order to calculate the saprobic index and biotic indices.

Canonical correspondence analysis (CCA) was performed to relate the macroinvertebrate species compositions to environmental variables using the program CANOCO (Ter Braak & Šmilauer 1998). Fifteen samples were subjected to CCA. Sample 7 had to be omitted because there was no water when taking summer samples and measuring physical parameters. Fourteen environmental parameter variables were included into the analysis: altitude, slope, minimal and maximal width and depth, maximal water temperature, discharge, distance to source, stream order (Strahler),

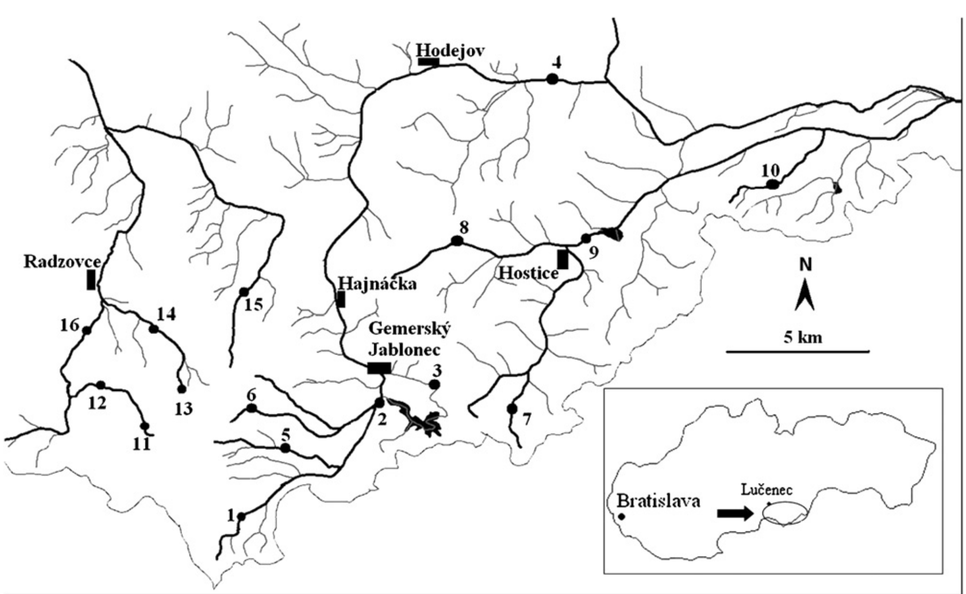

Fig. 1. Map of study area showing position of sampling sites.

Table 1. Physical and environmental characteristics of the streams at sampling sites

Local. nb.	Stream name	Altitude (m a.s.l.)	Slope (‰)	Width (m)	Depth (cm)	Max. Temp. (°C)	Discharge ($cm^3 s^{-1}$)	Distance to source (m)	Stream order (Sthrahler)	pH	Conductivity ($\mu S\,cm^{-1}$)	DO (%)	DO ($mg\,l^{-1}$)
1	Gortva 1	284	29	1–1.5	10–20	17	30	2800	3	8.1	664.5	90.2	8.5
2	Gortva 2	238	4	2–2.5	35–50	19	5	10,240	4	8	754.4	82.2	7.5
3	Gortva 3	235	8.7	1.5–2.5	10–20	21	12	15,166	4	7.8	738	81	7
4	Gortva 4	183	5	1.5–2	20–30	23	32	37,916	4	7.9	982	84.8	7.1
5	Čoma	344	16	0.5–1	3–8	21	10	1730	2	8.1	608	85.7	7.5
6	Malỳ potok	494	196	1–1.5	10–15	13.5	30	30	2	8	391.4	94.3	9.6
7	Fenek	230	10	0–0.5	0–5	23	<5	1030	1	7.6	750	60	5
8	Dechtársky potok	210	5.3	0.4–1	5–10	23	5	4300	2	7.6	754.4	67	5.6
9	Mačací potok	193	3	3–4	40–50	20	5	9242	3	7.5	895	20	1.8
10	Chrámeckỳ potok	195	9	0.4–0.6	3–5	23	<5	1146	2	7.6	750	60	5
11	Bukovinskỳ potok 1	321	34.6	1–1.5	5–10	20.5	10	2550	2	7.9	503	85.3	7.5
12	Bukovinskỳ potok 2	306	34	1–1.5	8–10	20	15	4209	2	7.5	566	74	6.5
13	Monickỳ potok 1	486	121	1–1.5	10–30	17	5	5	1	8.1	457.7	91.1	8.6
14	Monickỳ potok 2	296	37	0.5–1	5–10	19.3	10	1710	3	7.7	694	74.2	6.7
15	Čamovskỳ potok	277	116	1–1.5	5–7	16	<5	1710	2	7.9	685	86.8	8.4
16	Belina	264	14.4	1.5–2	15–30	18	8.8	4880	4	7.4	679	63.4	5.9

