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Comparison of aquatic Diptera between two streams in Poloniny National Park (East Carpathians, Slovakia)

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ABSTRACT

In 1999 - 2000 immature stages of aquatic Diptera were studied at 6 sampling sites on two streams, one with a watershed disturbed by timber harvesting. Presented here are the results of an analysis of quantitative samples from the study. In total, 79 taxa (61 species) from 12 dipterous families were identified. The sampling site situated furthest upstream on the treatment stream (disturbed watershed) was exceptional from the point of view of taxa richness and density, which were two times higher compared with the corresponding site on the reference stream (undisturbed watershed). CCA analysis revealed water temperature and nitrates to be statistically significant environmental variables. The group of taxa confined to the uppermost site on the treatment stream was most strongly correlated with nitrates and most negatively correlated with temperature. The effect of nitrates on dipteran assemblages is explained as an indirect influence of nutrients on periphyton growth. The density and proportion of scrapers at the site was unusually high and did not correspond with its position in a river continuum. It is suggested that dipteran assemblages responded to a greater diversity of food resources and habitat structure at this site. There were much more conspicuous differences in community attributes among sites (upstream-downstream) on the treatment stream, as compared to the reference stream. The results indicate a potential of aquatic Diptera assemblages to reflect changes in watersheds and in streams. The responses are more interpretable under conditions of clear cutting technique, and early successive stages after deforestation.

Key words:
aquatic Diptera, streams, Poloniny National Park, timber harvesting, watershed, CCA analysis

INTRODUCTION

Poloniny National Park, a part of the Bukovské vrchy Mts., is situated at the junction of the boundaries of Slovakia, Poland, and the Ukraine. It occupies a unique position in Slovakia as well as in Central Europe. In terms of biogeography, it is situated in an important transition zone between the West and East Carpathian mountain systems, which is indicated by the composition of its plant and animal communities. The park's remoteness from industrial centres and its sparse settlement have permitted the preservation of fragments of primeval forest and many other natural attributes. Despite strict protection of these areas, most forests have been damaged by intensive timber harvesting in the last century, principally after the Second World War. The first biological records of the territory can be dated to the beginning of the 20th century. Studies on Diptera began in the 1960s. The oldest faunistical data were collected by ČEPELÁK et al. (1984, 1986). The most comprehensive work on the dipteran fauna of the East Carpathians, based principally on imago findings, was presented by ROHÁČEK et al. (1995). KLASA et al. (2000) published a list of Diptera species in the adjacent Polish part of the East Carpathians (Biescczady). The first information on preimaginal stages of aquatic Diptera as a part of lotic communities has been published in the last few years (BITUŠÍK & NOVIKMEC 1997, MIDRIAK et al. 1997, KUBOVČÍK & NOVIKMEC 2001, NOVIKMEC & KUBOVČÍK 2001).

In 1999 - 2001, a limnological study of two streams in Poloniny National Park was carried out with the aim of finding the fundamental factors affecting lotic communities in streams with differing anthropogenic stress in their catchment basins. Benthic macroinvertebrates are commonly used in monitoring and assessment of the impact of timber harvesting on lotic communities (e.g. CARLSON et al. 1990, STOUT et al. 1993, BROWN et al. 1997, LEMLY & HILDEBRAND 2000). Many studies have documented changes in community structure in response to changing environmental conditions, but results have not always been unequivocal.

The aims of the presented study were: i) to identify the main environmental factors affecting the structure of dipteran assemblages, ii) to explore the potential of aquatic Diptera as indicators of landscape changes in watersheds.

