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Ecological study of a high-mountain stream ecosystem (Hincov potok, High Tatra Mountains, Slovakia)

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Abstract. The objective of this study is to describe a high-mountain stream ecosystem, with the main emphasis on particulate organic matter, structure of food guilds and the impact of predation upon macroinvertebrates. In the brook Hincov the concentration of total phosphorus and coarse particulate organic matter (CPOM) increased considerably with the increase in water flow that occurred at spring snow melt; fine organic matter (FPOM) and ultrafine organic matter (UFPOM) peaked in summer. Moss predominated during the cold period, whereas the biomass of periphyton was higher from March to November than in winter. Production of macrozoobenthos peaked in May, when water flow and benthic detritus reached their maximum and water temperature was rising, and dropped during summer. The macroinvertebrate food guilds indicated that this high-mountain stream is a typical autotrophic system. Annual production of macrozoobenthos was very low (2.4 g$\times$m$^{-2}\times$yr^{-1} dry weight) and influenced by fish predation. An unusual phenomenon was observed: the production of macrozoobenthos declined due to trout predation despite the increasing temperature of the stream. Macroinvertebrate production in comparable biotopes with no fish was two-times higher. Retention and turnover times of organic matter corresponded to those recorded in a recent study for springs in the same region. In contrast, transport and turnover of organic matter were analogous to the situation in larger streams with high greater flows of water.

High-mountain stream, organic matter, benthos, production, trout predation, stream metabolism, river continuum, Central Europe, Palaearctic region

INTRODUCTION

Running water, because its long shorline is an open aquatic ecosystem, closely associated with terrestrial ecosystems. Vannote et al. (1980) consider running water to be an ancient but flexible system, which rapidly reflects environmental change. Aquatic ecosystems are greatly affected by past geological processes (Thienemann 1950). Current conditions in the high-mountain environment (with the exception of water sources and turbidity) resemble the conditions that prevailed at lower altitudes in Central Europe during the postglacial era. For example, lack of shore vegetation, frozen rivers and soils, temperature and water flow fluctuation and summer floods associated with high turbidity and hydraulic stress (Statzner 1987) prevented the wide-spread distribution of stenoecous species in our region. The role of springs in this system was replaced by shallow unshaded ponds with very unstable daily and annual temperatures (Statzner 1987). Later, the fluctuations, in these decisive abiotic factors decreased. Steffan (1971) and Ward (1994) defined glacier streams as "kryal", characteristically fed by cold, very variable quantitatives glacial meltwater. Kownacka & Kownacki (1972) broadened this concept and included high-mountain streams resulting from the meltwater of permanent snowfields. In addition, Ward (1994) described rhithral stream segments in alpine catchments, which were characterised by soft water, an extended period of snowmelt runoff and a broader temperature range compared to kryal and krenal biotopes. Moss, macroalgae, diatoms, turbellaria, oligochaetes, mayflies, stoneflies, caddisflies and flies make up the benthic communities of these streams. In the present hydrobiological study, the focus was on high-mountain streams – the epirhithral. Many investigations and studies of flowing water are ecosystem based (Fisher & Likens 1973, Anderson & Sedell 1979, Newbold et al. 1982, Minshall et al. 1985, Benke et al. 1988, Šporka & Krno 2003). Central to all of these studies is the fact that the bioenergetics of organisms in flowing waters is affected primarily by certain abiotic factors, such as temperature, discharge, substratum, nutrients and pH. Of the biotic factors, size of individual organisms, duration of development, food quality and quantity, and the mode of feeding are also important. If the primary production of periphytic algae is affected by nutrients and light, then the secondary production of macrozoobenthos depends mainly on the stability of the substratum, temperature and food supply. High-mountain ecosystems are controlled by abiotic rather than biotic factors (Reice 1985). In general terms, when assessing the ecological integrity of a stream, the biological and physical elements, and processes need to be evaluated (Covich et al. 1998, Buffagni & Comin 2000). Measures of ecological integrity should be based on population, community and ecosystem responses to disturbance. Functional measures are usually employed at the ecosystem level: e.g., energy flow, nutrient cycling, primary and secondary production.

The main aim of this study is to highlight the energy budget of a high-mountain stream ecosystem, With particular emphasis on a effect on the secondary production of invertebrates, fish predation, and stream metabolism.