pH, conductivity, DOC and % DO. To explore the significance of individual environmental variables, forward selection was used and the Monte Carlo permutation test (499 permutations, $P<0.05$) was employed to assess their statistical significance. Prior to analyses, data were log $(x+1)$ transformed and rare taxa were downweighted.

The relationships between structure of the macroinvertebrate communities and environmental parameters were also analyzed by a non-parametric correlation (Spearman rank correlation coefficient) (Systat Software, Inc., 2004).

The analysis of similarity (ANOSIM) (Clarke 1988, 1993) was performed using the program Community Analysis Package (CAP) to test the significance of the groups that had been defined a priori (by CCA). If the assigned groups are meaningful, samples within groups will be more similar in composition than samples from different groups.

Because the sample from site 7 had to be omitted from CCA analysis, the Sorensen coefficient of similarity was used to determine which sites it is most similar to.

Five metrics were calculated using AQEM river assessment system. (AQEM consortium 2002): Saprobic index (Zelinka & Marvan 1986), the Biological Monitoring Working Party (BMWP) and ASPT indices (Armitage, Moss, Wright, & Furse 1983), the EPT index and the diversity index. BMWP is the total of the scores of all families present in a taxa list; ASPT is the BMWP divided by the number of BMWP families present in the taxa list. EPT is the number of EPT taxa. Diversity was assessed using the Shannon–Wiener Index (Shannon & Weaver 1949).

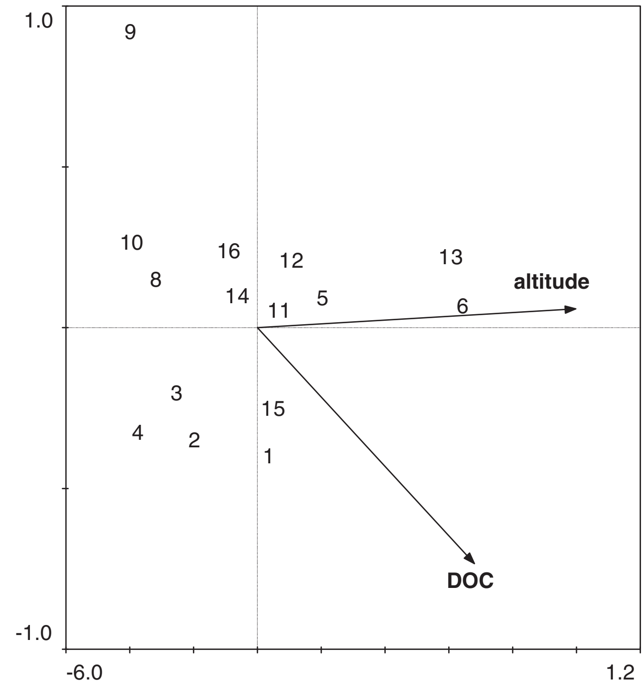

Fig. 2. CCA diagram of summer samples showing the most important environmental factors and the distribution of samples along their gradient. Site 7 had to be omitted because there was no water when taking summer samples and measuring physical parameters. Instead, Sorensen coefficient of similarity was used to determine which sites it is most similar to (see the section Materials and methods).