STUDY AREA AND SAMPLING SITES

The study was undertaken in two streams in Poloniny National Park. A general description of the park's environment can be found in VOLOŠČUK (1999). Stužická Rieka Brook, the reference stream in the study (sampling sites Stu 1 - Stu 3), is a right tributary of the Uh River. The section of the brook falling within Slovakia is about 6 km long, and more significant left-side tributaries spring at 1 200 m a.s.l. The catchment area is covered by pristine fir - beech forest (National Reservation Stužica). The brook is considered to be a reference stream in this study. All the Stužická Rieka sampling sites can be located in the Databank of Fauna of Slovakia (DFS) in mapping grid number 6901, 720. Hluboký Potok Brook is one of a number of sources of the Ulička River. It springs at an elevation of 900 m and drains a catchment basin that was damaged by clear cutting and forest road construction 20 years prior to the time of the present study. Stands consist of even-aged, principally beech forests. The surroundings of the spring area are covered by low stands of spruce and beech on the left (south) side of the stream. Elsewhere, trees create dense canopy cover (DFS mapping coordinates of the sites: 6900, 720). Treatment sampling sites (Hlu 1 - Hlu 3) were chosen to be comparable with undisturbed stations on Stužická Rieka. Both brooks, considered to be mountain (epirithral) - submountain (metarithral) streams, (RUŽIČKOVÁ et al. 1996) flow on sandstone beds (flysch). Some hydrological, physical, and chemical characteristics of the sites are provided in Tab. 1.

MATERIAL AND METHODS

Immature stages of Diptera as a part of the macrozoobenthos were collected in June, September and November 1999, and April and July 2000, at three sampling sites on each stream. Cylindrical bottom samplers (200 µm mesh bag) with two different diameters (0.03 and 0.07 m2) were used. Benthic samples were taken in triplicate on each occasion at the downstream sampling sites (Stu 2, Stu 3, Hlu 2, Hlu 3) using the larger sampler, while five samples were taken at the upstream stations (Stu 1, Hlu 1) using the smaller sampler. Particulate organic matter, periphyton and physico-chemical parameters were collected or measured at the same time. For more details related to field methods and laboratory analyses see KRNO et al. (2002, in press). Physiographical characteristics of the sites were described in June 1999 following PLATTS et al. (1983). In addition, qualitative „kick“ samples and surface samples were taken on each sampling date.

Macrozoobenthos samples were immediately preserved in 4% formalin. The preserved material was sorted and the animals analysed under a stereomicroscope (10-times magnification). Blackflies (Simuliidae) were identified according to KNOZ (1965, 1980) and nomenclature is adopted according to CROSSKEY & HOWARD (1997). MIDGES (Chironomidae) were identified according to WIEDERHOLM et al. (1983) and BITUŠÍK (2000), and other flies were identified according to WAGNER (1978), ROZKOŠNÝ (1980), and NILSSON (1997). Larvae of Ceratopogonidae were not identified to a lower taxonomic level.

The multivariate method canonical correspondence analysis (CCA; TER BRAAK & ŠMILAUER 1998) was used to find relationships among 79 Diptera taxa and 22 environmental variables (Tab. 1). Abundance data were logarithmically transformed. Forward selection of environmental variables was used to select variables that significantly influenced Diptera assemblages.

Tab. 1 Some hydrological and physico-chemical characteristics (average values) in the sampling sites of Hluboký potok (Hlu1 – Hlu2) and Stužická rieka (Stu1 – Stu3)

	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
altitude (m)	760	610	535	840	717	630
stream order	2	4	4	2	3	4
stream link	2	8	18	2	8	14
discharge ($l.s^{-1}$)	12.6	41.1	62.1	77.9	199.6	352.2
current velocity ($cm.s^{-1}$)	0.36	0.35	0.6	0.82	0.39	0.55
water temp. (^0C)	4.94	10	12.02	9.8	10.45	10.74
sand	0	33	0	0	3	7
gravel	18	20	4	11	7	9
pebbles	29	39	46	20	33	17
cobbles	25	8	50	58	41	52
boulders	28	0	0	11	16	15
pH	7.8	7.84	7.88	7.5	7.62	7.68
O_2 ($mg.l^{-1}$)	10.6	9.8	9.64	9.18	9.6	9.6
dissolved matt. ($mg.l^{-1}$)	121.6	94.4	106	64.8	79.2	75.2
insoluble matt. ($mg.l^{-1}$)	22.8	17.6	10.4	14	14	11.2
total hardness	5.52	4.94	4.48	2.6	3.38	3.08
alkalinity ($mval.l^{-1}$)	1.98	1.72	1.7	1.02	1.26	1.04
conductivity ($\mu S.cm^{-1}$)	212.8	181.4	178.6	95.2	124.8	118
$P\text{-}PO_4$ ($\mu g.l^{-1}$)	32.4	27	25.4	31.2	19.8	31.4
$N\text{-}NO_3$ $mg.l^{-1}$	1.7	0.67	0.512	0.97	0.93	0.97
$N\text{-}NH_4$ ($\mu g.l^{-1}$)	43.2	26.6	19.5	32	20	22.2
BSK_5 ($mg.l^{-1}$)	1.14	0.66	0.98	1	1.04	1.28