STUDY AREA

The sampling site area, a 50 m length of the brook "Hincov potok" situated in the sub-alpine zone of the High Tatra Mountains (49° 09' 17" N, 20° 04' 45" E), 1480 m above sea level. It forms a part of the catchment of the River Poprad. The drainage basin is granite. The stream is fringed with scrub-pine trees and experiences permanent torrential water flows. The site is subjected to long period of snow cover (five moths), low temperatures and rapid changes in discharge (Fig. 1). The bottom of the brook consists mainly of boulders and stones (68%), with the remainder consisting of gravel and sand. The bottom of the brook surface area is 1.9-times larger than that the water. Approximately 10% of the bottom is covered by moss.

MATERIAL AND METHODS

Physiographical characteristics of the location are used by Plats et al. (1983). 3–4 transects across the brook, with a distance of 15 m between each, were recorded width of the stream, and depth and velocity (using a hydrometric wing) at 1/5,2/5, 3/5, 4/5 of the width. These values were used to estimate the approximate flow and speed of the current. At 30 cm intervals along each transect the dominant substratum, occurrence of macrophytes and filamentous algae were determined.

Field sampling

CPOM, wood, together with macrozoobenthos, was sampled from September 1996 to August 1997, using a cylindrical bottom sampler (area 0.07 m^2). Monthly samples were taken from different mesohabitats: three to four samples from rocks, boulders and moss on boulders, and two to three together from gravel and sand, with the exception of January – February when the creek was completely covered with ice. Samples were preserved in 10% formaldehyde.

FPOM and UFPOM were collected by inserting a sharply pointed tube (area 0.006 m^2) 10–15 cm into the substratum. The material inside the cylindrical bottom sampler was raked out and mixed with hand of water from which a subsample of 0.5 litre was taken. This procedure was repeated several times for both stony and sandy mesohabits. The same sampler was used for micro- and meiozoobenthos. Samples were taken from four different substrata – rocks, fine gravel, detritus, and moss in pools, and in riffles. The samples were transported in isothermic bottles (volume 0.5 l) live to the laboratory .

Plant material (periphyton) adhering to 7–10 stones was removed with a nylon brush and the surface area of the stones measured with aluminium foil according to the method described in Punčochář (1986). To assess amount transported organic matter (TOM), samples of 2–3 litres were collected from the stream . Particulate organic matter (POM) was separated by passing the samples through nested series of sieves (1.0 mm, 50 μm) and

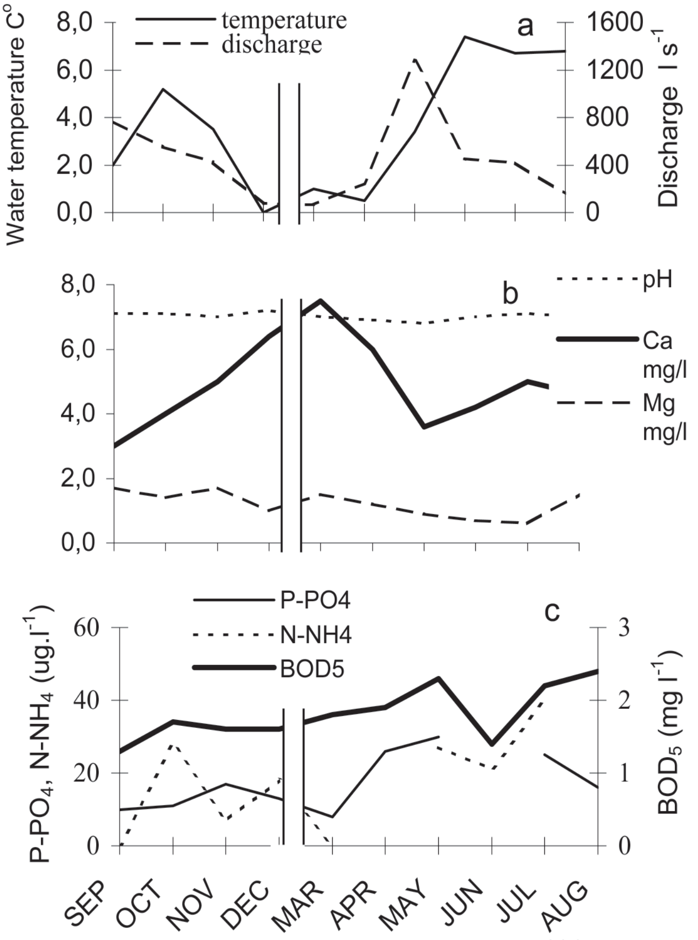

Fig. 1. Seasonal dynamics of some abiotic of the variables: a – temperature and discharge regime; b – Ca, Mg and pH; c – PO_4, NH_4 and BOD_5.