Results

Macroinvertebrate communities

During the study, 70 taxa of EPT were recorded. Based on CCA results, two variables were selected as the most important – altitude and DOC. The first two canonical axes account for 21.7% of the variance of the species data. The eigenvalues of the two first canonical axes are $\lambda_1 = 0.41$ and $\lambda_2 = 0.36$. The first axis of the standardized CCA explains 11.6% of the total variance. Altitude is significantly correlated (−0.97) with this axis. The second axis explains 10.1% of the total variance and DOC is significantly negatively correlated (−0.69) with this axis. A significant correlation of altitude with slope ($r = 0.85$) and distance to source ($r = -0.56$) was also detected. These variables describe the stream position along the river continuum. Thus the first axis could be interpreted as the natural stream gradient. The significant correlation between DOC and conductivity ($r = -0.6$) indicates that the DOC vector in the diagram explains the pollution gradient of the sites. There are also significant correlations between variables describing stream position and organic pollution-indicating variables, so both axes present both natural and pollution gradients. The position of sampling sites on the CCA diagram corresponds to this mixed gradient. The sites characterised by high altitude, slope, high DOC and low summer temperatures are situated in the right part of the diagram. To the left, altitude, slope and DOC decrease while temperature increases together with depth and width (Fig. 2).

Biotic indices

Biotic indices (BMWP, ASPT and EPT) are highest at sites on natural streams. These streams are characterized by the highest species richness and a high proportion of pollution sensitive taxa. On disturbed streams, these indices have comparably lower values (Table 2). Strong temporal fluctuations were also recorded. The indices reached the highest values at most of the sites in the spring. The unpolluted sites 7 and 10 have similar index values as the polluted sites. Low discharges, desiccation

Table 2. Metric values of study sites: a – spring, b – summer, c – autumn

Locality	Si (Zelinka and Marvan)	BMWP	ASPT	EPT	Diversity (Shannon–Wiener)
1a	1.722	89	5.933	13	1.797
1b	1.78	74	5.692	10	1.768
1c	1.791	82	6.308	9	1.026
2a	2.314	49	4.083	6	2.299
2b	2.288	30	3.75	3	1.709
2c	2.8	6	2	0	0.846
3a	2.144	48	4.364	8	2.304
3b	1.808	33	4.125	7	1
3c	1.701	22	3.667	4	0.406
4a	1.828	34	4.857	7	1.283
4b	1.61	25	4.167	6	0.15
4c	1.6	23	5.75	0	0.486
5a	1.613	89	5.933	8	1.33
5b	1.655	68	5.667	11	1.17
5c	1.942	73	6.636	9	1.706
6a	1.179	127	6.684	17	2.072
6b	1.265	72	6	8	2.242
6c	1.32	131	6.238	12	2.072
7a	1.875	52	4.333	4	1.804
8a	1.533	82	5.125	11	1.637
8b	1.6	32	4.571	1	1.899
8c	1.615	36	5.143	5	0.299
9a	—	25	5	2	1.515
9b	2.578	31	4.429	1	1.667
9c	2.6	7	3.5	1	0.637
10a	1.556	37	5.286	2	1.005
10b	1.6	37	4.111	1	1.709
10c	1.608	35	4.375	1	0.322
11a	1.735	113	7.062	20	2.055
11b	1.695	99	7.071	12	1.358
11c	1.717	78	7.091	11	1.701
12a	1.941	117	6.158	18	2.426
12b	1.815	68	5.231	8	1.698
12c	1.715	85	5.667	10	0.877
13a	1.173	99	6.188	10	2.03
13b	0.39	56	6.222	4	2.201
13c	—	3	1.5	0	0.902
14a	1.702	67	5.583	10	2.428
14b	1.664	34	5.667	4	1.784
14c	1.419	48	5.333	7	2.126
15a	1.604	44	6.286	4	1.738
15b	1.574	29	5.8	3	1.591
15c	1.584	35	7	3	0.808
16a	1.86	52	5.778	7	2.149
16b	2.67	36	3.6	2	2.163
16c	2.289	36	3.6	5	2.12

and overheating in summer and subsequent low DOC were probably responsible for the non-development of assemblages comparable with other unpolluted streams situated in the protected area.

