

# Benthic macroinvertebrates as indicators of biological integrity in lotic freshwater ecosystems of large-scale protected areas in the Czech Republic: preliminary results

## Makrozoobentos jako indikátor biologické integrity lotických sladkovodních ekosystémů ve velkoplošných chráněných územích České republiky: první výsledky

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### Abstract

Investigation into benthic macroinvertebrate communities and water quality has been carried out in three protected regions (Šumava NP, Český kras and Křivoklátsko PLA). – The results support the earlier hypothesis that many lotic ecosystems of the Šumava National Park and Biosphere Reserve are very valuable for their good water quality. This status is indicated also by the highest diversity of aquatic insect community, especially in streams with higher conductivity. The benthic community of the Šumava mountains was dominated by members of the *Plecoptera*. More than five genera of this order were frequently recorded, including some rare species. Similarly, a diverse community of benthic macroinvertebrates was found in less polluted streams of the Křivoklátsko Protected Landscape Area. – On the contrary, in the Šumava mountains low biodiversity was observed in some acidified streams with low conductivity, as well as in some strongly polluted streams of Český kras and Křivoklátsko, the two protected landscape areas in Central Bohemia. – Biological evaluation of water quality suggests that the majority of lotic ecosystems in all protected regions corresponds to oligosaprobic conditions and that these ecosystems are therefore only slightly polluted by organic matter. Water quality in more enriched streams corresponds to beta-mesosaprobity or to alfa-mesosaprobity.

*Key words:* protected regions, lotic ecosystems, water quality, pollution, benthic macroinvertebrates, diversity and saprobic indices

### Introduction

Lotic freshwater ecosystems are very important landscape elements. They form a narrow connection with the terrestrial environment and are influenced, to a different extent, by human activities. Lotic ecosystems in the Šumava National Park and Biosphere Reserve are especially valuable water sources in the Czech Republic.

Benthic macroinvertebrates are frequently used as environmental indicators of biological integrity in running waters. They play a significant role in food webs and ecosystem productivity. These organisms can describe water quality or health of aquatic ecosystems because they show distinct responses to a wide array of pollutants. Large numbers of species, limited mobility and relatively long life cycles are the primary basic advantages which rank benthic

macroinvertebrates among the most important biological components in the monitoring of environmental quality.

## Methods

Benthic macroinvertebrates and water quality were investigated in May 1995 in selected streams of three protected regions which differ in altitude, geological structure and human impacts on water quality :

1. Šumava National Park and Biosphere Reserve  
Vydra (Čeňkova pila), Hrádecký (Srní), Hamerský (Antýgl), Modravský and Roklanský (Modrava), Prášílský and Křemelná (Vysoké lávky), Jezerní (Prášily), Slatinný (Slučí tah)
2. Křivoklátsko Protected Landscape Area  
Úpořský (V luhu), Klíčavský (Kobylí hlava), Vuznice (nad Nižborem), Habrový (Otročiněves), Zbirožský (Slap), Rakovnický (Městečko)
3. Český kras Protected Landscape Area  
Loděnice (sv. Jan), Karlický (Dolní Roblín)

Standard hydrobiological methods have been used for sampling and processing of chemical samples and biological materials. Within the framework of the research more than 1600 benthic organisms were identified, and the diversity and pollution indices of the aquatic insect community were calculated.

The diversity index (SHANNON & WEAVER 1963 in KLEM & al. 1990) describes the extent to which a stressed community differs from an ideal structure. The pollution index based on the saprobian approach (PANTLE & BUCK 1955 in HELLAWELL 1986) is derived from the responses of indicator taxa to organic pollution. Despite the many criticisms of biological indices summarized by HELLAWELL (1986), biological assessment is successfully used in water quality monitoring.

## Results and Conclusions

(1) The lotic ecosystems of the Šumava National Park and Biosphere Reserve are particularly remarkable for their good water quality. Results of the physical and chemical analysis in the Vydra and Křemelná rivers watershed are summarized in Table 1. Primarily conductivity, alkalinity, total hardness and concentrations of ions such as nitrate, phosphate, chloride and calcium are several times lower than in other protected regions.

However, many of the investigated stream ecosystems of the Šumava mountains are affected by acidification and pH value below 5 were recorded in highly acidified Roklanský and Jezerní streams as well as pH less than 4.5 in strongly acidified Modravský stream.

In comparison with nutrient poor aquatic ecosystems of the Šumava mountains, the Český kras and Křivoklátsko Protected Landscape Areas are very rich in nutrients. The most polluted streams are Rakovnický (phosphates, chlorides, organic pollution), Loděnice (phosphates, chlorides) and Karlický (nitrates). High values of conductivity, alkalinity, total hardness and calcium cations are also determined by the geological structure of these regions.

(2) The aquatic insect community of the Šumava NP and BR is dominated by *Plecoptera* (Table 2). This group forms about 55–87 per cent of the benthic community in most investigated streams. More than five genera of *Plecoptera* are frequently recorded and some rare species occurred (such as *Brachyptera*, *Isoperla*, *Perlodes*, *Diura*, *Chloroperla*).