Table 1. Abiotic and biotic characteristics of the brook Hincov; * – min to max

characteristics	annual mean	±SD	characteristics	annual mean	±SD
water temperature (^{o}C)	3.7	2.8	dissoluble substances (mg dm^{-3})	25.4	8.5
current velocity (cm s^{-1})	88.4	49.7	P-PO$_4$ (mg dm^{-3})	17.3	7.9
discharge (dm^3 s^{-1})	466.6	380.6	N-NO$_3$ (mg dm^{-3})	549.0	153.5
PH	7.0	6.9–7.2*	N-NH$_4$ (mg dm^{-3})	17.6	14.4
O$_2$ (mg dm^{-3})	11.3	0.5	Ca (mg dm^{-3})	4.9	1.4
O$_2$ saturation (%)	86.0	7.1	Mg (mg dm^{-3})	1.2	0.4
BOD$_5$(mg dm^{-3})	1.8	0.4	Conductivity (mS cm^{-1})	32	4

finally through 1.0 µm glassfibre filters (Whatman GF/C). Material trapped by the sieves and filters consisted of coarse, fine and ultrafine particulate organic matter respectively. Wet biomass was recalculated as Dry Matter (DM) and Ash Free Dry Matter (AFDM), respectively. POM and periphyton were recorded in terms of AFDM. The surface area of gravel, pebbles, and boulders randomly collected of each sampling site (50 pieces) were measured using aluminium foil (Punčochář 1986).

Algae for the qualitative analysis were collected from several rocks of the sample site, which had a visible growth of algae. Diatoms were removed from stones (about 10 stones) using a toothbrush, and washed directly from the surface of the stones into a sample bottle. Then the sample was preserved by adding a 4% final solution of formaldehyde . Diatoms were identified by examining permanent slides of them prepared by the hot hydrogen peroxide method (Hindák et al. 1975) and mounted in Naphrax. Epilithic diatoms in the qualitative samples were studied and a list of species, identified according to Krammer & Lange-Bertalot (1986, 1988, 1991a, b) is presented.

Samples from epilithon for measuring of the amount of chlorophyll-a were removed using a toothbrush from the entire surface of 5 rocks within a 1m^2 area, and then processed by the ISO method (using ethanol) for measuring of chlorophyll-a (mg×m^{-2}). The surface area of the rocks was calculated using the same method as for the periphyton samples.

Fish were sampling in August 1997 by electrofishing, using a ZB6 apparatus (150–300 V), (Producer: R. Bednář, Czech Republic). The apparatus was not adjusted for low water conductivity, and thus it was difficult to catch all the fish attached by the current. Therefore, it is assumed, that fish abundance is slightly underestimated. We estimated the total abundance according to Kirka (1968) and the age of the fish from their scales.

Water for chemical analyses was collected from the brook using polyethylene bottles previously washed with hot water and rinsed with distilled water. Samples were stored in the dark at 4°C and analysed within two days of collection.

Laboratory analyses

Chemical analyses. The concentration of ammonia – nitrogen (N-NH$_4$) was determined colorimetrically with Nessler reagent after distillation. Nitrate - nitrogen (N-NO$_3$) and phosphate – phosphorus (P-PO$_4$) were determined according to Hrbáček (1972). Ca and Mg were determined by titration complexometrically. Conductivity was measured at 25 °C.

Microzoobenthos. Samples of the microzoobenthos and meiozoobenthos were processed *in vivo* immediately after arrival in the laboratory i.e., within 18 hrs of collection, in a drop not covered by coverglass. Identification was performed under a light microscope using common vital dyes. Disputable species were isolated, fixed and stained with protargol according the method of Wilbert (1975). Taxonomic identification was accomplished using keys of Foissner et al. 1991, 1992, 1994, 1995, Song & Wilbert 1989, Kahl 1930–1935), and other available publications.

Live samples for quantitative evaluation were collected with a micro-pipette (volume 20 µl) with trimmed tip from 50 spot sites of taken sample. All the ciliated protozoa collected by this method (and quantitatively other constituents of the micro- and meiozoobenthos) were identified and counted.

