Milan Novikmec, Marek Svitok & Peter Bitušík (eds.)

LIMNOLOGY OF STREAMS IN THE POLONINY NATIONAL PARK (THE EAST CARPATHIANS, SLOVAKIA)

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Abstract

Structure of hydrocoenoses of the streams in the Poloniny National Park were studied during the years 1999 and 2000. Composition of epilithic diatom communities, microzoobenthos, interstitial communities, all the main groups of macrozoobenthos (permanent fauna, Ephemeroptera, Plecoptera, Coleoptera, Trichoptera, Diptera) and basic hydrological, abiotic (water chemistry) and biotic (organic matter) factors were studied within two model streams during two years sampling procedure in order to compare hydrocoenoses of streams with different catchment management.

We have compared a near pristine East Carpathian stream with a nearby-situated stream with similar stream channel characteristics, but heavily logged catchment.

Spatial and temporal differences in food supply, overall species density and taxonomic richness and communities composition were assessed. Temporal changes in FPOM, UFPOM and chlorophyll-a were documented (RM MANOVA; $p < 0.05$). However, we did not record any spatial differences between corresponding sampling sites of compared streams.

Species richness and density of macroinvertebrate communities did not appear to vary spatially or temporally. Nevertheless, some differences have been recorded within species composition of sensitive groups of macroinvertebrates (e.g. stoneflies). Our study did not support expected dramatic effect of silvicultural practices and post logging changes in catchment.

Basic faunistic- ecological investigation of particular groups of stream dwelling organisms was performed at some other streams of the Poloniny National Park. Depending on the sampling design at these streams, data on longitudinal distribution, community composition similarity and ecological notes to particular groups of organisms are presented.

Key words: interstitial, epilithic diatoms, microzooobenthos, timber harvest, macroinvertebrates, organic matter, habitat structure, longitudinal zonation, East Carpathians, Slovakia, Bukovské vrchy Mts.

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Contents

1. Introduction

The structure and function of stream ecosystems are closely linked with their drainage basins and the terrestrial vegetation (Vannote et al. 1980, Gregory et al. 1991). Streams in forested ecosystems are usually heavily shaded and fauna is dependent on a food base derived from allochthonous inputs (Herlihy et al. 2005). Without adequate controls, silvicultural activities have the potential to cause significant changes of stream ecosystem by altering basins and riparian zone conditions (Naiman 1992). Their impacts on streams are dominated by heightened delivery of fine sediments (Waters 1995) and by flashy hydrological regimes (Eisenbies et al. 2007). Logging can alter the nature and timing of inputs of plant production into the stream and change the amount and type of particulate organic matter (Webster et al 1983, Gurtz & Wallace 1984, Davies et al. 2005). Forest cutting was shown having a great influence also on pH, water temperatures and conductivity of watershed ecosystem (Likens et al. 1970).

Increasing solar radiation reaching the stream bottom and decreasing terrestrial canopy inputs potentially shifts food sources from allochthonous to autochthonous (Stockner & Shortreed 1976, Kedzierski & Smock 2001). Higher insolation is often coupled with increase in stream water temperatures (Swift 1983, Golladay et al. 1987, Holopainen et al. 1991). Removal of vegetation through harvesting can also increase leaching of nutrients from the soil system into surface waters and groundwaters (Swank 1988, Hartman & Scrivener 1990).

Those effects are usually accompanied by declines in diversity of macroinvertebrates, as well as changes in community composition, growth rates, reproductive success and behavior of aquatic biota (e.g. Newbold et al. 1980, Noel et al. 1986, Stone & Wallace 1998). On the other hand, removing of overhead canopy could increase biomass, abundance and seasonal production of benthic macroinvertebrates (Behmer & Hawkins 1986) - woody debris dams enhance retention of CPOM in streams, support higher macroinvertebrate density and biomass (Smock et al. 1989, Carlson et al. 1990, Trotter 1990), and provide suitable habitat for many species of benthic macroinvertebrates (Hoffman & Hering 2000).

Macroinvertebrate communities in headwater streams are heavily influenced by edge interactions with the surrounding terrestrial habitat. Stream macroinvertebrate communities are therefore commonly used in monitoring and impact assessment of logging activities (see Brown et al. 1997).

A major problem in assessing the impact of these activities on aquatic ecosystem is often the lack of reliable reference conditions (Liljaniemi et al. 2002). We attempted to find two streams of similar character but different catchments forest management in Slovak part of the East Carpathians (National Park Poloniny).

Streams in Slovakia have been significantly changed since 19th century. A variety of factors, including logging, regulations, pollution and their interactions altered original streams conditions and their communities (e.g. Derka 1998, Krno & Valachová 1999, Illéšová et al. 2007). Sustainable management of streams and their basins is accented under the strategy of the European Water Framework directive (Council of the European Communities 2000) but requires reference state information on pre-disturbance conditions to guide management decisions (Griffiths 2002). The acceptable reference stream for Slovakia's East Carpathians could be Stužická rieka brook and some of its tributaries because it represents preserved natural stream system where critical ecosystem processes, particularly organic matter dynamic, light and discharge regimes, had not been altered by human. Evidence exists for limited cutting and small forest railway wood transport as early as the beginning of 20th century. However, cutting ceased in the middle1950s, when the catchment of Stužická rieka was established as the Natural Reserve to exclude human influences.

The presented study was aimed at hydrobiological research of upper zones of two streams on the territory of the National Park Poloniny. Study of structure and dynamics of communities and fundamental factors that affect lotic ecosystems in decisive way were principal goals of the project. The objective of this study was to compare a pristine East Carpathian stream that has experienced long-term preservation with a nearby-situated stream with similar stream channel characteristics, but heavily logged catchment.

Comparison of the data obtained from both streams would allow better understanding of the role of factors affecting the structure and interactions in lotic ecosystems. The data would be basis for principles in stream management, assessment of human activities in stream basins and renaturalization projects of streams in flysch region of Slovakia.

In spite of relatively undisturbed character and interestingness of the whole area of the East Carpathians, streams and rivers of this region have been out of interest of hydrobiological research. From hydrobiological point of view, the National Park Poloniny belongs to the least surveyed parts of Slovakia. Published macrozoobenthos data have faunistic character (Straškraba 1962, Obrdlík 1981) and/or they are focused on some taxonomic group (Deván 1992, Hudec et al. 1995, 1996). The

,only complex research of structure of macrozoobenthic communities of upper zone of Zbojský potok brook was performed in the framework of the Project GEF-BPP/CS/95 „Protection of biodiversity of the Zbojský potok“ (Bitušík & Novikmec 1997).
Presented research work was a part of grant No. 1/6275/99 ”Limnology of mountain streams in East Carpathians” Some studies made within project have been already published (Bitušík & Hamerlík 2001, Bitušík et al. 2004, Illéšová & Halgoš 2001, Krno 2002, Novikmec et al. 2000, 2005,).
Since there is a lack of information about structure of benthic communities of the East Carpathians streams, some fundamental faunistic–ecological investigations of particular groups of benthic organisms of some other streams are also included within the presented study. However, concluding chapter deals only with the data obtained at two compared streams.
Thus, the presented study cover complex view on the limnology of two streams with different catchments forest management. Some faunistical notes to the selected East Carpathians streams are included within chapters, which concern particular groups of stream dwelling organisms.
Groups of stream dwelling organisms were processed by specialists – E. Štefková (epilithic algae), M. Illyová (interstitial), E. Tirjaková (micro- and meiozoobenthos), F. Šporka (macroinvertebrates - permanent fauna), T. Derka (mayflies), I. Krno (stoneflies), Z. Zaťovičová – Čiamporová (beetles), M. Novikmec and J. Lukáš (caddisflies), P. Bitušík (chironimids), E. Bulánková, D. Illéšová and J. Halgoš (flies excl. chironomids).

2. Research area characteristics

Poloniny National Park is situated in the easternmost part of Slovakia, at the junction of the boundaries of Slovakia, Poland and Ukraine. Area of the National Park is part of Bukovské vrchy Mts., which consist mainly of coarse sandy flysch, greenish-grey and red claystones and fine sandstones. Studied area belongs to the moderately warm region (with less than 50 summer days annually in average, daily maximum air temperature ≥ 25°C and the July mean temperature 16°C or more), subregion moderately cool. From hydrological point of view, it belongs to middle mountain area with snow-rain combined runoff regime (Q_{max} in April, Q_{min} in January-February and September-October). Average total precipitation of area is 1000–1200 mm, January average 60 mm, July average 100–120 mm (Anonymus 2002).

In terms of biogeography, it is situated in an important transition zone between the West and East Carpathian mountain system, which is indicated by the composition of its plant and animal communities.

The main part of study was performed in two streams, which were chosen according to main aims of the project: Stužická rieka and Hlboký potok (Fig. 2.1). First one is brook flowing in the natural fir beech forest, while the other one has catchment basin influenced by human activities (mainly clear cutting).

Stužická rieka is a right-hand tributary of the Uh River. Slovakian stretch of the brook is approx. 6 km long. It springs at 1200 m a.s.l. Catchment area of Stužická rieka belongs to region with cold climate, with average January temperature from –6 to –7°C an average July temperature 11.5–13.5°C. Brown forest soils and calcaric cambisoils on flysch subsoil are dominant soil types. Potential natural vegetation consisted of acidophilous beech forests and fir forests. At present, the catchment area is covered by pristine fir-beech forest (National Nature Reserve Stužica) (Michalko et al. 1986, Anonymus 2002).

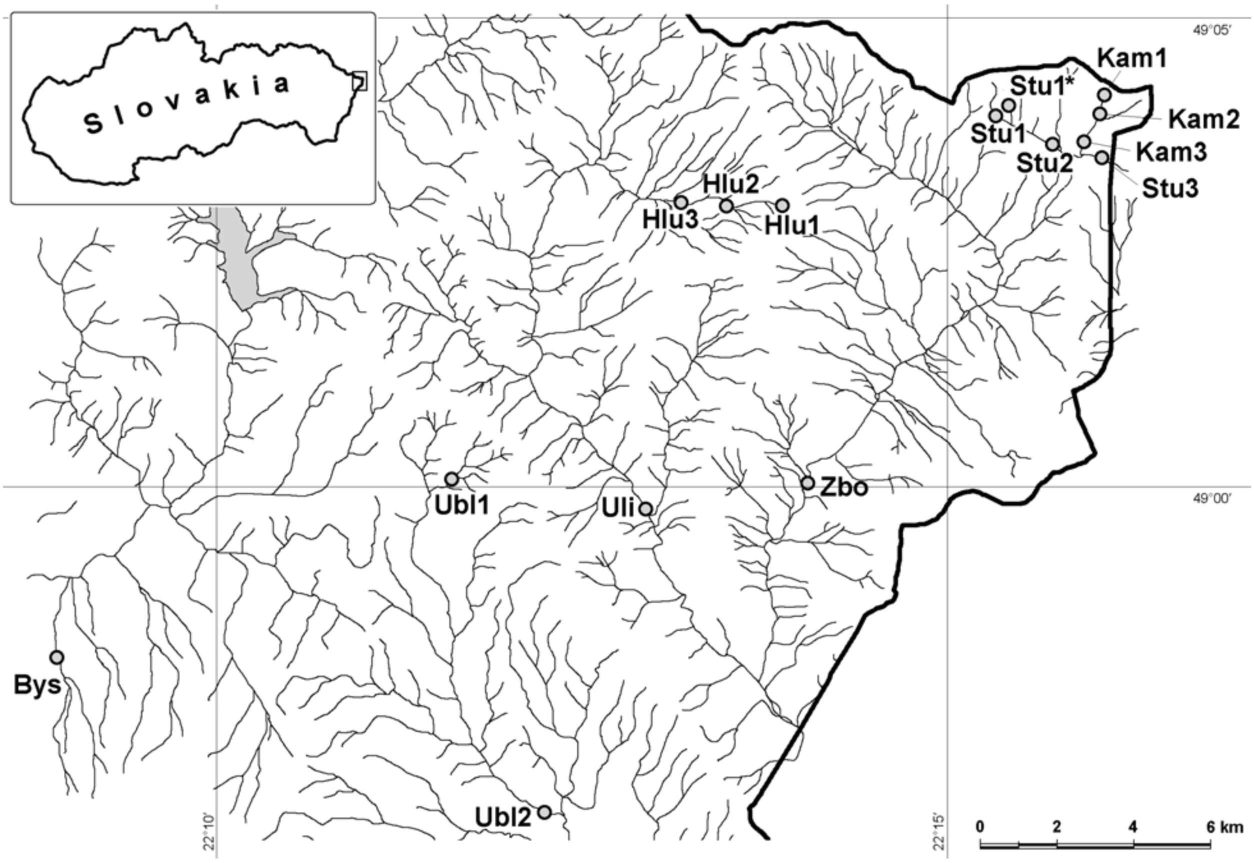

Fig. 2.1 Map of the studied area (for sampling sites codes see Tab. 1)

Hluboký potok is one of a number of sources of the Ulička River. It springs at elevation 900 m and it empties into Ulička River at elevation about 502 m bellow the Runina village. The catchment's area of Hluboký potok lies within region with moderately cold climate, with average January temperatures ranging from –4 to –6°C and average July temperatures 16–17°C. Brown forest soils and calcaric cambisoils on flysch subsoil dominate in soil composition. Primal vegetation of the catchment consisted

of neutrophilous beech forests.
Hluboký potok drains a catchment basin that was damaged by clear cutting and forest road construction 20 years ago.
Three sampling sites were chosen at both of the streams (Fig. 2.1), according to elevation and some other stream characteristics, in order to study more or less corresponding stretches of stream with near pristine and disturbed catchment area respectively (Tab 2.1).
Basic hydrological, chemical and biotic characteristics of sampling sites are presented in Tab. 2.2, 2.3, 2.4.
Spring area of tributaries of Stužická rieka (sites Stu1, Stu1*) is covered by beech forest, with *Asperula odorata*, *Carex* sp., *Dryopteris filix-mas* and *Rubus caesius* in undergrowth. In growing season, sampling site is entirely shaded. Afterwards (sampling sites Stu2 and Stu3), it flows through beech forest with mixture of spruce, ash and elm with similar undergrowth (*Asarum europaeum*, *Carex* sp., *Asperula odorata*, *Dryopteris filix-mas*, *Paris quadrifolia*, *Rubus caesius*, *Senecio nemorensis*, *Dentaria bulbifera*). Shading in growing season range from 70 to 80%.
The surrounding of the spring area of Hluboký potok (Hlu1) is covered by low young stands of spruce and beech forest on the right side of the stream. Left side is covered by glade with growth of raspberries, young willows and birches.
Riparian vegetation of sampling site Hlu2 consist of young beech stands with mixture of maple (5%), with 80% of shading. *Asperula odorata*, *Dentaria bulbifera*, *Dryopteris filix-mas*, *Petasites albus*, *Rubus idaeus* and *Senecio nemorensis* are presented in undergrowth.

Tab. 2.1 Some basic physiogeographical characteristics of sampling sites.

sampling site	abbr.	DFS	latitude DMS	longitude DMS	elevation (m)	stream order	stream link
Hluboký potok 1	Hlu1	6900 B	N 49°03'47"	E 22°26'19"	760	2	2
Hluboký potok 2	Hlu2	6900 B	N 49°03'45.3"	E 22°25'23.4"	610	4	8
Hluboký potok 3	Hlu3	6900 B	N 49°03'51"	E 22°24'24"	535	4	18
Stužická rieka 1	Stu1	6901 A	N 49°05'13"	E 22°31'24.5"	840	2	2
Stužická rieka 1*	Stu1*	6901 A	N 49°05'13"	E 22°32'14"	840	2	2
Stužická rieka 2	Stu2	6901 A	N 49°04'44"	E 22°31'51.5"	717	3	8
Stužická rieka 3	Stu3	6901 A	N 49°04'28"	E 22°33'07"	630	4	14
Kamenistý potok 1	Kam1	6901 A	N 49°05'04.4"	E 22°33'04.4"	935	1	1
Kamenistý potok 2	Kam2	6901 A	N 49°05'51,3"	E 22°32'35.9"	800	1	1
Kamenistý potok 3	Kam3	6901 A	N 49°04'31,9"	E 22°32'37"	700	2	3
Bystrá	Bys	7099 A	N 48°57'44"	E 22°11'31"	340	2	4
Ublianka 1	Ubl1	7099 B	N 49°00'17"	E 22°19'00"	420	3	8
Ublianka 2	Ubl2	7099 B	N 48°54'22"	E 22°22'22"	220	5	108
Ulička	Uli	6900 C	N 49°00'52"	E 22°22'12"	310	5	132
Zbojský potok	Zbo	7000 B	N 49°00'12.5"	E 22°26'55"	292	5	178

Note: DFS – mapping grid of the Databank of Fauna of Slovakia; geographical coordinates and elevation of sampling sites were measured using GPS device Garmin-Vista.

At sampling site Hlu3, stream flows through young, all aged mixed stands of beech, hazel, willows and poplar.Canopy shading is about 70% in growing season, undergrowth consists of *Asarum europaeum*, *Asperula odorata*, *Cirsium* sp., *Daphne mezereum*, *Dryopteris filix-mas*, *Filipendula ulmaria*, *Oxalis acetosella*, *Paris quadrifolia*, *Petasites albus*, *Rosa canina*, *Rubus idaeus*, *Senecio nemorensis.* According to the Slovak Norm Classifications of the quality of surface waters (STN 75 7221), water of both of streams belongs to first class of quality (very clean water). Slightly increased values (second class of quality) were recorded for N-NO_3 and P-PO_4, what is caused probably by leaching from subsoil (flysch). The highest concentrations of nitrates and orthophosphates were recorded at sampling site Hlu1. Higher concentrations of suspended solids and conductivity were also recorded at upper part of Hluboký potok (Hlu1 and Hlu2).
Presence of colloidal matter was showed during filtration of water through Whatman filters within measuring of transported organic matter (TOM) amount. After starting filtration of samples from sampling site Hlu1, the filter was clogged very soon.
Values of measured physical and chemical parameters of Hluboký potok and Stužická rieka suggest two-times higher concentrations of dissolved mater, conductivity and calcium in Hluboký potok. The highest concentration were determined within the first two upper sampling sites of Hluboký potok also for the other parameters (suspended solids, N-NH_4, N-NO_3 and alkalinity).
Some qualitative sampling of particular benthic organisms was conducted within the main field trips. Sites for qualitative sampling were selected: 1) to permit a sampling of faunisticaly interesting stream reaches, 2) to exhibit high within sites heterogeneity, 3) to permit comparison of macroinver-

Tab. 2.2 Hydrological characteristics of sampling sites of two main streams (Hluboký potok and Stužická rieka)

sampling site	water temp. (°C) mean (min/max)	discharge ($l.s^{-1}$) mean (min/max)	discharge fluctuation (%)	flow velocity ($m.s^{-1}$) mean (min/max)	dominant substrate (%)	riffles and pools (%)	riffles : stream width ratio
Hlu1	6.5 (6.1 / 6.8)	12.6 (0.13 / 51.5)	1.03 – 408.7	0.36 (0.17 / 0.61)	p (29), b (28), c (25)	sr (70), sp (20), dp (10)	1:1
Hlu2	10.0 (6.1 / 12.4)	41.1 (8.4 / 135.1)	20.4 – 328.5	0.35 (0.13 / 0.79)	p (39), s (33), g (19)	sr (77), sp (13), dr (10)	3:2
Hlu3	13.8 (11.5 / 15.0)	62.1 (15.8 / 171.1)	25.4 – 275.5	0.60 (0.38 / 0.79)	c (50), p (46)	sr (90), sp (10)	4:1
Stu1	12.5 (11.8 / 13.2)	7.6**	**	0.15**	c (57), p (20)	sr (83), dr (17)	2:1
Stu1*	8.0 (6.8 / 10.4)	77.9 (34.6 / 124.3)	44.4 – 159.6	0.82 (0.35 / 1.42)	c (57), p (20)	sr (83), dr (17)	2:1
Stu2	9.7 (6.5 / 11.7)	199.6 (9.8 / 523.8)	4.9 – 262.4	0.39 (0.29 / 0.58)	c (41), p (33), b (16)	sr (75), dr (10), dp (10), sp (5)	1:2
Stu3	12.0 (9.7 / 13.2)	352.2 (88.5 / 767.0)	25.1 – 217.8	0.55 (0.23 / 0.87)	c (52), p (17), b (15)	sr (44), dr (44), dp (22)	1:1

Note: c – cobbles, p – pebbles, s – sand, g – gravel, b – boulders, sr – shallow riffle, dr – deep riffle, sp – shallow pool, dp – deep pool; average values of temperature, flow velocity and discharge are based on measurements done in time of sampling; **measurement of discharge performed only at one sampling occasion.

Tab. 2.3 Some chemical characteristics of sampling sites of Hluboký potok and Stužická rieka (mean values).

sampling site	pH	O_2 ($mg.l^{-1}$)	dissolved matt. ($mg.l^{-1}$)	insoluble matt. ($mg.l^{-1}$)	total hardness	alkalinity ($mval.l^{-1}$)	conductivity ($\mu S.cm^{-1}$)	$P\text{-}PO_4$ ($\mu g.l^{-1}$)	$N\text{-}NO_3$ ($mg.l^{-1}$)	$N\text{-}NH_4$ ($\mu g.l^{-1}$)	BOD_5 ($mg.l^{-1}$)
Hlu1	7.8	10.6	121.6	22.8	5.52	1.98	212.8	32.4	1.70	43.2	1.14
Hlu2	7.8	9.8	94.4	17.6	4.94	1.72	181.4	27.0	0.67	26.6	0.66
Hlu3	7.9	9.6	106.0	10.4	4.48	1.70	178.6	25.4	0.51	19.5	0.98
Stu1	7.5	9.2	64.8	14.0	2.60	1.02	95.2	31.2	0.97	32.0	1.00
Stu2	7.6	9.6	79.2	14.0	3.38	1.26	124.8	19.8	0.93	20.0	1.04
Stu3	7.7	9.6	75.2	11.2	3.08	1.04	118.0	31.4	0.97	22.2	1.28

Tab. 2.4 Biotic characteristics of sampling sites of Hluboký potok and Stužická rieka (mean values).

sampling site	CPOM ($g.m^{-2}$ AFDM)	FPOM ($mg.m^{-2}$ AFDM)	UFPOM ($mg.m^{-2}$ AFDM)	TOM ($mg.m^{-3}$ AFDM)	TAM ($g.m^{-3}$)	periphyton ($g.m^{-2}$ AFDM)	chlorophyll-a ($\mu g.m^{-2}$)
Hlu1	30.7	74.4	17.5	12.2	6.3	2.5	4892.0
Hlu2	5.3	53.5	47.5	7.8	2.3	1.5	1992.0
Hlu3	16.1	71.4	26.2	9.6	2.4	1.6	3220.4
Stu1	13.2	111.9	21.3	13.1	5.0	1.2	1441.8
Stu2	8.8	93.2	41.4	5.8	0.4	2.9	2651.8
Stu3	12.1	60.3	29.4	6.7	0.3	1.9	2865.6

tebrate communities of different catchments of the East Carpathians streams. Since the main part of the presented study was performed at Stužická rieka and Hluboký potok, we bring only brief characteristic of the rest of the sampling sites (Tab. 2.1).

Kamenistý potok brook (Kam1, Kam2, Kam3) is a left hand tributary of Stužická rieka. It flows into Stužická rieka between sampling sites Stu2 and Stu3. Sampling site Kam1 was located on the 1st right hand tributary (the spring area of the Kamenistý potok), Kam2 represents right hand tributary of Kamenistý potok and sampling site Kam3 was located on the main channel of Kamenistý potok.

Ulička river is a right hand tributary of Uh river (Tisa basin). Sampling site Ulička (Uli) lies upstream of Kolbasov village.

Zbojský potok brook is a left hand tributary of Ulička. Sampling site Zbojský potok (Zbo) was located upstream of Uličské Krivé village.

Ublianka river is right hand tributary of Uh river (Tisa basin). Sampling site Ubl1 was located upstream of Kalná Ráztoka village (Nature Reserve Havešová), Ubl2 was located upstream of Ubľa village.

Bystrá brook is small left hand tributary of Cirocha river (Tisa river basin). Sampling site was located in bungalow area of the Sninské Rybníky near to Snina.

+Note: Since the original sampling site of the spring area of Stužická rieka (Stu1) partially dried up after some sampling occasions, it was replaced by sampling site Stu1*. Both of the sites are similar with respect to stream channel characteristics and both are included within some of the comparisons of taxa compositions of selected taxonomical groups in this study. When the only Stu1 is given (some of the chapters), then this label concern both of the localities as if they were the same.

3. Material and methods

The main studied streams of the study (Hluboký potok and Stužická rieka) have been visited five times during 1999 and 2000. Methods, sampling dates and number of sampling occasions performed at the additional sampling sites differed according to particular aims and character of sampled organisms. Likewise, there are differences in data processing within performing results on particular organisms group. Thus, herein we give basic description of common sampling and processing methods. Some specific techniques (especially data analyses) are briefly described within particular chapters.

Physiogeographical characteristics and abiotic factors
We used physiogeographical characteristics evaluation methods according to Platts et al. (1983) for characteristics of sampling sites of Stužická rieka and Hluboký potok. At each sampling site we selected 2–3 transects and we recorded stream width, depth and stream velocity (using hydrometric wing). Afterwards, these values were used for discharge rate calculations. We examined each 30 cm section of chosen transect and determined the dominant substrata.
Abiotic factors were monitored at the main sampling sites (Hlu1–3, Stu1–3) regularly in time of macrozoobenthos sampling. At each sampling site, the actual water temperature was measured. Quantity of dissolved O_2 was determined by titration method according to Winkler. Levels of pH were measured in field using acidimeter f. Radelkis (type OP-208), conductivity was measured using conductometer f. Radelkis (Radelkis: OK-102/1) at 20 °C.
All the chemical analyses (determination of P-PO_4, N-NO_3, N-NH_4, BOD_5, total hardness, alkalinity, dissolved matter, insoluble matter) were performed according to methods modified for conditions of surface waters (Hrbáček et al. 1972).

Benthic and transported matter
Benthic and transported organic matter were investigated in the same time as quantitative macroozoobenthos sampling. Two samples of benthic organic matter were taken at each site using sharply edged tube, which was inserted into substratum. Bottom area restricted by the tube was thoroughly whirled and 0,5 l of water was taken from the water column for analyses. Size fractions of the benthic organic matter were separated in laboratory using the system of sieves with different diameter. Amount of organic material was expressed in $mg.m^{-2}$ of ash free dry mass (AFDM).
Quantity of transported organic material (TOM) was determined by taking 2.5 l of water from the stream at each sampling occasion. Afterwards, water was filtered in laboratory and amount of TOM was expressed in mg of AFDM. For details of sampling and processing of organic material see Rodriguez & Derka (2003) and Šporka & Krno (2003).

Macrozoobenthos
Quantitative samples of macrozoobenthos were collected from the sampling sites of Hluboký potok and Stužická rieka in June, September and November 1999 and April and July 2000. Samples were taken by Hess`s benthometer of two sizes (sampling area 329 cm^2 and 707 cm^2, respectively), with mesh size 0.5 mm (Helan et al. 1973). The choice of size of sampling benthometer depended on the sampling sites conditions. We took either 5 samples by small benthometer (total sampling area 1645 cm^2) or 3 samples by large one (total sampling area 2121 cm^2). All the densities of macrozoobenthos groups were recalculated on the area of $1m^2$ for data processing.
Samples were preserved with 4% formaldehyde in field and processed by standard hydrobiological methods in laboratory.
From sampling sites of other streams, we took just qualitative samples using kick nets (mesh size 0,5 mm). Samples were taken from all types of substratum occurring at sampling sites. Processing of samples was the same as in case of quantitative samples.

Epilithic algae
Epilithic algae were taken from 9 localities. A total of 43 samples were obtained, from which 30 samples from 6 sampling sites from Stužická rieka (Stu1, Stu2, Stu3) and Hluboký potok (Hlu1, Hlu2, Hlu3), 10 samples from sites of Ulička (Uli) and Zbojský potok (Zbo) and 3 samples from Kamenistý potok (Kam1-3).
Samples for qualitative analyses were taken up from the stones visibly grown by algae. Epilithon was removed from more stones of the stream from the whole of the surface using toothbrush and then by repeated washings into a sample bottle. The samples were preserved by addition of solution of formaldehyde to final concentration 3-4% in the sample. Diatom slides were prepared by standard methods by using H_2O_2. Cleaned diatoms were mounted in Naphrax and then determined under oil immersion 100x.
Chlorophyll-a was investigated at 6 sampling sites (Stu 1, Stu 2, Stu 3 and Hlu 1, Hlu 2, Hlu 3) in the years 1999-2000 using ISO method with extraction in ethanol. Samples were taken from stones. Content of chlorophyll-a was expressed in $\mu g.m^{-2}$.

Interstitial
Samples from the Hluboký potok (Hlu1, Hlu2 and

Hlu3), Stužická rieka (Stu1, Stu2 and Stu3), Kamenistý potok (Kam1), Ulička (Uli) and Zbojský potok (Zbo) were taken in June, September and November 1999 and in April and July 2000. The samples were taken as for the qualitative as for the quantitative evaluation. Samples from the spring of the Kamenistý potok were taken in September 1999 and July 2000 for the qualitative evaluation of crustaceans.

The samples we took according to the method of Karaman–Chappuis (Schwoerbel 1967). A hole of 30 cm in diameter and of 30-60 cm in depth was dug 50 cm apart of the stream. The samples were taken with a 70-μm-mesh net. To assess hyporheos density (ind.m^{-3}), 20 l of interstitial water were taken and filtered through the plankton net. The material from the whole volume of filtered water was conserved by 4% formaldehyde and than identified in the laboratory. Crustacea (Cladocera, Copepoda: Cyclopidae, Harpacticoidae, Malacostraca: Bathynellacea) were identified to the specific level. Insect larvae (Ephemeroptera, Plecoptera and Diptera: Chironomidae, Ceratopogonidae and Simuliidae) and other groups (Ostracoda, Nematoda and Oligocheata) were identified at the level of higher taxa. The later occurred either regularly or sporadically at individual sampling sites.

Microzoobenthos and meiozoobenthos

Samples of micro- and meiozoobenthos were collected in the years 1999–2000 and we investigated several substrata (stones, gravel, fine gravel, detritus, moss). Samples were collected 5x during the observed period (June, September, November 1999 and April, July 2000) from 3 localities of the Hluboký potok (Hlu1, Hlu2, Hlu3), 4 localities of Stužická rieka (Stu1, Stu1*, Stu2, Stu3), 3 localities of Kamenistý potok (Kam1, Kam2, Kam3) and from 1 locality of Zbojský potok (Zbo) and Ulička (Uli). Samples were taken into the glass bottles (0.25 l). They were processed in vivo immediately after bringing them to the laboratory (max. till 18 hrs after sampling). Protargol impregnation method according to Wilbert (1975) was used for fixation. Samples designed for quantitative evaluation were collected by micropipette (volume of 20 μl). All ciliated protozoa were determined and counted in each drop. Because of relatively poor quantitative representation, 1 ml of sample was investigated. In addition to the ciliated protozoa, the other groups of micro- and meiozoobenthos were quantitatively studied as well (Mastigophora, Rhizopoda, Rotifera, Gastrotricha, Tardigrada, Oligochaeta, Turbellaria). Species identity was counted according to Sörensen (1948).

An assessment of human impact (comparison of Stužická rieka and Hluboký potok)

The whole macroinvertebrate communities of two key streams of this study were used for assessment of timber harvest management impact. Species density, total density and total taxonomic richness were calculated for each sampling occasion and site. These data were used for the analysis of communities.

Data on transported organic matter (TOM), fine particulated organic matter (FPOM), ultra fine benthic organic matter (UPOM), coarse bethic organic matter (CPOM), aufwuchs and chlorophyll-a were used for the food resource analysis.

Our sampling design involved two unreplicated streams with contrasting basin management. This design limits inferences about the effect of silvicultural practices, because the effect of management practices may be spatially confounded with natural differences between streams. Thus, we can make inference regarding the differences between two particular streams only and therefore we refer to factor „stream" rather than „management". It should be clearly noted, that factor stream tested for differences between Hluboký potok and Stužická rieka not between management practices since sampling sites were nested within streams and treated as replications (cf. Hurlbert 1984).