According to the Sorensen coefficient of similarity site 7 was most similar to site 9 (51%) and site 8 (45%).

Following the results of multivariate analysis, taxonomic composition and metric values, several types of macroinvertebrate communities can be distinguished forming two major groups.

1. *EPT communities of natural streams*: These streams are characterized by unpolluted water and relatively unmodified stream morphology. Rheophilous species are typical for these sites: *Baetis rhodani* (Pictet, 1843–1845), *Ecdyonurus* cf. *subalpinus*, *Electrogena ujhelyii* (Sowa, 1981), *Ephemera danica* (Müller, 1764),

Habroleptoides confusa (Sartori and Jacob, 1986) (Ephemeroptera), *Hydropsyche fulvipes* (Curtis, 1834), *H. saxonica* (McLachlan, 1874), *Odontontocerum albicorne* (Scopoli, 1763), *Sericostoma* sp. (Trichoptera). Within this group three subgroups can be distinguished:

1.1. *EPT communities of the source spring with strong water fluctuations*: Site (13, spring of Monický brook). During springtime, the rheophilous species mentioned above occurred. *Crunoecia irrorata* (Curtis, 1834) (Trichoptera) is a unique species for this site. The Saprobity index indicates oligosaprobity, DOC and DO% were high (9.6 mg L^{-1} and 91%), and maximum temperature did not exceed 17 °C. Physical factors (DOC, % DO, conductivity) and catchment characteristics (altitude, slope) are very similar to those of site 6. High values for diversity and biotic indices were detected. In summer during the study, the water level descended and isolated pools and wet substrate occurred, resulting in a decline of taxa richness and almost the disappearance of all mentioned species; this is why this site is put into a separate subgroup.

1.2. *EPT communities of submontane permanent spring*: Site (6 – Malý potok brook). The macroinvertebrate community reflects the specific conditions of this site. The talus spring has the highest altitude of studied sites, with a very high slope (196‰), high oxygen saturation (94.3%), balanced flow over the whole year and low summer temperature (13.5 °C). The macroinvertebrate community is represented by oligo-stenothermous rheobiont and rheophilous submontane species. Unique species occurring just at this site are *Protonemura aestiva* (Kis, 1965), *Leuctra prima* (Kempny, 1894) (Plecoptera), *Philopotamus montanus* (Donovan, 1813), *Rhyacophila polonica* (McLachlan, 1879), *Synagapetus iridipennis* (McLachlan, 1879), *Tinodes rostocki* (McLachlan, 1878) (Trichoptera). Biotic index values are high and saprobic index indicates oligosaprobity.

1.3. *EPT communities of natural submontane streams*: Sites 1 (Gortva 1 – upper part), 5 (Čoma), 11 (Bukovinský potok brook 1 – upper part), 12 (Bukovinský potok brook 2 – upstream from the Šiatorská Bukovinka village), 14 (Monický potok brook), 15 (Čamovský potok brook). These streams are situated at altitudes of 277–350 m, with summer temperatures up to 21 °C. *Electrogena samalorum* (Landa & Soldán, 1982), *Rhithrogena semicolorata*-Gr. (Ephemeroptera), *Capnia bifrons* (Newman, 1839) (Plecoptera), *Chaetopteryx fusca* (Brauer, 1857), *Halesus digitatus* (Schrank, 1781), *H. radiatus* (Curtis, 1834) and *Rhyacophila fasciata* Hagen, 1859 (Trichoptera) are characteristic species for these sites. Biotic indices ranged during the year from high spring values to intermediate values in summer.