Macrozoobenthos. The preserved material was sorted and the animals identified under a stereomicroscope (10-times magnification). Turbellaria were identified according to Hrabě (1954), Oligochaeta according to Hrabě (1981) and Sperber (1950) and Hirudinea according to Hrabě (1954). Mayflies were identified according to Bauernfeind (2001), stoneflies according to Raušer (1980) and Lillehammer (1988), caddisflies according to Waringer & Graf (1997), blackflies (Simuliidae) according to Knoz (1965, 1980) but the nomenclature follows Crosskey & Howard (1997), midges (Chironomidae) according to Wiederholm et al. (1983, 1986), and Bitušík

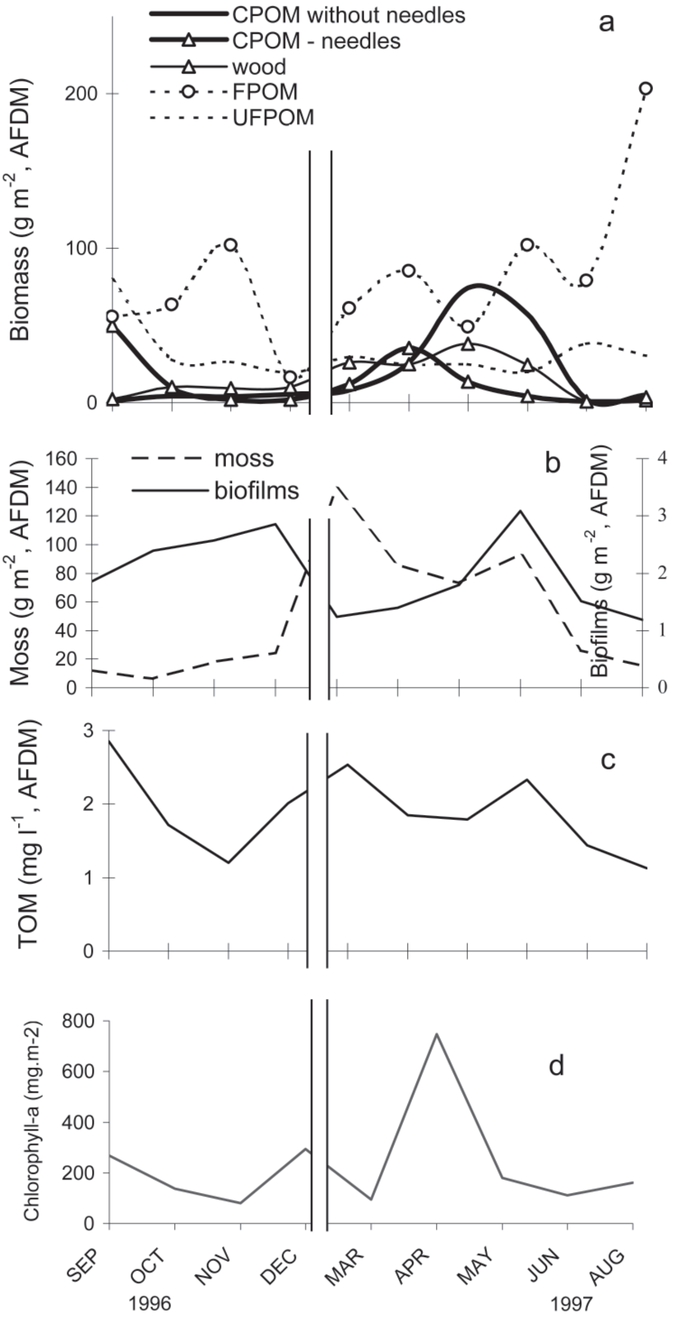

Fig. 2. Seasonal dynamics of some biotic variables: a – benthic organic matter, b – periphyton, c – transport organic matter; d – chlorophlyll-a concentration.

Table 2. Annual budget of the high-mountain stream ecosystem; * – annual mean biomass, ** – annual mean biomass on the bottom of the surface below 1 m^2 of water-surface, according to Punčochář (1986), ^{a} – annual P/B ratio of macrozoobenthos according to Statzner (1987)