Obtained data were analysed using two slightly different ways according to the differences in sampling strategy. Biomass of TOM, aufwuchs and chlorophyll-a were analysed using multivariate approach to repeated measures analysis of variance (RM-MANOVA, StatSoft Inc. 2001). This method takes into account correlation between successive samples and resulting non-independence. Moreover, RM-MANOVA does not require the restrictive assumption of sphericity in contrast to univariate approach (von Ende 2001). The between subject factor was stream and within subject factors were time and stream by time interaction. Biomass of CPOM, FPOM and UFPOM were analysed using nested RM-MANOVA. Sites nested within streams were considered as a fixed-effect because sampling sites were chosen non-randomly in accordance to altitude. For significant effects, the relevant pairwise comparisons were done using Fisher's least significant difference tests. Prior to statistical analysis, data were formally tested for normality and heteroscedasticity using Shapiro-Wilk W test (Shapiro-Wilk 1965) and Bartlett's test (Bartlett 1937), respectively. When necessary, data were $\log_{10}$ or square root transformed, which resulted in more symmetric distributions and more stable variances. However, untransformed data were displayed in plots to facilitate viewing and interpretation.

Spatial and temporal differences in overall species density and taxonomic richness were tested using RM-MANOVA (see above). Further, we subdivided overall density into five functional feeding groups (FFG): gatherers, filtrators, scrapers, shredders and predators, and analysed separately. The community data matrix (samples × taxa) was analysed using distance-based MANOVA (Anderson 2001). This method allows fitting the full linear additive models, including interaction terms, to the distance matrix of choice (McArdle & Anderson 2001). Our model included main effects of stream and time, and their interaction. Individual terms were coded as matrices of orthogonal contrast vectors (Neter et al. 1996) and tested in separate analyses (Anderson 2004). We accounted for autocorrelation inherent in the sampling design by inclusion of matrix that coded the repeatedly sampled sites. This matrix was then used as a denominator design matrix in the construction of test statistics for the between subject effect. P values were obtained using 9999 Monte Carlo samples rather than permutations because of low sample size and therefore limited number of possible permutations (Anderson & Robinson 2003). The community analysis was based on Bray-Curtis distance (Bray & Curtis 1957) that is appropriate for ecological data (Faith et al. 1987). Species densities were square root transformed to reduce asymmetrical influence of the dominant species while ensuring that quantitative information was not lost. For significant effects, the relevant pair-wise comparisons were done using the same method. Non-metric multidimensional scaling (MDS, Kruskal 1964) was used to visualise differences in community composition among streams and sampling dates. Again, Bray-Curtis distance on square root transformed densities was chosen as an appropriate dissimilarity measure for MDS. Random starting configuration with a maximum number of 1000 starts, a maximum of 50 iterations per start and level of convergence set to 0.001 was employed in searching for stable solution (Oksanen et al. 2007). Only two- and three-dimensional solutions were considered. To facilitate the interpretation, final ordination was centered, rotated by principal component rotation and rescaled so that one unit along an axis corresponds to a halving of community similarity (half-change scaling). Relationships between environmental variables and MDS configuration were examined by Spearman rank correlation. Moreover, scores of characteristic species (see below) were added into ordination as weighted averages of sample scores. Indicator species analysis (Dufrêne & Legendre 1997) was used to identify species characteristic for particular stream. Those species with indicator values (IndVal) greater than 70% were regarded as characteristic indicator species for the stream in question. To avoid temporal pseudoreplication, monthly data on species densities were pooled for each site. Significance of indicator values was not tested because of low sample size.

Quantitative data on benthic invertebrates were used as basis for calculation of a set of metrics (program ASTERICS - AQEM/STAR Ecological River Classification System). Metrics belong to several groups (sensitivity/tolerance metrics, composition/abundance metrics, richness/diversity metrics, and functional metrics). This set of metrics was proposed in projects AQEM and STAR as tool for assessment of ecological status of streams of EU states according to demands of Water Framework Directive. A set of metrics was calculated for every sampling site and sampling date. Detailed description of metrics is available in Hering et al. 2004 and Šporka et al. 2006.

Individual metrics were compared between two studied streams (metric values for different sampling date were pooled together) in order to detect if some differences between macroinvertebrate communities of these two streams exist in terms of harvest management impact. For this purpose visual estimate was carried out using box-and-whisker plots.

4. Epilithic diatoms

An important part of hydrobiological observes is phytobenthos, mainly diatoms which are the most significant part of the algal assemblages reflecting water quality in streams. Studying mountain streams in Slovakia aforetime was not given adequate remarks. In the part of Malé Karpaty, Pokorná (1959) studied species composition of algae in stream Bystrička and established its saprobity. Cyanophytes and algae flora of the Fofovský potok brook was investigated by Štefková (1983). In the nineties more attention was devoted to studying algae in streams. The streams from the territory of Malé Karpaty, Poľana and the High Tatra Mountains were studied, e.g. Krno et al. (2000). From the area of the East Carpathian no papers regarding algae have yet been published.

The aim of the present work was to study the species composition of diatom assemblages of selected sites of Hluboký potok, Stužická rieka, Kamenistý potok, Ulička and Zbojský potok in the Bukovské vrchy Mts. (Poloniny National Park, the East Carpathians). Chlorophyll-a was investigated at Stužická rieka and Hluboký potok.

Species composition of epilithic diatom communities of the examined streams showed a great floristic similarity. They differed from each other mainly in prevailing of particular species in various sites. A total of 80 taxa of diatoms were found at all sampling sites (Tab. 4.1). The richest species composition of diatoms was found in the sampling sites of Ulička and Zbojský potok (46 taxa). The lowest number of taxa (23) was recorded in the sampling site Kamenistý potok. About 40 taxa were found in the sampling sites of Hluboký potok and Stužická rieka. All the taxa recorded were those preferring oligotrophic waters.

The richest species composition of diatoms can be noticed in unpolluted streams in the spring and summer (Kawecka 1980). Seasonal changes of diatom community structure are influenced by a complex of physico-chemical environmental factors e.g. water temperature, amount of mineral substances, pH, light, water level, current velocity, floods (Kawecka 1980). The species composition of diatom communities of studied streams was quite similar. It was changed during the year and in certain season different species prevailed in some sampling sites.

Cluster analysis of observed localities (Fig. 4.1) on the grounds of species composition of diatom assemblages created two base groups (A, B). In the first group (A) all the sampling sites of Hluboký potok, Stužická rieka and Kamenistý potok were grouped, in the second (B) there were Ulička and Zbojský potok. Within the frame of the first group, three subgroups (C, C1, C2) were created. In subgroup (C1) all 3 sampling sites of Hlu1, Hlu2, Hlu3 were involved, whilst in subgroup (C2) there were sampling sites of Stu2 and Stu3. It is possible to rank all of these profiles as submontane streams, with maximum temperature up to 15 °C. Typical species with high abundance present in these sampling sites were *Achnanthes minutissima, A. biasolettiana, Cocconeis diminuta, C. placentula, Gomphonema angustatum, G. angustum.*

The springs Kamenistý potok and Stu1 were isolated within the cluster analysis. The sampling site of Stu1 (C) was specially isolated as it is possible to designate it as a montane stream. Both localities had narrow species spectrum of epilithic diatoms with characteristic species for cold waters. Strong dominance of one or more species (*Achnanthes minutissima, Cocconeis placentula*) was typical. No algae species occur solely in springs.

We can assign the sampling sites Ulička and Zbojský potok as lower reaches of submontane streams. Similar results using cluster analysis of different animal groups were obtained also for stoneflies, interstitial communities and beetles.

Hluboký potok

46 taxa were found together in three searched sampling sites. Apart from the diatoms, filamentous cyanophytes were also present (mainly Hlu1). The highest number of diatoms was found in the Hlu3 and presented altogether 36 species.

In the sampling site Hlu1 (altitude 760 m) *Gomphonema angustum, Achnanthes minutissima, Diatoma hyemale* and *Meridion circulare* prevailed. In the site Hlu2 (altitude 610 m) *Cocconeis placentula, C. placentula var. euglypta, C. neodiminuta, Gomphonema angustum* and *G. angustatum* were the most numerous. Sampling site Hlu3 (altitude 535 m) was typical with species dominance of *Cocconeis placentula, C. neodiminuta, Achnanthes biasolettiana, Fragilaria arcus, Gomphonema angustum, G. angustatum, G. olivaceum and Cymbella sinuata*.

Stužická rieka

In three sampling sites of Stužická rieka together 47 diatom taxa were found. In the first sampling site Stu1 (June 1999) prevailed *Cocconeis placentula* and *Achnanthes minutissima.* The prevailed diatom species in the sampling site Stu1 (September 1999) were *Cocconeis placentula, C. placentula* var. *euglypta, C. neodiminuta, Fragilaria arcus, Gomphonema olivaceum, G. angustum* and *Achnanthes minutissima. Gomphonema angustum, Achnanthes minutissima, A. biasolettiana, Cocconeis placentula, Gomphonema angustatum* and *Fragilaria arcus* were the most abundant in the sampling site Stu2 (altitude 717 m). The richest species representation of diatoms in site Stu3 (altitude 630 m) was caused by the occurence of more species of genus *Gomphonema,* e.g. *G. an-*

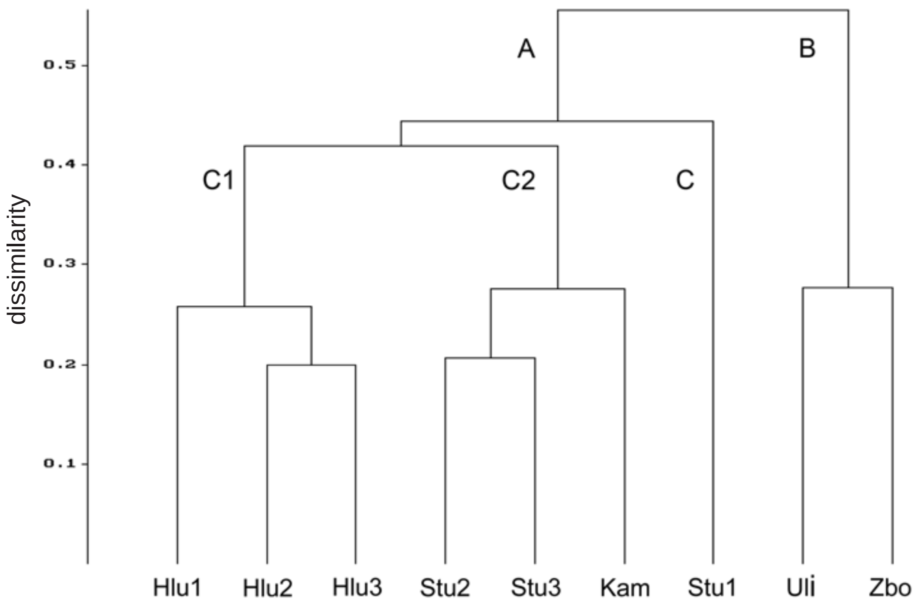

Fig. 4.1 Cluster analysis of observed localities on the ground of diatom species composition (Average linkage method, Sörensen 's similarity index).

gustum, G. angustatum, G. olivaceum, and other as *Cocconeis placentula, Achnanthes biasolettiana, Fragilaria arcus* and *F. ulna.*

Ulička and Zbojský potok

Sampling sites Ulička and Zbojský potok with their diatom species composition were particularly different from the former sampling sites. Both streams represent lower stretches of submontane streams with altitude of about 300 m. We registered a higher number of diatom taxa (nearly 50) in both of these localities. Mainly dominant species of diatoms within various sampling were different. Algal filaments of species *Cladophora glomerata, Ulothrix tenuissima* and *U. zonata* also occurred very often.

Didymosphenia geminata, which formed bulky epilithic growth, was markedly present during 1999 and in July 2000 at the sampling site Ulička. This species was registered only once before in the Slovak territory. It was recorded in the outflow of Morské Oko in the High Tatras in the altitude of 1393 m (Bílý 1941). As it is stated in Krammer & Lange-Bertalot (1986), this species is boreo-alpine diatom, spread only in the alpine European region in oligotrophic cold waters. In the last years this species appeared in more Carpathian rivers in Poland (Kawecka & Sanecki 2003) and Czech Republic (Gagyorová & Marvan 2002).

Other diatoms species were also numerous e.g. *Fragilaria ulna, Achnanthes biasolettiana, A. minutissima, Cymbella minuta, Fragilaria arcus, F. capucina* var. *vaucheariae, Gomphonema olivaceum.*

Characteristic species of diatoms for the sampling site Zbojský potok were *Diatoma vulgare* (summer and winter), *Fragilaria arcus, F. ulna, F. capucina, Achnanthes minutissima, A. biasolettiana, Cocconeis pediculus, Gomphonema olivaceum* and *Cymbella prostrata*. Species *Didymosphenia geminata* was also found here but, its frequency was lower than in the profile of Ulička. Its higher frequency was registered only in November 1999.

Kamenistý potok

Kamenistý potok is a spring with low water temperature not higher than 6.8°C throughuout the year. The lowest number of diatom species was registered at this sampling site. The most common species with high counts were species *Diatoma mesodon, Achnanthes minutisssima, Cocconeis placentula, C. neodiminuta* and *Navicula gallica* var. *perpusilla.*

Chlorophyll-a

Discharge and the current velocity are recognised as important factors affecting algal distribution in streams and rivers, yet investigations into their effects have been almost entirely restricted to epilithon (Stevenson 1984; Peterson 1986).

The lowest values of chlorophyll-a were registered in April 2000 in all the localities (Fig. 4.2). This was connected with high discharge and current velocity. The values of chlorophyll-a ranged from 200 to 3374 $\mu g.m^{-2}$. In the time of low discharge and current velocity, the amounts of chlorophyll-a were much higher. The highest amounts of chlorophyll-a (Fig. 4.2) were measured at Hlu1 in September 1999 (5900 $\mu g.m^{-2}$) and November 1999 (5785 $\mu g.m^{-2}$), at Stu3 in June 1999 (5170 $\mu g.m^{-2}$). The lowest amounts were measured at Stu2 in April 2000 (200 $\mu g.m^{-2}$). The highest average values of chlorophyll-a were found at the Hlu1 (4892 $\mu g.m^{-2}$) and the lowest at the Stu1 (1153 $\mu g.m^{-2}$).

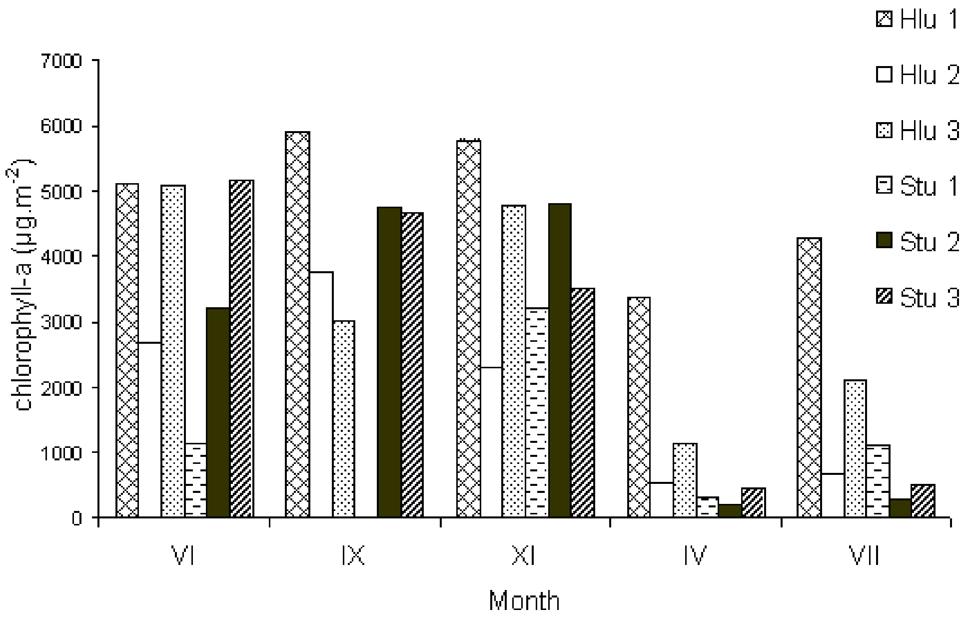

Fig. 4.2 Chlorophyll-a concentration on profiles Hluboký potok and Stužická rieka (June 1999 – July 2000).

Tab. 4.1 Species composition of diatom assemblages on different sampling sites.

	sampling site								
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	Uli	Zbo	Kam
Achnanthes biasolettiana Grunow	+	+	+		+	+	+	+	+
Achnanthes flexella (Kütz.) Brun					+	+	+		+
Achnanthes helvetica (Hust.) Lange-Bert.		+				+			+
Achnanthes lanceolata (Bréb. ex Kütz.) Grunow	+	+	+	+	+	+	+	+	+
Achnanthes minutissima Kütz	+	+	+	+	+	+	+	+	+
Achnanthes sp.	+	+	+		+	+			+
Amphipleura pellucida (Kütz.) Kütz						+	+	+	+
Amphora libyca Ehrenb		+	+					+	
Amphora pediculus (Kütz.) Grunow	+	+	+	+	+	+	+	+	+
Cocconeis neodiminuta Krammer	+	+	+	+	+	+		+	+
Cocconeis pediculus Ehrenb	+		+				+	+	
Cocconeis placentula Ehrenb	+	+	+	+	+	+	+	+	+
Cocconeis plac. var. *euglypta* (Ehrenb.) Cleve				+	+				+
Cocconeis plac. var. *lineata* (Ehrenb.) Van Heurck				+	+				
Cocconeis sp.				+					
Cymatopleura librilis (Bréb.) W. Sm.							+	+	
Cymbella affinis Kütz.	+	+	+				+		
Cymbella aspera (Ehrenb.) H. Perag.				+					
Cymbella cymbiformis C. Agardh	+		+	+			+		
Cymbella helvetica Kütz			+			+		+	
Cymbella lanceolata (Ehrenb.) Kirchn.							+	+	
Cymbella microcephala Grunow								+	
Cymbella minuta Hilse	+	+	+		+		+	+	
Cymbella prostrata (Berk.) Cleve							+	+	
Cymbella silesiaca Bleisch								+	
Cymbella sinuata W. Greg.	+	+	+	+	+	+	+	+	+
Cymbella sp.	+							+	

Tab. 4.1 (continued) Species composition of diatom assemblages on different sampling sites.

	sampling site								
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	Uli	Zbo	Kam
Denticula tenuis Kütz			+						
Diatoma ehrenbergii Kütz.							+		
Diatoma hyemale (Roth) Heib.	+			+	+	+	+	+	
Diatoma mesodon (Ehrenb.) Kütz.	+	+	+		+	+			+
Diatoma vulgaris Bory	+						+	+	
Didymosphenia geminata (Lyngbye) M. Schmidt							+	+	
Diploneis elliptica (Kütz.) Cleve	+								
Epithemia adnata (Kütz.) Bréb.			+						
Epithemia sp.						+			
Eunotia sp.			+		+		+	+	
Fragilaria arcus (Ehrenb.) Cleve	+	+	+	+	+	+	+	+	
Fragilaria capucina Desm.	+	+	+	+	+	+	+	+	
Fragilaria capuc. var. *vaucheriae* (Kütz.) Lange-Bert.							+		
Fragilaria capuc. var. *rumpens* (Bréb.) Lange-Bert.								+	
Fragilaria ulna (Nitzsch) Lange-Bert.		+	+		+	+	+	+	
Fragilaria ulna var. *acus* (Kütz.) Lange-Bert.								+	
Fragilaria sp.		+		+			+		
Frustulia vulgaris (Thwaites) De Toni							+		
Gomphonema angustatum (Kütz.) Rabenh.	+	+	+	+	+	+	+	+	+
Gomphonema angustum C. Agardh	+	+	+		+	+	+		
Gomphonema clavatum Ehrenb.					+				
Gomphonema minutum (C. Agardh) C. Agardh	+				+	+	+		
Gomphonema olivaceum (Hornem.) Bréb.			+	+		+	+	+	
Gomphonema parvulum (Kütz.) Kütz.	+								
Gomphonema pumillum (Grunow) Reichardt	+	+	+			+	+		+
Gomphonema ventricosum W. Greg.								+	
Gomphonema sp.		+	+		+				
Melosira varians C. Agardh				+			+	+	
Meridion circulare (Grev.) C. Agardh	+	+	+	+	+	+	+	+	+
Navicula capitoradiata H. Germ.	+	+	+				+	+	
Navicula digitulus (W. Greg.) Ralfs	+								
Navicula gallica var. *perpusilla* (Grunow) Lange-Bert.				+	+	+			+
Navicula margalithii Lange-Bert.	+			+	+			+	
Navicula menisculus Schum.	+	+	+	+	+	+	+	+	+
Navicula mutica Kütz.								+	
Navicula pupula Kütz.								+	
Navicula radiosa Kütz.						+	+	+	
Navicula cf. *recens* (Lange-Bert.) Lange-Bert.						+	+	+	
Navicula cf. *splendicula* Van Landingham							+		+
Navicula ventralis Krasske							+		
Navicula tripunctata (O. F. Müll.) Bory.	+	+	+		+	+	+	+	
Navicula sp.	+	+	+	+	+	+	+	+	+
Neidium binodis (Ehrenb.) Hust.			+						
Nitzschia acicularis (Kütz.) W. Sm.							+		
Nitzschia dissipata (Kütz.) Grunow	+		+				+	+	
Nitzschia linearis (C. Agardh) W. Sm.	+	+			+	+	+	+	+
Nitzschia sp.	+	+	+	+	+	+	+	+	+

Tab. 4.1 (continued) Species composition of diatom assemblages on different sampling sites.

	sampling site								
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	Uli	Zbo	Kam
Pinnularia viridis (Nitzsch) Ehrenb.						+			
Pinnularia sp.			+	+					
Rhoicosphaenia abbreviata (C. Agardh) Lange-Bert.	+	+	+	+	+	+			+
Surirella brebissonii Krammer et Lange-Bert.							+	+	
Surirella minuta Bréb.							+		
Surirella sp.							+	+	

5. Micro– and meiozoobenthos

From the evaluation standpoint of various anthropogenic influences, especially in flowing waters, micro- and meiozoobenthos belong to significant indicatory groups. Elementary component of that is created by unicellular organisms (Flagellata, Rhizopoda and Ciliophora). The microscopic multicellular ones are Rotifera, Nematoda, Gastrotricha, Turbellaria, Oligochaeta and Tardigrada. The species spectrum, abundance and mutual proportion of individual component representation of micro- and meiozoobenthos have a very good statement value on the running processes in the water. These excellent results were achieved mainly by evaluation of blast pollution, increasing eutrophication, increased erosion etc. In the frame of micro- and meiozoobenthos, protozoa mainly belong to the decisively indicating organisms and from them ciliated protozoa (Ciliophora) especially. Just from this point of view we concentrated on that group of unicellular organisms and the remaining components of micro- and meiozoobenthos were observed quantitatively.

In respect of the relatively low animation in the oligotrophic streams these ones did not attract such an attention in the past as the streams with higher trophic level. In the framework of European streams, the territories of Austria and Germany (Foissner 1997, Blatterer 1994, Packroff & Zwick 1996, 1998) belong to the best-reconsidered territories. In the Slovak territory, an intense attention was devoted to that problem. From the evaluation standpoint of anthropogenic influences on microfauna more streams were observed in frame of the Slovak flowing waters research e.g. Veľký Javorník (Tirjaková 1997a), some streams in the High Tatry Mts. (Tirjaková 2001, 2004), underneath Vtáčnik Mts. (Krno et al. 1995), many streams in Slovenský kras (Tirjaková 1997c, Tirjaková & Stloukal 1997), Turiec river (Tirjaková 1993, Krno et al. 1996), Orava river (Matis & Tirjaková 1995), river basin of Hron (Tirjaková 1998), Gidra river and its tributaries (Tirjaková 2003, Tirjaková & Stloukal 2004) etc. No studies have yet been published concerning the territory of the East Carpathians.

All components of micro– and meiozoobenthos were regularly represented in the investigated localities. From the quantity point of view, the representatives of Ciliophora (max. 530 ex.ml^{-1} – Ulička) and Rotifera in the highest abundance up to 500 ex.ml^{-1} (Stu1) were especially dominating. The whole abundance of Rotifera mostly fluctuated in the span of 10–50 ex.ml^{-1}. During the whole studied period we did not record any increased development of flagellated protozoa in localities that would demonstrate a blast organic pollution. Rotifera and Ciliophora prevailed in the community. In Stužická rieka, Hluboký potok and Kamenistý potok localities, the abundance of ciliated protozoa varied up to 100 ex.ml^{-1}. In Zbojský potok and Ulička the abundance varied from 300–530 ex.ml^{-1}. The frequent occurrence of Rhizopoda in these two localities suggests a raised content of bacteria and thus an increased eutrophication of these streams. Other components of micro- and meiozoobenthos occurred occasionally in very low abundances in all studied localities. From the production point of view these do not have a great importance in the studied streams.

Species spectrum and abundance of ciliated protozoa

From the indicatory group of ciliated protozoa 135 taxa were determined in the investigated territory. The species spectrum is particularly interesting, for up to 12 species of the identified amount (Matis et al. 1996) belong to the first found in the Slovak territory (*Enchelyodon armatus* Kahl, 1926; *Fuscheria lacustris* Song & Wilbert, 1989; *Gastrostyla minima* Hemberger, 1985; *Lacrymaria robusta* Vuxanovici, 1959; *Litonotus crystallinus* (Vuxanovici, 1960); *Paracolpidium truncatum* (Stokes, 1885); *Phialina jankowski* Foissner, 1984; *Pseudoblepharisma crassum* Kahl, 1927; *Pseudochilodonopsis polyvacuolata* Foissner & Didier, 1981; *Pseudochlamydonella rheophyla* Buitkamp, Song & Wilbert, 1989; *Stegochilum schoenborni* Foissner, 1986; *Thigmogaster nanus* Song & Wilbert, 1989).

Relatively low numbers of even-tempered species were found in localities of Kamenistý potok (12-21), Hluboký potok (25-34) and Stužická rieka (19-36). The recorded amounts correspond to character of the studied biotops and they are in accordance with other streams of similar character in Slovakia and Europe (Foissner 1997; Tirjaková 1997a, 1997b, 1997c, 2001, 2003). We can classify all of these localities into the category of springs, mountain brooks and submountain streams with low temperature and trophic level, as well as a very low abundance of ciliated protozoa (mostly up to 100 ex.ml^{-1}, often still lower). This refers to the uniqueness of the given streams in which only decomposition of autochtonous and allochtonous material happens (silts).

The highest number of species (47 and 59) were found in the localities of Zbojský potok and Ulička. These localities differ expressively by their community structure and especially by the abundance from the preceding ones. Moreover, they refer to the increased eutrophication, which is manifested by species amount growth and the abundance of ciliated protozoa, especially in the locality of Ulička. Large species pretensions to a food amount predominate there in particular (genera like *Paramecium, Stylonychia, Stentor, Trithigmostoma* and others (Tab. 5.1). These pretensions do not occur in

Tab. 5.2 Species identity values.

HLU	STU	ZBO	ULI	KAM	
-	50	32	40	43	HLU
	-	35	48	46	STU
		-	55	30	ZBO
			-	34	ULI
				-	KAM

the streams with low trophic level or appear very rarely. Their occurrence is confirmed by copiousness of bacterial food especially.

Small euryecous species such as *Aspidisca cicada, A. lynceus, Cinetochilum maragritaceum, Cyclidium heptatrichum, Ctedoctema acanthocryptum, Glaucoma scintillans, Holosticha pullaster, Trochilia minuta* belong to the eudominant species in all of the studied territory in all streams. It corresponds to the character of the observed streams and that is in accordance with other oligotrophic streams in Slovakia (Tirjaková 1997a, 1997b, 2001). The relatively great species representation of the rapacious genera *Litonotus* (6 species) and *Amphileptus* (4 taxa) is very interesting.

Of all the 135 taxa we recorded 60 (i.e. 44%) one time, respectively in 1 locality. Therefore, comparing the individual basins, it is clear that a specific community of ciliated protozoa occurs in the given streams whilst the species identity (Sörensen 1948) attains relatively low values of 30–55 %. Each stream (from the species spectrum point of view) practically includes a specific community of ciliated protozoa. Low species identity could be influenced by specific conditions (preferably by low trophic level of most observed localities) and by the low amount of collected species in the individual localities. Furthermore, the species identity comparison in other streams of Slovakia (betamesosaprobic and beta- up to alphamesosaprobic as well) demonstrates that species identity values are essentially higher (Tirjaková 1991). We also found comparatively low values of species identity in oligotrophic streams in the Vysoké Tatry (High Tatra) Mts., where the species identity fluctuated in the span of 20–51 %. This confirms the given assumption. Species identity values are illustrated in Tab. 5.2 (evaluated all basins).

Anthropogenic influences

By comparison of 2 studied streams of the near-pristine Stužická rieka and Hluboký potok influenced by wood-cutting in the past, we recorded differences in the community structure. As shown in Fig. 5.1 and Fig. 5.2, the average abundance of ciliated protozoa in Stužická rieka is relatively even-tempered and depends on seasonal swings only.

These values correspond with the results of chlorophyll-a ones as well (see Epilitic diatoms). The average abundance values in Hluboký potok are considerably unsteady and confirm an instability

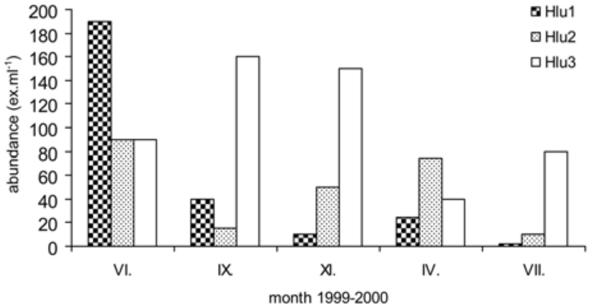

Fig. 5.1 Ciliated protozoa (Ciliophora) abundance on the localities of Hluboký potok (1999-2000).

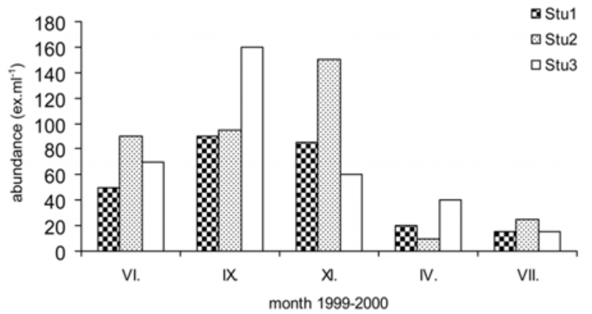

Fig. 5.2 Ciliated protozoa (Ciliophora) abundance on the localities of Stužická rieka (1999-2000).

of the community, which may be influenced by higher erosion in the basin.The influence of the higher erosion was clearly manifested during the spring period in the whole basin of Hluboký potok (especially Hlu2), as well as the inferior section (Zbojský potok, Ulička) due to the increased portion along with abundance of terrestric species (gen. *Colpoda, Gonostomum, Leptopharynx*).

In the localities of Stužická rieka these effects were not manifested during the spring period. Although terrestric species scarcely occurred in this stream during the year in relation to the character of the biotope, we cannot ascribe their occurrence to the increased erosion. Occasional occurrence of those species in flowing waters is expected (Ganner & Blatterer 1997, Primc 1988).