* DFS = mapping grid of the Databank of Fauna of Slovakia

RESULTS AND DISCUSSION

The study presented here is based on quantitative samples. Complete lists of dipteran species (or taxa) recorded in both brooks, with notes on ecology and distribution of interesting species with respect to zoology and biogeography, have been published elsewhere (BITUŠÍK & HAMERLÍK 2001, ILLÉŠOVÁ & HALGOŠ 2001, BITUŠÍK 2002, BULÁNKOVÁ 2001, BULÁNKOVÁ et al. 2002). In total, 79 dipteran taxa (61 species) belonging to 12 families were identified, 51 of which were found in Stužická Rieka and 61 in Hluboký Potok (Tab. 2). Chironomidae were the taxonomically richest group at all investigated sites.

Some taxa present in Stužická Rieka were never collected in the sampling sites of Hluboký Potok: *Emodotipula saginata* (Tipulidae), *Eloeophila mundata* (Limonnidae), *Tricyphona immaculata* (Pediciidae), *Prosimulium hirtipes* (Simuliidae), *Nilotanypus dubius, Thienemannimyia* sp., *Diamesa cf. insignipes, Prodiamesa olivacea, Brillia* *longifurca, Heterotrissocladius marcidus,* and *Rheosmittia sp.* (Chironomidae). The number of taxa that were present Hluboký Potok but missing in Stužická Rieka was much higher: *Orimarga* spp. (Limoniidae), *Liponeura vimmeri* (Blephariceridae), *Berdeniella unispinosa, B. manicata*, *Clytocerus* spp., *Tonoiriella pulchra* (Psychodidae), *Simulium ornatum, S. vernum, S. variegatum, S. auricoma, S. rostratum* (Simuliidae), *Chryspos caecutiens* (Tabanidae), *Wiedemannia* spp. (Empididae), *Zavrelimyia spp., Diamesa dampfi* group*, Pseudodiamesa branickii, Eukiefferiella coerulescens, E. gracei* group*, Orthocladius frigidus, Paratrichocladius rufiventris,* and *Parorthocladius cf. nudipennis* (Chironomidae).

Tab. 2 Mean density (n.m-2) of dipteran taxa in the sampling sites of Hluboký potok (Hlu1 – Hlu2) and Stužická rieka (Stu1 – Stu3)

taxon	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Limoniidae						
Orimarga spp.	0.2	0.0	0.0	0.0	0.0	0.0
Eloeophila submarmorata (Verrall, 1887)	0.0	0.0	0.2	0.7	0.0	0.4
Eloeophila maculata (Meigen, 1804)	0.0	0.0	0.4	0.0	0.0	0.2
Eloeophila mundata (Loew, 1871)	0.0	0.0	0.0	0.0	0.6	0.2
Hexatoma spp.	0.0	0.2	0.4	0.3	0.0	0.0
Ellipteroides (*P.*) *alboscutellatus* (von Roser, 1840)	0.0	2.6	3.4	2.7	0.2	2.4
Molophilus spp.	0.6	0.0	0.0	0.0	0.2	0.2
Pediciidae						
Dicranota spp.	2.2	0.8	1.8	0.7	0.8	0.8
Pedicia (*C.*) *straminea* (Meigen, 1838)	1.0	0.2	2.0	0.0	1.2	0.4
Pedicia rivosa Linnaeus, 1758	1.8	0.0	0.0	0.3	0.0	0.0
Tricyphona immaculata (Meigen, 1804)	0.0	0.0	0.0	0.0	0.4	0.0
Tipulidae						
Tipula (*E.*) *saginata* Bergroth, 1891	0.0	0.0	0.0	0.0	0.0	0.2
Blephariceridae						
Liponeura vimmeri Mannheims, 1954	0.2	0.0	0.0	0.0	0.0	0.0
Liponeura cinerascens minor Bischoff, 1922	0.0	4.2	3.8	0.0	0.0	1.4
Psychodidae						
Berdeniella unispinosa (Tonnoir, 1919)	0.6	0.0	0.0	0.0	0.0	0.0
Berdeniella manicata (Tonnoir, 1920)	0.2	0.0	0.0	0.0	0.0	0.0
Pneumia stammeri (Jung, 1956)	4.6	0.0	0.2	21.7	0.6	0.8
Bazarella subneglecta (Tonnoir, 1922)	3.2	0.0	0.0	0.0	0.2	0.0
Clytocerus spp.	0.2	0.0	0.0	0.0	0.0	0.0
*Tonnoiriella pulchra (*Eaton, 1893)	0.2	0.0	0.0	0.0	0.0	0.0
Dixidae						
Dixa.maculata group	0.0	0.2	0.0	0.0	0.0	0.0