2. *EPT communities of disturbed streams*: Sites (2, 3, 4, 7, 8, 9, 10, 16) of lower altitudes belong to this group (200–280 m). They are placed in the bottom and right part of the CCA diagram (Fig. 2). Lower values of DOC and higher summer temperatures determined the composition of the macroinvertebrate communities. Index values are low in comparison with the first group.

2.1. *Middle and lower parts of the Gortva stream*: Sites (2, 3, 4) form an isolated subgroup situated in the bottom part of CCA diagram (Fig. 2). Higher DOC compared to the other sites probably enabled the presence of more diverse communities. Taxa from the family Baetidae are typical representatives of Ephemeroptera – *Baetis buceratus* (Eaton, 1870), *B. pentaphlebodes* (Ujhelyi, 1966), *B. tracheatus* (Keffermüller & Machel, 1967), *B. vernus* (Curtis, 1834).

2.2. *EPT communities of slower streams*: Sites (7 – Fenek brook, 8 – Dechtársky potok brook, 9 – Mačací potok brook, 10 – Chrámecký potok brook, 16 – Belina brook) are separated from others by their poor macroinvertebrate assemblages. They are similar more because of the EPT species which they lack rather than EPT species that they have in common. According to the main stressor two subgroups can be distinguished:

2.2.1. *EPT communities of organically polluted sites*: Sites 8, 9, and 16 form this group. Site 9 – Mačací potok brook have a very poor EPT community due to the influence of nearby water reservoir and *Cloeon dipterum* (Linneus, 1761) is the typical representative of this site. *Baetis buceratus, B. vernus* (Ephemeroptera), and *Hydropsyche angustipennis* (Curtis, 1834) (Trichoptera) prevail at other sites.

2.2.2. *EPT communities of streams without organic pollution*: A low discharge and low DOC in summer was the stress factor influencing the last group of sites. These streams can be characterized as low-discharge streams situated at altitudes of 200–230 m: site 10 (Chrámecký potok brook – in summer, this stream was characterized by standing pools with several cm of depth) and site 7 (Fenek brook – water occurred only in spring). The higher values of the saprobic index and lower values of biotic indices are also similar to those of the group of polluted streams. Because of the lack of organic pollution sources in their surroundings, they are grouped separately from the organically polluted streams. They have very low EPT – 5 taxa were detected – in common: The Plecopteran species *Nemoura marginata* Pictet, 1836 in the spring, *Plectrocnemia conspersa* (Curtis, 1834), *Micropterna lateralis* (Stephens, 1837), *M. nycterobia* McLachlan, 1875 (Trichoptera) at site 7, *Limnephilus auricula* Curtis, 1834 (Trichoptera) at site 10.

The allocation of sites into groups was verified by ANOSIM. Samples within defined groups are more similar than samples from different groups ($P = 0.001$). Also, ANOSIM results show no difference ($P = 0.47$) between organically polluted sites (8, 9, 16) and sites 7 and 10, which confirms the assignment of these two sites.

Correlation of indices and environmental variables

Correlation analysis shows that environmental variables are relatively closely related to each other. Variables characterizing stream position (altitude, slope, distance to source) are significantly correlated ($r > 0.6$, $P < 0.05$) with variables indicating organic pollution (conductivity, DOC). Biotic indices, index of diversity and saprobic index are significantly correlated with variables characterizing stream position (altitude, slope, distance to source, stream order) and also with variables indicating organic pollution (conductivity, DOC) ($r > 0.6$, $P < 0.05$).