Tab. 5.1 List of ciliated protozoa (Ciliophora) taxa in some localities of NP Poloniny.

	sampling site											
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Zbo	Uli	Kam1	Kam2	Kam3
Acineria uncinata Tucolesco, 1962									+			
Amphileptus plerosigma (Stokes, 1884)								+				
Amphileptus punctatus (Kahl, 1926)	+											
Amphileptus sp.									+			
Amphileptus sp1.								+				
Anteholosticha monilata (Kahl, 1928)			+	+			+	+	+	+		
Aspidisca cicada (Mueller, 1786)	+	+	+	+		+	+	+	+			
Aspidisca lynceus (Mueller, 1773)	+	+	+		+	+	+		+	+	+	+
Bryometopus pseudochilodon Kahl, 1932						+						
Calyptotricha lanuginosa (Penard, 1922)	+			+		+	+					
Cinetochilum margaritaceum (Ehrenberg, 1831)	+	+	+	+	+	+	+	+	+	+	+	+
Coleps hirtus (Mueller, 1786)			+		+		+		+			
Coleps hirtus var. *minor* Kahl, 1930						+	+					
Coleps nolandi Kahl, 1930								+				
Colpidium colpoda (Losana, 1929)				+			+	+	+			
Colpoda colpidiopsis Kahl, 1931	+				+							
Colpoda cucullus (Mueller, 1773)		+				+	+			+		
Colpoda inflata (Stokes, 1884)	+	+								+		
Colpoda maupasi Enriquez, 1908								+				
Colpoda sp.	+											
Colpoda steinii Maupas, 1883		+		+		+						
Cyclidium glaucoma Mueller, 1773	+		+				+	+	+	+		
Cyclidium heptatrichum Schewiakoff, 1893		+	+	+		+	+		+	+	+	
Ctedoctema acanthocryptum Stokes, 1884		+	+	+		+	+	+	+			
Dexiostoma campylum (Stokes, 1886)		+			+		+	+	+			
Dileptus sp.									+			
Dimacrocaryon amphileptoides (Kahl, 1931)								+	+			
Drepanomonas sphagni Kahl, 1931						+						
Dysteria fluviatilis (Stein, 1859)	+	+						+	+		+	
Enchelyodon armatus Kahl, 1926						+						
Euplotes affinis (Dujardin, 1841)								+	+			
Euplotes patella (Mueller, 1773)								+	+			
Frontonia acuminata (Ehrenberg, 1833)						+						
Frontonia ambigua Dragesco, 1972				+								
Frontonia angusta Kahl, 1931			+		+							
Fuscheria lacustris Song et Wilbert, 1989									+			
Gastronauta membranaceus Buetschli, 1889			+									
Gastrostyla minima Hemberger, 1985			+									
Gastrostyla steinii Engelmann, 1862										+		+
Glaucoma scintillans Ehrenberg, 1830	+	+	+	+	+	+	+		+		+	+
Glaucoma spp.	+					+	+			+		+
Gonostomum affine (Stein, 1859)		+					+					
Halteria grandinella (Mueller, 1773)	+		+									
Holophrya teres (Ehrenberg, 1833)									+			
Holosticha pulaster (Mueller, 1773)	+	+	+		+	+	+	+	+	+	+	+
Holosticha sp.						+						
Chilodonella uncinata (Ehrenberg, 1838)	+		+		+				+	+		+

Tab. 5.1 (continued) List of ciliated protozoa (Ciliophora) taxa in some localities of NP Poloniny.

	sampling site											
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Zbo	Uli	Kam1	Kam2	Kam3
Chilodontopsis depressa (Perty, 1852)						+		+	+			
Chilodontopsis muscorum Kahl, 1931		+							+			
Chlamydonella alpestris Foissner, 1979									+			
Chlamydonella rostrata (Vuxanovici, 1963)	+	+	+	+	+		+		+	+		
Kahlilembus attenuatus (Smith, 1897)								+				
Lacrymaria filiformis Maskell, 1886	+			+		+	+					
Lacrymaria olor (Mueller, 1786)							+	+	+		+	
Lacrymaria robusta Vuxanovici, 1959										+		
Lacrymaria sp.									+			
Lembadion bullinum (Mueller, 1786)			+					+				
Lembadion lucens (Maskell, 1887)									+			
Lembadion sp.									+			
Leptopharynx costatus Mermod, 1914		+										
Litonotus alpestris Foissner, 1978	+		+	+		+	+	+	+			
Litonotus crystallinus (Vuxanovici, 1960)			+									
Litonotus cygnus (Mueller, 1773)	+		+			+	+	+			+	
Litonotus fusidens (Kahl, 1926)							+					
Litonotus lamella (Mueller, 1773)							+	+	+			+
Litonotus varsaviensis (Wrzesniowski, 1866)		+				+	+					
Loxocephalus elipticus Kahl, 1931			+	+				+				
Loxocephalus luridus Eberhard, 1862			+									
Loxophyllum helus (Stokes, 1884)								+				
Loxophyllum meleagris (Mueller, 1773)	+											
Loxophyllum sp.			+									
Mesodinium acarus Stein, 1867								+	+			
Mesodinium pulex (Claparéde et Lachmann, 1859)			+	+		+		+	+			
Microthorax simulans (Kahl, 1926)							+					
Monilicaryon monilatus (Stokes, 1886)								+				
Nassula picta Greeff, 1888						+			+			
Ophryoglena sp.		+									+	
Ophryoglena utricularie Kahl, 1931			+									
Opisthonecta henneguyi Fauré-Fremiet, 1906						+						
Oxytricha setigera Stokes, 1891		+						+	+			
Oxytricha similis Engelmann, 1862	+			+	+		+		+		+	
Oxytricha sp.	+											
Paracolpidium truncatum (Stokes, 1885)			+	+	+			+	+	+		+
Paramecium aurelia komplex								+				
Paramecium bursaria (Ehrenberg, 1831)									+			
Paramecium caudatum Ehrenber, 1833									+			
Paramecium putrinum Claparéde at Lachmann, 1859									+			
Phialina jankowski Foissner, 1984			+									
Phialina pupula (Mueller, 1786)						+						
Phialina sp.										+		
Philasterides armatus (Kahl, 1926)							+		+		+	
Placus luciae (Kahl, 1926)				+		+						
Platyophrya spumacola Kahl, 1927			+		+					+		
Platyophrya vorax Kahl, 1926					+		+		+		+	+

Tab. 5.1 List of ciliated protozoa (Ciliophora) taxa in some localities of NP Poloniny.

	sampling site											
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Zbo	Uli	Kam1	Kam2	Kam3
Pleuronema coronatum Kent, 1881			+					+	+			
Pleuronema crassum Dujardin, 1841							+					
Pleuronema sp. (*setigerum* ?)			+									
Pseudoblepharisma crassum Kahl, 1927							+					
Pseudocohnilembus pusillus (Quennerstedt, 1869)		+				+			+			
Pseudochilodonopsis algivora (Kahl, 1931)								+	+			
Pseudochilodonopsis caudata (Perty, 1852)								+				
Pseudochilodonopsis fluviatilis Foissner, 1988	+											
Pseudochilodonopsis piscatoris (Blochmann, 1895)	+							+				
Pseudochilodonopsis polyvacuolata Foissner et Didier, 1981	+							+		+		
Pseudochilodonopsis sp.							+					
*Pseudochlamydonella rheophila B*uitkamp, Song, Wilbert, 1989	+									+		
Rubrioxytricha ferruginea (Stein, 1859)					+				+			
Spathidium cithara Penard, 1922						+						
Spathidium sp.										+		
Spirostomum ambiguum (Mueller, 1786)									+			
Spirostomum minus Roux, 1901	+											
Stegochilum schoenborni Foissner, 1986												
Stentor muelleri Ehrenberg, 1831								+	+			
Stentor roeselii Ehrenberg, 1835		+										
Sterkiella histriomuscorum (Foiss., Blatt., Berg., Kohm. 1991)		+										
Strobilidium caudatum (Fromentel, 1876)		+	+									
Limnostrobilidium viride (Stein, 1867)			+						+			
Stegochilum sp.												+
Stylonychia mytilus Komplex								+	+			
Stylonychia stylomuscorum (Foiss. Blatt. Berg. Kohm., 1991)					+	+						
Tachysoma pellionellum (Mueller, 1773)	+	+	+	+	+	+		+	+			+
Tetrahymena pyriformis Komplex	+				+				+			
Tetrahymena rostrata (Kahl, 1926)							+	+	+	+		
Thigmogaster nanus Song et Wilbert, 1989							+	+		+		+
Thigmogaster oppositevacuolatus Augustin et Foissner, 1989	+											
Trachelophyllum apiculatum (Perty, 1852)								+				
Tracheloraphis sp.	+											
Trithigmostoma cucullulus (Mueller, 1786)								+	+			
Trithigmostoma steini (Blochmann, 1895)	+			+								
Trochilia minuta (Roux, 1899)	+	+	+	+	+	+	+	+	+			+
Trochilioides recta (Kahl, 1928)								+	+			
Uroleptus gallina (Mueller, 1786)								+				
Uronema nigricans (Mueller, 1786)									+			
Urostyla grandis Ehrenberg, 1830									+			
Vorticella spp.							+	+				

6. Interstitial communities

Investigation of the interstitial communities does not have a long tradition in Slovakia. Vranovský (1979, 1982 and 1984) published interstitial and reoseston of the Belá River in the High Tatras. In the framework of investigation of different brooks in Slovakia (Krno et al. 1997, Šporka et al. 1997), interstitial communities in the Poľana Mts. (Illyová & Tomajka 1998) and the High Tatras (Illyová 2001) were also studied. The knowledge of the hyporheos of the East Carpathians brooks has been missing up to date. There were available only data on occurrence of copepods from interstitial of water flows in the Bukovské vrchy Mts. in East Slovakia (Štěrba 1961, 1962, 1964 and 1969).

The aim of our investigation was: a) to establish the species composition of crustaceans in the interstitial communities of the Bukovské vrchy Mts., b) to establish the influence of the longitudinal zonation of brooks on structure of copepod community and overall structure of hyporheos and c) to find out the difference between structure of interstitial of the natural brook (Stužická rieka) and a brook (Hluboký potok) in a deforested river basin.

Altogether one species of Cladocera, *Chydorus sphaericus*, and 20 species of Copepoda: 14 taxa of Harpacticoida and six species of Cyclopoidae were recorded in the interstitial of the studied streams (Tab. 6.1). The dominant species, among Harpacticoids, were *Bryocamptus* (*E.*) *echinatus* (24%) and *Attheyella wierzejskii* (14%), and *Diacyclops languidoides* (10%) among cyclopoids. *Parastenocaris phreatica, Moraria poppei* and *Bathynella* spp. represented the true subterranean fauna. The species composition of copepods (Tab. 6.1) reflected the longitudinal zonation of brooks.

Mountain springs: the highest profile of Hluboký potok with eight species of Harpacticoida and springs of Kamenistý potok (Kam 1) with only three species. Out of the dominant *E. echinatus*, the East Carpathians species *Bryocamptus tarnogradskyi, Bryocamptus* (*Rh.*) *spinulosus occidentalis* and *Bryocamptus* (*Rh.*) *zschokkei caucasicus* occurred in both localities or they even dominated there. The cyclops species were completely absent in the springs (Tab. 6.1). The second group includes the mountain torrents (Ružičková et al. 1996), hence the upstream stretches of metarhitral (800-600 m). A higher number of copepods was recorded in the interstitial of Hluboký potok unlike Stužická rieka, where eight copepod species occurred and where presence of stygobionts (*Parastenocaris phreatica, Moraria poppei* and *Bathynella* spp.) indicated influence of ground waters. The third group consists of habitats situated in the downstream stretches of the metarhitral (>500 m).

The epigean fauna, first of all cyclops (Tab. 6.1) predominated in the interstitial, while the true subterranean fauna was represented by the dominant *Diacyclops languidoides*. Harpacticoids in hyporheos of each brook were represented by one species, viz. *Bryocamptus mrazeki* and *E. echinatus.*

Interstitial community composition

Taxonomic structure and average dominance of hyporheos is represented in Tab. 6.2. Dominance of hyporheal groups (Fig. 6.1) and seasonal dynamics of hyporheos abundance is represented in Figs 6.2-6.4. The average abundance of interstitial fauna, in all 40 samples taken within studied streams, is 3288 ind.m^{-3}. The highest average abundance (8600 ind.m^{-3}) was in the site Hlu1; the lowest one (1485 ind.m^{-3}) in the site Stu2. In general, the crustaceans (33%) predominated in the hyporheos community. The insect larvae (30%), Oligochatea (20%) and other groups (Nematoda, Hydracarina a Tardigrada) formed the rest of the community.

Hluboký potok

Hlu1. The average annual abundance of hyporheos was 8620 ind.m^{-3}, the maximum (14100 ind.m^{-3}) was recorded in September (Fig. 6.2). Larvae of Chironomidae were the most abundant group (3400 ind.m^{-3}) and dominated in the interstitial community (Tab. 6.2). Exclusively Harpacticoida, showing the average annual abundance (1400 ind.m^{-3}), represented crustaceans.

Hlu2. Average abundance of hyporheos was 2220 ind.m^{-3}; the maximum (3600 ind.m^{-3}) was recorded in November (Fig. 6.2). Crustacea, with mean density 1350 ind.m^{-3}, predominated in the interstitial community (Tab. 6.2).

Hlu3. The average abundance of hyporheos was 1932 ind.m^{-3}, the maximum (3850 ind.m^{-3}) was in June (Fig. 6.2). The chironomids reached the highest average abundance (692 ind.m^{-3}). Among other components of the interstitial community either Oligochaeta (450 ind.m^{-3}) or Cyclopoida (488 ind.m^{-3}) reached a relatively high average abundance.

Stužická rieka

Stu1. Average annual abundance of hyporheos was 3155 ind.m^{-3} with a maximum in June (4429 ind.m^{-3}) (Fig. 6.3). At this site, average abundance of the both, Cyclopoids (147 ind.m^{-3}) and harpacticoids (205 ind.m^{-3}) was low. Larvae of Chironomidae were the most abundant group (1057 ind.m^{-3}) in the interstitial community with maximum (2286 ind.m^{-3}) in June 1999. In the cold period, in September, November and April, Oligochaeta predominated.

Stu2. Average abundance of hyporheos was 1465 ind.m^{-3}, the maximum abundance (2829 ind.m^{-3}) was observed in June (Fig. 6.3). Copepods (163

Tab. 6.1 Denstity (ind.l^{-1}) of crustacean fauna in interstitial of brooks of NP Poloniny.

	sampling site								
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	Kam1	Uli	Zbo
Harpacticoida									
Attheyella wierzejskii (Mrázek, 1893)	10	4	1	5		1			
Bryocamptus minutus (Claus, 1863)		1							
Bryocamptus (*Rh.*) *pygmaeus* (Sars, 1863)	4								
Bryocamptus (*Rh.*) *zschokkei zschokkei* (Schmeil, 1893)	9	4			2				
B. (*Rh.*) *zschokkei caucasicus* (Borutzky, 1930)	5								
Bryocamptus (*Rh.*) *typhlops* (Mrázek, 1893)		3							
Bryocamptus spnulosus occidentalis Štěrba, 1934	1						1		
Bryocamptus mrázeki (Minkiewicz, 1916)								2	
Bryocamptus tarnogradskyi Borutzky, 1934	1	2			2		6		
Echinocaptus (*L.*) *echinatus* (Mrázek, 1893)	16	10	2	3	11	5	4		2
Echinocaptus luenensis Kiefer, 1933	3								
Moraria poppei (Mrázek, 1894)						1			
Paracamptus schmeili (Mrázek, 1929)		1			1				
Parastenocaris phreatica Chappuis, 1936			1						
Cyclopoida									
Diacyclops bicuspidatus (Claus 1857)		2						2	
Diacyclops languidoides (Lilljeborg 1901)		1	1					4	2
Diacyclops languidus (Sars 1863)		4		1				1	
Acanthocyclops vernalis (Fischer 1853)								1	1
Eucyclops serrulatus (Fischer 1851)									1
Paracyclops fimbriatus (Fischer 1853)		1							
Cladocera									
Chydorus sphaericus (O.F. Müller, 1785)					1				

ind.m^{-3}) and *Bathynella* gen. sp. (47 ind.m^{-3}) showed a very low average abundance. In the interstitial community, Oligochaeta dominated (27%) followed by larvae of Chironomidae (24%).
Stu3. The average annual density was 3800 ind.m^{-3}; maximum (5200 ind.m^{-3}) was in September (Fig. 6.3). When compared with the two upstream sites, Cyclopoidea (900 ind.m^{-3}) and Harpacticoida (580 ind.m^{-3}) reached the highest abundance. Crustacea also predominated at this site (42%). A relatively

Tab. 6.2 Taxonomic structure and relative density (%) of hyporheos (in period VI.1999 – VIII. 2000) in studied streams of NP Poloniny.

	sampling site							
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	Uli	Zbo
Ostracoda			1		1			1
Cladocera			1		1	1		1
Cyclopidae		39	26	5	11	24	31	39
Harpacticidae	17	22	2	6	11	16	7	7
Bathynellacea			1		3	1		
Ephemeroptera	6	1	2		1	1	5	10
Plecoptera	4	2	1	2	6	2	1	13
Chironomidae	35	18	36	33	24	22	18	11
Ceratopogonidae	1					3		
Simuliidae					1	1		
Nematoda	21	9	7	26	14	6	4	5
Oligochaeta	16	9	23	28	27	23	34	13

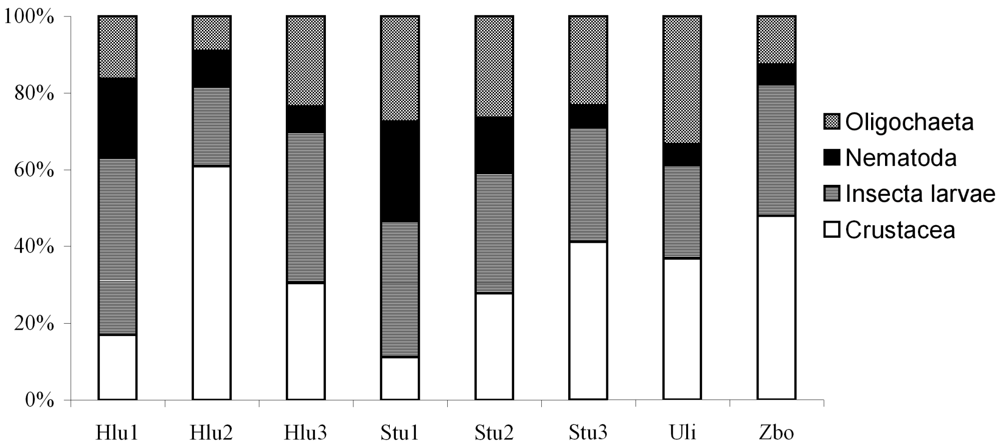

Fig. 6.1 Dominance of hyporheal groups at the sampling sites in NP Poloniny..

high abundance of cyclopoids (2000 ind.m^{-3}) was recorded in autumn 1999, but in 2000 their abundance decreased to 0-200 ind.m^{-3}.

Ulička
The average annual abundance of hyporheos was 3023 ind.m^{-3} with a maximum in November (5800 ind.m^{-3}) (Fig. 6.4). The cyclopoids reached a relatively high abundance in 1999 (1223 ind.m^{-3}). Due to this, the interstitial community was predominated by crustaceans (40%). Among the insect larvae, the chironomids showed a high abundance (1286 ind.m^{-3}) in June. When compared with other brooks studied, the interstitial communities of Ulička were characterised by high representation of Oligochaeta (Tab. 6.2).

Zbojský potok
The average annual abundance of hyporheos was 2020 ind.m^{-3} with a maximum in June (4800 ind.m^{-3}) (Fig. 6.4). Similarly as in the Ulička brook, the Cyclopida reached the highest average abundance (580 ind.m^{-3}), while dominance of all crustaceans was 48%. Among other groups, the larvae of Plecoptera predominated in June, while Oligochaeta in September.
Harpacticoid fauna of the brooks in the Bukovské vrchy Mts. was characterised by a high number of species recorded. The similar number of species (12 spp.) was recorded in the East Carpathians by Štěrba (1961, 1969).
We also confirmed occurrence of *Bryocamptus* (*Rheocamptus*) *spinulosus v. occidentalis* and *Bryocamptus tarnogradskyi.* The first species is a variety of the Caucasian species *B.* (*Rh.*) *spinulosus* that was recorded in Slovakia for the first time by Štěrba (1961) in the brook sediments in East Slovakia. *Bryocamptus tarnogradskyi* was originally discovered in Caucasus (Boruckiy 1952). In Slovakia it was recorded for the first time in brooks of the Vihorlat Mountains by Štěrba (1969). Conform to Štěrba (1969), this species occurred in all sites studied being situated above the altitude of 500 m. This also confirms with Štěrba (1969) opinion that this species does not penetrate to the lower altitudes. The harpacticoid *Bryocamptus* (*Rh.*) *spinulosus* var. *occidentalis* was observed only in the spring of the Kamenistý potok brook at the altitude of 900 m. However Štěrba (1969) and Vranovský (1979) also found it relatively abundantly at lower altitudes.
The area of the Bukovské vrchy Mts. has a cold or moderately cold climate. Due to it, the alpine species *Atteyella* (*A.*) *wierzejskii* distributed in mountain areas of West Europe and in cold waters (Borutzky 1952) predominated here. The fauna in the East Carpathians differed to that of the High Tatras by absence of the boreoalpine species *Bryocamptus* (*A.*) *cuspidatus* predominating in the brooks of High Tatras (Vranovský 1982, Illyová 2001).
Copepods fauna reflected the longitudinal zonation of brooks. In the upstream profiles, particularly the stygophilous harpacticoids like *A.* (*A.)* *wierzejskii* and *B. tarnogradskyi* and stygobionts *Bathynella* spp., *Parastenocaris phreatica* and *Moraria poppei* occurred. In the more downstream profiles, the representatives of the epigean crustaceans, mainly Cyclopoida predominated. This is also in accordance with our results from the brooks of the Poľana Mts. (Illyová & Tomajka 1998), where the abundance of hypogean crustaceans decreased in the brooks at a lower altitude (425 m) whereas that of the epigean Crustacea increased.
Cumulative abundance species of interstitial communities also reflected the longitudinal zonation of the brooks. The highest abundance of hyporheos was recorded in the spring of Hlboký potok. It could be caused by permanently low discharges of 12.6 l.s^{-1}. Kubíček (1978, 1986) studied influence of minimum discharges on changes in structure and dynamics of the benthic communities. He stated that about 1/3 more organisms from the bottom surface occurred in the interstitial with minimum discharge (Q_{364}) than in the control. In addition, the spring of Hlboký potok was rich in benthos, organic material, as well as periphyton, which could secondarily influence colonisation of the intersti-

tial. Except of the brook spring mentioned above, the natural character or deforestation of the water basin had a minor influence on the qualitative structure and abundance of the hyporheal than, for example, the abundance of insect larvae (e.g mayflies).

As it was already stated above, the average abundance of hyporheos in the brooks of the East Carpathians was low (3288 ind. m^{-3}). A similarly low abundance was also recorded in the hyporheos of the brooks of the Poľana Mts. (Illyová & Tomajka 1998) as well as in the mountain brooks of the High Tatras (2056 ind.m^{-3}). These values were considerably lower than those found in the hyporheos of mountain and submontane brooks studied by other authors. In the interstitial of Belá brook, Vranovský (1982) found the average abundance of hyporheos of 56000 ind.m^{-3}. This value is 17 times higher than the average value found out in the brooks of the Bukovské vrchy Mts. In Hučivá Desná brook, Tuša (1988) found the average abundance of 19175.1 ind.m^{2} that is also much higher than the average abundance of hyporheos of the brooks in the Bukovské vrchy Mts. In addition, Tuša (1988) stated, that abundance of hyporheos in the studied stretch of Hučivá Desná was lower than the values given by Williams & Hynes (1974) and Bretschko (1991) who found the hyporheos abundance reaching about 100 000 ind.m^{2}. These quantitative differences may be caused by different conditions in the water flows compared and by the sampling methods. Tuša (1988) took samples by a standpipe which forcing into the bottom did not last more than one minute. Bretschko (1991) used the N_2 Freeze Core method, in which the momentary interstitial community becomes frozen within several seconds. For comparison, digging of holes in our case lasted about 15 minutes. Therefore it is possible that a part of the individuals escaped earlier than the sample was taken. It is also possible that the authors cited above took the samples of the interstitial fauna directly from the brook bottom, where a higher abundance can be expected than in the interstitial of the banks, where we took the samples. Marmonier (1991) also stated that when the sampling stations were in contact with the river channel, species richness was high because there was a high rate of surface water infiltration.

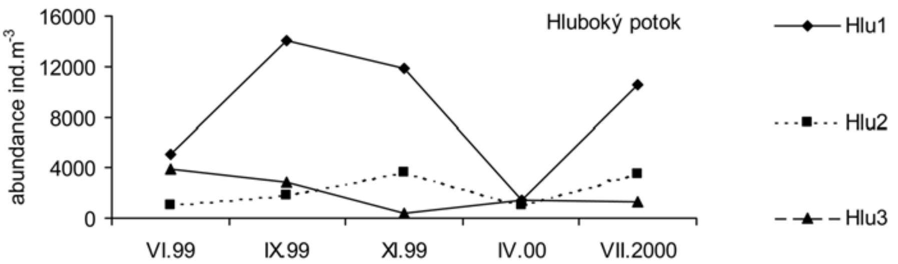

Fig. 6.2 Seasonal dynamics of abundance of hyporheos at sampling sites of the Hluboký potok.

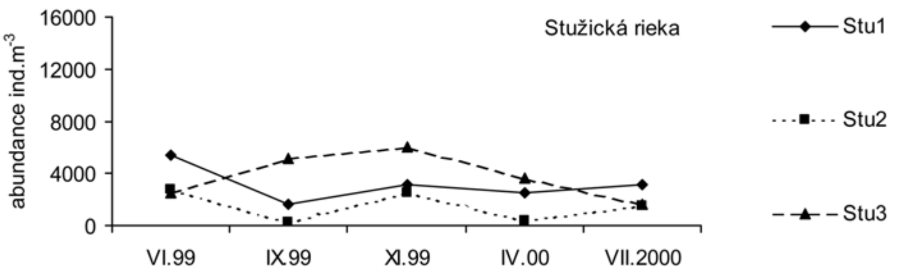

Fig. 6.3 Seasonal dynamics of abundance of hyporheos at sampling sites of the Stužická rieka.

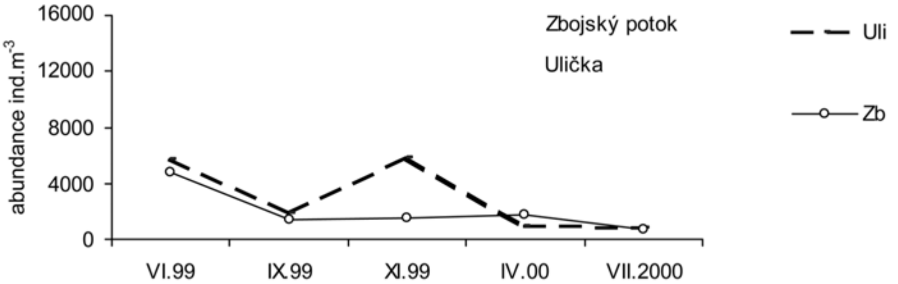

Fig. 6.4 Seasonal dynamics of abundance of hyporheos at sampling sites of the Zbojský potok and Ulička.

7. Permanent macroinvertebrte fauna

Streams draining the northeaster corner of Slovakia, in the Bukovské Vrchy Mts., belong to the Uh river catchments area. Permanent components of the benthic fauna living in these streams have not been studied with sufficient attention until the present. The first faunistical data have been published by Straškraba (1962), who dealt with amphipods and identified material for prof. Hrabě. Later, the permanent fauna in that area was studied by Obrdlík (1981), Šporka (1982), Bastl & Šporka (1986), Bitušík & Novikmec (1997) and Brtek (2001). Their papers are oriented faunistically.

The aim of our study was to obtain more detailed data about the structure of the permanent fauna in the streams of this area and to obtain the first data concerning the abundance and density of permanent fauna in two streams: Hluboký potok and Stužická rieka.

The permanent fauna of the investigated streams was represented by 20 taxa. Oligochaeta showed the highest species diversity with 11 taxa. Amphipods were represented by 3 taxa, Turbellaria by 2 taxa, Hirundinea and Mollusca by 1 taxon each (Tab. 7.1).

Turbellaria and Gastropoda

Among Turbellaria, only 2 species were recorded, as well as among Gastropoda. *Crenobia alpina* and *Bythinella austriaca* occurred in the upstream stretches of both streams, while *Dugesia gonocephala* and *Ancylus fluviatilis* occured in the downstream stretches.

Oligochaeta

In the studied stretches, Oligochaeta reached the highest species diversity. Among the recorded species, *Stylodrilus brachystylus* (Lumbriculidae) showed the largest density and together with representatives of the genus *Fridericia* (Enchytraeidae) they occurred in the largest number of streams. Species of the Naididae family were not well represented. The immature individuals of *Rhynchelmis* sp. found in Hluboký potok and Stužická rieka could belong to the species *Rhynchelmis vejdovskyii,* which has not been recorded in Slovakia until now. This species was originally described by Hrabě & Černosvitov (1926) in the samples from Ruthenian mountain (Ukraine) tributaries mouthing into the Biela Tisa river and in Terešva streamlet (a tributary of the Tisa river). Both of these streams are known to have similar characteristics as those from the present study. Except of Obrdlík (1981), who recorded *Haplotaxis gordioides* in streams Stužická rieka and Ruský potok brook, this area was only studied by Šporka (1982), who paid attention to Ublianka river near Ubľa village.

Hirudinea

Among the Hirundinea, only *Trochaeta bykowskii* was present in the studied streams. It occurred from the spring areas up to the downstream stretches of the streams Hluboký potok, Stužická rieka and Kamenistý potok. According to Košel (2004) the name *Trochaeta bykowskii* is considered to be a junior synonym of *Trochaeta cylindrica* Örley, 1886.

Amphipoda

Amphipoda were represented in the studied catchments by species like *Gammarus leopoliensis* and *Gammarus balcanicus,* which took a dominant position. Occurrence of *Gammarus kischineffensis* mentioned by Straškraba (1962) in Nová Sedlica and by Obrdlík (1981) in Stužická rieka, Ulička and Ubľanka and by Bitušík & Novikmec (1997) in stream Zbojský potok was not confirmed in our study. This allows us to state that their material was incorrectly identified. Our present opinion is supported by Jażdżewski & Konopacka (1989) work, which described species *Gammarus leopoliensis*. As Jażdżewski & Konopacka (1989) state further, the *Gammarus kischineffensis* occurs near Kishinau, in the Dniester River and in some lakes in Romania. Occurrence of *Gammarus leopolensis* in the Uh river catchments area was also mentioned by Brtek (2001), but distributional area of *Gammarus kischineffensis* lays southeasterly of Slovakia, in the northeaster part of Romania, Besarabia and in the southwester corner of Ukraine. Among amphipods, a new record for Slovak fauna was the finding of *Niphargus molnari*, which occurred in the streams Hluboký potok and Stužická rieka.

Catchment of Ulička

In Hluboký potok, the permanent fauna was represented by 6 groups of the benthic fauna (Tab. 7.2). Amphipods were represented by *Gammarus balcanicus*, *Gammarus leopoliensis* and *Niphargus molnari*. Among Oligochaeta, *Stylodrilus brachystylus* predominated. A new species in that area is the leech *Trochaeta bykowskii* in the sampling site Hlu3.

The highest average density was recorded in Amphopoda and Oligochatea. A high density of the permanent fauna was recorded in the sampling site Hlu1, while a much lower density was found in the sampling site Hlu2 and a much higher density in the sampling site Hlu3 (Tab. 7.2).

In both sampling sites of Ulička (Ulička below Topoľa and Kolbasov villages) only *Gammarus leopoliensis* represented the amphipods. Other taxa are given in Tab. 7.1. In Zbojský potok upstream of Uličské Krivé village the species *Stylodrilus heringianus* was recorded. In other streams it did not occur.

Tab. 7.1 List of permanent fauna taxa present in the investigated streams of the East Carpathians.

	sampling site											
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	Kam1	Kam2	Zbo	Uli	Ubl1	Bys
Nematoda g.sp.	+											
Mermithidae g.sp.	+		+									
Turbellaria												
Crenobia alpina (Dana, 1766)	+			+			+			+		
Dugesia gonocephala Duges, 1830		+	+		+	+	+	+				+
Oligochaeta												
Nais alpina Sperber, 1948			+									
Nais bretscheri Michaelsen, 1899									+		+	
Nais variabilis Piguet, 1906			+						+		+	
Nais stolci Hrabě, 1981										+	+	
Rhyacodrilus coccineus (Vejdovský, 1875)		+	+							+	+	
Tubifex ignotus (Štolc, 1886)											+	
Stylodrilus heringianus Claparède, 1862									+			
Stylodrilus brachystylus Hrabě, 1929	+	+	+	+	+	+	+	+	+		+	+
Rhynchelmis vejdovskyi Hrabě & Černosvitov, 1926		+				+						
Proppapus volki Michaelsen, 1916									+		+	
Cognettia sphagnetorum (Vejdovsky, 1877)	+			+		+						
Mesenchytraeus armatus (Levinsen, 1884)							+					
Fridericia sp.	+	+	+	+	+	+	+			+		
Enchytraeidae g.sp.	+	+				+			+		+	
Haplotaxis gordioides (Hartmann, 1821)	+	+	+	+	+	+						
Eiseniella tetraedra (Savigny, 1826)	+		+		+	+						
Hirudinea												
Trochaeta bykowskii Gedroyc, 1913			+	+		+	+					
Mollusca												
Ancylus fluviatilis									+			
Bythinella austriaca (Frauenfeld, 1857)	+	+		+	+		+					
Amphipoda												
Gammarus balcanicus (Schäferna, 1922)	+	+		+	+	+	+				+	
Gammarus leopoliensis (Jażdżewski & Konopacka, 1989)		+	+	+	+	+		+	+	+	+	
Niphargus molnari (Mehely, 1927)	+			+	+	+						

Tab. 7.2 Average density (ind.m^{-2}) of permanent fauna from investigated streams of the East Carpathians from 6 samples between 1999 and 2000.

	sampling site					
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Nematoda g.sp.	16					
Mermithidae g.sp.	5		6			
Turbellaria						
Crenobia alpina (Dana, 1766)	38			2		
Dugesia gonocephala Duges, 1830		3	11		1	12
Oligochaeta						
Nais alpina Sperber, 1948			1			
Nais variabilis Piguet, 1906			4			
Rhyacodrilus coccineus (Vejdovský, 1875)		1	2			
Stylodrilus brachystylus Hrabě, 1929	468	10	9	225	36	77
Rhynchelmis vejdovskyi Hrabě & Černosvitov, 1926		1				1
Cognettia sphagnetorum (Vejdovsky, 1877)	9			9		1
Fridericia sp.	17	1	2	9	2	1
Enchytraeidae g.sp.	6	1				2
Haplotaxis gordioides (Hartmann, 1821)	167	25	9	125	35	139
Eiseniella tetraedra (Savigny, 1826)	2		2		1	2
Hirudinea						
Trochaeta bykowskii Gedroyc, 1913			1	5		3
Mollusca						
Bythinella austriaca (Frauenfeld, 1857)	5	1		11	5	
Amphipoda						
Gammarus balcanicus (Schäferna, 1922)	1974	1		173	2	6
Gammarus leopoliensis (Jaždewski & Konopacka, 1989)		553	2814	306	884	1044
Niphargus molnari (Mehely, 1927)	6			8	8	1
Density total	2712	598	2860	871	975	1288

Catchment of Stužická rieka

In Stužická rieka, the permanent fauna was represented by 5 benthic groups (Tab. 7.2). The highest density occurred for Amphipoda and Oligochaeta. Among Oligochatea, *Stylodrilus brachystylus* and *Haplotaxis gordioides* were dominant species. Hirundinea were represented by *Trochaeta bykowskyi.* This species also occurred in the sampling site situated at the highest altitude, together with the turbellarian *Crenobia alpina* and the mollusc *Bythinella austriaca.* Density of the permanent fauna increased proportionally with decreasing altitude. The highest density was recorded in Amphipoda (particularly *Gammarus leopoliensis).* The lowest density was recorded in *Stylodrilus brachystylus* and *Haplotaxis gordioides* (Oligochatea). Structure of the permanent fauna in Kamenistý potok was identical to Stužická rieka. In addition, *Nais variabilis* (Tab. 7.1) was recorded in the downstream sampling site.