organic matter AFDM		macrozoobenthos (mg.m^{-2} DW)			
input of CPOM (gm^{-2})	181.80	annual production / mean biomassannual P/B ratio			
input of FPOM+UFPOM (g m^{-2})	540.70	Turbellaria	8.2	2.1	4.0
TOM (g m^{-3})*	1.90	Oligochaeta	49.8	24.9	2.0
TAM (g m^{-3})*	0.01	Ephemeroptera	732.4	164.5	4.5
periphyton (g m^{-2})**	3.80	Plecoptera	980.4	167.9	5.6
macrophytes (g m^{-2})*	47.67	Coleoptera	2.0	1.5	1.3
stream dynamics of POM		**Trichoptera**	323.8	115.1	2.8
retention	496.00	Chironomidae	93.0	6.1	14.9
rate of downstream movement (km d^{-1})	0.05	Simuliidae	180.0	16.5	10.8
turnover length (km)	81.80	other Diptera	46.9	13.2	3.6
turnover time (yr^{-1})	3.09	macrozoobenthos	2416.5	511.8	4.7
annual production and P/B ratio of the food guilds in the macrozoobenthos (g.m^{-2}AFDM)					
shredders	0.25	predators	0.82		
gathering collectors	0.21	macrozoobenthos	2.30		
filter feeders	0.16	annual P/B ratio^a	4.20		
scrapers	0.86				

(2000), the others flies were identified according to Wagner (1978), Rozkošný (1980) and Nilsson (1997). Population densities, biomass and production were calculated per bottom surface below 1 m^2 of water surface. Biomass was evaluated as wet weight – either directly (formaldehyde weight) or by using length-size relationships (Smock 1980). Wet biomass was recalculated as DM and AFDM according to Waters (1977). Secondary annual production of macrozoobenthos (in DM) was evaluated using size-frequency analysis (Hamilton 1969, Menzie 1980). The seasonal trend in the daily production of macrozoobenthos was evaluated by the method of Zelinka (Zelinka & Marvan 1976).

For calculating the annual stream metabolism we made use of Webster´s equations (1983) describing the velocity of microbial breakdown of POM and its dependence upon temperature, organic spiralling in the stream (Newbold et al. 1982), feeding activity of detrivores (macroinvetebrates) (Petersen al., 1989), retention capacity, rate of downstream movement, recycling rate, turnover length and turnover time of POM according to Naiman et al. (1987).

ABBREVIATIONS

DM – dry matter; AFDM – ash free dry matter; CPOM – coarse particulate organic matter (CPOM> 1mm) (leaves and needles and their fragments); Wood – wooden fraction of CPOM debris; FPOM – fine particulate organic matter (1mm> FPOM >0.05mm); UFPOM – ultra fine particulate organic matter (0.05mm> UFPOM> 0.5µm); POM – particle organic matter (CPOM+FPOM+UFPOM); TIM – transported inorganic matter; TOM – transported organic matter; RCC – river continuum concept.

RESULTS

During the study period high discharge (Fig. 1) from the Hincov potok catchment occurred in late spring (May) and was not accompanied by high turbidity (Fig. 2c). Large and deep Tatra lakes, such as Lake Hincovo and the •abie Lakes, are the main source of water for Hincov potok. With the exception of summer, the discharge (Fig. 1a) from Hincov potok shows the same pattern as temperature. The creek is covered with ice from mid-December to mid-April. Summer temperatures do not exceed 7.5°C. Hincov brook flows through the dwarf pine zone and therefore is shaded. Water is well oxygenated throughout the year. During the spring snowmelt the amount of phosphorus increases (Fig. 1c) (Kopáček et al. 1996).

The amount of CPOM and wood increased markedly with the increase in discharge in spring (Fig. 2a), unlike FPOM and UFPOM, which peaked in summer and were at a minimum during periods of high discharge (May) and when initially covered by ice (December). TOM was more or less constant throughout the year (Fig. 2c) and values of TIM on all dates were negligible (>0.1 mg). Moss (*Fontinalis antipyretica*) predominated during the cold period and in June (Fig. 2b), unlike the periphyton, which was most abundantduring the growing period from March to November. The spring increase in periphyton was associated with decreasing ice-cover (more light) and an increasing amount of phosphorus (Fig. 1c). The autumn increase in periphyton was probably associated with stabilisation of the bottom during the period of low discharge. Th*e* maximum amount of chlorophyll-*a* in the periphyton (Fig. 2d) occurred in April, the minimum in November.

In the algal communities (Table 3) epilithic diatoms predominated, throughout the year. In total, 58 taxa of diatoms were identified. Among the diatoms *Achnanthes minutissima* var. *minutissima*, *A. flexella, A. lanceolata*, *Ceratoneis arcus*, *Cocconeis placentula*, *Cymbella sinuata*, *Diatoma hyemalis*, *D. mesodon*, *Fragilaria capucina*, *Gomphonema clavatum*, *G. olivaceum* and *Meridion circulare* were dominant throughout the year. Two species of diatoms *Amphora inariensis* and *Eunotia parallela* were found in Slovakia for the first time. Filaments of *Draparnaldia glomerata* (Chlorophyceae, Ulotrichales), *Hydrurus foetidus* (Chryso-phyceae, Chrysocapsales) and *Homoeothrix janthina* (Cyanophyceae, Osillatoriales) formed another important part of the algal community. During the cold period (October to December), *Hydrurus foetidus* formed macroscopic slimy colonies attached to rocks and stones.