Discussion

The taxonomic composition of EPT communities in streams of the Cerová vrchovina highland is quite low, represented by 16 Ephemeroptera, 8 Plecoptera and 36 Trichoptera taxa. In the southern part of the Little Carpathians in Slovakia with similar hydrological conditions, 23 Plecopteran species have been recorded. Krno (1984, 1986, 2003b) described Plecoptera communities of these streams and found some specific features. He observed a similarity between stonefly taxocenoses of eutrophied streams and low-discharge streams. Critical low discharge in summer was associated with high water temperatures, limiting the development of some mountain and submontane species, above all *Leuctra* spp., *Protonemoura* spp. and species of the Perlidae family with a several-year life cycle. The Plecoptera fauna of streams in the Cerova vrchovina highland is poorer, represented by eight species which can be characterized as submontane and highland species with univoltine life cycle. A specific feature of streams of the Cerová vrchovina highland is the absence of predatory species of Perlidae, Perlodidae and Chloroperlidae. From the catchments of the Ipel' and Slaná rivers, 13 predatory Plecopteran species have been recorded at similar altitudes (200–500 m) (Krno 2003a). It can be concluded that the low discharge and summer decrease of water level in our studied streams probably contribute greatly to the poor Plecoptera fauna.

The typical representative of Plecoptera is the spring species *Nemoura marginata*. This species is bound to the crenal of streams in the southern part of the Little Carpathians (Krno 1984, 2003b), however in the Cerová vrchovina highland it was not restricted to the crenal but occurred in almost all sites. Its preference for cold waters is reflected by its occurrence only in spring. The absence of competition with other stonefly species probably also enabled such a wide distribution. *Protonemura aestiva* was the dominant species at site 6 (Malỳ potok brook). Kis (1964) described it from Transylvania, and later Újhelyi (1969) recorded it as a new species of the Hungarian fauna and found it in springs and hypocrenal brooks at about 600 m in altitude. It has spread from the south-east to the Slovakian Carpathians and was recorded in Slovakia in the East Carpathians (Bitušík & Novikmec 1997) and now also in the Cerova vrchovina highland.

From all 16 Ephemeroptera taxa, mainly rheophilous species *Baetis rhodani*, *Ecdyonurus* cf. *subalpinus*, *Electrogena ujhelyii*, *Habroleptoides confusa* and *Ephemera danica* prevail in the natural streams. The record of *Baetis tracheatus* Keffermüller and Machel, 1967, a rare lowland species, in Gortva (site 3) is remarkable. This species has so far been recorded at only a few localities in West Slovakia in small lowland streams (Soldán 1981; Deván 1997; Bulánková, Halgoš, & Krno 2000; Rodriguez & Derka 2000) and in paleopotamal Klátovské rameno (Deván 2000).

Caddisflies (Trichoptera) are mainly represented by submontane rheophilous taxa. The species of the family Limnephilidae, preferring low currents or backwaters, were also recorded. They were captured usually as single individuals and just at one or two sites: *Anabolia furcata* (Brauer, 1857) (site 3), *Ironoquia dubia* (Stephens, 1837), *Limnephilus extricatus* McLachlan, 1865 (site 8), *Limnephilus rhombicus* (Linnaeus, 1758) (site 3, 8), *Micropterna nycterobia* (sites 7, 13). Smith, Wood, & Gunn (2003) and Wood, Gunn, Smith, & Aba-Kutty (2005) refer to some Trichoptera taxa as being characteristic for intermittent streams due to their life cycle adaptations to such habitats. These taxa (*Limnephilus auricula, L. lunatus* (Curtis, 1834), *Micropterna lateralis, M. sequax* McLachlan, 1875) were found in streams with minimum water in summer (sites 7, 8, 9, 10).