Catchment of Ublianka

In this catchment, samplings were made only in Ublianka upstream of the Havešová village (Ubl1). In total, 10 taxa were recorded (Tab. 7.1). Both *Gammarus* species (*Gammarus balcanicus* and *Gammarus leopoliensis*) were present, while *Tubifex ignotus* was observed only in this sampling site.

Catchment of Cirocha

In the stream Bystrá (Bys) only two taxa were recorded (Tab. 7.1).

In the Hluboký potok and Stužická rieka, where sampling was carried out more frequently, no significant differences between the permanent fauna were recorded. Number of taxa recorded in Hluboký potok reached 10-12 taxa and was 9-12 in the Stužická rieka. In both streams, the vertical zonation of Turbellaria and Amphipoda was observed. In the upstreams sampling sites, *Crenobia alpina* and *Gammarus balcanicus* were present, while in the downstream sampling sites they were replaced by *Dugesia gonocephala* and *Gammarus leopoliensis*. The highest density was recorded in the species of genus *Gammarus (G. balcanicus* and *G. leopoliensis*). The highest density was reached by the oligochaetes *Stylodrilus brachystylus* and *Haplotaxis gordioides*. Tubificidae were represented by the only species *Rhyacodrilus coccineus* and, in addition, occurred only in Hluboký potok. Enchytraeidae and Naiidae also manifested a poor representation in spite of the fact that usually both these families belong to the quantitatively and qualitatively predominant components of mountain streams. The low quantitative representation of Naididae could be a consequence of a low algal growth (periphyton), which is not only the best substrate for Naididae, but also the best food. A relationship between the quantity of phytobentos and the density of representatives of Naididae was observed in Turiec River (Šporka 1996). The little development of algae in Hluboký potok and in two upstream sampling sites of Stužická rieka was caused by the shadow of their riverbed and by the suspended inorganic particles present after rain. This is a typical phenomenon for streams of the flysch zone.

8. Mayflies (Ephemeroptera)

Poloniny National Park is an important protected area in SE Slovakia. The mayfly fauna of the Poloniny National Park and Bukovské vrchy Mts. is only little known. Obrdlík (1981) reported 15 mayfly species from catchments of Ubľanka, Ulička and Stužická rieka. Landa (1969) and Landa & Soldán (1989) mentioned faunistic data from various localities. The most important faunistic data published Deván (1992). He sampled 13 localities in Stružnica, Cirocha and Udava rivers, where he found 33 mayfly species. Bitušík & Novikmec (1997) studied the structure of macrozoobenthos communities of the Zbojský potok. They recorded 20 mayfly species; one of them was East Carpathians endemite for the first time reported from Slovakia (Novikmec & Krno 1998). The Polish side of the studied mountains was investigated by Kukula (1991). He sampled 15 localities in the catchment of the Wolosatka river. An overwiev of articles of Polish authors concerning zoobenthos at Polish side of the Poloniny was made by Kłonowska-Olejnik (2000).

The study had two aims. The first was to explore little known mayfly fauna at the area of the Poloniny National Park and describe mayfly communities of selected streams. The second aim was to study the impact of forest cutting on the mayfly communities. For this purpose, we have calculated ecological indices and we have performed multivariate analyses.

Shannon index of species diversity and eveness were counted on the basis of number of individuals of species using the natural logarithm. Cluster analysis with the clustering method complete linkage and Wishart's index of similarity was used in order to compare the mayfly communities at eight study sites. The association of mayfly species to particular study sites was ascertained using the ordination method of correspondence analysis (CA). Dominance values of mayfly species were used for both analyses.

Twenty mayfly species were recorded at the studied localities (Tab. 8.1, 8.2). No significant differences in species composition and communities' structure between streams were observed (Fig. 8.1, 8.2). The species richness values increase along booth streams except locality Stu2, where a decrease in comparison with localities Stu1 and Stu1* was observed. Communities of spring streams (sampling sites Hlu1, Kam1) are similar at both streams and are hereby clearly different from other communities (Fig. 8.1, 8.2). East Carpathian endemic species *R. gorganica* dominates in springs. It represents till 86% of individuals at sampling site Hlu1. Only four species were recorded at Hlu1, while eight species were recorded at sampling site Kam1, where *R. gorganica* represents 36% of all individuals. Codominants are *B. alpinus* and *B. rhodani* (Tab. 8.2). Remaining localities have different species composition, which is apparent from their separation into independent cluster (Fig. 8.1). It can be divided into two subgroups, each with communities from both, reference and disturbed streams. Dominant species are *B. alpinus, B. rhodani, H. confusa, R. iridina* and *R. carpatoalpina.*

Species from the *Ecdyonurus helveticus* - group were recorded at all localities. However, only *E. subalpinus* and *E. picteti* could be identified. Besides *E. subalpinus* and *E. picteti*, nymphs from genus *Ecdyonurus* idetified as *Ecdyonurus* cf. *austriacus* were captured. They probably belong to a new undescribed species. Unfortunately, adults were not captured. Without adult individuals it is not possible to identify the material collected.

Species richness, diversity, evenness and mean density values increase along the stream in Hluboký potok, while in Stužica similar pattern was observed only for mean density values (Tab. 8.1). The higher species diversity was recorded at sampling site Hlu3, the lowest ones at sampling site Hlu1. Total number of species collected in catchments is similar, 16 spp. in Hluboký potok and 18 spp. in Stužická rieka catchment.

We did not record striking differences between mayfly communities of reference and influenced streams. The statistical analyses showed more similarity between communities in similar stream types, regardless of reference or influenced conditions, than between different communities in the same stream (Figs. 8.1, 8.2). Thus, the assumption that from the comparison of localities at reference and influenced streams of similar character we could assess the forest cutting influence was not confirmed. This result could have two explanations. Firstly, the reference and influenced streams are not exactly comparable. Influenced stream probably had been naturally different from reference stream before the logging impact. Moreover, it is difficult to find exactly corresponding reference locality for selected influenced localities. The second reason could be the fact, that mayflies are not so sensitive group as for example stoneflies, which are particularly susceptible to environmental changes, and thus very suitable for detection of initial changes in the real centers of biodiversity, e. g. mountain regions (Soldán et al. 1998).

The sensitivity of stoneflies was confirmed in studied streams by finding higher abundances of families Perlidae, Chloroperlidae and Taeniopterygidae at reference localities, while ecologically more plastic families Perlodidae and Leuctridae prevailed at influenced localities. However, we found some differences between reference and disturbed streams. It is, however, not certain whether the differences could be assigned to logging influence or

Tab. 8.1 Abundance, species richness, diversity, eveness and mean density of mayflies collected at 8 sample sites.

		sampling site							
species	code	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Kam1
Baetis alpinus (Pictet, 1843)	Bae alp	12	87	16	6	35	7	51	21
Baetis melanonyx (Pictet, 1843)	Bae mel	0	6	11	0	2	0	1	2
Baetis rhodani (Pictet, 1843)	Bae rho	0	158	20	42	42	6	49	14
Baetis vernus Curtis, 1843	Bae ver	0	0	0	0	0	0	1	5
Baetis (Alainites) muticus (Linnaeus, 1758)	Ala mut	0	2	0	1	0	0	16	0
Ecdyonurus macani Thomas et Sowa, 1970	Ecd mac	0	0	1	0	0	0	1	0
Ecdyonurus picteti (Meyer-Dur, 1864)	Ecd pic	0	2	0	0	0	0	0	0
Ecdyonurus subalpinus Klapálek, 1905	Ecd sub	4	7	0	10	0	0	0	2
Ecdyonurus torrentis Kimmins, 1842	Ecd tor	0	0	0	0	0	0	1	0
Ecdyonurus venosus (Fabricius, 1775)	Ecd ven	0	0	0	0	0	1	1	0
Ecdyonurus cf. *austriacus*	Ecd cf.p	0	1	0	0	11	0	1	3
Ecdyonurus helveticus gr. juv.	Ecd h.gr	1	20	29	30	13	3	6	3
Ecdyonurus sp. juv.		0	0	0	0	0	0	1	0
Epeorus assimilis Eaton, 1885	Epe syl	0	0	19	21	1	7	42	0
Rhithrogena carpatoalpina Klonowska et al., 1984	Rhi car	0	93	56	14	28	4	5	0
Rhitrogena gorganica Klapálek, 1907	Rhi gor	132	2	4	17	53	0	1	29
Rhitrogena iridina (Kolenati, 1859)	Rhi iri	0	211	38	120	79	43	245	0
Rhitrogena semicolorata (Curtis, 1834)	Rhi sem	0	0	0	1	0	0	1	0
Rhithrogena carpatoalpina gr. juv.	Rhi c.gr	4	240	478	30	24	120	61	1
Ephemerella mucronata (Bengtsson, 1909)	Eph muc	0	0	23	0	0	0	2	0
Seratella ignita (Poda, 1761)	Ser ign	0	0	34	0	0	0	4	0
Habroleptoides confusa Sartori et Jacob, 1986	Hab noc	0	19	89	0	0	32	68	0
Ephemera danica Linnaeus, 1758	Eph dan	0	0	4	0	0	0	0	0
Total number of individuals		153	848	822	292	288	223	558	80
Species richness		4	11	13	9	8	8	17	8
Shannon diversity		0.51	1.57	2.21	1.51	1.71	1.53	1.62	1.58
Evenness		0.37	0.66	0.86	0.69	0.82	0.74	0.57	0.76
Mean density (ind.m^{-2})		75	263	612	-	200	222	385	-

not. The spring streams in Stužická rieka catchment showed two times higher species richness values (Tab. 8.2). It is probably due to different character of spring streams, which are shallower and wider. It cause higher water temperature in summer (Tab. 8.1) and penetration of species typical for submontane streams, e.g. *B. vernus*, *E. assimilis*, *R. carptoalpina.* According to Soldán et al. (1998) larvae of *E. assimilis* are not found in smaller streams of epirhithral; however it is not true in the Stužická rieka catchment. It is evident for localities Stu1 and Stu3, which have identical maximum water temperature (see Research area characteristics) and dominant species. Other reasons for higher species richness values could be higher microhabitat diversity in wider stream and lower hydrological stress in forested catchment with higher water retention capacity. Higher abundance values of *E. helveticus* group representatives were found in Stužická rieka catchment (Tab. 8.2). They occur in more conservative environment of spring streams and mountain streams (Hefti et al. 1989). We can conclude that our results did not support expectations about great impact of forest cutting on the mayfly communities.

Almost all species we recorded had been recorded previously by Bitušík & Novikmec (1997). Communities described by Deván (1992) are similar to the communities we found at the study localities. However, some species new for the studied area were recorded, e.g. *Ecdyonurus macani*. Noticeable are the findings of nymphs from *E. helveticus* group, determined as *Ecdyonurus* cf. *austriacus.* They probably belong to a new undescribed species. Similar problem published Kukula (1991) and Svitok (2006). Kukula (1991) found two species from the *E. helveticus* group at the Polish side of the Bukovské vrchy Mts. that, according to his opinion, belonged to the undescribed species. Svitok (2006) recorded *E. austriacus* – like larvae from the Zubrovica stream (Nízke Tatry Mts., Slovakia). He supposed that, according to the great intraspecifc

Tab. 8.2 Dominance (%) of mayfly species collected at 8 sample sites.

	sampling site							
species	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Kam1
Baetis alpinus (Pictet, 1843)	7.8	10.3	1.9	2.1	12.2	3.1	9.1	26.3
Baetis melanonyx (Pictet, 1843)	0.0	0.7	1.3	0.0	0.7	0.0	0.2	2.5
Baetis rhodani (Pictet, 1843)	0.0	18.6	2.4	14.4	14.6	2.7	8.8	17.5
Beatis vernus Curtis, 1843	0.0	0.0	0.0	0.0	0.0	0.0	0.2	6.3
Baetis muticus (Linnaeus, 1758)	0.0	0.2	0.0	0.3	0.0	0.0	2.9	0.0
Ecdyonurus macani Thomas et Sowa, 1970	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0
Ecdyonurus picteti (Meyer-Dur, 1864)	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Ecdyonurus subalpinus Klapálek, 1905	2.6	0.8	0.0	3.4	0.0	0.0	0.0	2.5
Ecdyonurus torrentis Kimmins, 1842	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Ecdyonurus venosus (Fabricius, 1775)	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0
Ecdyonurus cf. austriacus	0.0	0.1	0.0	0.0	3.8	0.0	0.2	3.8
Ecdyonurus helveticus gr. juv.	0.7	2.4	3.5	10.3	4.5	1.3	1.1	3.8
Epeorus assimilis Eaton, 1885	0.0	0.0	2.3	7.2	0.3	3.1	7.5	0.0
Rhithrogena carpatoalpina Klonowska et al., 1984	0.0	11.0	6.8	4.8	9.7	1.8	0.9	0.0
Rhitrogena gorganica Klapálek, 1907	86.3	0.2	0.5	5.8	18.4	0.0	0.2	36.3
Rhitrogena iridina (Kolenati, 1859)	0.0	24.9	4.6	41.1	27.4	19.3	43.9	0.0
Rhitrogena semicolorata (Curtis, 1834)	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0
Rhithrogena carpatoalpina gr. juv.	2.6	28.3	58.2	10.3	8.3	53.8	10.9	1.3
Ephemerella mucronata (Bengtsson, 1909)	0.0	0.0	2.8	0.0	0.0	0.0	0.4	0.0
Seratella ignita (Poda, 1761)	0.0	0.0	4.1	0.0	0.0	0.0	0.7	0.0
Habroleptoides confusa Sartori et Jacob, 1986	0.0	2.2	10.8	0.0	0.0	14.3	12.2	0.0
Ephemera danica Linnaeus, 1758	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0

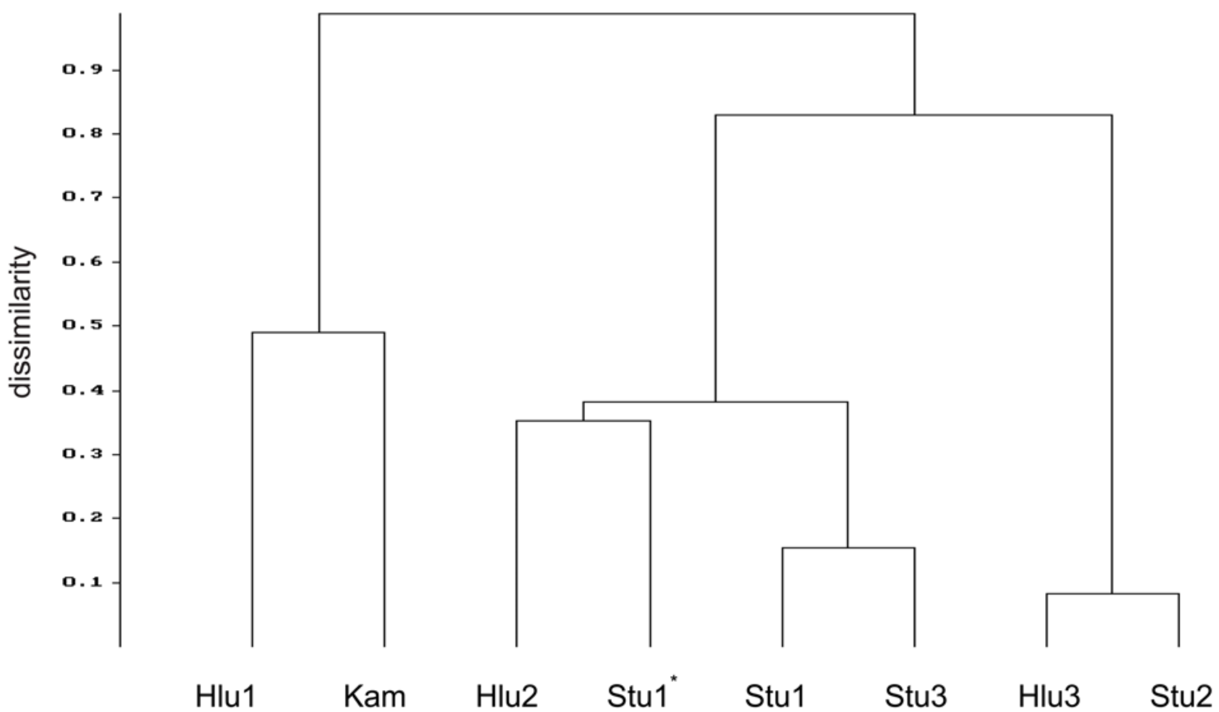

Fig. 8.1 Classification of the eight mayfly communities based on the dominance of species (complete linkage clustering method, Wishart's index of similarity; vertical axis = dissimilarity level).

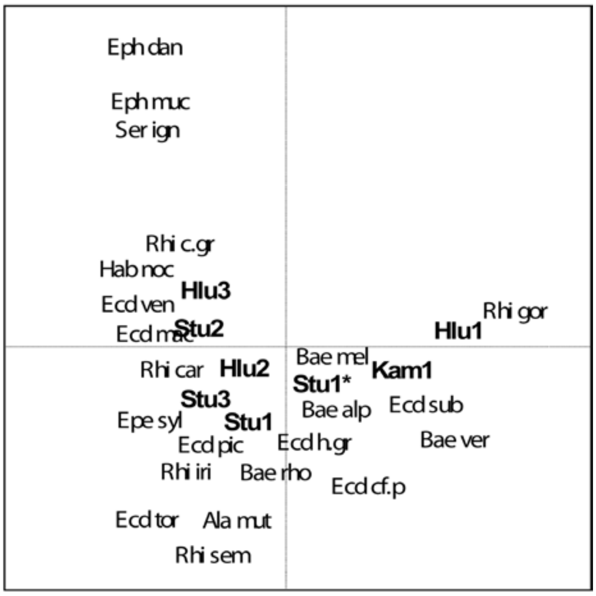

Fig. 8.2 First two axes of CA as a biplot of mayfly species and localities. The first two ordination axes (λ_1 = 0.644 and λ_2 = 0.275) accounted for 74.0 % of the total variance of the species data. See Tab. 8.1 for codes of species.

morphological variability of the species belonging to the *E. helveticus* group, presence of more new species and/or subspecies could be expected in the Carpathians.

Another rare species is *Rhithrogena gorganica*, for the first time published from Slovakia by Bitušík & Novikmec (1997) and Novikmec & Krno (1998). This East Carpathian endemit was known only from one locality in Slovakia. Our observations indicate that this species inhabits spring streams and epirhithral reaches of the East Carpathian streams. Findings of *Rhithrogena alpestris* published by Obrdlík (1981) were probably misidentified nymphs of *R. gorganica*. Kukula (1991) reported *R. gorganica* from similar localities in Wolosatka catchment. We did not find *Rhithrogena wolosatkae*, which was described from streams at northern slopes of Bukovské vrchy Mts. (Bieszczady Mts.). *R. wolosatkae* is a member of *R. hybrida* group consisting of species inhabiting cold mountain streams. The different thermal and hydrological regime (higher water temperatures, lower discharges) of streams at southern slopes of the Bukovské vrchy Mts. could be the reason why *R. wolosatkae* is known only from the Polish part. However, more intense faunistic research should be performed for confirmation of presence or absence of this species in Slovakia.

9. Stonefies (Plecoptera)

Published data concerning the occurrence of Plecoptera in the Bukovské vrchy Mts. are only limited to two works published on macrozoobenthos (Obrdlík 1991; Bitušík & Novikmec 1997). The authors altogether recorded 26 species of Plecoptera. More abundant data come from the Polish side of the Bieszczady Mts. The results are summarized by Kittel & Wojtas (1991). The authors recorded 50 species in this territory. The latest literary data from the Bodrog river basin, including the Bukovské vrchy Mts., were recorded by Krno (2002); the author recorded 60 species there.

The study took place in the basin of three streams – Stužická rieka, Ulička and Ublianka.

In addition to macroinvertebrate sampling, imagoes were caught by entomological net in regular intervals. The statistical analysis was based upon the canonical correspondence analysis (Ter Braak & Šmilauer 1998).

Forty species of Plecoptera have been recorded in the river basins under study (Tab. 9.1). The description of larvae is absent in several Eastern Carpathians species. We succeeded in catching and identifying of larvae belonging to species *Nemoura fusca* Kis, 1963, *Protonemura aestiva,* Kis, 1965 (Krno 2004), *Leuctra bronislawi* Sowa, 1966 (Krno & Holova 2005), *Leuctra quadrimaculata* Kis, 1963, *L. carpathica* Kis, 1966.

The longitudinal distribution of Plecoptera in the studied river basins (Fig. 9.1; Tab. 9.1) clearly signals the existence of several habitats:

1. Montane spring areas (Ružičková et al. 1996). These are spring sections of the tributaries of Stužická rieka and Hluboký potok 0.8-2.0 m in width. The temperature there did not exceed 7°C. There are two dominant species; *Isoperla sudetica* and *Protonemura aestiva.* The characteristic species are *Nemoura fusca* and *Leuctra quadrimaculata*. Crenophilous species are the prevailing ones with the exception of *L. autumnalis* and *L. pseudosignifera.* Only a small portion of rhithrophilous species occurs there.

2. A mountain brook (Ružičková et al. 1996) (Stu2). The temperature did not exceed 11°C and the width of a stream ranged from 2.0 to 3.0 m. Plecoptera assemblage is very similar to that of the previous association (Tab. 9.1), however, more rhithrophilous species (*Brachyptera seticornis, Protonemura hrabei, Perla pallida* and *Siphonoperla torrentium transsylvanica*) are present there. Characteristic species are *Protonemura nimborum* and *Leuctra inermis*. The following montane species are characteristic of montane spring areas and montane torrents (985-780 m a.s.l.): *Leuctra armata, L. carpathica, Arcynopteryx compacta* and *Perlodes intricatus.*

3. The other localities can be included among submountain streams (685-235 m a.s.l.) (Ružičková et al. 1996). The only exception is the locality Stu1 (840 m a.s.l.). However, it is a torrent that dries up from time to time in the autumn season and the temperature it reaches is higher than that of Stužická rieka in which it inflows. The maximum temperature fluctuates between 12.2-17.8°C. The characteristic species are *Nemoura cambrica, Protonemura intricata, Perlodes microcephalus* and *Siphonoperla torrentium transylvanica.*

3a. Upper and middle sections of submountain streams (685-415 m a.s.l.) 2.0-4.1 m in width. Maximum water temperature does not exceed 15°C. The dominant species in these streams are *Leuctra autumnalis* and *Perla pallida.*

3b. Lower sections of submountain streams (323-235 m a.s.l.) 2.0-4.1 m in width. Maximum water temperature exceeds 15°C. The dominant species in these streams are *Leuctra fusca, L. hippopus* and *Perla burmeisteriana.* The characteristic species are *Brachyptersa risi, Nemoura flexuosa, Leuctra albida* and *Isoperla grammatica.*

Certain differences were recorded when comparing the colonization of the Plecoptera taxocoenoses in the original catchment of Stužická rieka with the catchment significantly deforested in the past (the catchment of Hluboký potok). The species typical for the Stužická rieka catchment are *Nemoura carpathica, Protonemura hrabei, P. nimborum, Leuctra braueri, Leuctra bronislawi* and *Arcynopteryx compacta.* On the contrary, there are more euryoecous species *Nemoura cinerea, N. flexuosa, Protonemura intricata, P. nitida, Leuctra aurita, L. albida, L. hippopus, I. oxylepis* and *Perla marginata* in the Hluboký potok catchment.

Fifty species were recorded on the Polish side of the East Carpathians (Kittel & Wojtas 1991). However, some data seem to be questionable. For example, there is a lot of species recorded in that work (Balkan, Iberian, Alpine, Hercynian or Hercynian-alpine species) the occurrence of which is very improbable in the Eastern Carpathians, e.g. *Nemoura subtilis* Klapálek, 1894, *Nemoura fulviceps* Klapálek, 1902, *Protonemura lateralis* (Pictet, 1936), *Protonemura nimborella* Mosely, 1930, *Leuctra handlirschi* Kempny, 1898, *Leuctra psedocingulata* Mendl, 1968, *Dictyogenus fontium* Ris, 1896, *Isoperla goertzi* Illies, 1952 and *Siphonoperla montana* (Pictet, 1841).

Vertical distribution of *Protonemura aestiva* is analogous to the distribution of the Central European vicariant species *Protonemura auberti*. *Nemoura fusca*, which is the vicariant species of the *N. monticola* is distributed not only in spring areas but also in upper sections of streams. Another species, *Leuctra carpathica,* has the developmental phenology similar to the relative Central European species *L. autumnalis.* However, the focus of its occurrence is shifted more to mountain locations and spring ar-

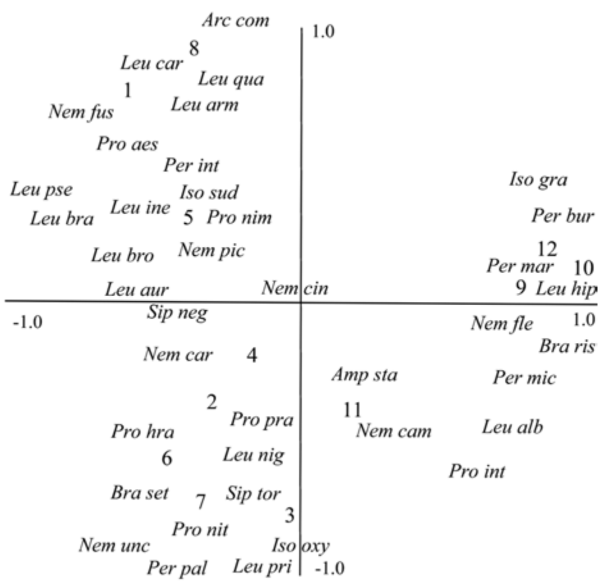

Fig. 9.1 Principal component analysis (PCA) plot of 40 stonefly species and 12 sampling sites from the upper Uh river basin. (1 – Hlu1, 2 – Hlu2, 3 – Hlu3, 4 – Stu1, 5 – Stu1*, 6 – Stu2, 7 – Stu3, 8 – Kam, 9 – Uli, 10 – Zbo, 11 – Ubl1, 12 – Ubl2).

eas. Kis (1974) indicated the occurrence of imagoes belonging to these species from August to October. In the mountains of the Bukovské vrchy Mts. *L. carpathica* emerged from August to November but the peak of the emergence was in September. Emergence of another species, *L. autumnalis,* was shifted till the end of October and lasted from September to November. The species *Leuctra quadrimaculata* emerges in the mountains of Bukovské vrchy from June to the first half of July and replaces the montane species *L. pusilla* in spring areas. *Perla pallida* has a clearly different ecological expectations than the other species of the genus *Perla,* especially the close relative species *P. marginata* distributed in Slovakia (Krno 2000). It commonly intervenes in poorly watered montane and submontane streams and avoids extremely cold spring areas and bigger submontane rivulets. The subspecies *Siphonoperla torrentium transsylvanica* penetrates to higher elevations and montane areas like its subspecies *S. t. torrentium* (Krno 2000). Oligostenothermal species *Nemoura carpathica, N. uncinata, Leuctra prima* and *Siphonoperla neglecta* penetrate more downwards into the valleys as opposed to their montane or spring area distribution in the Western Carpathians. Eurythermal species (Krno 2000) *Nemoura flexuosa, Protonemura praecox, Leuctra aurita, L. hippopus, Isoperla oxylepis* and *Perla marginata,* that do not penetrate deeply into the valleys are much more rare in higher altitudes in comparison with their distribution in the Western Carpathians (Krno 2000). Similar distribution of stoneflies from the catchment of Zbojský potok is mentioned also by Bitušík & Novikmec (1997).

Deforestation of catchments means higher frequency of floods, temperature variations and the decrease in frequency of natural wood deposition and debris (lower bottom stability). On the other hand, it causes higher portion of biofilms, and fine sediment. Catastrophic floods reduce biodiversity, more nutrients get into these streams at higher water levels and the portion of scrappers increases (Allan 1995). Higher portion of the predatory families of Perlidae and Chloroperlidae and the family Taeniopterygidae was recorded in the original catchment of Stužická rieka (Fig. 9.2).

On the contrary, in the deforested catchment of Hluboký potok more plastic families from ecological point of view occurred–predatory Perlodidae and Leuctridae (fine detritus collectors). Webster et al. (1988) found, that quantity and quality of seston in the original streams is the result of biological processes and autochthonous enrichment. Quality of seston in streams with deforested catchments is more affected by physical factors (it contains less organic substances and is of lower quality) and it accumulates in lower sections of streams. In the first period (10-20 years, Webster et al. 1988) covering the monitored hydrobiological research of Hluboký potok the transport of organic matter culminates and afterwards it decreases significantly. It is lower than in original streams. The quantity of CPOM (Golladay et al. 1989) is significantly higher in undisturbed streams and its transport culminates during autumn. The variability of CPOM is much less seasonal in logged catchments. On the contrary, amounts of FPOM and UFPOM are higher in catchments that overcome the succession stage after deforestation. We did not find any important differences in FPOM and UFPOM accumulation (see Research area characteristics). Catchments of deforested areas have weaker retention ability not only with respect to POM but also to nutrients (Golladay et al. 1992; Allan 1995). As opposed to it, autochthonous production is higher in non-shaded streams of deforested areas (Bilby & Bisson 1992; Allan 1995). We recorded increased bio-

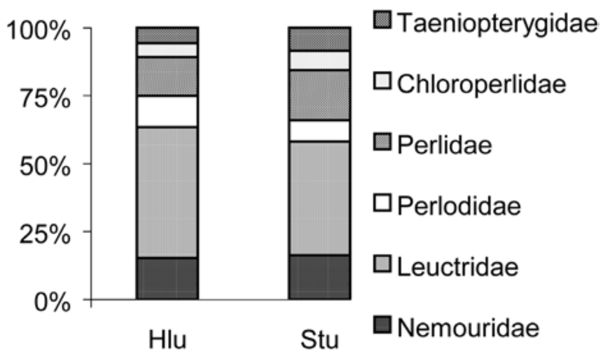

Fig. 9.2 Occurrence of taxonomic groups of stoneflies in Hluboký potok (Hlu) and in Stužická rieka (Stu).