Tab. 2 cont.

taxon	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Chironomidae						
Conchapelopia cf. *pallidula* (Meigen, 1818)	0.0	1.2	14.1	4.6	0.0	15.3
Nilotanypus dubius (Meigen, 1804)	0.0	0.0	0.0	0.0	0.0	3.5
Thienemannimyia sp.	0.0	0.0	0.0	0.0	0.0	1.2
Zavrelimyia sp.	0.0	0.0	1.2	0.0	0.0	0.0
Diamesa dampfi group	4.6	0.0	0.0	0.0	0.0	0.0
Diamesa cf. *insignipes* (Kieffer, 1908)	0.0	0.0	0.0	0.0	1.8	0.0
Potthastia longimana (Kieffer, 1922)	0.0	0.0	9.4	0.0	0.0	9.4
Pseudodiamesa branickii (Nowicki, 1873)	1.5	0.0	0.0	0.0	0.0	0.0
Prodiamesa olivacea (Meigen, 1818)	0.0	0.0	0.0	0.0	1.2	0.0
Brillia longifurca Kieffer, 1921)	0.0	0.0	0.0	0.0	0.0	0.9
Brillia modesta (Meigen, 1830)	1.5	0.0	0.0	0.0	3.5	1.2
Chaetocladius sp.	7.6	0.0	0.0	0.0	1.2	0.0
Corynoneura spp.	0.0	0.0	1.8	1.5	1.2	0.0
Eukiefferiella coerulescens (Kieffer, 1926)	0.0	0.0	0.9	0.0	0.0	0.0
Eukiefferiella gracei group	4.6	0.0	0.0	0.0	0.0	0.0
Heleniella serratosioi Ringe, 1976	25.8	2.4	5.3	10.6	9.4	18.8
Heterotrissocladius marcidus (Walker, 1856)	0.0	0.0	0.0	1.5	0.0	22.1
Krenosmittia spp.	1.5	0.0	0.0	0.0	0.0	1.2
Orthocladius (s.str.) *frigidus* (Zetterstedt, 1838)	22.8	0.0	0.0	0.0	0.0	0.0
Parametriocnemus spp.	16.7	14.1	29.7	10.6	9.4	41.8
Paratrichocladius rufiventris (Meigen, 1830)	1.5	0.0	0.0	0.0	0.0	0.0
Parorthocladius cf. *nudipennis* (Kieffer, 1908)	1.5	0.0	0.0	0.0	0.0	0.0
Rheocricotopus fuscipes (Kieffer, 1909)	0.0	0.0	0.9	0.0	1.2	0.0
Rheosmittia sp.	0.0	0.0	0.0	0.0	1.2	3.5
Symposiocladius lignicola (Kieffer, 1915)	4.6	0.0	0.0	6.1	5.3	1.8
Synorthocladius semivirens (Kieffer, 1909)	1.5	0.0	4.7	0.0	0.0	1.8
Tvetenia calvescens (Edwards, 1929)	3.0	0.0	0.9	3.0	10.9	13.2
Polypedilum (s.str.) cf. *convictum* (Walker, 1856)	0.0	0.0	8.2	3.0	0.0	3.5
Chironomini gen? sp.?	0.0	0.0	2.6	0.0	0.0	0.0
Micropsectra spp.	1.5	3.5	13.2	0.0	5.9	144.7
Rheotanytarsus sp.	31.9	0.0	0.0	3.0	0.0	0.0
Stempellinella flavidula (Edwards, 1929)	0.0	1.8	1.8	0.0	1.2	0.0
Tanytarsus heusdensis (Goetghebuer, 1923)	1.5	0.0	9.4	4.6	0.0	16.5