*Ephemeroptera* and *Trichoptera* prevail in the Křivoklátsko PLA. *Trichoptera* form more

**Tabulka 1.** – Výsledky analýzy kvality vody ve zkoumaných lotických ekosystémech tří velkoplošných chráněných oblastí (vodivost  $\mu\text{S}\cdot\text{cm}^{-1}$ , alkalita a celková tvrdost –  $\text{mmol}\cdot\text{l}^{-1}$ , ostatní hodnoty v  $\text{mg}\cdot\text{l}^{-1}$ )

**Table 1.** – The results of water quality analysis in lotic ecosystems of large – scale protected areas (conductivity –  $\mu\text{S}\cdot\text{cm}^{-1}$ , alkalinity and total hardness  $\text{mmol}\cdot\text{l}^{-1}$ , the other values  $\text{mg}\cdot\text{l}^{-1}$ )

	Šumava NP and BR	Křivoklátsko PLA	Český kras PLA
Conductivity	12.0–30.3	360.0–666.0	731.0–870.0
pH	4.4–6.3	6.6–7.7	7.3–7.4
Alkalinity	0.1–0.3	1.5–3.9	4.0–4.9
Total hardness	0.1–0.3	1.9–3.4	4.6–4.8
COD Mn	4.2–9.6	5.9–11.8	3.8–6.8
Nitrate	1.2–3.2	6.5–37.0	26.5–47.5
Phosphate	0.0–0.2	0.1–0.9	0.1–0.4
Chloride	0.0–3.4	11.5–44.1	35.3–45.1
Calcium cations	1.0–3.0	52.1–82.2	18.0–68.1

**Tabulka 2.** – Struktura společenstev vodního hmyzu (%) v tocích tří chráněných krajinných oblastí

**Table 2.** – The structure of aquatic insect community (%) in streams of three protected landscape areas

	Plec	Ephe	Trich	Dipt	Col	Meg
<b>ŠUMAVA</b>						
Křemelná	87.0			10.6	2.4	
Jezerní	86.2		1.2	12.6		
Hrádecký	73.0	11.7	6.3	8.7	0.3	
Hamerský	71.3	17.9	3.6	7.2		
Slatinný	66.4	17.7	13.1	0.9	1.9	
Modravský	55.1	8.2	34.7		2.0	
Prášílský	41.5	26.4	2.3	29.8		
Roklanský	28.6	11.4	60.0			
<b>KŘIVOKLÁTSKO</b>						
Úpořský	13.6	42.4	40.2	1.9	1.9	
Rakovnický		85.4	8.3	6.3		
Zbirožský		49.1	39.6	11.3		
Habrový		44.8	55.2			
Klíčavský		36.8	57.5	5.7		
Vuznice		18.0	73.1	5.9		3.0
<b>ČESKÝ KRAS</b>						
Karlický	1.8	9.1	83.7	3.6		1.8
Loděnice		9.3	88.0	2.7		

than 80 per cent of the insect community in the Český kras PLA. *Plecoptera* (genera *Isoperla*, *Leuctra*, *Nemoura*, *Perla*) are more abundant only in the Úpoř stream, which has the best water quality among lotic ecosystems investigated in both regions.

**Tabulka 3.** – Diverzita a saprobní indexy společenstev vodního hmyzu ve třech velkolešných chráněných územích (D = průměrná diverzita, rozpětí 0.0–3.32 a S = saprobní index, rozpětí 0.51–1.5 pro oligosaprobní a 1.51–2.5 pro beta-mesosaprobní podmínky)

**Table 3.** – The diversity and saprobian indices of aquatic insect community in three large-scale protected areas (D = mean diversity, range 0.0–3.32 and S = saprobian index, range 0.51–1.5 for oligosaprobian and 1.51–2.5 for beta-mesosaprobian conditions)

Šumava	Slat	Práš	Hrád	Ham	Jez	Rokl	Modr	Křem
D	3.14	2.95	2.91	2.73	1.92	1.88	1.63	0.96
S	0.87	0.97	0.84	1.02	0.91	0.59	0.64	0.91
Křivoklátsko	Klíč	Úpoř	Zbir	Vuz	Habr	Rak		
D	2.89	2.68	2.23	2.14	1.78	0.74		
S	1.33	1.37	1.55	0.88	1.36	1.52		
Český kras	Kar	Lod						
D	2.01	0.98						
S	1.20	1.87						

*Gammarus (Crustacea)* is abundant mainly in more polluted streams (Loděnice, Habrový, Klíčavský) where it accounts for more than 50 per cent of the benthic community. Similarly *Erpobdella (Hirudinea)* dominates in the Rakovnický stream which is strongly affected by human activity.

(3) Streams with higher conductivity in the Šumava mountains (Table 3) have the highest diversity of aquatic insect community (D range 2.9–3.1). In comparison with previous observations, biodiversity is low in some acidified streams with lower conductivity (such as Jezerní, Roklanský, Modravský).

In the Křivoklátsko PLA and BR we found high community diversity ( $D > 2.5$ ) mainly in Úpořský and Klíčavský streams. Very low biodiversity ( $D = 0.74$ ) was found in strongly affected Rakovnický stream as well as in the Loděnice ( $D = 0.98$ ) in the Český kras PLA.

(4) Saprobian index ranges between 0.5 and 1.5 in the majority of lotic ecosystems in all protected regions (Table 3). Consequently, these streams have oligosaprobian conditions and are only slightly polluted by organic matter. Zbirožský and Loděnice streams in the Křivoklátsko and Český kras PLA, have organically more enriched water ( $S > 1.5 =$  beta-mesosaprobity). Water quality in heavy polluted Rakovnický stream responds to beta-mesosaprobity, or better to alfa-mesosaprobity, as a result of the frequent occurrence of the genus *Erpobdella (Hirudinea)*.

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