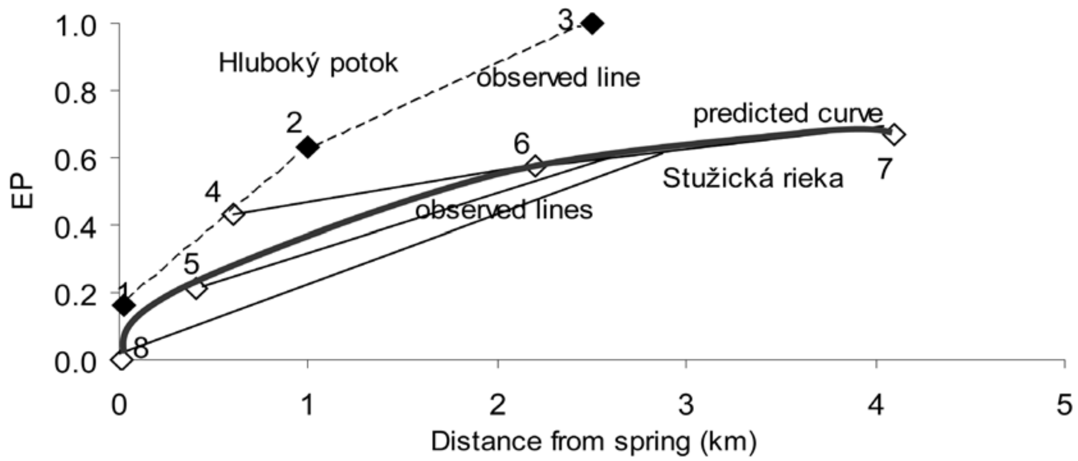

Fig. 9.3 Correspodence analysis (CA) of 8 sampling sites: 1-3 sites of the Hluboký potok, break line connected these stretch of stream; 4-8 - sites of the Stužiká rieka stream basin (numbers indicate samplig sites according to explanations within Fig. 9.1), solid line connected stream stretches according to river network; EP - ecological position of sites on 1. axis (CA)

mass of accretions in Hluboký potok (see chapter Epilithic diatoms). Lamberti et al. (1991) indicated that significantly higher flow rates in catchments on clear-cut areas during floods affect late return of stoneflies of the family Perlidae. It lasts almost 3-6 years. The increase in the portion of sediments that is released during erosion in the catchment significantly reduces biodiversity of stoneflies (Relyea et al. 2000). A higher portion of fine substrates was recorded in the Hluboký potok catchment. Correspodence analysis (CA) of Plecoptera taxocoenoses in these two catchments (Fig. 9.3) indicated clearly that continual zonation in the original catchment (with the exception of drying location Stu1) is more gradual than in the Hluboký potok catchment, where the clear-cuts have changed the zonation of the environment dramatically.

The return of ecological condition of the stream into its original condition takes place rather in smaller spring areas than in its bigger lowermost stream section. It is, *inter alia*, due to more stabile conditions in the catchment from climatic as well as hydrological point of view.

Tab. 9.1 Stoneflies of the Bukovské Mts. (Explanations: L – larvae, M – males, F – females)

	sampling site														
species	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Kam	Uli	Zbo	Ubl1	Ubl2	L	M	F
Brachyptera risi (Morton, 1896)			3						2	7		1	7	3	8
Brachyptera seticornis (Klapálek, 1902)		55	4	1	8	33	28			3	5		126	10	17
Amphinemura standfussi (Ris, 1894)											2		2		
Nemoura cambrica (Stephens, 1835)				2		1	2	1	2	1	4		13	2	2
Nemoura carpathica Illies, 1963	1	2				14			1				18	6	3
Nemoura cinerea (Retzius, 1793)	2										1		3	2	1
Nemoura flexuosa Aubert, 1949			2						4		2	6	14	2	3
Nemoura fusca Kis, 1963	5	1		2	2	2		2					14	5	2
Nemoura uncinata Despax, 1934		8	3			4	3						18	1	
Nemurella pictetii Klapálek, 1900	3			1	1								5		
Protonemura aestiva Kis, 1965	50	12	2	11	10	9	3	14			2		113	21	24
Protonemura hrabei Raušer, 1956		10			4	6	8						28	2	5
Protonemura intricata (Ris, 1902)			6	2			4		7	5	3		27	5	6
Protonemura nimborum (Ris, 1902)					2								2	1	
Protonemura nitida (Pictet, 1835)		5	4										9	1	2
Protonemura praecox (Morton, 1894)							3				1		4	2	
Leuctra albida Kempny, 1899		1	18						4	1		2	26	2	2
Leuctra armata Kempny, 1899	4				6			2					12	3	2
Leuctra aurita Navas, 1919			2										2		
Leuctra autumnalis Aubert, 1948	27	10	2	17	15	6	24	5			2		108	24	28
Leuctra braueri Kempny, 1898	6	1	1	4	8	2	5	4					30	5	11
Leuctra bronislawi Sowa, 1966				4	7	8	1	3					23	1	1
Leuctra carpathica Kis, 1966	56	27		5	30	4	9	27					158	22	27
Leuctra fusca (Linnaeus, 1758)									20	27		9	56	8	10
Leuctra hippopus Kempny, 1899		1	7			4	1		42	65	9	19	148	17	25
Leuctra inermis Kempny, 1899	5			1	5								11	3	4
Leuctra quadrimaculata Kis, 1963	3	1			4			15					23		6
Leuctra nigra (Olivier, 1811)	3	13	7	8	4	4	8	2			4		53	12	17
Leuctra prima Kempny, 1894	3	35	27	2	8	38	45		2		9		169	21	35

Tab. 9.1 (continued) Stoneflies of the Bukovské Mts. (Explanations: L – larvae, M – males, F – females)

	sampling site														
species	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Kam	Uli	Zbo	Ubl1	Ubl2	L	M	F
Leuctra pseudosignifera Aubert, 1954	60	44	6	2	37	40	9	9			3		210	24	30
Arcynopteryx compacta (Mc Lachlan, 1872)					4			5					9	8	11
Isoperla grammatica (Poda, 1761)									2	3			5	2	2
Isoperla oxylepis (Despax, 1936)											1		1		
Isoperla sudetica (Kolenati, 1859)	80	9	2	10	12	1	1	13			2		130	9	12
Perlodes intricatus (Pictet, 1841)	5			1	1	1		1					9		
Perlodes microcephalus (Pictet, 1833)		3	2			3	9		2		1	6	26	2	1
Perla burmeisteriana Claassen, 1936									10	15		6	31	5	7
Perla marginata (Panzer, 1799)			1						28	24		2	55	6	6
Perla pallida Guerin, 1838		43	63	29	11	34	39				7		226	12	15
Siphonoperla neglecta (Rostock, 1881)	3	5	3	2	3	3							19	7	5
Siphonoperla torrentium transsylvanica Zwick,1972		6	15	12	6	2	8		4		1		54	11	14
Total	315	282	180	116	188	219	210	103	130	144	48	42	1977	267	343

10. Aquatic beetles (Coleoptera)

Beetles represent one of the most numerous orders of insects. They are typical terrestrial animals; only several families are to different extent adapted for living in aquatic environment. In spite of about 350 species of water beetles known from Slovakia, little attention is still paid to this group. Especially data from the East Carpathians are very rare. Obrdlík (1981) does not mention beetles in his hydrobiological work from Bukovské vrchy Mts. Bitušík & Novikmec (1997) recorded only 5 taxa and they did not determine adults at all. In the faunistic survey of the beetles of the Poloniny National Park (Jászay 2001) there are, in addition to mainly terrestrial species, mentioned also some water beetles from various aquatic biotopes of that area. Finally, two new records from Slovakia and several rare species were recorded in the streams of the Nízke Beskydy region, which were more intensively studied only recently (Čiampor Jr. & Zaťovičová 2004, Kodada et al. 2004, Zaťovičová et al. 2004).

The aim of this work was to study the structure of water beetle assemblages at selected sites and their changes along the longitudinal gradient of streams and to observe the effects of deforestation on these assemblages in the basin of Hluboký potok in comparison with untouched and well preserved Stužická rieka.

For these purposes, hierarchical classification analysis of the data was made by the PC Ord software (McCune & Mefford 1999) using average linkage clustering method and Jaccard´s index of similarity. The t-test analysis included in the SigmaStat 3.1 computer package was used to look for significant differences between density data and values with $P < 0.05$ were considered significant.

In total, 17 taxa of water beetles belonging to 3 families were recorded at 10 sites of the selected streams of the river Uh basin (Tab. 10.1).

Elmidae (riffle beetles) are typical inhabitants of flowing waters (both larvae and adults) with long life cycles. They do not swim, but strong legs with claws enable them to hold on the substrate also in fast flowing water. Long-time remaining under the water is ensured by plastron respiration, larvae use tracheal gills. Their food is composed mainly of epilithic algae and organic matter (Crowson 1981, Kodada et al. 2003). Eleven recorded taxa of elmids belong to 3 genera and 8 species. Larvae, though they constitute the majority of obtained material, were due to difficult identification determined only to the genus level (*Elmis* sp., *Esolus* sp., *Limnius* sp.), but they probably belong to the determined adults. From the faunistic point of view the most interesting species was *Limnius intermedius* found on Hlu1, Hlu2, Stu3 and Kam. Its occurrence in Slovakia is rare and all records are restricted only to the area of the East Carpathians, concretely to Nová Sedlica env. (Jászay 2001) and Nízke Beskydy region (Zaťovičová et al. 2004).

Five species of the genus *Hydraena* Kugelann, 1794 from the family Hydraenidae (minute moss beetles) were recorded. All they are rheobionthic with aquatic adults and larvae inhabiting wet soil of banks. *Hydraena* species feed on algae scraped from substrate, additionally on organic matter. The most valuable was finding of one specimen of *Hydraena hungarica* on the site Hlu1 that is from our territory published only from Nová Sedlica env. (Jászay 2001). Another species, *Hydraena truncata*, is from the area of Bukovské Vrchy Mts. published for the first time.

Family Scirtidae (marsh beetles) was represented only by several undetermined larvae of the genus *Elodes* Latreille, 1796 captured at two sites of Stužická rieka. *Elodes* larvae prefer running waters. Adults are not aquatic, they usually inhabit riparian vegetation.

It is almost certain, that the whole species spectrum of water beetles was not noticed using standard hydrobiological methods and sampling only relatively uniform stony substrate. Beetles inhabiting faster flowing waters namely prefer specific microhabitats (submerged wood and roots, periphyton on rocks, mosses, macrophytes…) or they are too small in size and use to be overlooked. For example, comparison of data from standard hydrobiological quantitative samplings with those from individual collecting in the Nízke Beskydy showed high differences in species richness recorded within each sampling site (Zaťovičová et al. 2004).

These expectations are supported by the latest qualitative data from the same sampling sites in Bukovské Vrchy Mts. (2004, 2005), when two specimens of *H. hungarica* were found on Stu2 and several additional species on Zbojský potok (*H. truncata*, *H. hungarica*, *H. saga*, *E. angustatus*, *L. intermedius*, *L. perrisi*, *Ochthebius* spp., *Stenelmis*–larva, *Oreodytes sanmarkii*) and Ulička (*Elmis obscura*, *L. intermedius*, *L. volckmari*, *Hydraena pygmaea*) (Zaťovičová, Čiampor Jr., unpublished data).

Therefore it is necessary to apply specialized sampling methods (e.g. Holland 1972, White 1983) to explore the composition of water beetle assemblages more precisely.

On the grounds of the species composition of aquatic beetle assemblages at all investigated sampling sites (Tab. 10.1) and the results of hierarchical cluster analysis (Fig. 10.1), several different biotops were recognized along the longitudinal gradient of streams (according to Bitušík et al. 1996): The first group representing springs (cluster A, Fig. 10.1) consists of the uppermost site of Hluboký potok (Hlu1) and Kamenistý potok (Kam) streams. They are characterized mainly by low water tempera-

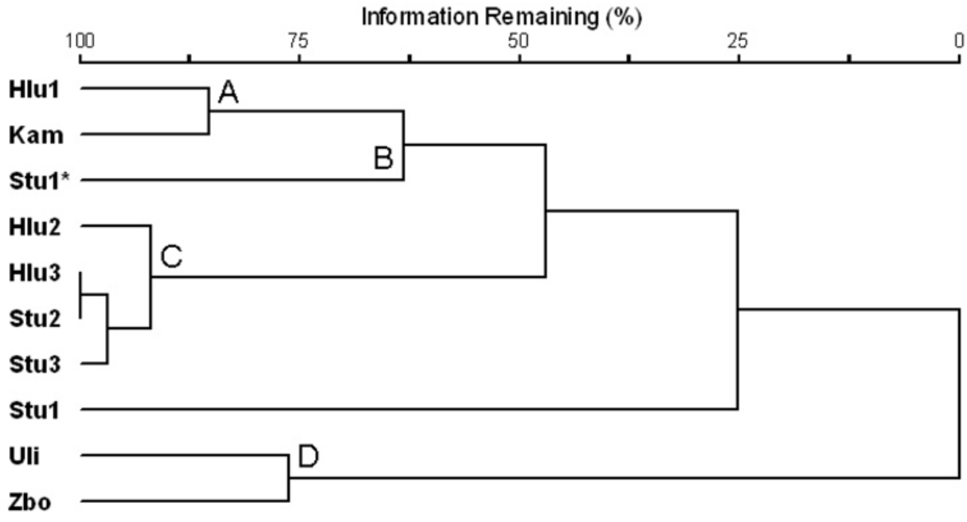

Fig. 10.1 Hierarchical cluster analysis (average linkage method, Jaccard´s index of similarity) of the selected sites of streams in the Bukovské vrchy Mts. based on presence/absence data of water beetle species. Hlu1 - 3, Stu1 - 3, Stu1*, Kam, Zbo, Uli – site codes (for explanation see Research area characteristics); A - D – clusters (see text).

ture, which did not exceed 6.8°C during the year. Dominant species of these sites was oligostenothermic *E. latreillei*, typical for the cold waters of mountain streams and springs (Więźlak 1986, Kodada et al. 2003).

Sampling site Stu1*, with altitude 840 m and maximum measured water temperature 10.5ºC, corresponds with epirhithral (B, Fig. 10.1). The most common species there were *L. perrisi* and *E. angustatus* preferring cold running waters, which are characteristic for the zone of epirhithral (Kodada et al. 2003). Site Stu1 has singular status. Although it lies at the same altitude as Stu1* and its stream type is in agreement with epirhithral, water reached much higher maximum temperatures. This site was due to autumnal drying up substituted for more representative Stu1*.

All the remaining sampling sites correspond with characteristics of submountain stream – metarhithral. Hlu2, Hlu3, Stu2 and Stu3 formed cluster C (Fig. 10.1), representing upper stretches of metarhithral with maximum temperature up to 15°C, altitudes 535 – 717 m and the stream width up to 4 m. Besides species common for the epirhithral zone, the basis of community of this part is formed by eurythermic species typical for submountain streams: *E. parallelepipedus*, *L. volckmari*, *E. aenea*, *H. gracilis*, *H. minutissima* (Więźlak 1986, Bitušík et al. 1996, Kodada et al. 2003). Cluster D (Fig. 10.1), including streams Ulička and Zbojský potok, represents lower stretches of submountain streams with altitudes about 300 m and stream width 7–8 m. The oligostenothermic species of the epirhithral are completely absent there and *E. parallelepipedus*, *E. aenea* and *L. volckmari* prevailed as mentioned above. However, the occurrence of *E. maugetii* that is more typical for submountain rivers (Kodada & Degma 1996, Kodada et al. 2003) suggests changes and zonation also within the metarhithral.

Very similar longitudinal zonation of investigated sites was confirmed also by analyzing other biological data (e.g. diatoms, interstitial communities or stoneflies). Concerning these facts, beetle assemblages of the running waters are subject to relatively distinct and characteristic changes in species composition along the longitudinal gradient, which can be detected using standard benthological methods. But for detailed knowledge on the communities of various biotops along the stream and transitions between them it is necessary to cover the whole species spectrum.

One of the aims of this study was to estimate the effects of logging on aquatic assemblages in the basin of Hluboký potok in comparison with untouched and well preserved basin of Stužická rieka. In general, deforestation causes increase of maximum water temperatures and sunlight exposure, higher deposition of nutrients and fine organic matter into the stream and also the increase of abundance and biomass of periphyton (Allan 1995).

In terms of aquatic Coleoptera taxocenoses, Hluboký potok and Stužická rieka were very similar in species composition (except of the one specimen of rare species *H. hungarica* found at Hlu1) and species richness was at analogous sites of both streams almost equal. Sporadic occurrence of *Elodes* larvae feeding on decomposing fallen leaves (Rozkošný 1980) at Stužická rieka (Tab. 10.1) could be the consequence of higher production of leaf litter in old primary forest in comparison with young and disturbed streamside vegetation of Hluboký potok.

The main differences between streams reflected in the density of taxa (Tab. 10.1). Genera *Elmis*, *Limnius* and *Hydraena*, which are mainly scrapers, additionally collectors of organic matter, pre-

Tab. 10.1 Dominance (%) / density (ind.m^{-2}) and presence (+ – data from qualitative samples) of water beetles of the investigated streams.

	sampling site									
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu1*	Stu2	Stu3	Kam	Uli	Zbo
ELMIDAE										
Elmis aenea (Müller, 1806)									+	+
Elmis latreillei Bedel, 1878	3.6 / 6	5.9 / 10			+			+		
Elmis maugetii Latreille, 1798									+	+
Elmis sp.	91.6 / 151		6.7 / 13		3.4 / 5	4.3 / 4	0.9 / 2	+	+	+
Esolus angustatus (Müller, 1821)		3.5 / 6	4.7 / 9	5.9 / 7	15 / 22	17.2 / 16	8.2 / 19			
Esolus parallelepipedus (Müller, 1806)		0.6 / 1	3.1 / 6			1.1 / 1	+		+	+
Esolus sp.		8.7 / 15	7.3 / 14	5.9 / 7	26.5 / 39	37.6 / 35	46.1 / 107	+	+	+
Limnius intermedius Fairmaire, 1881	1.2 / 2	+					0.4/ 1	+		
Limnius perrisi (Dufour, 1834)	1.2 / 2	9.3 / 16	7.3 / 14	5.9 / 7	3.4 / 5	12.9 / 12	2.6 / 6	+	+	
Limnius volckmari (Panzer, 1793)	1.2 / 2	1.2 / 2	5.2 / 10			1.1 / 1				+
Limnius sp.		65.5 / 112	42.2 / 81	82.3 / 98	49 / 72	21.5 / 20	38.8 / 90	+		
HYDRAENIDAE										
Hydraena gracilis Germar, 1824	1.2 / 2	5.3 / 9	22.9 / 44		+	3.2 / 3	2.6 / 6	+		+
Hydraena hungarica Rey, 1884	+									
Hydraena minutissima Stephens, 1829			0.6 / 1				x			
Hydraena saga d´Orchymont, 1930		+	+			1.1 / 1	0.4 / 1			
Hydraena truncata Rey, 1885			+			+	+			
SCIRTIDAE										
Elodes sp.					2.7 / 4	+				

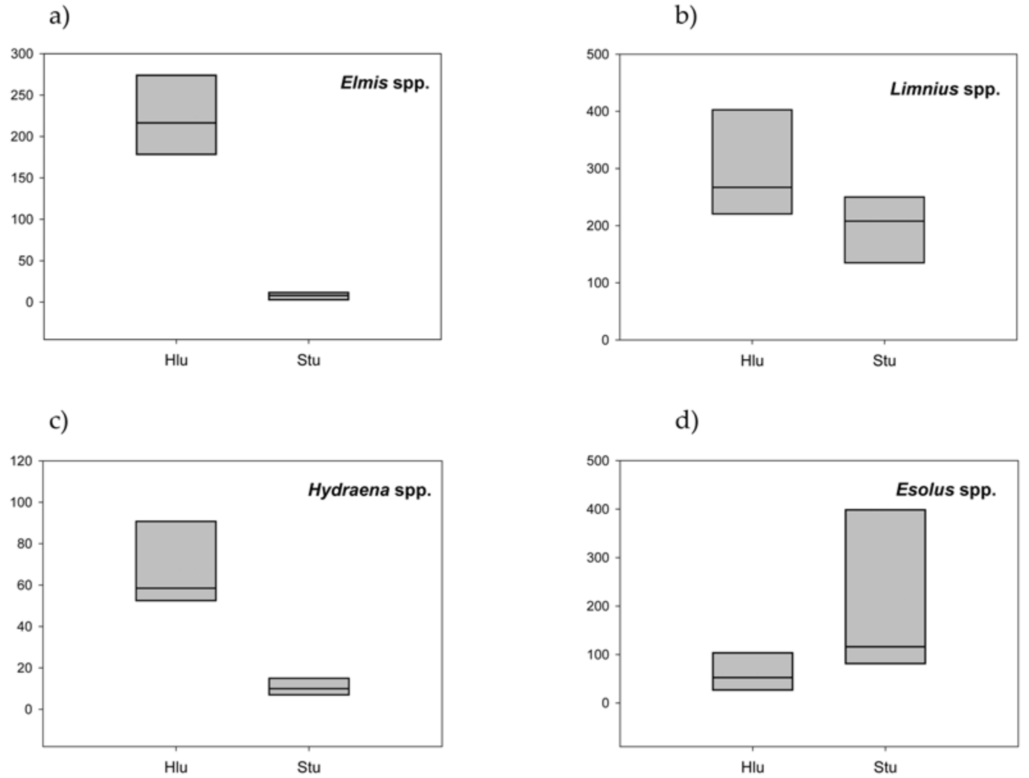

Fig. 10.2 Box plots of density values (ind.m^{-2}) distribution for genera a) *Elmis*, b) *Limnius*, c) *Hydraena* and d) *Esolus* in Hluboký potok (Hlu) and Stužica (Stu) brooks. Boxes are interquartile ranges (25th to 75th percentile), maximum and minimum values are not shown; solid line = median, dashed line = mean.

vailed at Hluboký potok (Fig. 10.2). Comparison of mean densities (t-test) between sampling sites of Hluboký potok and Stužická rieka showed statistically significant differences in genus *Elmis* (P = 0.016; Fig. 10.2a) and *Hydraena* (P = 0.016; Fig. 10.2c). In the case of *Limnius* the difference was not significant, but obvious (P = 0.121; Fig. 10.2b). These findings agree with other authors, according to whom the results of changes relating with deforestation of stream basin reflect in increasing of macrozoobenthos abundance, mainly collectors of fine detritus and scrapers of epilithic algae (Friberg 1997, Bitušík & Novikmec 1997). On the other hand, higher density of the genus *Esolus* at sites of Stužická rieka also indicates the difference between both streams (P = 0.131; Fig. 10.2d). This genus, regarding the distinct structure of its mouthparts, has probably different feeding preferences from other elmids and hydraenids (Beier 1948, Kodada & Degma 1996). It is assumed, that it searches for sites with different feeding supply then previous ones, where it reaches higher density.

In conclusion, deforestation in the stream basin, very likely, does not affect the structure and species richness of water beetle assemblages. Differences between primary and anthropogenic influenced streams could be recognized in the density of single functional feeding groups (sensu Cummins 1973).

11. Caddisflies (Trichoptera)

There is only one complex study (Chvojka 1993), which brings the results of research of the imaginal stages of caddisflies from Slovak part of the East Carpathians. Some data on caddis fly larvae can be found in the hydrobiological studies (Bitušík & Novikmec 1997). Szcesny (2000) presents results of the broad study of Trichoptera from the Polish part of the East Carpathians as well as a review of papers relevant to this part of the East Carpathians. Our primary objective was to assess the composition of the caddisfly communities of two streams of distinct logging impact in Poloniny National Park (the East Carpathians) – Hluboký potok and Stužická rieka. Since the caddisfly fauna of the Slovak East Carpathians is not yet sufficiently known, we also wanted to contribute to the knowledge concerning caddisflies of the studied area.
Caddisfly community structure was characterized by several variables: abundance, species richness, Shannon-Weaver diversity (using natural logarithm), evenness and the relative abundances of functional feeding groups (sensu Cummins 1973). Despite the low number of sampling occasions, which produced quantitative data, we used non – parametric Mann-Whitney U test to test for significant differences in abundance and diversity attributes between paired sampling sites. Tests were done using software STATISTICA.
A total of 42 Trichoptera taxa were identified from the benthic samples, 30 taxa from Hluboký potok and 36 taxa from Stužická rieka (Tab. 11.1). From the faunistical point of view, the finding of uncertain taxa of Limnephilinae (Limnephilinae gen.? sp.?) is interesting. *Drusus brunneus* Klapálek, 1898, endemic species to Carpathians was one of the most abundant species.
With concern to total species richness, nearly no differences were found between paired localities of reference and impacted stream. Taxonomically the richest locality was Stu3, where 22 taxa of caddisflies were found. The lowest number of taxa was recorded at Hlu3 (16). Overall number of recorded taxa was exactly the same at all other pairs of the sampling sites. Number of taxa increased longitudinally in Stužická rieka but in Hluboký potok the opposite effect was observed. No significant differences in diversity (Shannon-Weaver index) as well as in evenness were found between the corresponding sites with maximum mean diversity index recorded at Hlu1 (Tab. 11.1). Both diversity and evenness had the same trend as the number of taxa – they increased at Stužická rieka and declined at Hluboký potok longitudinally.
There were only slight differences in species composition between the corresponding sites and the occurrence of some taxa was confined exclusively to sites of Stužická rieka (*R. laevis, R. fasciata, R. obliterata, A. fuscipes, S. iridipennis, W. occipitalis, P. conspersa, P. latipennis, P. nigricornis*) and Hluboký potok (*Tinodes* cf. *rostocki*, *S. pallipes*, *Ernodes* sp.) respectively. Source streams sites (Hlu1 and Stu1) were the exceptions. These sites were different from other sites, but also considerably differed from each other. Both of these sites were characterised by occurrence and dominance of different crenophilous resp. epirhitrophilous species. Site Hlu1 was absolutely dominated by individuals of family Drusinae (*D. brunneus, D. discolor*), *R. polonica* and *R. philopotamoides*. For site Stu1 *R. polonica*, *S. iridipennis*, *P. ludificatus*, *D. brunneus* were dominant and *P. nigricornis, Plectrocnemia* sp. were characteristic. Total mean densities ranged from 19 to 148 ex. m^{-2}. The highest mean density was recorded at site Hlu1 (Fig. 11.1). Although there are considerable differences in mean densities between the paired sampling sites, the only difference between Hlu3 and Stu3 was statistically significant (Mann-Whitney U test, $p < 0.05$).
At Stužická rieka, the density increased longitudinally, while at Hluboký potok longitudinal decrease of this parameter was recorded.
Functional feeding group scrapers dominated at Hlu1 (Fig. 11.2). It was also the only evident difference in composition of functional feeding groups of Trichoptera between the compared streams.
All the taxa identified were known from the East Carpathians (Szcesny 2000) and most of them also from the Slovak part. *Drusus discolor* is the only new species for the Slovak East Carpathians. We have found one specimen of *A. fuscipes,* but Szcesny (2000) listed *A. fuscipes* as a doubtful species for the East Carpathians.
Since our finding is not confirmed by adults' determination, we may not be absolutely sure about occurrence of this species in the Slovak part of the East Carpathians. Two individuals indicated as Limnephilinae gen.? sp.? remind us of larvae of *Chaetopterygopsis maclachlani* Stain, 1874, but there are some differences in colour patterns and case composition. *Ch. maclachlani* was not recorded from the East Carpathians up to now and mentioned larvae may belong to some East Carpathians endemic caddisfly (*Chaetopteryx subradiata* Klapálek, 1907; *Isogamus aequalis* (Klapálek, 1907), larvae of which it is not known so far (Chvojka pers. comm.). Our results indicate no obvious distinctions in taxonomical characteristics between studied streams. Likewise, Carlson et al. (1990) found out no significant differences in the number of taxa and diversity of Trichoptera assemblages between logged and paired undisturbed streams. No differences between clear-cut and forested riparian zones were also found by Newbold et al. (1980). However, we agree with Quinn & Keough (2002),

Tab. 11.1 List of Trichoptera species recorded at sampling sites of Hluboký potok and Stužická rieka.

	sampling site					
taxa	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Rhyacophila fasciata (Hagen, 1859)					+	
Rhyacophila laevis Pictet, 1834				+		
Rhyacophila cf. *obliterata* McLachlan, 1863					+	
Rhyacophila philopotamoides McLachlan, 1879	+			+	+	+
Rhycophila polonica McLachlan, 1879	+	+		+	+	+
Rhyacophila tristis Pictet, 1834	+	+	+	+	+	+
Rhyacophila (*Hyporhyacophila*) sp.	+		+		+	
Rhyacophila s. str.	+	+	+			+
Rhyacophila spp. juv.	+	+	+		+	
Glossosoma conformis Neboiss, 1863		+	+	+	+	+
Glossosoma intermedium (Klapálek, 1892)		+	+			+
Glossosoma spp. juv.					+	+
Agapetus fuscipes Curtis, 1834				+		
Synagapetus iridipennis McLachlan, 1879				+		+
Philopotamus ludificatus McLachlan, 1878	+			+	+	+
Philopotamus montanus (Donovan, 1813)	+	+	+	+	+	+
Philopotamus variegatus (Scopoli, 1763)		+				
Philopotamus spp. juv.	+	+				+
Wormaldia occipitalis (Pictet, 1834)				+		
Wormaldia sp. juv.				+		
Hydropsyche sp. juv.			+			+
Plectrocnemia conspersa (Curtis, 1834)				+		
Plectrocnemia sp. juv.				+		
Tinodes cf. *rostocki* McLachlan, 1878			+			
Apatania sp.	+			+		
Drusus brunneus Klapálek, 1898	+	+		+		
Drusus discolor (Rambur, 1842)	+	+				
Ecclisopteryx madida (McLachlan, 1867)		+	+		+	+
Drusinae g. sp. juv.	+			+		+
Limnephilinae gen.? sp.?	+					+
Potamophylax cf. *latipennis* (Curtis, 1834)					+	
Potamophylax cf. *luctuosus* (Piller et Mitterpacher, 1783)		+	+		+	+
Potamophylax nigricornis (Pictet, 1834)				+		
Potamophylax spp.	+	+	+			+
Limnephilinae g.sp. juv.	+	+	+	+	+	+
Lithax niger (Hagen, 1859)	+	+		+	+	+
Silo pallipes (Fabricius, 1871)		+				
Goeridae g. sp. juv.	+					
Ernodes sp.	+					
Oecismus monedula (Hagen, 1859)			+		+	+
Sericostoma spp.	+	+	+	+	+	+
Odontocerum albicorne (Scopoli, 1763)		+	+		+	+
mean diversity (H)	3.485	3.104	2.856	2.994	3.026	3.265
mean evenness	1.163	1.054	1.03	0.999	1.028	1.056

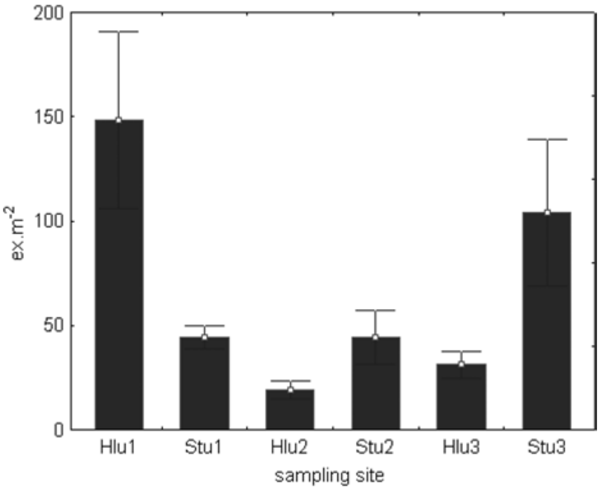

Fig. 11.1 Mean densities of caddis fly communities at sampling sites of Hluboký potok and Stužická rieka.

that it must be distinguished between statistical and biological or ecological significance. Though we have not found statistically significant distinctions, the characteristics of taxonomic structure indicated certain adverse effect of logging activities in catchment of Hluboký potok.

The catchment of Stužická rieka (as undisturbed area) has a probably higher retentive capacity than the catchment of Hluboký potok and therefore also the hydrological stress in stream channel is probably weaker than in Hluboký potok. Hydrological stress is one of the major factors influencing communities of benthic macroinvertebrates in streams of the studied area (Bitušík & Novikmec 1997). This feature could contribute to the longitudinal differences in increase and decrease of number of taxa and diversity indices between streams under investigation.

Brown et al. (1997) have shown significantly higher densities of Trichoptera in streams with timber harvest when compared to references. Carlson et al. (1990) also reported that caddisflies were significantly more numerous at logged sites than at paired undisturbed sites. High density at Hlu1 was due to the great number of individuals of family Drusinae. This site is indeed an exceptional stand from among all the sites. It is an open stand presenting a good opportunity for scraping caddisflies. Increases in macroinvertebrates densities at logged sites are usually attributed to the increases in the growth of algae and vascular plants because of the increased exposure to sunlight (see Carlson et al. 1990). These properties, together with a rather stabile habitat enable utilisation of sampling site Hlu1 by abundant and quite diverse community of caddisflies. Densities of caddisflies of the next paired sites were higher at Stužická rieka.