Tab. 2. cont.

taxon	Hlu1	Hlu2	Hlu3	Stu1	Stu2	Stu3
Ceratopogonidae	0.2	0.2	0.0	0.0	0.2	0.6
Simuliidae						
Prosimulium hirtipes (Fries, 1824)	0.0	0.0	0.0	0.7	8.4	0.2
Prosimulium tomosvaryi (Enderlein, 1921)	0.0	1.4	4.2	0.0	0.2	0.0
Simulium (*N.*) *costatum* (Friederichs, 1920)	0.0	0.2	0.0	0.0	0.0	0.2
Simulium (*N.*) *brevidens* (Rubtsov, 1956)	0.0	0.2	0.0	0.0	0.0	0.2
Simulium (*N.*) *vernum* (Macquart, 1838)	0.0	1.4	1.0	0.0	0.0	0.0
Simulium (O.) auricoma (Meigen, 1818)	0.0	0.4	12.4	0.0	0.0	0.0
Tab. 2. cont.		taxon				Hlu1 Hlu2 Hlu3 Stu
Simulium (s.str.) *ornatum* Meigen, 1820	0.2	2.2	2.4	0.0	0.0	0.0
Simulium (s.str.) *trifasciatum* Curtis, 1839	0.0	0.8	1.0	0.0	0.0	0.6
Simulim (s.str.) *argyreatum* Meigen, 1838	0.0	0.4	3.4	0.0	0.0	0.2
Simulium (s.str.) *monticola* (Friederichs, 1920)	3.2	3.6	12.6	0.0	1.0	1.2
Simulium (s.str.) *variegatum* Meigen, 1818	0.0	0.0	4.2	0.0	0.0	0.0
Simulium (s.str.) *rostratum* (Lundstrőm, 1911)	0.0	0.0	0.4	0.0	0.0	0.0
Athericidae						
Ibisia marginata (Fabricius, 1781)	0.0	6.6	2.0	0.0	0.0	0.6
Atherix ibis (Fabricius, 1798)	0.0	1.2	0.8	0.0	0.6	1.0
Tabanidae						
Chryspos caecutiens (Linnaeus, 1758)	0.0	0.2	0.0	0.0	0.0	0.0
Empididae						
Chelifera spp.	1.0	0.0	1.4	0.0	1.0	0.8
Wiedemannia spp.	0.8	0.0	0.0	0.0	0.0	0.0
Hemerodromia sp.	1.2	0.0	0.4	0.0	0.2	1.2
number of taxa	35	24	36	17	27	36
mean density (n.m^{-2}) -total	155	50	163	76	69	314
proportion on mean macrozoobentos density (%)	4.7	4.9	4.4	5.6	4.7	12.2

The number of taxa at Stu 1 of the reference stream was two times lower than at the corresponding site on the treatment stream (Hlu 1 - 35 taxa). Taxonomic richness of the remaining sites of both streams was found to be similar (Stu 2 - 27, Hlu 2 - 24, Stu 3 - 36, Hlu 3 - 36 taxa).

Mean densities ranged from 50 to 163 ind. m^{-2} in Hluboký Potok and from 69 to 314 ind. m^{-2} in Stužická Rieka. The highest densities were observed in the furthest downstream sites on both streams, and the lowest densities in the middle sites (Hlu 2, Stu 2). The high value of mean density at Stu 3 was due to a high number of young

Micropsectra larvae in September 1999. There was a conspicuous difference in density between upstream sites (Stu 1 - 76 ind. m^{-2}, Hlu 1 - 155 ind. m^{-2}).