Saprobic and biotic indices assessment

The biotic indices (BMWP, ASPT, EPT) indicate low organic loading to streams situated in the protected area. These streams represent sites with the highest species richness and the presence of pollution-intolerant taxa. The increased level of organic pollution in the water at the sites under anthropogenic pressure resulted in the decrease of biotic index values. Also decrease of water in summer had similar results. The fluctuation of biotic indices at individual sites shows the worsening of conditions for the development and survival of macrozoobenthos communities in summer. The metrics at almost all sites reached their highest values in spring. Decreased discharges connected with increased water temperature and low DOC in summer formed limiting factors for the development of macroinvertebrate assemblages and led to the decrease in the number of invertebrate groups sensitive to pollution. Pires, Cowx, & Coelho (2000) also reported a decline of biotic index values (BMWP, ASPT) during the low-discharge period in Mediterranean intermittent streams due to lower oxygen content. Bickerton, Petts, Armitage, & Castella (1993) drew similar conclusions. They stated that extremely low discharges in studied streams led to changes in environmental conditions and consequently to a decrease in taxa number and abundance, and low values of biotic indices (BMWP, ASPT). Moreover, human activities may impact lotic systems with naturally periodic low discharges more than other stream types (Gasith & Resh 1999). Studies about the effects of low discharges on aquatic ecosystems are scarce and opportunistic, because many studies have arisen unintentionally, when droughts occurred during the study period (Lake 2000, 2003; Boulton 2003; Humphries & Baldwin 2003). Several authors have reported that the taxonomic composition of intermittent streams shows some differences when compared to nearby perennial streams, such as lower taxa richness and lower abundances (Wiggins, Mackay & Smith 1980; Alba-Tercedor, Gonzalez, & Puig 1992; Williams 1996; Aguiar, Ferreira, & Pinto 2002; Smith & Wood 2002; Smith et al., 2003; Wood et al. 2005). This agrees with our findings, where two sites (7, 10) characterized by very low flow and/or desiccation in summer show very poor EPT communities – up to just four taxa. Biotic indices of these sites are lower when compared to other sites located in the protected area and are closer to values found at organically polluted sites. Also, CCA results show a similarity of communities from the unpolluted sites 7 and 10 with those from the organically polluted sites (2, 3, 4, 8, 9, 16). This corresponds to the findings of Krno (1986), who studied Plecoptera of Little Carpathians low-discharge streams in Slovakia, where the similarity between stonefly communities of the eutrophied and the low-discharge streams was obvious.

Correlation analysis revealed a significant relation between biotic indices and the variables describing the stream position in the river continuum (altitude, slope, distance to source, stream order) on the one hand, and between biotic indices and variables reflecting the organic pollution gradient (conductivity, DOC) on the other hand. These results probably reflect the fact that macroinvertebrate communities responded not only to the environmental gradient downstream in terms of RCC, but also to the organic pollution gradient in this area. The variables which describe the stream position along the river continuum and pollution-indicating variables are also significantly correlated. Altitude and slope show close relation to conductivity and DOC. From this it appears that the natural environment stream gradient and organic pollution gradient overlapped and their influences could not be distinguished. The values of biotic indices indicate that streams situated in the protected area are in better ecological condition than other streams in this region. It should be considered that extreme hydrological conditions in this region lead to an increased vulnerability of the ecological stability of streams.

Conclusions

At 16 study sites, 16 Ephemeroptera, 8 Plecoptera and 36 Trichoptera taxa were recorded. Concerning Ephemeroptera, the finding of the rare species *Baetis tracheatus* is remarkable. The species spectrum of Plecoptera was limited. Predators of the families Perlidae, Perlodidae and Chloroperlidae were absent. Low flows and also high temperatures of water and a decline in DOC in summer led to the decline of EPT taxa and prevented the development of Plecoptera with semivoltine life cycle. Biotic indices (BMWP, ASPT) and index of diversity reached the highest values in spring; in summer and/or in autumn their values were significantly lower.

According to the CCA analysis and index values, two main groups of EPT communities were identified: EPT communities of natural streams and EPT communities of disturbed streams, where two types of stress could be identified – organic pollution and low flows. Streams under human pressure (organic pollution) and streams with a tendency to partially dry up in the summer showed similarities in terms of reduced EPT communities, a higher saprobic index and lower biotic indices.

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