This is probably attributable to the above-mentioned smaller temporal variability in flow characteristics of pristine Stužická rieka. In conclusion, at least two reasons may explain quite similar com-

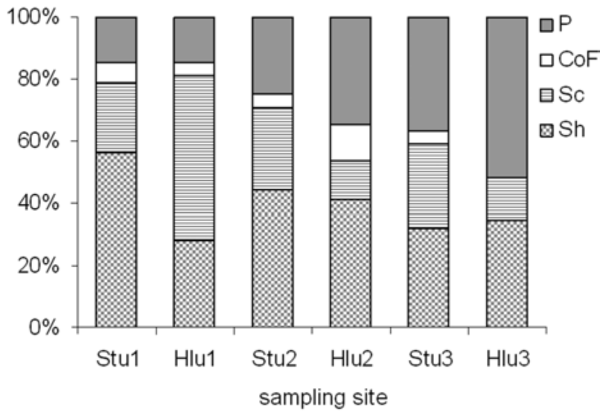

Fig. 11.2 Proportional composition of functional feeding groups of Caddisflies at sampling sites of Hluboký potok and Stužická rieka.

position of caddisfly assemblages in the studied streams with markedly different catchment land use: It is impossible to find reliable reference stream (Liljaniemi et al. 2002), thus individual features of the streams may in part overlay the impact of land use. Interpretation of results is also a bit restricted by the low number of samples, which may lead to insignificance of differences.

12. Chironomids (Diptera, Chironomidae)

Although chironomids have been studied intensively during the last 25 years in Slovakia, faunistic data from many water bodies, especially in the eastern part of the country, are scarce. Information on preimaginal stages of chironomids has been obtained in the last few years (Bitušík & Novikmec 1997, Klasa et al. 2000, Kubovčík & Novikmec 2001, Novikmec & Kubovčík 2001).

The chironomid study formed part of a broader investigation into the effects of different anthropogenic stress in catchment basins on lotic macroinvertebrate communities in Poloniny National Park. Some results have been published by Bitušík & Hamerlík (2001), Bitušík et al. (2004), Novikmec et al. (2005). Previous papers based either on pupal exuviae data have presented basic information on species composition, or on larval data (quantitative and qualitative) that have identified the main environmental factors affecting the structure of chironomid assemblages.

The present study based on all chironomid data intends to show how far chironomid assemblages have changed as a result of the timber harvest disturbance and which taxa are most sensitive to the changes.

The qualitative, quantitative and drift samples were combined to obtain a more comprehensive incidence matrix. The data from successive sampling dates were pooled for each site in order to avoid temporal pseudoreplication (Hurlbert 1984).

The assessment of faunal similarity was performed by hierarchical cluster analysis (CAP 3.0; Seaby & Henderson 2004). The complete linkage method with the Sörensen index as the similarity measure was chosen as an appropriate method to classify patterns of spatial differences in assemblages (Murgía & Villaseñor 2003).

Mean similarity dendrogram (Van Sickle 1997) was used as a concise graphical comparison of between- and within-class similarities for classification of sites according to streams (Hluboký potok vs. Stužická rieka). In a strong classification, similarities between sites that are in the same class tend to be substantially greater than similarities between sites that are in different classes (Van Sickle & Hughes 2000). We have tested whether the overall strength of a priori classification was significantly greater than classification strength of randomly chosen class of sites (Mielke et al. 1976, Clarke & Green 1988, Smith et al. 1990). Since there are only 20 possible permutations (two groups, with three sites in each), it was more reliable to use an exact test for small classifications than classical randomization procedure (Van Sickle 1998). Again, the Sörensen index was used for the mean similarity analysis.

A total of about 1350 chironomid larvae and 420 pupal exuviae were collected during the study. In all, 72 species/ taxa belonging to six subfamilies were identified, 45 of which were found in Stužická rieka and 56 in Hluboký potok (Tab. 12.1). Chironomidae were the taxonomically richest macroinvertebrate group at both investigated brooks.

Subfamily Orthocladiinae contributed the largest number of species/ taxa (50), the other subfamilies are represented by few species/ taxa (Podonominae 1 species, Tanypodinae 6 taxa, Diamesinae 6, Prodiamesinae 1, Chironominae 8). A complete taxonomic list could be longer but larvae of some genera were difficult to identify into species. *Corynoneura* spp., *B. bifida*, *E. coerulescens*, *H. serratosioi*, *Krenosmittia* sp., *O.* (*S.*) *lignicola*, *Parametriocnemus* spp., *S. semivirens*, *T. calvescens* and *Micropsectra* spp. were the most common taxa and were recorded at all sampling sites. On the other hand, *P. minutissimus* and *Rheosmittia* sp. C, *Parakiefferiella* sp. and *Heleniella* sp. "*reticulata*" with atypical pupal exuviae characteristics have not yet been found elsewhere in Slovakia.

As an indicator of faunal similarity, Sörensen index ranged from 0.4 (few common species, Hlu 1 vs. Hlu 3) to 0.7 (very similar species composition, Stu 2 vs. Stu 3) (Fig. 12.1). The clustering procedure arranged sampling sites into two major clusters. First cluster consisted of one sampling site only (Hlu 1). Hlu 1 was composed of very specific assemblage. Presence of *Krenopelopia* sp., *Diamesa* sp., *D. dampfi/ permacra*, *P. branickii*, *E. brevicalcar* group, *E.* cf. *minor*, *M. fuscipes* group, *P. rufiventris*, and *P.* cf. *nudipennis* was indicative for this site.

The second cluster comprised of remaining sampling sites can be characterized by presence of *C. pallidula*, *N. dubius* and *P. convictum* which were common in all sites, and *R. fuscipes*, *Rheosmittia* sp. C, *S. flavidula* recorded in the most sites. Although pupal exuviae of some species, *Corynoneura* Pe 2a, *K. camptophleps*, *Parametriocnemus* sp. A, *Parametriocnemus* Pe 2 were collected from stations of the cluster, larvae of these genera were taken from the site Hlu1, too. The division of the cluster separated sites Stu2 and Stu3 from the triplet Hlu2, Hlu3, and Stu1.

There was no evidence ($M = 1.01$, $p = 0.75$) that the investigated streams (Hluboký potok and Stužická rieka) effectively separated chironomid assemblages into distinct groups. The sites in different streams shared, on average, almost 60% of their chironomid species, while sites within the same stream shared about 63% (Stužická rieka) and even less than 55% (Hluboký potok) of their species (Fig. 12.2). Thus overall within-stream similarity was not different from between-stream similarity. In other words, the overall classification strength of sites a priori classified according to streams was

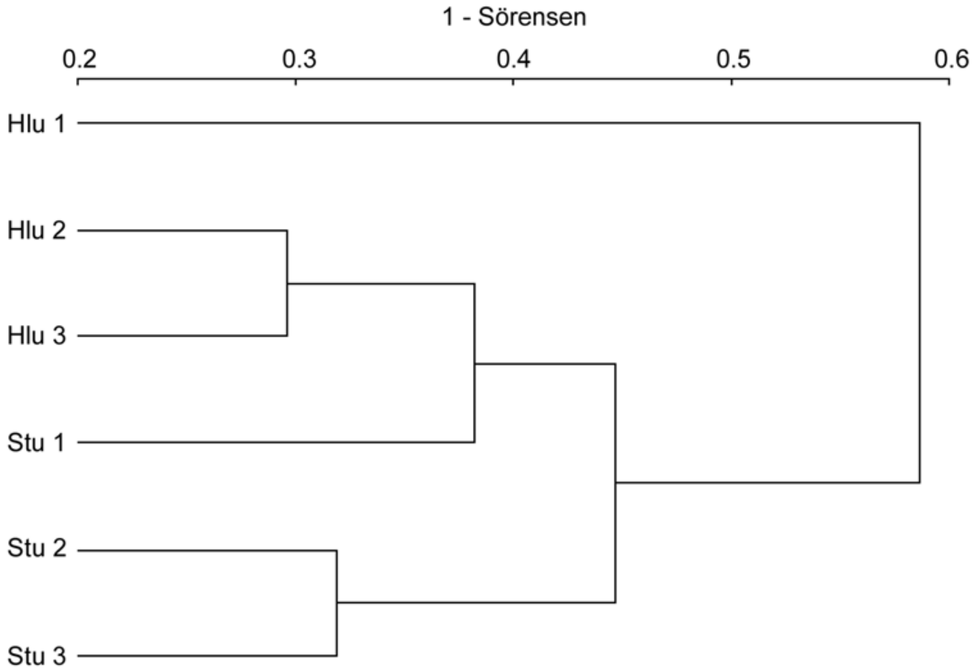

Fig. 12.1 Complete linkage dendrogram of sampling sites based on the community composition (presence/absence). Axis represents magnitude of dissimilarity (1 – Sörensen index).

not greater than would be seen in random groups of sites. However, due to low statistical power of test (very small sample size and/or high variability within streams), there was little chance of detecting the difference between streams even if it exists.

The previous study (Bitušík et al. 2004) identified Chironomidae as responsive dipteran family to changes induced by different silvicultural practices in the watersheds of the investigated brooks. Inspection of taxonomic structure of chironomid assemblages and chironomid larvae density (not shown in Tab. 12.1), among sampling sites revealed Hlu1 as an exceptional site. While there was no difference in the species richness between Hlu1 and reference site Stu1, there were substantial differences in larval densities not only between Hlu1 and Stu1 but between Hlu1 and lowermost sites on Hluboký potok. Some studies have revealed significant changes in chironomid density and taxonomic composition in streams disturbed by timber harvesting (Berg & Hellenthal 1992, Brown et al. 1997).

It could be suggested that chironomids responded to more diversified food resources and habitat structure. In addition to the high input of CPOM, the role of periphyton and transported organic matter should be taken into account. Although light was not measured in this study, there is a reason to suggest that the light input into Hluboký potok at the station Hlu1 is higher than at the reference site (Stu1), due to insufficient canopy cover. Moreover, increased solar radiation was combined with the highest nitrate concentrations and supported an unusually high periphyton growth at Hlu1. Mean biomass of periphyton and chlorophyll-a content at Hlu1 were respectively nearly twice and three times higher than at the reference site Stu1 (see chapter Epilithic diatoms). Some studies have underlined the importance of epiphytic algae as a food source for chironomids (see Berg 1995), and have demonstrated clear positive response of chironomid larvae grazers to an increase of the periphyton standing crop (e.g. Ward & Williams 1986, Welton et al. 1987). High proportion of chironomid species associated with epiphytic algae (*Diamesa* spp., *Eukiefferiella* spp., *O. frigidus*, *P. rufiventris*, *P.* cf. *nudipennis*, *T. calvescens*) may reflects high periphyton development at Hlu1. Grazers constituted 28% of larval density at site Hlu1 but only 6.1% at site Stu1, and 0.0 to 1.9% at sites Hlu2 and Hlu3, respectively.

High density of the filtering collector *Rheotanytarsus* larvae (~ 24%, not shown in Tab. 12.1) at Hlu1 may be explained in terms of availability of attachment sites (mosses were much more abundant at this site) for their cases, and probably, of the amount of transported particles. The amount of organic and inorganic matter in Hluboký potok

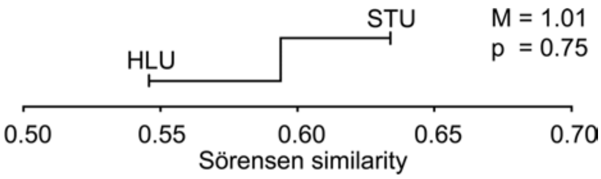

Fig. 12.2 Mean similarity dendrogram of chironomid presence/absence in Stužická rieka (STU) and Hluboký potok (HLU). Dendrogram node was plotted at overall mean between-stream similarity, and each branch end was plotted at the mean within-stream similarity for that class.

may reflect erosive processes in the watershed. The higher abundance of filtering collectors compared with Stužická rieka could be a response to this.

On the other hand, different structure of the chironomid assemblage at Hlu1 may be a response to different temperature conditions compared with the reference site Stu1. The effect of the uppermost spring Hlu1 cannot be excluded. Cold-stenothermic species *O. frigidus*, *P. branickii*, *P. nudipennis* are considered to be characteristic of mountain brooks (eprithral) in the Carpathians, however they occur in springs and spring-outlets, respectively (Ružičková et al. 1996, Kownacki et al. 1997, Hamerlík 2007). Consequently, chironomid assemblage responses to both open canopy, and temperature conditions.

Despite some differences in taxonomic composition, changes in other assemblage attributes were not so conspicuous at the downstream sites of Hluboký potok as the corresponding sites on the reference stream. Apparently, dense canopy cover played an important role and made the sites more similar to those on the reference stream. Brown et al. (1997) have found 10 m buffer strips on each side of stream channels to provide effective protection of benthic communities against any harvest techniques in watersheds.

Tab. 12.1 List of chironomid taxa collected in Hluboký potok (sites Hlu1 – Hlu3) and Stužická rieka (sites Stu1 – Stu3). Abbreviations: Pe – pupal exuviae, L – larvae.

taxa		sampling sites					
		Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Podonominae							
Paraboreochlus minutissimus (Strobl, 1894)	Pe			+			
Tanypodinae							
Conchapelopia pallidula (Meigen, 1818)	L, Pe		+	+	+	+	+
Krenopelopia sp.	L	+					
Macropelopia sp.	L					+	+
Nilotanypus dubius (Meigen, 1804)	L, Pe		+	+		+	+
Thienemannimyia sp.	L						+
Zavrelimyia sp.	L			+			
Diamesinae							
Diamesa dampfi (Kieffer, 1924)/ *permacra* (Walker, 1856)	L	+					
Diamesa cf. *insignipes* Kieffer, 1908	L					+	
Diamesa tonsa group	L	+					
Diamesa sp.	L	+					
Potthastia longimanus Kieffer, 1922	L			+			+
Pseudodiamesa branickii (Nowicki, 1873)	L	+					
Prodiamesinae							
Prodiamesa olivacea (Meigen, 1818)	L					+	
Orthocladiinae							
Brillia longifurca Kieffer, 1921	L						+
Brillia bifida (Kieffer, 1909)	L, Pe	+	+	+	+	+	+
Bryophaenocladius subvernalis (Edwards, 1929)	Pe					+	
Cardiocladius capucinus (Zetterstedt, 1850)	Pe			+			
Chaetocladius sp.	L	+				+	
Corynoneura celtica Edwards, 1924	Pe			+			+
Corynoneura cf. *coronata* Edwards, 1924	Pe			+			
Corynoneura cf. *gratias* Schlee, 1968	Pe			+			
Corynoneura cf. *lacustris* Edwards, 1924	Pe			+			+
Corynoneura Pe 2a Langton 1991	Pe		+	+		+	+
Corynoneura Pe 4 Langton, 1991	Pe			+			+
Corynoneura spp.	L	+	+	+	+	+	+
Cricotopus (s. str.) *curtus* Hirvenoja, 1973	Pe			+			
Eukiefferiella brehmi group	L	+					
Eukiefferiella brevicalcar group	L	+					

Tab. 12.1 (continued) List of chironomid taxa collected in Hluboký potok (sites Hlu1 – Hlu3) and Stužická rieka (sites Stu1 – Stu3). Abbreviations: Pe – pupal exuviae, L – larvae.

taxa		sampling sites					
		Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Eukiefferiella coerulescens (Kieffer,1926)	L, Pe	+	+	+	+	+	+
Eukiefferiella devonica group	L				+		
Eukiefferiella fuldensis Lehmann, 1972	Pe			+			
Eukiefferiella cf. *minor* (Edwards, 1929)	L, Pe	+					
Heleniella serratosioi Ringe, 1976	L, Pe	+	+	+	+	+	+
Heleniella sp. *"reticulata"*	Pe						+
Heterotrissocladius marcidus (Walker, 1856)	L				+		+
Krenosmitiia boreoalpina (Goetghebuer, 1944)	Pe			+		+	+
Krenosmitiia camptophleps (Edwards, 1929)	Pe			+	+	+	+
Krenosmittia spp.	L	+	+	+	+	+	+
Limnophyes ninae Saether, 1975	Pe					+	
Limnophyes sp.	L					+	
Metriocnemus fuscipes group	L	+					
Orthocladius (Eudactylocladius) fuscimanus (Kieffer, 1908)	Pe					+	
Orthocladius (Euorthocladius) frigidus (Zetterstedt, 1838)	L, Pe	+	+	+			
Orthocladius (Euorthocladius) rivicola Kieffer, 1921	Pe			+			
Orthocladius (Symposiocladius) lignicola (Kieffer, 1914)	L, Pe	+	+	+	+	+	+
Orthocladius (s. str.) *rubicundus* (Meigen, 1818)	Pe				+		
Orthocladius (s. str.) *ruffoi* Rossaro et Prato, 1991	Pe		+	+	+		
Orthocladius (s. str.) sp.	L		+				
Paracricotopus niger (Kieffer, 1913)	Pe			+			
Parakiefferiella sp.	L		+				
Parametriocnemus sp. A	Pe		+	+	+	+	+
Parametriocnemus Pe 2 Langton 1991	Pe		+	+	+	+	+
Parametriocnemus spp.	L	+	+	+	+	+	+
Paratrichocladius rufiventris (Meigen, 1830)	L	+					
Parorthocladius cf. *nudipennis* (Kieffer, 1908)	L	+					
Paratrissocladius excerptus (Walker, 1856)	Pe						+
Pseudorthocladius berthelemyi Moubayed, 1988	Pe			+			
Rheocricotopus (s. str.) *effusus* (Walker, 1856)	Pe			+	+		
Rheocricotopus (s. str.) *fuscipes* (Kieffer, 1909)	L, Pe		+	+	+	+	
Rheosmittia sp. A	Pe			+	+		
Rheosmittia sp. C	Pe			+	+	+	+
Rheosmittia spp.	L		+		+	+	+
Smittia sp.	L		+				
Synorthocladius semivirens (Kieffer, 1909)	L, Pe	+	+	+	+	+	+
Thienemannia sp.	L	+	+		+		
Thienemaniella Pe 2a Langton, 1991	Pe			+			+
Thienemaniella spp.	L	+			+		+
Tvetenia bavarica (Goetghebuer, 1934)	Pe			+	+		
Tvetenia calvescens (Edwards,1929)	L, Pe	+	+	+	+	+	+
Chironominae - Chironomini							
Demicryptochironomus vulneratus (Zetterstedt, 1838)	L				+		
Polypedilum (Uresipedilum) convictum (Walker, 1856)	L, Pe		+	+	+	+	+
Chironominae - Tanytarsini							
Micropsectra cf. *lindrothi* Goetghebuer 1931	Pe						+

Tab. 12.1 (continued) List of chironomid taxa collected in Hluboký potok (sites Hlu1 – Hlu3) and Stužická rieka (sites Stu1 – Stu3). Abbreviations: Pe – pupal exuviae, L – larvae.

taxa		sampling sites					
		Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Micropsectra Pe3 Langton 1991	Pe			+			+
Micropsectra spp.	L	+	+	+	+	+	+
Neozavrelia Pe1 Langton 1991	Pe			+			
Rheotanytarsus pentapoda (Kieffer, 1909)	L, Pe	+			+		
Stempellinella flavidula (Edwards, 1929)	L, Pe		+	+		+	+
Tanytarsus heusdensis Goetghebuer, 1923	L, Pe	+	+	+	+		+

13. Other flies (Diptera, excl. Chironomidae)

Collections of the Diptera in the Bukovské vrchy Mts. have been made since sixties and compiled later (Čepelák et al. 1984, 1986). Roháček et al. (1995) listed altogether 2 254 species of Diptera in a monograph of the fly fauna of the Bukovské vrchy Mts. Chironomidae and Simuliidae from the East Carpathians were described by Bitušík & Hamerlík (2001), Kubovčík & Novikmec (2001) and Illéšová & Halgoš (2001). For two bioregions – the West and the East Carpathians evaluated Krno et al. (2005) a stressor gradient for organic pollution with some common macroinvertebrate metrics.

The aim of this study is to compare the differences in the structure of Diptera (excl. Chironomidae) assemblages along a longitudinal gradient of two important streams of the Bukovské vrchy Mts: Hluboký potok and Stužická rieka.

Cluster analysis with the method of complete linkage and Euclidean distance index was used to assess the similarity of localities according to Sörensen index.

In all, 51 Diptera taxa (excl. Chironomidae) belonging to 14 families were found at 6 localities: in the Hluboký potok 46 taxa and in the Stužická rieka 31 taxa (Tab. 13.1). The differences in structure of Diptera assemblages were caused by different character of two stream types: epirhithral and metarhithral. Influence of water temperature reflects in taxonomical composition of Diptera of both springs.

Nineteen taxa were found in the spring of the Hluboký potok (Hlu1) whilst only 8 taxa (Tab. 13.1) were found in the spring of Stužická rieka (Stu1). The occurrence of two oligostenothermophilous taxa was confirmed in Hlu1: *Orimarga* spp., *Berdeniella illiesi* Wagner, 1973. *B. illiesi* was found in the epirhithral a metarhithral of the Turiec River basin (Bulánková & Degma 1993). In the epirhithral of the Stužická rieka were found oligostenothermophilous species *Dixa puberula* Loew, 1849 and *Prosimulium hirtipes* (Fries, 1824). Higher alfa-diversity in Hlu1 is caused by higher habitat diversity and by anthropic influence too. The spring of Hluboký potok has a lot of cascades, a high slope and a lot of moss-covered rocks. Mosses are a suitable habitat for the species of the family Psychodidae, first of all species of the tribus Pericomini (Bulánková 1999). Occurrence of the species *Simulium ornatum* Meigen, 1820 is probably caused by clearcutting.

Metarhithral of both streams could be divided into upper and lower section, respectively. There are some differences in riparian vegetation between the Hluboký potok and Stužická rieka. Riparian vegetation of the Stužická rieka is coniferous woodland and distribution of trees along the banks is continuous. Land-use within both banks of Hluboký potok is more diverse: there are shrubs and scrubs, trees and improved grassland. The higher diversity of mesohabitats (land-use, channel features) of Hluboký potok supports the higher diversity of Diptera taxa. Bioindicator taxa from the fam. Dixidae, Blephariceridae and Athericidae occur in both streams, highest diversity was found in Hluboký potok. Only in the natural part of the Gidra River basin were found rheophilous taxa from the family Blephariceridae together with taxa fam. Dixidae prefering lenitic parts of the stream (Bulánková 2003).

The differences were found in the structure of the Simuliidae family of both metarhithrals. In upper part of Stužická rieka (Stu2) occured 3 species: *Prosimulium hirtipes, P. tomosvaryi, Simulium monticola.* Occurrence of the species *P. hirtipes* in Stužická rieka confirms the natural character of the stream (Stloukalová, 1997). In the upper part of Hluboký potok were found 9 species of the family Simuliidae, some of them are eurytopic like *Simulium vernum, S. ornatum, S. trifasciatum*.

In the upper part of metarhithral of Hluboký potok (Hlu2) occured 9 species from the family Simuliidae. The habitat is not shaded because of the clearcutting and this is the reason of occurrence of some eurytopic species, e.g. *Simulium vernum, S. ornatum, S. trifasciatum*. On the other side, according to the occurence of *Simulium costatum, S. brevidens*, *S. monticola* and *S. auricoma* we can state good ecological quality of water. The same can be observed in the lower part of Stužická rieka (Stu3). Only a few oligo - meso trophic taxa like *Liponeura cinerascens minor*, *Chelifera* sp., *Hemerodromia* sp., *Simulium costatum, S. brevidens, S. monticola* live here. Lower habitat diversity is the reason for lower species diversity.

The lower part of Hluboký potok (Hlu3) has a similar taxonomical composition like Stužická rieka (Stu3) with the exception of the species from Simuliidae family. In Hlu 3 we found 9 species of blackflies, some of them (e.g. *Simulium argyreatum, S. variegatum* and *S. ornatum*) were settled in high number in degraded streams (Feld et al. 2002). *Simulium rostratum* is a characteristic species of lower metarhithral with a high discharge.

Cluster analysis (Fig. 13.1) confirmed similarity of the epirhithrals and metarhithrals. The cluster analysis based on qualitative samples clearly distinguished two clusters A – Hluboký potok and B – Stužická rieka. In both clusters springs differed from other localities. It is caused by presence of crenophilous and crenobiont taxa in Hlu1 and Stu1 (Tab. 13.1). The highest similarity (70%) showed metarhithral of Hluboký potok (Hlu2 and Hlu3), metarhithral of Stužická rieka was 65% similar.

On the basis of our results we can assume a good ecological quality of water of Hluboký potok and

Stužická rieka. High habitat diversity of Hluboký potok supply antropic influence (clearcutting) showed in presence of *Simulium ornatum.*

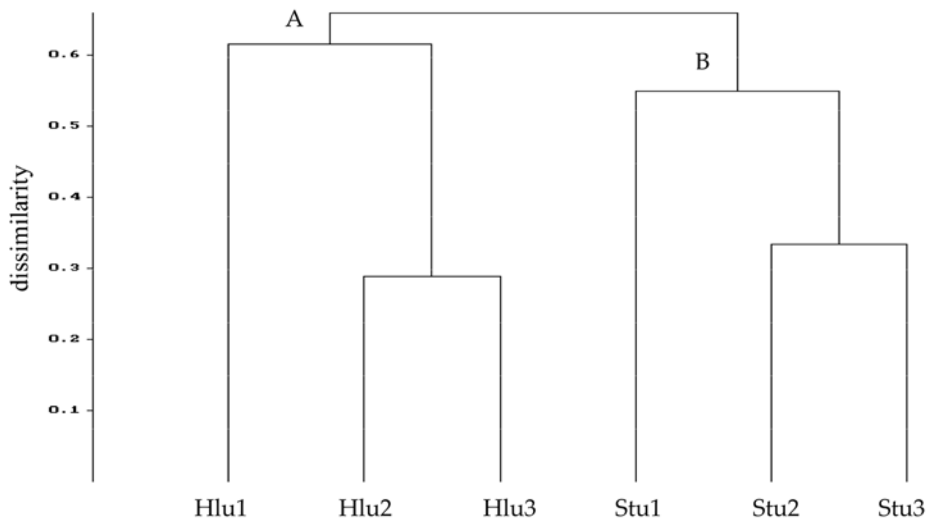

Fig. 13.1 Cluster analysis (complete linkage) of localities of Hluboký potok and Stužická rieka based on the presence of Diptera taxa (excl. Chironomidae).

Tab. 13.1 List of Diptera (excl. Chironomidae) taxa of investigated localities of Hluboký potok and Stužická rieka (East Carpathians). Dominance: 0-1% SR (subrecedent), 1-2 % R (recedent), 5-10% SD (subdominant), 10-20% D (dominant), 20-100% ED (eudominant), ET –ecological tolerance: E - euryoecious, St – stenoecious.

	sampling site						
taxon	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	ET
Limoniidae							
Eloeophila submarmorata (Verrall, 1887)		SR	SR	R		R	S
Eloeophila maculata (Meigen, 1804)		R	R			SD	S
Eloeophila mundata (Loew, 1871)					SD		S
Hexatoma spp.	R	SR	SR	R			S
Ellipteroides alboscutellatus (von Roser, 1840)		D	SD	SD	SR	ED	S
Molophilus spp.	R				SR	SR	S
Orimarga spp.	SR						S
Rhypholophus haemorrhoidalis (Zetterstedt, 1838)	SR						S
Pediciidae							
Dicranota spp.	D	SD	SD	SD	SD	SD	E
Pedicia (C.) straminea (Meigen, 1838)	SD		SD		D	SD	S
Pedicia (P.) rivosa Linnaeus, 1758	SD			R			S
Tricyphona immaculata (Meigen, 1804)	SR				SD		S
Tipulidae							
Tipula (A.) fulvipennis Degeer, 1776	SR						S
Tipula (E.) saginata Bergroth, 1891					R	SR	S
Blephariceridae							
Liponeura cinerascens minor Bischoff, 1922	SD	D	SD	SD	SR	SD	S
Psychodidae							
Berdeniella illiesi Wagner, 1973	SR						S
Berdeniella unispinosa (Tonnoir, 1919)	R						S
Pneumia stammeri (Jung, 1956)	ED	SR	SR	ED	D	SD	S
Bazarella subneglecta (Tonnoir, 1922)	D				SR		S

Tab. 13.1 (continued) List of Diptera (excl. Chironomidae) taxa of investigated localities of Hluboký potok and Stužická rieka (East Carpathians). Dominance: 0-1% SR (subrecedent), 1-2 % R (recedent), 5-10% SD (subdominant), 10-20% D (dominant), 20-100% ED (eudominant), ET –ecological tolerance: E - euryoecious, St – stenoecious.

	sampling site						
taxon	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3	ET
Clytocerus spp.	SR						S
Berdeniella manicata (Tonnoir, 1920)	SR						S
Tonnoiriella pulchra (Eaton, 1893)	R						S
Dixidae							
Dixa dilatata Strobl, 1984						SR	S
Dixa gr. maculata (Meigen, 1818)	SR	SR	SD				S
Dixa nebulosa Meigen, 1818			SR				S
Dixa nubilipennis Curtis, 1832	SR	R					S
Dixa puberula Loew, 1849			SR	R			S
Ceratopogonidae	SR	R	SR	SD	SD	SD	S
Simuliidae							
Prosimulium hirtipes (Fries, 1824)				R	ED	SR	S
Prosimulium tomosvaryi (Enderlein, 1921)		SD	SD		SR		E
Simulium (N.) costatum (Friederichs, 1920)		SR				SR	S
Simulium (N.) brevidens (Rubtsov, 1956)		SR				SR	S
Simulium (N.) vernum (Macquart, 1838)		SD	SR				E
Simulium (S.) ornatum Meigen, 1820	SR	SD	SD				E
Simulium (S.) trifasciatum Curtis, 1839		SD	R			SD	E
Simulium (S.) argyreatum Meigen, 1838		R	SD			SR	E
Simulium (S.) monticola (Friederichs, 1920)	SD	D	D		SD	SD	S
Simulium (S.) variegatum Meigen, 1818			SD				E
Simulium (O.) auricoma (Meigen, 1818)		R	D				S
Simulium (S.) rostratum (Lundstrőm, 1911)			SR				E
Thaumaleidae							
Thaumalea sp.	SR			D	SR	SD	S
Athericidae							
Ibisia marginata (Fabricius, 1781)		ED	D		SD	SD	S
Atherix ibis (Fabricius, 1798)		SD	SD	R		SD	S
Atrichops crassipes Meigen, 1820					SR		S
Tabanidae							
Chrysops caecutiens (Linnaeus, 1758)		SR					E
Empididae							
Chelifera stigmatica (Schiner, 1862)	SD		SD			R	S
Chelifera flavella (Zetterstedt, 1838)			R		SD	SD	S
Wiedemannia spp.	SD	R					S
Hemerodromia spp.	SD		SR		SD	SD	S
Dolichopodidae							
Liancalus virens (Scopoli, 1763)			SR				S
Scatophagidae							
Acanthocnema glaucescens (Loew, 1864)	R						S

14. Organic matter and macroinvertebrate communities of Hluboký potok and Stužická rieka brooks: An assessment of human impact

Silvicultural practices are considered to be one of the major anthropogenic factor influencing structure and function of headwater streams worldwide (for review see Introduction).
As it was mentioned in earlier chapters, we attempted to study effect of intensive logging (clear-cut) on two similar East Carpathian streams. Some notes to influence of forest harvest management on stream macroinvertebrates in vulnerable conditoins of flysch mountains of the East Carpathians are given by Bitušík & Novikmec (1997).
All the detailed description of comparison and assessment procedures used in evaluating the effect of silvicultural practices on the East Carpathian streams is given within general methods description (see chapter Material and Methods), henceforward we comment on briefly our results. Some depiction of differences between communities of investigated organisms group of two compared streams is given within previous chapters (e.g. Mayflies, Stoneflies, Chironomids). Herein we attempt to asses the impact on the whole macroinvertebrate community, its energy base, its structure and functional organisation.

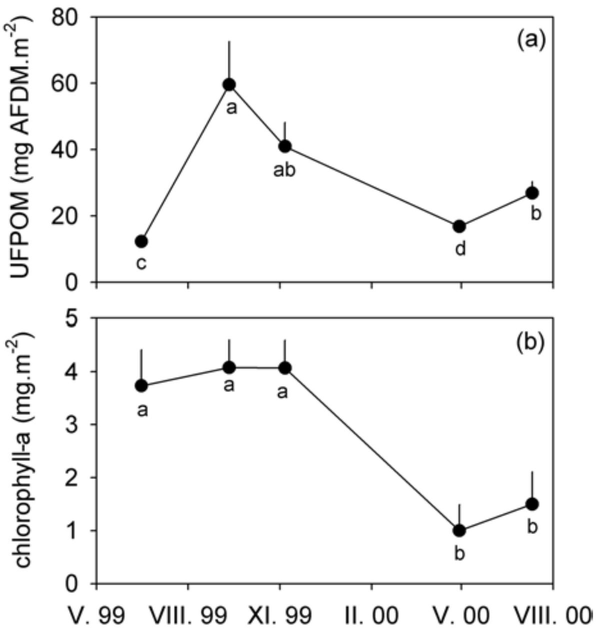

Fig. 14.1 Temporal variability in UFPOM (a) and chlorophyll-a (b). Each value represents the mean for replicates pooled across streams and sites (+ 1 × SE). Symbols with the same lowercase letters are not significantly different (pair-wise comparison, $p < 0.05$).