The contribution of Diptera larvae to total macrozoobenthos density ranged from 4.4 to 4.9% at the Hluboký Potok sites and from 4.7 to 12.2% in Stužická Rieka. Generally, this proportion did not exceed 6% at any site, with the exception of Stu 3. The Diptera density pattern followed downstream changes in density of total macrozoobenthos in Hluboký Potok. Mean macrozoobenthos density increased from Stu 1 to Stu 3 in the reference stream.

The results of CCA are summarised in Figs 1, 2. The first two ordination axes were strong (eigenvalues $\lambda_1 = 0.388$ and $\lambda_2 = 0.279$) and captured 12.6 % of the variation in the species data. Only nitrates and water temperature were shown to significantly influence the dipteran community. Fig. 1 shows a biplot of dipteran taxa and significant environmental variables. A group of taxa positively correlated with the nitrate factor are confined to the site Hlu 1 (Fig. 2). These taxa are also negatively correlated with water temperature. Some taxa in this group were found only at Hlu 1, and other taxa in the group were more abundant there than at other sites, or were even predominant there (e.g. *Rheotanytarsus* sp., Tab. 2). Many of them can be considered to be oligostenothermic (*O. frigidus, P.* cf *nudipennis*, *Orimarga* spp., *Rheotanytarsus* sp.).

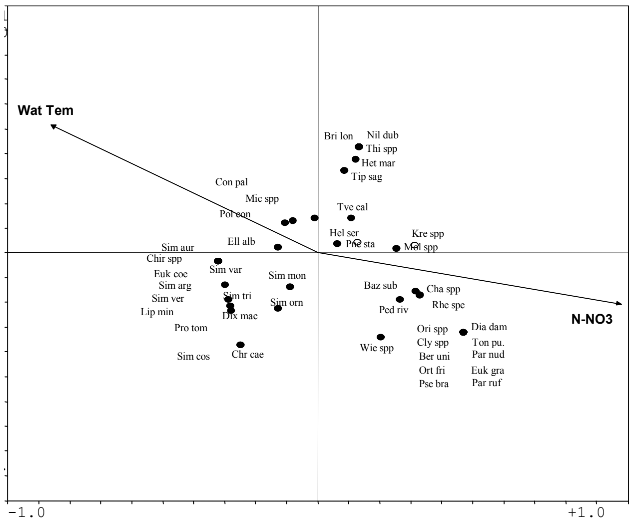

Fig. 1 The first two axes of canonical correspondence analysis (CCA) as a biplot of Diptera taxa and environmental variables. Diptera taxa are coded as follows: Baz sub - *Bazarella subneglecta*, Ber uni - *Berdeniella unispinosa*, Bri lon - *Brillia longifurca*, Cly spp - *Clytocerus* spp., Con pal - *Conchapelopia* cf. *pallidula*, Dia dam - *Diamesa* cf. *dampfi*, Dix mac - *Dixa maculata* gr Ell alb - *Ellipteroides alboscutellatus*, Euk coe - *Eukiefferiella coerulescens*, Euk gra - *Eukiefferiella gracei* gr., Hel ser - *Heleniella serratosioi*, Het mar - *Heterotrissocladius marcidus*, Cha spp - *Chaetocladius* sp., Chir

spp - *Chironomini*, Chr cae - *Chrysops caecutiens*, Kre spp - *Krenosmittia* spp., Lip min – *Liponeura cinerascens* minor, Mic spp - *Micropsectra* spp., Mol spp - *Molophilus* spp., Nil dub - *Nilotanypus dubius*, Ori spp - *Orimarga* spp., Ort fri - *Orthocladius frigidus*, Par nud - *Parorthocladius* cf. *nudipennis*, Par ruf - *Paratrichocladius rufiventris*, Ped riv - *Pedicia rivosa*, Pne sta - *Pneumia stammeri*, Pol con - *Polypedilum* cf. *convictum*, Pro tom - *Prosimulium tomosvaryi*, Pse bra - *Pseudodiamesa branickii*, Rhe spe - *Rheotanytarsus* sp., Sim arg - *Simulium argyreatum*, Sim aur - *S. auricoma*, Sim cos - *S. costatum*, Sim mon - *S.monticola*, Sim orn - *S.ornatum*, Sim tri - *S.trifasciatum*, Sim var - *S.variegatum*, Sim ver - *S.vernum*, Tip sag - *Tipula saginata*, Thi spp - *Thienemannimyia* sp., Ton pu. - *Tonnoiriella pulchra*, Tve cal - *Tvetenia calvescens*, Wie spp - *Wiedemannia* spp.

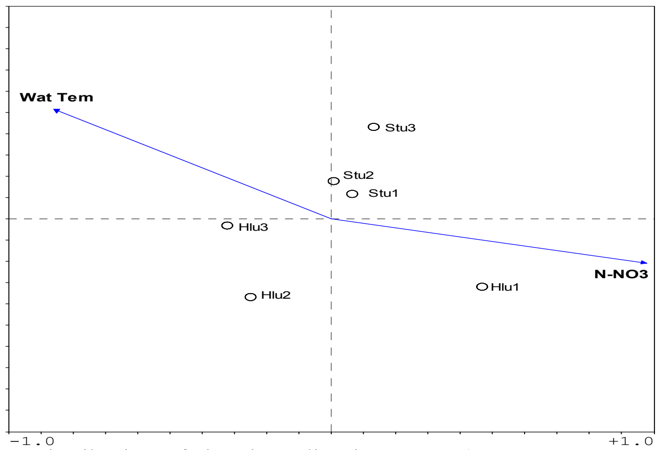

Fig. 2 Distribution of sites in ordination space (Stu 1 – Stu 3: Stužická rieka, Hlu 1- Hlu 3: Hluboký potok)

The effect of nitrates on dipteran assemblages can be explained as an indirect influence of nutrients on growth of periphyton. Higher levels of nitrates in water bodies situated in watersheds disturbed by timber harvesting have been well documented (VITOUSEK et al. 1979, KOPÁČEK & HEJZLAR 1998). Nitrogen usually affects considerable growth of periphytic algae in combination with phosphorus, but some algal taxa can be limited by N alone (FAIRCHILD et al. 1985). The addition of nutrients (P, N) into streams both in laboratory and field conditions have been shown to increase benthic algal biomass (STOCKNER & SHORTREED 1978), and consequently cause an increase in density of zoobenthos. Chironomidae and Ephemeroptera showed the greatest response (MUNDIE et al. 1991).

Other factors, such as light, current velocity, substratum and temperature have important effects on algal growth. Although light was not measured in this study, there is reason to suggest that light input into Hluboký Potok at the station Hlu 1 is higher than at the reference site (Stu 1), due to insufficient canopy cover. Light can be limiting particularly under dense forest canopies. Some studies documented situations where light input overrides any effect of nutrients (GREGORY 1980, LOWE et al. 1986).

Mean biomass of periphyton and chlorophyll-*a* content at Hlu 1 were respectively nearly twice and three times higher than at the reference site Stu 1 (ŠTEFKOVÁ, unpubl. data). Most taxa positively correlated with nitrates were scrapers. The density and proportion of this functional feeding group compared with the reference and other sites are unusually high (Fig. 3) and not typical for a headwater site according to the river continuum concept (VANNOTE et al. 1980).