Organic matter
Biomass of UFPOM of studied streams significantly varied in response to time (Tab. 14.1). Average biomass of UFPOM was higher during the autumn months, than during the rest of the year (Fig. 14.1a). Amount of FPOM differed among months, but there was significant interaction between time and stream showing that the effect of time depended on stream (Tab. 14.1). Temporal variability in FPOM was considerable in Stužická rieka but not in Hluboký potok (Fig. 14.2).
The quantity of chlorophyll-a varied among months (Tab. 14.2). In general, average amount of chlorophyll-a in streams was higher in the first year of study (Fig. 14.1b). We did not find any significant spatial or temporal differences in the biomass of CPOM, TOM, and aufwuchs.
One of the major consequences resulting from the clear-cut logging is the change in the energy base of the stream system (Kadzierski & Smock 2001). FPOM increases would be expected as result of increased algal production stimulated by more sunlight reaching the stream (McCord et al. 2007). On the other hand, amount of CPOM would decrease after canopy loss (Martin et al. 1981).
In the present study, we did not record any clear shifts in the amount of CPOM vs. FPOM among studied sites. The average amount of fine organic matter was even higher at sites of logged Hluboký potok.
Many studies have documented seasonal changes in benthic organic matter and seasonal limitation of food supply for stream dwelling macroinvertebrates (cf. Haapala & Muotka 1998). Benthic organisms consumption reduce amount of benthic organic matter gradually, in contrast to discharge fluctuation or other type of disturbance which may impact food resources immediately (Grubbs & Cummins 1996). Petersen et al. (1989) have found that short-term discharge fluctuations had the strongest impact on the amount of benthic organic matter.
The discharge regimes may explain different temporal dynamics of FPOM in the compared streams. First, relative discharge fluctuation was higher at sites of Hluboký potok (see chapter Research area characteristics). Streams draining flysch subsoils catchments have strong susceptibility to fluctuation of discharge regime (Bitušík & Novikmec 1997). In general, the deforestation of catchments cause flashy hydrological regimes (Eisenbies et al. 2007). Second, the higher mean amount of the both organic and anorganic transported matter was recorded at the sites of Hluboký potok (see chapter Research area characteristics).
Thus, we may speculate about strength of the discharge disturbance and its effect on the amount of food resources and transported matter as well.

Macroinvertebrate communities
A total of 160 species or higher taxa were identified across all sites and months. Thirty-two of them were

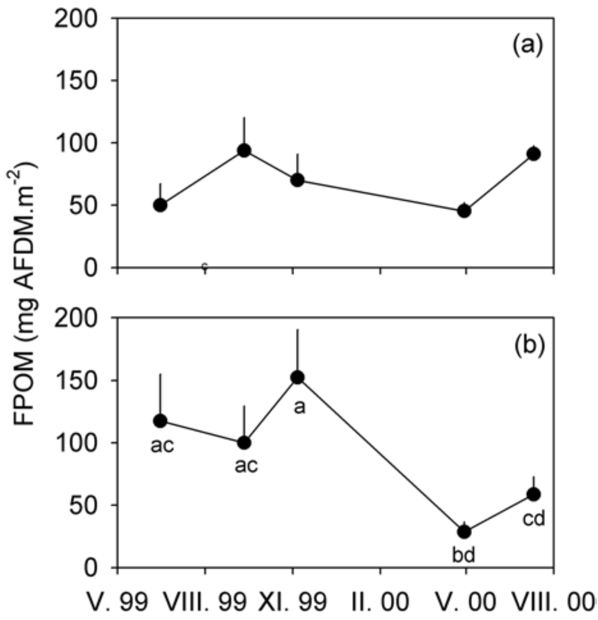

Fig. 14.2 Temporal variability in FPOM at Hluboký potok (a) and Stužická rieka (b). Each value represents the mean for replicates pooled across sites (+ 1 × SE). Symbols with the same lowercase letters are not significantly different (pair-wise comparison, $p < 0.05$).

found solely in Stužická rieka and 25 in Hluboký potok. Total taxonomic richness varied from 16 taxa (Hlu2, September 1999) to 43 taxa (Stu3, November 1999). Overall macroinvertebrate density ranged from 720 ind.m^{-2} (Hlu2, July 2000) to 6456 ind.m^{-2} (Hlu1, November 1999). However, we did not find any significant differences in density and richness between streams or among months (Tab. 14.3). The same was true for the analysis of FFG (results not shown).

The whole community patterns were displayed using two-dimensional solution of the MDS ordination (Fig. 14.3a). The main dissimilarity was represented by the first axis that separated sites of both streams along altitudinal gradient. This dimension was positively correlated with UFPOM and temperature and negatively correlated with CPOM, ammonium-N and nitrate-N (Fig. 14.3b). Visual inspection of the ordination showed that corresponding sites of questioned streams are clustered together, especially those in the middle of the altitudinal range (Hlu2 and Stu2). A notable exception was site Hlu1 with community quite different from its counterpart (Stu1) and other sites as well.

Species indicator analysis identified 9 characteristic species (IndVal > 70%) for Stužická rieka and 2 characteristic species for Hluboký potok (Fig. 14.3c).

Differences along vertical dimension (MDS2) reflect mainly seasonal variability. This axis was negatively correlated with amount of UFPOM and positively with transported anorganic matter (TAM). Distance-based MANOVA showed that sites differed in species composition through

Tab.14.1 Results of nested RM-MANOVA of the effects of stream, site and time on changes in the CBOM (log transformed), FPOM (square root transformed) and UFPOM (log transformed). F statistics for within subject effects are based on Wilks' lambda. Values of statistics labelled with asterisks indicate significant results at $p < 0.05$ (*), $p < 0.01$ (**) and $p < 0.001$ (***).

	CPOM				FPOM				UFPOM			
source of variation	df	SS	MS	F	df	SS	MS	F	df	SS	MS	F
between subject effect												
stream	1	0.020	0.020	0.068	1	10.527	10.527	1.493	1	0.038	0.038	0.375
site(stream)	4	3.340	0.835	2.897	4	74.009	18.502	2.624	4	1.122	0.281	2.735
residual	6	1.729	0.288		6	42.302	7.050		6	0.616	0.103	
within subject effect										2.548	0.637	
time	4	4.046	1.012	7.004	4	113.024	28.256	17.348*	4	0.207	0.052	21.777*
time × stream	4	0.600	0.151	0.824	4	100.332	25.083	9.700*	4	1.285	0.080	5.564
time × site(stream)	16	4.200	0.263	1.157	16	142.538	8.909	1.470	16	0.969	0.040	2.372
residual	24	5.920	0.248		24	195.901	8.163		24	0.038	0.038	
total	59	19.855			59	678.633			59	6.823		

Note: the stream variable is Hluboký potok and Stužická rieka. The site variable is upper, middle, and lower situated site within stream.

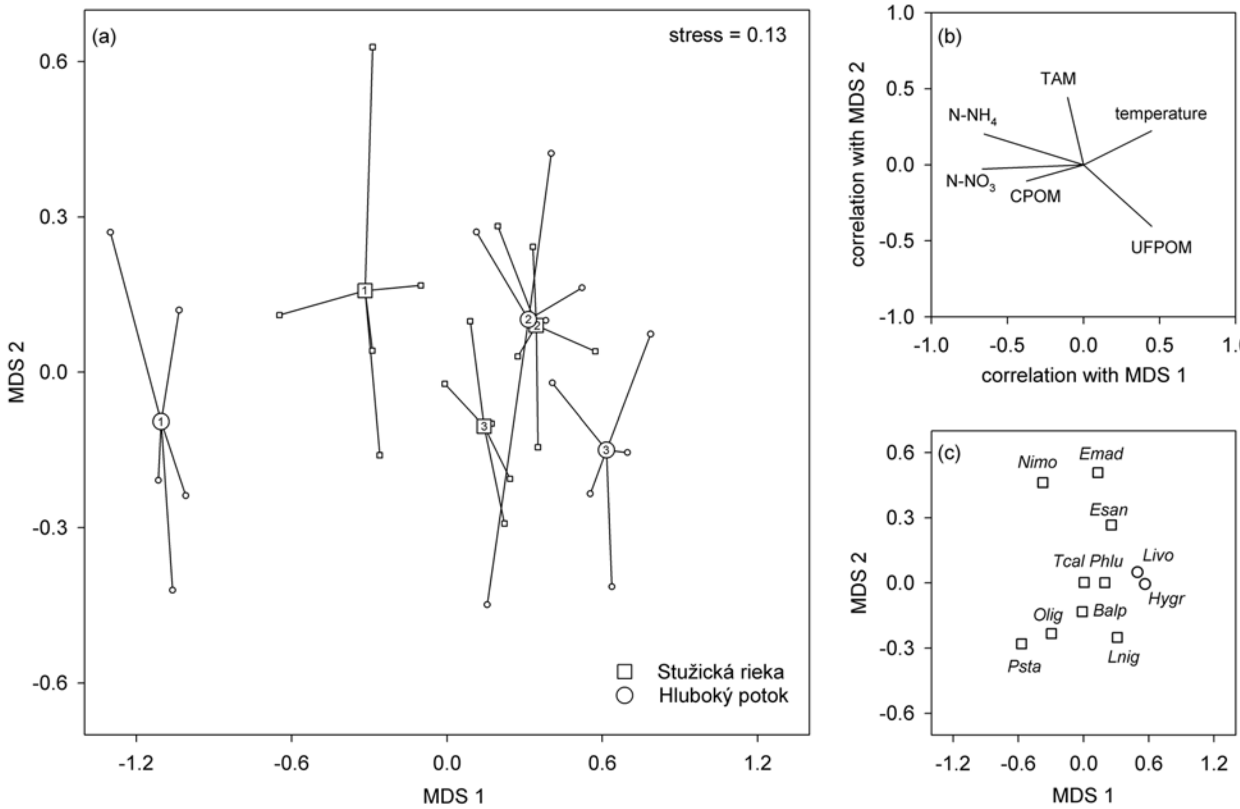

Fig. 14.3 Results of MDS analysis based on square root transformed densities of benthic macroinvertebrates showing similarity (Bray-Curtis distance) of monthly samples and its centroids (a). Environmental variables significantly ($p < 0.05$) correlated with MDS configuration (b) and scores of characteristic species (IndVal > 70%) (c) are displayed. Squares and circles represent samples from Stužická rieka and Hluboký potok, respectively. The same signs were used for plotting of species scores. Abbreviations of species names are as follows: Balp – *Baetis alpinus*, Emad – *Ecclisopteryx madida*, Esan – *Esolus angustatus*, Hygr – *Hydraena gracilis*, Livo – *Limnius volkcmari*, Lnig – *Leuctra nigra*, Nimo – *Niphargus molnari*, Phlu – *Philopotamus ludificatus*, Psta – *Pneumia stammeri*, Slig – *Orthocladius lignicola* and Tcal – *Tvetenia calvescens*.

time, perhaps reflecting species phenology (Tab. 14.1). Subsequent pair-wise comparison between months revealed that only sample pairs June 1999 *vs.* April 2000, September 1999 *vs.* November 1999 and April 2000 *vs.* July 2000 did not differed significantly in their community composition (results not plotted). Spatial differences were not statistically significant.

Macroinvertebrate densities and biomass are often higher in streams disturbed by timber harvest (Noel et al. 1986, Hawkins et al. 1982, Hetrick et al. 1998), but logging effect on taxa richness and diversity of stream macroinvertebrates are often split, Carlson et al. (1990) found out no significant differences in the number of taxa and diversity of benthic assemblages between logged and paired undisturbed streams. Likewise, Newbold et al. (1980) did not find any differences between clearcut and forested riparian zones streams.

Herlihy et al. (2005) conclude (based on cited studies), that richness, proportion and community assemblage measures are much less sensitive to logging disturbances than abundance measures.

Functional structure (composition of FFG) is strongly related to energy base. In our case (without any dramatic shifts in energy sources, l. c.), any structural changes in macroinvertebrate communities of compared streams would be even surprising.

The only site with exceptional composition of macroinvertebrate communities was site Hlu1. Increased exposure to sunlight supported high periphyton growth at this site (see chapter Epilithic diatoms) and consequently higher proportion of grazing species of macroinvertebrates (e.g chironomids *Diamesa* spp., *Eukiefferiella* spp., caddisflies of fam. Drusinae). Moreover, these taxa were present in higher densities, what is usually attributed to the increases in the growth of algae at logged sites (Carlson et al. 1990). Alternativelly, the unlikeness of site Hlu1 could possibly be also caused by its thermal conditions and by presence of oligothermophilous species (see chapter Chironomidae).

Some of structural characteristics expressed by metrics showed differences between Hluboký potok and Stužická rieka. All of these metrics are considered to be sensitive to organic pollution or/and degradation in stream morphology (Hering et al. 2004). Because there was insufficient number of data for statistical testing, comparison of selected

Tab. 14. 2 Results of RM-MANOVA of the effects of stream and time on changes in the TOM (log transformed), chlorophyll-a and aufwuchs. F statistics for within subject effects are based on Wilks' lambda. Values of statistics labelled with asterisks indicate significant results at $p < 0.05$ (*), $p < 0.01$ (**) and $p < 0.001$ (***).

	TOM				chlorophyll-a				aufwuchs			
source of variation	df	SS	MS	F	df	SS	MS	F	df	SS	MS	F
between subject effect												
stream	1	0.009	0.009	0.063	1	5648170	5648170	0.969	1	0.079	0.079	0.026
residual	4	0.567	0.142		4	23307332	5826833		4	11.986	2.997	
within subject effect												
time	4	0.331	0.083	0.293	4	58759098	14689775	761.860*	4	4.658	1.165	0.552
time × stream	4	0.597	0.149	2.662	4	3855922	963981	14.557	4	1.903	0.476	0.212
residual	16	0.479	0.030		16	12812342	800771		16	12.738	0.796	
total	29	1.983			29	104382864			29	31.364		

Note: the stream variable is Hluboký potok and Stužická rieka.

Tab. 14.3 Results of RM-MANOVA of the effects of stream and time on taxonomic richness, total density (log transformed) and results of distance-based MANOVA of the same effects on composition of macroinvertebrate community (square root transformed densities). F statistics for within subject effects on richness and density are based on Wilks' lambda. Values of statistics labelled with asterisks indicate significant results at $p < 0.05$ (*), $p < 0.01$ (**) and $p < 0.001$ (***).

	taxonomic richness				total density				community composition			
source of variation	df	SS	MS	F	df	SS	MS	F	df	SS	MS	pseudo-F
between subject effect												
stream	1	87	87	0.721	1	0.141	0.141	0.475	1	3446	3446	0.466
residual	4	481	120		4	0.905	0.226		4	29575	7394	
within subject effect												
time	4	245	61	2.332	4	0.494	0.124	39.035	4	10947	2737	3.002***
time × stream	4	116	29	1.144	4	0.160	0.040	0.801	4	4436	1109	1.217
residual	16	734	46		16	0.350	0.022		16	14586	912	
total	29	1663			29	2.050			29	62990		

Note: the stream variable is Hluboký potok and Stužická rieka.

streams were not supported by statistical analysis. Comparison of two studied streams, when three sampling sites of both streams were pooled together, showed differences in several aspects of invertebrate community structure (Fig. 14.4, Tab. 14.4).
Number of families sensitive to human impact (BMWP index) and diversity (Shannon-Wiener index) reached higher values in non-impacted stream. Also some differences were detected in substrate preferences; taxa preferring psammal ([%] Type Psa (scored taxa = 100%)) had higher relative abundance in non-impacted stream. Considering functional feeding groups xylophagous taxa, shredders and filter feeders ([%] Xyloph. + Shred. + ActFiltFee. + PasFiltFee.) had higher proportion in non-impacted stream. This is related to higher standing stock of woody debris, which results in higher percentage of xylophagous taxa and shredders, supplemented by filter feeders dependent on FPOM generated by shredders (Lorenz et al. 2004). In term of taxonomic composition, number of Ephemeroptera, Plecoptera and Trichoptera taxa (EPT taxa) was also higher in non-impacted stream. Better conditions for development of EPT communities were also reflected in higher abundances of Plecoptera and Trichoptera in lower sections of Stužická rieka comparing with Hluboký potok. Detailed information about plecopteran and trichopteran assemblages in both compared streams is mentioned in previous chapters, where negative influence of catchment deforestation on density and also some taxa occurrence were documented. Comparing lower sections of studied streams (without spring sampling sites) revealed other differences. Increase of saprobity of impacted stream was more intense comparing with non-impacted stream. This could be the result of higher concentration of dissolved matter and conductivity in Hluboký potok (see Research area characteristics). Moreover, the proportion of gathers/collectors was higher in non-impacted stream, what is related to higher proportion and density of Oligochaeta. Similar pattern was observed in Turiec river. After reservoir construction, the decline of gatherers/collectors was the result of changes in hydrological regime (Krno et al. 1995). In case of Hluboký potok negative effect of deforestation on hydrological regime could cause observed differences. Higher discharge fluctuations as a result of deforestation in Hluboký potok catchment could cause scouring the fine sediments from the bottom. Higher proportion of Oligochaeta and Gathers/Collectors in non-impacted stream signify more stable bottom suitable for colonisation of permanent fauna. This idea is supported also by higher proportion of taxa preferring unstable substrate psammal in Stužická rieka. Lower proportion of shredders in Hluboký potok could also reflect the flushing of POM during high discharges.

Tab. 14.4 Metric comparison between Hluboký potok (Hlu) and Stužická rieka (Stu). Averege values are displayed.

metric	Hlu	Stu
Saprobic Index (Zelinka & Marvan)	1.3	1.1
BMWP	87.7	106.1
Diversity (Shannon-Wiener-Index)	1.6	2.1
[%] Shredders	1.8	3.3
[%] Gatherers/Collectors	10.8	19.5
[%] Type Psa (scored taxa = 100%)	13.7	20.4
[%] Xyloph. + Shred. + ActFiltFee. + PasFiltFee	2.1	3.9
EPT-Taxa	12.5	16.2
Oligochaeta [%]	2.5	8.5
Oligochaeta density	34	148.8
Plecoptera density	82.6	122.4
Trichoptera density	12.8	64.1

In spite of the fact, that there were not significant differences in the amount of POM among studied sites and differences in macroinvertebrate communities structure can not be statistically analysed, these results indicate that macroinvertebrate community in Hluboký potok could be influenced by harvest management. More data from these streams should be gathered to support this conclusion.
However, it must be reminded that even if we did not find overall statistically significant changes, the differences exist, especially in the species composition within particular sensitive groups (e.g. more euryoecous species of stoneflies in Hluboký potok; see chapter Stoneflies). Restricted distributions of particular species can be explained by slight changes in some of the individual characteristics of the streams (Liljaniemi et al. 2002). As it was stated before, investigators usually meet the problem of reliable reference condition in assessment the effect of silvicultural practices on stream invertebrates. In our case, we found two streams indeed very similar in stream channel characteristics. Probably, the main reason why also species assemblages appeared relatively similar may be lacking of the major differences in habitat characteristics and water quality (potentially caused by earlier deforestation) between the reference and impacted stream.
Moreover: i) there was little chance of detecting the difference between streams because of low statistical power of tests resulting from the quite small sample sizes and/or high within-stream variability.
ii) our conclusions are based on two years study with a few years lapse from the intensive logging activities in one of the catchments. "Time aspect" is often very important in logging impact assess-

ment (McCord et al. 2007) and some authors caution that long term studies are needed to evaluate any effects (Hutchens et al. 2004).

Thus, we hope that our study will be at least contribution to treatise on a complicated issue, which stream response to silvicultural activities undoubtedly is.

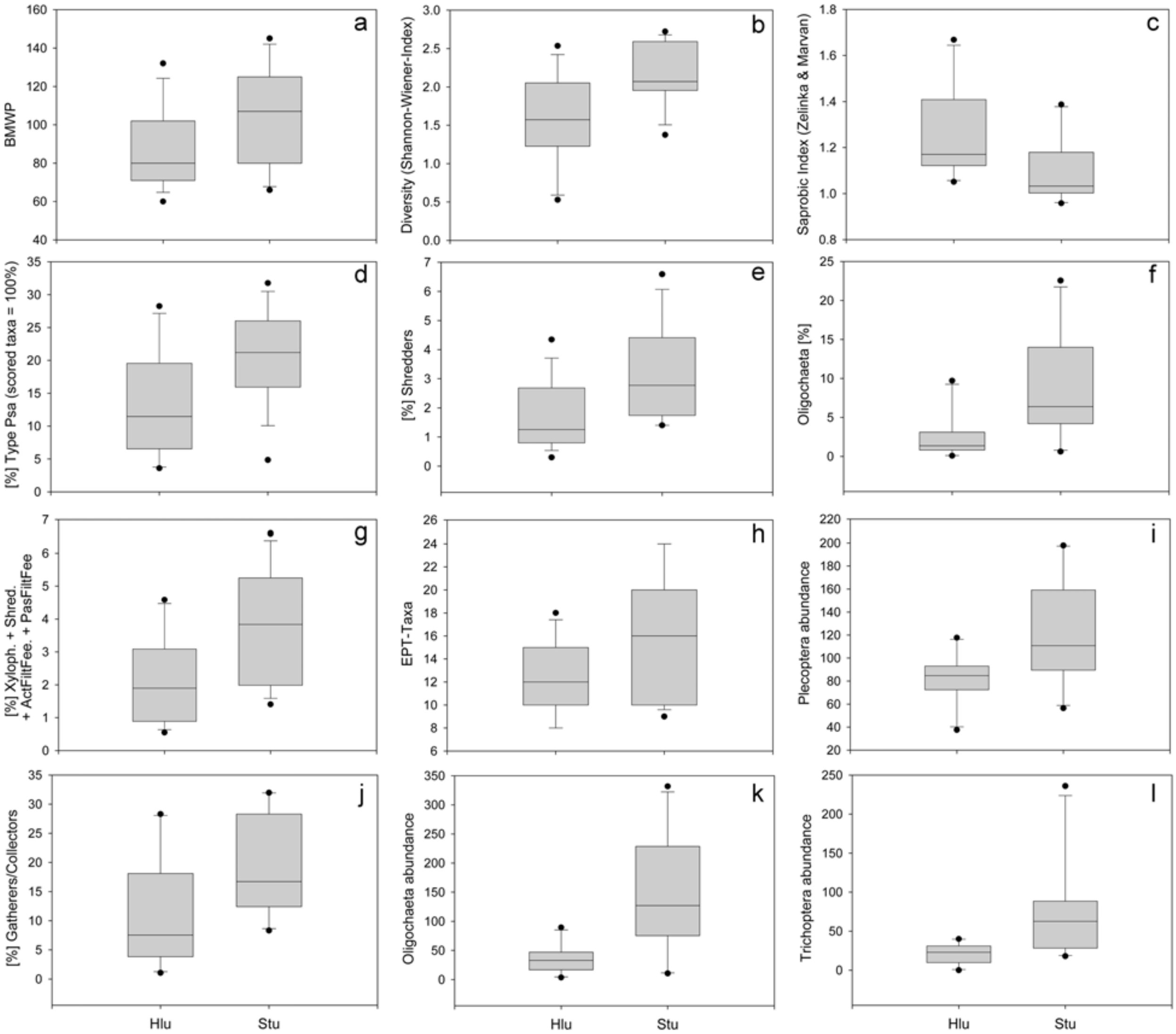

Figure 14.4 Box-and – whisker plots of selected metrics showing the differences between invertebrate communities of all sampling sites of Hluboký potok (Hlu) and Stužická rieka (Stu). a) BMWP index, b) Diversity index (Shannon-Weaner, c) saprobic index (Zelinka & Marvan), d) % of taxa preferring psammal, e) % of shredders, f) % of Oligochaeta, g) % of xylophagous taxa+shredders+active filter feeders + passive filter feeders, h) number of Ephemeroptera, Plecoptera and Trichoptera taxa, i) Plecoptera abundance, j) % of gathers/collectors, k) Oligochaeta abundance and l) Trichoptera abundance.

15. References

Allan J. D., 1995: Stream Ecology – Structure and function of running waters. Chapman & Hall, London, UK, 338 pp.

Anderson M. J., 2001: A new method for non-parametric multivariate analysis of variance. Aust. Ecol. 26: 32–46.

Anderson M. J., 2004: DISTLM v.5: a FORTRAN computer program to calculate a distance-based multivariate analysis for a linear model. Department of Statistics, University of Auckland, New Zealand.

Anderson M. J. & Robinson J., 2003: Generalised discriminant analysis based on distances. Australian & New Zealand Journal of Statistics 45: 301–318.

Anonymus, 2002: Landscape atlas of the Slovak republic, 1st edition. Bratislava: Ministry of Environment of the Slovak Republic; Banská Bystrica: Slovak Environmental Agency, 344 pp.

Bartlett M. S., 1937: Properties of sufficiency and statistical tests. Proceedings of the Royal Statistical Society, Series A 160: 268–282.

Bastl I. & Šporka F., 1986: Ichtyofauna a zoobentos povodia vodárenskej nádrže Starina a návrh na jej účelové rybárske obhospodarovanie (štúdia). Laboratórium rybárstva a hydrobiológie, Bratislava, 23pp.

Behmer D. J. & Hawkins Ch. P., 1986: Effects of overhead canopy on macroinvertebrate production in a Utah stream. Freshwater Biology 16: 287–300.

Beier M., 1948: Zur Kenntnis von Körperbau und Lebensweise der Helminen. Rev. esp. Ent. 24: 123–211.

Berg M. B., 1995: Larval food and feeding behaviour. In Armitage P. D., Cranston P. S. & Pinder L. C. V. (eds.), The Chironomidae: Biology and ecology of non-biting midges, Chapman & Hall, London, p. 136–168.

Berg M. B. & Hellenthal R. A., 1992: The role of Chironomidae in energy flow of a lotic ecosystem. Neth. J. Aquat. Ecol. 26: 471–476.

Bilby R. E. & Bisson P. A., 1992: Allochthonous versus autochthonous organic matter contributions to the trophic support of fish populations in clear-cut and old-growth forest streams. Can. J. Fish. Aquat. Sci. 49: 540–551.

Bílý J., 1941: Příspěvek ku poznání květeny rozsivek Vysokých Tater. Práce Moravské přírodověd. Společnosti sv. 13, spis 2, sign. F 127, Brno, p. 1–12.

Bitušík P. & Hamerlík L., 2001: Chironomids (Diptera, Chironomidae) of two streams in the Poloniny National Park (West Carpathians, Slovakia). Acta Universitatis Carolinae, Biologica 45: 15–18.

Bitušík P. & Novikmec M., 1997: Štruktúra makrozoobentosu Zbojského potoka (BR CHKO Východné Karpaty). Ochrana prírody 15: 127–139.

Bitušík P., Bulánková E., Černý J., Fajmonová E., Halgoš J., Kodada J., Krno I., Šporka F. & Vranovský M., 1996: Tečúce vody. In Ružičková H., Halada Ľ., Jedlička L. & Kalivodová E. (eds.), Biotopy Slovenska, príručka k mapovaniu a katalóg biotopov. ÚKE SAV, Bratislava, p. 117–125.

Bitušík P., Bulánková E., Halgoš J., Illéšová D., Neméthová D. & Šporka F., 2004: Comparison of aquatic Diptera between two streams in Poloniny national Park (East Carpathians, Slovakia). Folia Fac. Sci. Nat. Univ. Masaryk Brun., Biol. 109: 51–64.

Blatterer H., 1994: Die Ciliaten oberösterreichischer Fliessgewässer mit besonderer Berücksichtigung der südlichen Inn-Zubringer. Kataloge des ÖÖ. Landesmuseums N.F. 71: 149–163.

Borutzky E. W., 1952: Harpacticoida presnykh vod. Fauna SSSR, Rakoobraznye 3, 4: 1–424.

Bray J. R. & Curtis J. T., 1957: An ordination of upland forest communities of southern Wisconsin. Ecological Monographs 27: 325–349.

Bretschko G., 1991: The limnology of a low order alpine gravel stream (Ritrodat-Lunz study area, Austria). Verh. Internat. Verhein. Limnol. 24: 1908–1912.

Brown A. V., Aguila Y., Brown K. B. & Fowler W. P., 1997: Responses of benthic macroinvertebrates in small intermittent streams to silvicultural practices. Hydrobiologia 347: 119–125.

Brtek J., 2001: Príspevok k poznaniu amphipod Slovenska (I. Gammaroidea, Crangonyctoidea, Corophioidea). Acta Rer. Natur. Mus. Nat. Slov. 47: 65–89.

Bulánková E., 1999: Výskyt vybraných skupín vodných dvojkrídlovcov v BR Poľana. Folia Faunistica Slovaca 4: 151-156.

Bulánková E., 2003: Communities of Diptera (excl. Chironomidae, Simuliidae) of the Gidra River Basin. Acta Zool. Univ. Comenianae, Bratislava 45: 85–94.

Bulánková E. & Degma P., 1993: Structure of Taxocoenoses of Preimaginal Stages of Diptera (excl. Chironomidae, Simuliidae) in the Turiec River Basin (West Carpathians). Acta Zool. Univ. Comenianae, Bratislava 37: 3–15.

Carlson J. Y., Andrus C. W. & Froehlich H. A., 1990: Woody debris, channel features and macroinvertebrates of streams with logged and undisturbed riparian timber in northeastern Oregon, U. S. A. Can. J. Fish. Aquat. Sci. 47: 1103–1111.

Čepelák J. (ed.), 1984a: Diptera Slovenska I, Veda, SAV, Bratislava, 288 pp.

Čepelák J. (ed.), 1984b: Diptera Slovenska II, Veda, SAV, Bratislava, 435 pp.

Chvojka P., 1993: New data on the caddis fly fauna (Trichoptera, Insecta) of Slovakia from the East Carpathians. Biológia, Bratislava 48: 217–221.

Čiampor Jr. F. & Zaťovičová Z., 2004: First record of *Esolus pygmaeus* (Coleoptera: Elmidae) from Slovakia. Biologia, Bratislava 59, p. 218.

Clarke K. R. & Green R. H., 1988: Statistical design and analysis for a biological effects Study. Marine Ecology - Progress Series 46: 213–226.

Council of the european communities, 2000: Directive 2000/60/EC of the European parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, 72 pp.

Crowson R. A., 1981: The biology of the Coleoptera. Academic press, London, 802 pp.

Cummins K. W., 1973: Trophic relations of aquatic insects. Annual Review of Entomology 18: 183–206.

Davies P. E., Cook L. S. J., McIntosh P. D. & Munks S. A., 2005: Changes in stream biota along a gradient of logging disturbance, 15 years after logging at Ben Nevis, Tasmania. Forest Ecology and Management 219: 132–148.

Derka T., 1998: Effect of regulation of a submontane river on mayfly communities (Insecta, Ephemeroptera) Biologia, Bratislava 53: 189–194.

Deván P., 1992: K poznaniu Podeniek (Ephemeroptera)

Východných Karpát. Ochrana Prírody 1: 235–244.

Dufrêne M. & Legendre P., 1997: Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345–366.

Eisenbies M. H., Aust W. M., Burger J. A. & Adams M. B., 2007: Forest operations, extreme flooding events, and considerations for hydrologic modeling in the Appalachians-A review. Forest Ecology and Management 242: 77–98.

Faith D. P., Minchin P. R. & Belbin L., 1987: Compositional dissimilarity as a robust measure of ecological distance. Vegetatio 69: 57–68.

Foissner W., 1997: Faunistic and taxonomic studies on ciliates (Protozoa, Ciliophora) from clean rivers in Bavaria (Germany), with descriptions of new species and ecological notes. Limnologica 27: 179–238.

Friberg N., 1997: Benthic invertebrate communities in six Danish forest streams: Impact of forest type on structure and function. Ecography 20: 19–28.

Gágyorová K. & Marvan P., 2002: *Didymosphenia geminata* a *Gomphonema ventricosum* (Bacillariophyceae) v Moravskoslezských Beskydech. Czech Phycology, Olomouc 2: 61–68.

Ganner B. & Blatterer H., 1997: Ciliate communities in rivers Tirol and Voralberg with regard to their degree of organic Pollution. J. Euc. Microbiol., 44: Abstr. 117: 29A.

Golladay S. W., Webster J. R. & Benfield E. F. 1987: Changes in stream morphology and storm transport of seston following watershed disturbance. J. N. Am. Benthol. Soc. 6: 1–11.