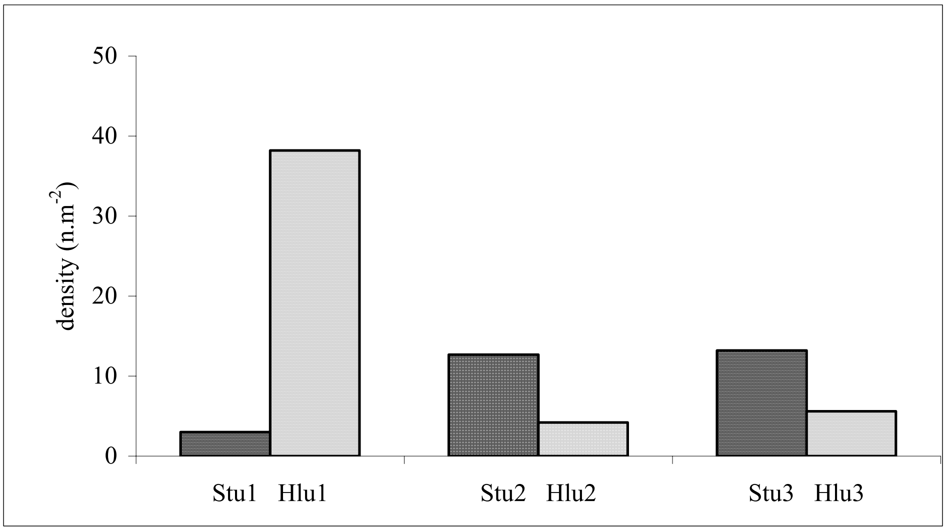

Fig. 3 Mean densities of scrapers in reference (black) and treatment (grey) sites on the two investigated streams in Poloniny National Park

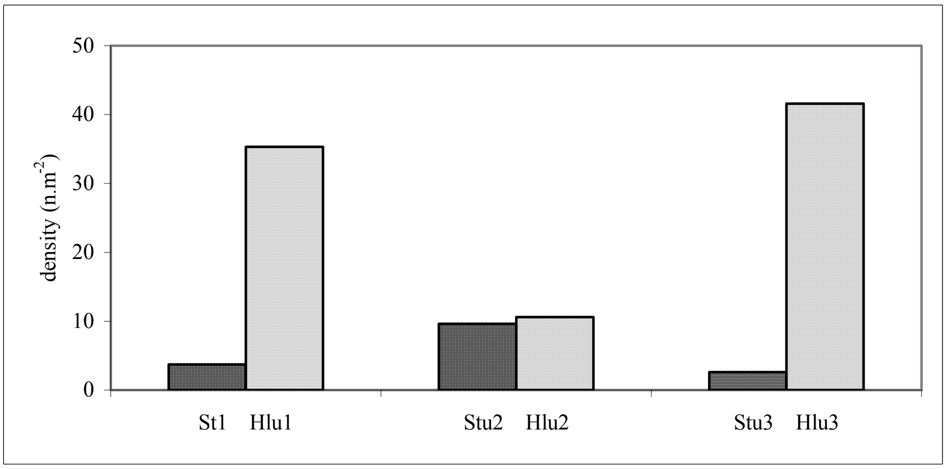

Fig. 4 Mean densities of filtering collectors in reference (black) and treatment (grey) sites on the two investigated streams in Poloniny National Park

Larvae of the filtering collector *Rheotanytarsus,* which were the predominant taxa at Hlu 1, benefited from available attachment sites (rocks, moss) for their cases, and probably from the amount of transported particles. The amount of organic and inorganic matter in Hluboký Potok may reflect erosive processes in the watershed; and, the higher abundance and diversity of filtering collectors there compared with Stužická Rieka could be a response to this (Fig. 4).

Taxa grouped along the water temperature axis are not strongly positively correlated with this variable. The group consists of taxa that were collected from the lowest sections of both streams (Fig. 2).

Inspection of mean dipteran density and taxa richness among sampling sites revealed Hlu 1 as an exceptional site. Both parameters were relatively high and comparable rather with the furthest downstream sites. Some studies have revealed increases in macrozoobenthos density and biomass in streams disturbed by timber harvesting (CARLSON et al. 1990, WILZBACH & CUMMINS 1986, HAWKINS et al. 1982) with significant effect on chironomid density and taxonomic composition (BROWN et al. 1997, BERG & HELLENTHAL 1992).

It could be suggested that dipteran assemblages at the site Hlu 1 are responding 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. Compared with other investigated sites, aquatic mosses were much more abundant at this site. The presence of some taxa, e.g. Psychodidae, found nearly exclusively at Hlu 1 could be explained by their association with rich moss growths. On the other hand, despite some differences in taxonomic composition, changes in other community attributes were not so conspicuous at the downstream sites on Hluboký Potok compared with 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.

Nevertheless, the results of this study indicate that dipteran assemblages reflect disturbances in watersheds and stream processes. It seems that the use of Diptera in an assessment of environmental changes can be more easily interpreted under conditions of stronger impacts in watersheds such as clear cutting and the early successive stages following it.

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