Golladay S. W., Webster J. R. & Benfield E. F., 1989: Changes in benthic organic matter following watershed disturbance. Holarct. Ecol. 12: 96–105.

Golladay S. W., Webster J. R., Benefield E. F. & Swank W. T., 1992: Changes in stream stability following forest clearing as indicated by storm nutrinet budgets. Arch. Hydrobiol. 90, Suppl. 1: 1–33.

Gregory S. V., Swanson F. J., McKee W. A. & Cummins K.W., 1991: An ecosystem perspective of riparian zones. BioScience 41: 540–551.

Griffiths M. 2002: The European Water Framework Directive: An Approach to Integrated River Basin Management. European Water Management Online, Official Publication of the European Water Association (EWA), 15 pp.

Grubbs S. A. & Cummins K. W., 1996: Linkages between riparian forest composition and shredder voltinism. Arch. Hydrobiol. 137: 39–58.

Gurtz M. E. & Wallace J. B., 1984: Substrate-mediated response of stream invertebrates to disturbance. Ecology 65: 1556–1569.

Haapala A. & Muotka T., 1998: Seasonal dynamics of detritus and associated macroinvertebrates in a channelized boreal stream. Arch. Hydrobiol. 142: 171–189.

Hamerlík L. 2007: Taxocenózy pakomárovitých (Dipera, Chironomidae) litorálu, prítoku a odtokov troch vysokotatranských jazier. Dizertačná práca, Fakulta ekológie a environmentalistiky Tech. univerzity vo Zvolene, 115 pp.

Hartman G. F. & Scrivener J. C., 1990: Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Can Bull. Fish. Aquat. Sci. 223: p. 148.

Hawkins C. P., Murphy M. L., & Anderson N. H., 1982: Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade Range streams of Oregon. Ecology 63: 1840–1856.

Hefti D., Tomka I. & Zurwerra A., 1989: Revision of morphological and biochemical characters of the European species of the Ecdyonurus helveticus-group (Ephemeroptera, Heptageniidae). Bull. Soc. Entomol. Suisse 62: 329–344.

Helan J., Kubíček F., Losos B. & Zelinka M., 1973: Production conditions in the trout brooks of the Beskydy mountains. Folia Fac. Sci. Natur. Univ. Purkyn. Brun., Biol. 14: 1–105.

Hering D., Moog O., Sandin L. & Verdonschot P. F. M., 2004: Overview and application of the AQEM assessment system, Hydrobiologia 516: 1–20.

Herlihy A. T., Gerth W. J., Li J. & Banks J. L., 2005: Macroinvertebrate community response to natural and forest harvest gradients in western Orgon headwater streams. Freshwater Biology 50: 905–919.

Hetrick N. J., Brusven M. A., Bjornn T. C., Keith R. M. & Meehan W. R., 1998: Effects of canopy removal on invertebrates and diet of juvenile coho salmon in a small stream in southeast Alaska. Transactions of the American Fisheries Society 127: 876–888.

Hoffmann A. & Hering D., 2000: Wood-associated macroinvertebrate fauna in Central European streams. Internat. Rev. Hydrobiol. 85: 25–48.

Holland D. G., 1972: A key to the larvae, pupae and adults of the British Species of Elminthidae. Freshwater Biological Association, Scientific Publication 26, 45 pp.

Holopainen A. L., Huttunen P. & Ahtiainen M., 1991: Effects of forestry practices on water quality and primary productivity in small forest brooks. Verh. Internat. Verein. Limnol. 24: 1760–1766.

Hrabě S. & Černosvitov L., 1926: Über eine neue Lumbriculiden-Art (Rhynchelmis vejdovskyi n. sp.) Zool. Anz. 65: 265–268.

Hrbáček J., Blažka P., Brandl Z., Fott J., Kořínek V., Lellák J., Procházková L., Straškraba M., Straškrabová V. & Zelinka M., 1972: Limnologické metódy. Státní pedagogické nakladatelství, Praha, 204 pp.

Hudec I., Barabas D. & Platko J., 1996: Distribution of Crustacea in Slovakia's Eastern Carpathians and problems of preservation. In Breymeyer A. & Noble R. (eds.), Biodiversity conservation in transboudary protected areas. National Academy Press (Washington DC), 252–257 pp.

Hudec I., Koščo J. & Platko J., 1995: Badanie i charakterystyki populacji rakow w CHKO BR Východné Karpaty. Roczniki Bieszczadskie 3: 151–155.

Hurlbert S. H., 1984: Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54: 187–211.

Hutchens J. J. Jr., Batzer D. P. & Reese E., 2004: Bioassesment of silvicultural impacts in streams and wetlands of the eastern United States. Water Air and Soil Pollut.: Focus 4: 37–53.

Illéšová D. & Halgoš J., 2001: Contribution to knowledge of black flies (Diptera, Simuliidae) in eastern Slovakia. Acta Zool. Univ. Comenianae, Bratislava 45: 95–100.

Illéšová D., Halgoš J. & Krno I., 2007: Blackfly assemblages (Diptera, Simuliidae) of the Carpathian river: habitat characteristics, longitudinal zonation and eutrophication. Hydrobiologia (in press)

Illyová M., 2001: Harpacticoids (Crustacea, Harpacticoida) in interstitial of several mountain and submountain streams of Slovakia. Folia Faunistica Slovaca 6: 47–53.

Illyová M. & Tomajka J., 1998: Interstitial community composition in several montane and submontane streams in the West Carpathians. Biologia, Bratislava 53: 159–169.

Jászay T., 2001: Coleoptera of the National park Poloniny. ŠOP SR Banská Bystrica, Správa NP Poloniny, Snina, 234 pp.

Jażdżewski K. & Konopacka A., 1989: Gammarus leopoliensis nov. sp. (Crustacea, Amphipoda) from Eastern Carpathians. Bulletin Zoölogisch Museum, Universiteit van Amsterdam. 11: 185–196.

Kawecka B., 1980: Sessile algae in European mountain streams. 1. The ecological characteristics of communities. Acta Hydrobiol. 22: 361–420.

Kawecka B. & Sanecki J., 2003: *Didymosphenia geminata* in running waters of southern Poland–symptoms of change in water quality? Hydrobiologia 495: 193–201.

Kedzierski W. M. & Smock L. A., 2001: Effects of logging on macroinvertebrate production in a sand bottomed, low-gradient stream. Freshwater Biology 46: 821–833.

Kis B., 1974: Plecoptera. Fauna Rep. Soc. Romania, Bukarest, Insecta 8, 271 pp.

Kittel W. & Wojtas F., 1991: Materials to the knowledge of Plecoptera from West Bieszczady mountains. Acta Univ. Lodz., Folia Limnol. 4: 91–99.

Klasa A., Palaczyk A. & Soszynski B., 2000: Muchowki (Diptera) Biescczadów. Monografie Bieszczadzkie 8: 305–369.

Kłonowska-Olejnik M., 2000: Jętki (Ephemeroptera) Bieszczadów Zachodnich (Mayflies (Ephemeroptera) in Western Bieszczady Mountains). Monografie Bieszczadzkie 7: 145–155.

Kodada J. & Degma P., 1996: Beetles (Coleoptera). In Krno I. (ed.), Limnology of the Turiec river basin (West Carpathians, Slovakia). Biologia, Bratislava 51/ Suppl. 2, p. 65–68.

Kodada J., Jäch M. A. & Cséfalvay R., 2003: Coleoptera. In Šporka F. (ed.), Vodné bezstavovce (makroevertebráta) Slovenska, súpis druhov a autekologické charakteristiky. Slovenský hydrometeorologický ústav, Bratislava, p. 43–52.

Kodada J., Zaťovičová Z. & Čiampor Jr. F., 2004: First record of *Stenelmis puberula* (Coleoptera, Elmidae) from Slovakia. Entomol. Probl. 34: 143–144.

Košel V., 2004: Taxonomical position of two species of Trochaeta (Hirudinea) described from Central Europe. Biologia, Bratislava 59/ Suppl. 15: 25–28.

Kownacki A., Dumnicka E., Galas J., Kawecka B. & Wojtan K., 1997: Ecological characteristics of a high mountain lake-outlet stream (Tatra Mts., Poland). Arch. Hydrobiol. 139: 113–128.

Krammer K. & Lange-Bertalot H., 1986: Bacillariophyceae, 1. Teil: Naviculaceae. Süßwasserflora von Mitteleuropa 2/1: 1–876.

Krno I., 2000: Distribution of stoneflies (Plecopetera) in Slovakia. Správy Slov. Zool. Spol. 18: 39-54.

Krno I., 2002: Pošvatky (Plecoptera) pramenísk a horských a podhorských tokov povodia Bodrogu. Acta Fac. Ecol. 9: 67–78.

Krno I., 2004: Nemouridae (Plecoptera) of Slovakia: Autecology and distribution, morphology of nymphs. Entomological Problems 34: 125–138.

Krno I., Holova M., 2005: First record of Leuctra bronislawi (Plecoptera, Leuctridae) from Slovakia, Biologia, Bratislava 60, p. 512.

Krno I. & Valachová S., 1999: Changes in macrozoobenthos of the Revúca river basin (The Velľká Fatra Mountains) during the period 1971 – 1993. Ekológia, Bratislava 18: 310–324.

Krno I., Šporka F., Bulánková E., Tirjaková E., Illyová M., Štefková E., Tomajka J., Halgoš J., Bitušík P., Illéšová D. & Lukáš J., 1997: The influence of organic inputs, acidification and fluctuating discharge on a spring ecosystem. In Bretschko G. & Helešic J. (eds.) Advences in River Bottom Ecology, Backhuys Publishers, The Netherlands, p. 99–106.

Krno I., Šporka F., Derka T., Pastuchová Z., Zaťovičová Z., Bulánková E., Hamerlík L. & Illéšová D., 2007: Assessment of the Ecological Status of Streams in Two Carpathian Subregions. Internat. Rev. Hydrobiol. 92: 564–581.

Krno I., Šporka F., Tirjaková E. & Bulánková E., 1995: Influence of the construction of the Turček reservoir on the organisms of the river bottom. Folia Fa. Sci. Nat. Univ. Masaryjianae Brunensis 91: 53–62.

Krno I., Šporka F., Tirjaková E., Bulánková E., Deván P., Degma P., Bitušík P., Kodada J., Pomichal R. & Hullová D., 1996: Limnology of the Turiec river basin (West Carpathians, Slovakia). Biologia, Bratislava 51/ Suppl. 2, 122 pp.

Krno I., Tomajka J., Tirjaková E., Bulánková E., Halgoš J. & Košel V., 1995: Vplyv kyslých zrážok na faunu pramenísk pohoria Vtáčnik. Rosalia (Nitra) 10: 21–34.

Kruskal J. B., 1964: Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. Psychometrika 29: 1–27.

Kubíček F., 1978: Mechanisms of permanent biological activity of running waters. Folia Fac. Sci. natur. Univ. Purk. Brun., Biol. 64: 33–44.

Kubíček F., 1986: Československý hydrobiologický výzkum podpovrchové části říčního dna. In Říční dno, jeho funkce, oživení a ochrana, se zvláštním zřetelem na podpovrchovou část dna. Sborník, UP Olomouc, p. 11–15.

Kubovčík V. & Novikmec M., 2001: Preimaginal stages of Diptera from different substrates of the Zbojský potok brook (Poloniny National Park). Acta Universitatis Carolinae, Biologica 45: 89–96.

Kukula K., 1991: Mayflies (Ephemeroptera) of the Wolosatka stream and its main tributaries (The Bieszczady National Park, southeastern Poland). Arch. Hydrobiol. (Krakow) 33: 31–45.

Lamberti G. A., Gregory S. V., Ashkenas L. R., Wildman R. C. & Moore K. M. S., 1991: Stream ecosystem recovery following a catastrophic debris flow. Can. J. Fish. Aquat. Sci. 48:196–208.

Landa V., 1969: Jepice - Ephemeroptera. Fauna ČSSR. Sv. 18. Academia, Praha, 341 pp.

Landa V. & Soldán T., 1989. Rozšíření řádu Ephemeroptera v ČSSR s ohledem na kvalitu vody. Studie ČSAV 17, Academia, Praha, 170 pp.

Likens G. E., Bormann F. H., Johnson N. M., Fisher D. W. & Pierce R., 1970: Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard brook watershed-ecosystem. Ecol. Monographs 40: 880–904.

Liljaniemi P., Vuori K.-M., Ilyashuk B & Luotonen H., 2002: Habitat characteristics and macroinvertebrate assemblages in boreal forest streams: relations to catchment silvicultural activities. Hydrobiologia 474: 239–251.

Lorenz A., Hering D., Feld Ch. K. & Rolauffs P., 2004: A new method for assessing the impact of hydromorphological degradation on the macroinvertebrate fauna of five German stream types. Hydrobiologia 516: 107–127.

Marmonier P., 1991: Effect of alluvial shift on the spatial distribution of interstitial fauna. Ver. Internat. Verein. Limnol. 24: 1613–1616.

Matis D. & Tirjaková E., 1995: Mikrozoobentos rieky Oravy. Zb. Rieka Orava a jej prírodné hodnoty. OÚŽP, Dolný Kubín, p. 24–28.

Matis D., Tirjaková E. & Stloukal E., 1996: Nálevníky (Ciliophora) v Databanke fauny Slovenska. Folia faunistica Slovaca 1: 3–38.

McArdle B. H. & Anderson M. J., 2001: Fitting multivariate models to community data: a comment on distance-based redundancy analysis. Ecology 82: 290–297.

McCord S. B., Grippo R. S. & Eagle D. M., 2007: Effects of silviculture using best management practices on stream macroinvertebrate communities in three ecoregions of Arkansas, USA. Water Air Soil Pollut. 184: 299–311.

McCune B. & Mefford M.J., 1999: PC-ORD. Multivariate Analysis of Ecological Data, Version 4. MjM Software Design, Glenedech Beach, Oregon, USA.

Michalko J., Berta J., Magic D., Rybníček J., Rybníčková E., Maglocký Š. & Špániková A., 1986: Geobotanical map of CSSR – SSR. VEDA, Bratislava, 168 pp., 12 maps.

Mielke P. W. Jr., Berry K. J. & Johnson E. S., 1976: Multiresponse permutation procedures for a priori classifications. Communications in Statistical Theory and Methods A5: 1409–1424.

Murguía M. & Villaseñor J. L., 2003: Estimating the effect of the similarity coefficient and the cluster algorithm on biogeographic cassifications. Ann. Bot. Fenn. 40: 415–421.

Naiman R. J. (ed.), 1992: Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, 560 pp.

Neter J., Kutner M. H., Nachstein C. J. & Wasserman W., 1996: Applied Linear Statistical Models, 4th edition. Irwin, Chicago, 1408 pp.

Newbold J. D., Erman D. C. & Roby K. B., 1980: Effect of logging on macroinvertebrates in stream with and without buffer strips. Can. J. Fish. Aquat. Sci. 37: 1076–1085.

Noel D. S., Martin C. W. & Federer C. A., 1986: Effects of forest clearcutting in New England on stream macroinvertebrates and periphyton. Environmental Management 10: 661–670.

Novikmec M. & Krno I., 1998: First record of *Rhithrogena gorganica* (Ephemeroptera) from Slovakia. Biologia, Bratislava 53: 188.

Novikmec M. & Kubovčík V., 2001: Comments on the benthic macroinvertebrate communities of different substrates of Zbojský potok brook (Slovakia, Poloniny National Park). Acta Facultatis Ecologiae (Zvolen) 8: 123–132.

Novikmec M., Derka T. & Hamerlík L., 2000: Predbežné výsledky výskumu vzťahu bentických Arthropoda a bentického organického materiálu (BOM) vo vybraných tokoch Východných Karpát. In Rulík M. (ed.), Limnologie na přelomu tisíciletí. Sborník referátu, XII. Limnologická konference, Kouty nad Desnou, 18–22. 9. 2000, 206–209 pp.

Novikmec M., Hamerlík L., Bitušík P., Svitok M., Derka T. & Šporka F., 2005: Effect of silvicultural practices and season on the functional attributes of benthic arthropods communities of two East Carpathian streams. Book of abstracts. River bottom VI., 19.–23. 9. 2005, Brno Czech Republic, p. 40.

Obrdlík P., 1981: K poznání zoobentosu povodí Ubľanky, Uličky a Stužické rieky. Biológia, Bratislava 36: 643–647.

Oksanen J., Kindt R., Legendre P. & O'Hara R. B., 2007: Vegan: Community Ecology Package version 1.8-5.

Packroff G. & Zwick P., 1996: The ciliate fauna of an unpolluted foothill stream, the Breitenbach, 1: Qualitative aspects. Limnologica 26: 255–262.

Packroff G. & Zwick P., 1998: The ciliate fauna of an unpolluted German foothill stream, the Breitenbach, 2: Quantitative aspects of the ciliates (Ciliophora: Protozoa) in fine sediments. Europ. J. Protistol. 34: 436–445.

Petersen R. C., K. W. Cummins & Ward G. M., 1989: Microbial and animal processing of detritus in a woodland stream. Ecol. Monogr. 59: 21–39.

Peterson C. G., 1986: Effects of discharge reduction on diatom colonization below a large hydroelectric dam. J. N. Am. Benthol. Soc. 5: 278–289.

Platts W., Megahan W. & Minshall G. W., 1983: Methods for evaluating stream, riparian and biotic conditions. Gen. tech. Rep. INT–138. Ogden VT: v.S. Depart. of Agricul., Forest serv., Intermount forest and range experiment. sta., 70 pp.

Pokorná J., 1959: Algologický rozbor potoka Bystrička a stanovenie stupňov sapróbie. Acta F. R. N. Univ. Comen. III, 10–12, Botanica: 571–585.

Primc B., 1988: Trophic relationships of ciliated Protozoa developed under different saprobic conditions in the periphyton of the Sava river. Period. Biol. 90: 349–353.

Quinn G. P. & Keough M. J., 2002: Experimental Design and Data Analysis for Biologists. Cambridge University Press, Cambridge, 537 pp.

Relyea Ch. D., Minshall G. W. & Danehy R. J., 2000: Stream insects as a bioindicators of fine sediment. Water Environment Federation Specialty Conference, Vancouver, B. C. p. 1–23.

Rodriguez A. & Derka T., 2003: Physiographical and hydrobiological characteristics of the Gidra river basin. Acta Zool. Univ. Com. 45: 11–18.

Roháček J., Starý J., Martinovský J. & Vála M., 1995: Diptera Bukovských vrchov. SAŽP–Správa CHKO a BR Východné Karpaty, Humenné, 232 pp.

Rozkošný R., 1980: Řád Brouci–Coleoptera. In Rozkošný R. (ed.), Klíč vodních larev hmyzu. Academia, Praha, p. 458–501.

Ružičková H., Halada Ľ., Jedlička L. & Kalivodová E. (eds.), 1996: Biotopy Slovenska; príručka k mapovaniu a katalóg biotopov. 2. vydanie. ÚKE SAV Nitra, 192pp.

Schwoerbel J., 1967: Das hyporheische Interstitial als Grenzbiotop zwischen oberirdischen und subterranem Ökosystem und seine Bedeutung für die Primär-Evolution von Kleinsthöhlenbewohnern. Arch. Hydrobiol./Suppl. 33, 1: 1–62.

Seaby R. M. H. & Hendreson P. A., 2004: Community Analysis Package 3.0. Pisces Conservation Ltd., Lym-

ington, 119 pp.
Shapiro S. S. & Wilk M. B., 1965: An analysis of variance test for normality (complete samples). Biometrika 52: 591–611.
Smith E. P., Pontasch K. W. & Cairns J., 1990: Community similarity and the analysis of multispecies environmental data: a unified statistical approach. Water Research 24: 507–514.
Smock L. A., Metzler G. M. & Gladden J. E., 1989: Role of debris dams in the structure and functioning of low-gradient headwater streams. Ecology 70: 764–775.
Soldán T., Zahrádková S., Helešic J., Dušek L. & Landa V., 1998: Distributional and quantitative patterns of Ephemeroptera and Plecoptera in the Czech Republic: a possibility of detection of long-term environmental changes of aquatic biotopes. Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia 98: 1–305.
Sörensen T. 1948: A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Biologiske Skrifter Det Kongelige Danske Videnskabernes Selskab 5: 1–34.
Šporka F., 1982: Vodné máloštetinavce (Oligochaeta) východného Slovenska. Biológia, Bratislava 37: 181–189.
Šporka F., 1996: Macrozoobenthos - permanent fauna. In I. Krno (ed.), Limnology of the Turiec river basin (West Carpathians, Slovakia). Biologia, Bratislava 51/ Suppl. 2: 23–28.
Šporka F. & Krno I., 2003: Benthic invertebrates and metabolism of West Carpathian (Slovakia) rivers. Internat Rev. Hydrobiol. 88: 274–283.
Šporka F., Krno I. & Štefková E., 1997: Dynamika nárastov, bentickej a transportovanej hmoty v povodí potoka Hučava. In Lukavský J. & Švehlová (eds), Sborník referatů z XI. České a Slovenské limnologické společnosti, Třeboň, p. 200–205.
Šporka F., Vlek H. E., Bulánková E. & Krno I., 2006: Influence of seasonal variation on bioassessment of streams using macroinvertebrates. In: Furse M.T., Hering D., Vrabec K., Buffagni A., Sandin L. & Verdonschot P.F.M. (Eds.), The Ecological Status of European Rivers: Evaluation and Intercalibration of Assessment Methods. Hydrobiologia 566: 543–555 pp.
StatSoft Inc., 2001: STATISTICA (data analysis software system), version 6.
Štefková E., 1983: Sinicová a riasová flóra Fofovského potoka v Jure pri Bratislave. Biológia, Bratislava 38: 445–454.
Štěrba O., 1961: Kořýši (Crustacea) z vod náplavů horního toku Laborce. Biológia, Bratislava 11: 821–825.
Štěrba O., 1962: Copepoda z intersticiálnych vod náplavů některých slovenských toků. Biológia, Bratislava 12: 893–901.
Štěrba O., 1964: Plazivky (Copepoda Harpacticoidea) Moravy a Slovenska Část I. Acta Universitatis Palackinae Olomucensis, Biologica VI, 16: 203–321.
Štěrba O., 1969: Űber die geographische Verbreitung der Harpacticiden (Copepoda: Harpacticoida) in der Thechoslowakei. Věstník Československé společnosti zoologické 33: 162–173.
Stevenson J. P., 1984: How currents on different Sides of Substrates in Streams Affect Mechanisms of Benthic Algal Accumulation. Int. Rev. ges. Hydrobiol. 69: 241–262.
Stloukalová V., 1997: Life cycle of Prosimulium hirtipes (Diptera, Simuliidae). Folia Fac. Sci. Nat. Univ. Masarykianae Brunensis, Biologia 97, Dipterologica bohemoslovaca 8: 173-179.
Stockner J. G. & Shortreed K. S., 1976: Autotrophic production in Carnation Creek, a coastal rainforest stream on Vancouver Island, British Columbia. Journal of the Fish Resources Board of Canada 33: 1553–1563.
Stone M. K. & Wallace J. B., 1998: Long-term recovery of a mountain stream from clear-cut logging: the effects of forest succession on benthic invertebrate community structure. Freswater Biology 39: 151–169.
Straškraba M., 1962: Amphipoden der Tschechoslowakei nach den Sammlungen von Prof. Hrabě. Věst. čs. zool. Společ. 26: 117–145.
Svitok M., 2006: Structure and spatial variability of mayfly (Ephemeroptera) communities in the upper Hron River basin. Biologia, Bratislava 61: 547–554.
Swank W. T., 1988: Stream chemistry responses to disturbance. In: Swank W. T. & Crossley Jr. D. A. (eds.), Forest hydrology and ecology at Coweeta. Ecological Studies 66, Springer-Verlag, New York, 339–357 pp.
Swift L. W., 1983: Duration of stream temperature increases following forest cutting in the southern Appalachian Mountains. In Johnson A. I. & Clark R. A. (eds.), Proceedings of the International Symposium on Hydrometeorology, 273–275 pp.
Szczesny B., 2000: Trichopterofauna Bieszczadów Zachodnich (Karpaty Wschodnie). In Pawlowski J. (red.) Monografie Bieszczadzkie, Tom VIII – Bezkregowce Bieszczadów zachodnich ze szczególnym uwzglednieniem Bieszczadzkiego Parku Narodowego, p. 189–251.
Ter Braak C. J. F. & Šmilauer P., 1998: CANOCO reference Manual and User´s Guide to Canoco for Windows: Software for Canonical Community Ordination (version 4). Microcomputer Power Ithaca, NY, USA, 352 pp.
Tirjaková E., 1991: Species identity of ciliates (Ciliophora) in different biotope types. Biológia, Bratislava 46: 865–871.
Tirjaková E., 1993: Štruktúra a dynamika populácií nálevníkov (Ciliophora) rieky Turiec. Biológia, Bratislava 48: 131–139.
Tirjaková E., 1997a: Nálevníky prameniska pod Veľkým Javorníkom. Folia faunistica Slovaca 2: 7–22.
Tirjaková E., 1997b: Nálevníky (Ciliophora) NPR Rozsutec (NP Malá Fatra): Folia faunistica Slovaca 2: 23–29.
Tirjaková E., 1997c: Nálevníky (Ciliophora) biosférickej rezervácie Slovenský kras. Naturae Tutella 4: 45–56.
Tirjaková E., 1998: Saprobiologické hodnotenie vôd žiarskej kotliny na základe druhového spektra a abundancie nálevníkov (Ciliophora). Folia faunistica Slovaca 3: 9–18.
Tirjaková E., 2001: Nálevníky (Ciliophora) niektorých lokalít vo Vysokých Tatrách. Folia faunistica Slovaca 6: 9–18.
Tirjaková E., 2003: Micro- and meiozoobenthos with focus on ciliates (Ciliophora) of the Gidra river basin. Acta Zoologica Univ. Comenianae 45: 29–40.
Tirjaková E., 2004: Structure and dynamics of ciliated protozoa communities (Protozoa: Ciliophora) in a mountain stream in the High Tatra Mts., Slovakia. Biologia, Bratislava 59/Suppl. 15: 3–9.
Tirjaková E. & Stloukal E., 1997: Saprobiologické hodnotenie tokov a vyvieračiek na základe relatívnej abundancie nálevníkov (Ciliophora). In Lukavský J. &

Švehlová D. (eds.), Sborník referatů z XI. České a Slovenské limnologické společnosti, Třeboň, p. 211.
Tirjaková E. & Stloukal E., 2004: Structure and dynamics of ciliated protozoa (Protozoa: Ciliophora) in an acidified spring area of the Malé Karpaty Mts. Biologia, Bratislava 59/Suppl. 15: 11–21.
Trotter E. H., 1990: Woody debris, forest-stream succession, and catchment geomorphology. J. N. Am. Benthol. Soc. 9: 141–156.
Tuša I., 1988: K poznání hyporheosu a zoobentosu pstruhového potoku (Hučivá Desná, Hrubý Jeseník). Čas. Slez. Muz. Opava (A) 37: 193–206.
Van Sickle J., 1997: Using mean similarity dendrograms to evaluate classifications. Journal of Agricultural, Biological, and Environmental Statistics 2: 370–388.
Van Sickle J., 1998: Documentation for MEANSIM, Version 6.0. A set of programs for Mean Similarity Analysis 10/29/98. Western Ecology Division, USEPA-NHEERL, Corvallis, Oregon.
Van Sickle J. & Hughes R. M. 2000: Classification strengths of ecoregions, catchments, and geographic clusters for aquatic vertebrates in Oregon. J. N. Am. Benthol. Soc. 19: 370–384.
Vannote R. L., Minshall G. W., Cummins K. W., Sedell J. R. & Cushing C. E., 1980: The River Continuum Concept. Can J. Fish. Aquat. Sci. 37: 130–137.
von Ende C. N., 2001: Repeated-measures analysis: Growth and other time-dependent measures. In Scheiner S. M. & Gurevitch J. (eds.), Design and analysis of ecological experiments. Oxford University Press, NY, p 134–157.
Vranovsky M., 1979: Zur Kenntnis der Mesofauna des interstitialen Wassers in den Sedimenten des Flusses Belá. Biologia, Bratislava 34: 861–867.
Vranovský M., 1982: Niektoré výsledky výskumu mezofauny intersticiálnych vôd v náplavoch tatranskej rieky Belej. In Zborník prác o TANAP, Martin, p. 225–231.
Vranovský M., 1984: Die Rheosestonmesofauna des Flusses Belá. Práce LRH, Bratislava, 4: 231–272.
Wallace B. J. & Gurtz M. E., 1986: Response of *Baetis* mayflies (Ephemeroptera) to catchment logging. Am. Midl. Nat. 115: 25–41.
Ward A. F. & Williams D. D., 1986: Longitudinal zonation and food of larval chironomids (Insecta: Diptera) along the course of a river in temperate Canada. Holarct. Ecol. 9: 48–57.
Waters T. F., 1995: Sediment in streams: sources, biological effects, and control. Am. Fish. Soc. Monogr. 7: p. 296.
Webster J. R., Gurtz M. E., Hains J. J., Meyer J. L., Swank W. T., Waide J. B. & Wallace J. B., 1983: Stability of stream ecosystems. In: Barnes J. R. & Minshall G. W. (eds.), Stream Ecology, Plenum Press, New York, 355–395 pp.
Webster R. R., Benefield S. W., Golladay S. W., Kazmierczak R. F., Perry W. B. & Peters G. T., 1988: Effects of watershed disturbance on stream seaston characteristics. Ecological Studies 66: 279–294.
Welton J. S., Ladle M. & Bass J. A. B., 1987: Quantitative response of chironomid communities to two water velocity regimes during a spring bloom of epilithic algae. Arch. Hydrobiol. 109: 525–539.
White R. E., 1983: A field guide to the beetles of North America. Houghton Mifflin Company, Boston, 368 pp.
Więźlak W. W., 1986: Klucze do oznaczania owadów Polski, XIX: Chrząszcze–Coleoptera. Państwowe Wydawnictwo Naukowe, Warszawa, Wrocław, 67 pp.
Wilbert N., 1975: Eine verbesserte Technik der Protargolimprägnation fűr Ciliaten. Microkosmos 6: 171–179.
Williams D. D. & Hynes H. B. H., 1974: The occurrence of bentos in the substratum of a stream. Freshwater Biology 4: 233–256.
Zaťovičová Z., Čiampor Jr. F. & Kodada J., 2004: Aquatic Coleoptera (Insecta) of streams in the Nízke Beskydy Region (Slovakia): faunistics, ecology and comparison of sampling methods. Biologia, Bratislava 59/Suppl. 15, p. 181–189.

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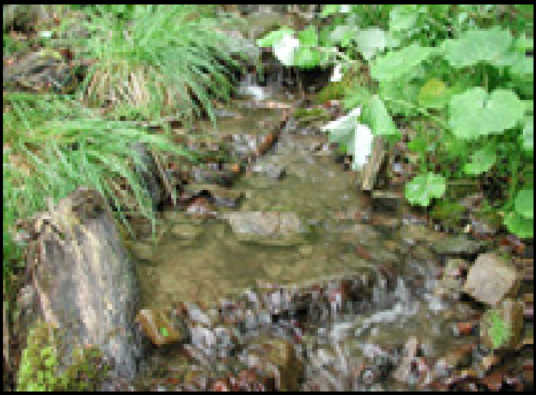


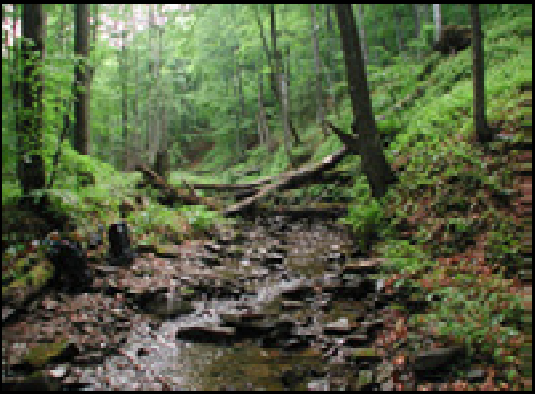

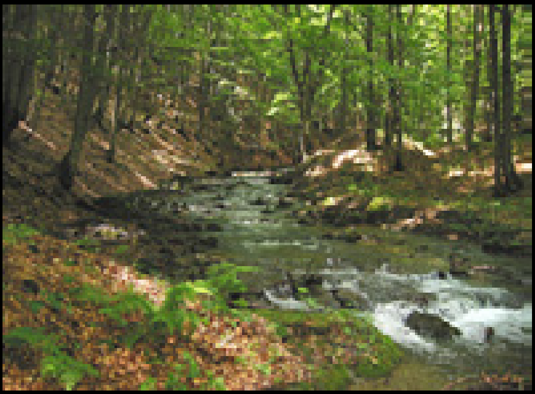

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