Microzoobenthos and meiozoobenthos made up an important part of the benthic community and periphyton. Mastigophora, Sarcodina, Ciliophora, Rotifera, Nematoda, Gastrotricha, Tardigrada and rarely also Turbellariomorpha were found in these substrata.. All components occurred regularly without conspicuous fluctuations in abundance. Of the metazoa, Rotifera and Nematoda predominated (100 individuals × ml^{-1} maximum). Protozoa (Table 4), were represented predominantly by Ciliophora. Mastigophora were not so abundant (200 individuals × ml^{-1} maximum), which suggests a oligotrophic status of this stream. In total, 60 taxa of ciliated protozoa were identified.

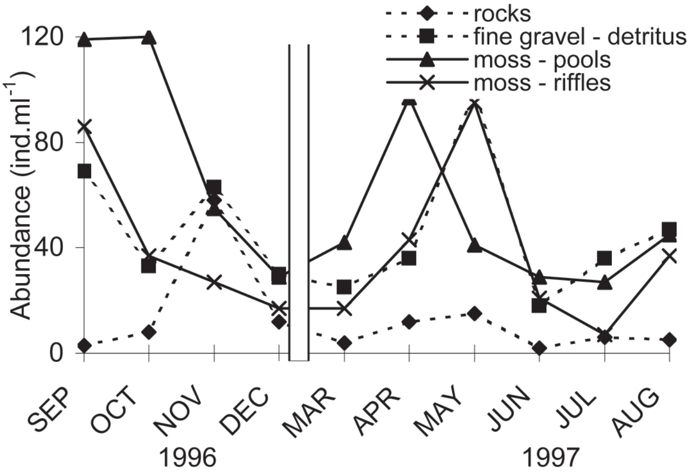

Fig. 3. Seasonal dynamics of Ciliophora in different substrata.

Table 3. Bacillariophyceae of the brook Hincov ; Explanation: * – first record for the fauna of Slovakia

taxon	9.96	10.96	11.96	12.96	3.97	4.97	5.97	6.97	7.97	8.97
Achnanthes biasolettiana Grunow								+		
Achnanthes flexella (Kütz.) Brun	+	+	+	+	+	+	+	+	+	
Achnanthes helvetica (Hust.) Lange-Bert.			+			+		+		+
Achnanthes lanceolata (Bréb. ex Kütz.) Grunow	+	+	+	+	+	+	+	+	+	+
Achnanthes lapidosa Krasske	+							+	+	+
Achnanthes levanderi Hust.						+				
Achnanthes minutissima Kütz.	+	+	+	+	+	+	+	+	+	+
Achnanthes subatomoides (Hust.) Lange-Bert.						+				
Achnanthes sp.								+		
Amphora fogediana Krammer	+				+				+	+
Amphora inariensis Krammer*								+	+	
Amphora pediculus (Kütz.) Grunow				+	+	+	+		+	+
Amphora sp.		+	+							
Anomoeoneis vitraea (Grunow) R. Ross								+		
Cocconeis neodiminuta Krammer									+	
Cocconeis placentula Ehrenb.	+	+		+	+	+	+	+	+	+
Cocconeis placentula var. *euglypta* (Ehrenb.) Cleve						+				
Cocconeis placentula var. *lineata* (Ehrenb.) Van Heurck				+						
Cocconeis sp.				+						
Cyclotella meneghiniana Kütz.		+								
Cyclotella sp.										+
Cymbella minuta Hilse	+	+	+	+	+	+		+	+	+
Cymbella silesiaca Bleisch			+	+	+			+		
Cymbella sinuata W. Greg.	+		+	+	+	+	+	+	+	+
Denticula tenuis Kütz.					+	+	+		+	+
Diatoma hyemalis (Roth) Heib.	+	+	+	+	+		+			
Diatoma mesodon (Ehrenb.) Kütz.	+			+	+	+		+	+	+
Diploneis subovalis Cleve									+	
Eunotia bilunaris (Ehrenb.) Mills	+				+					
Eunotia parallela Ehrenb.*									+	
Eunotia praerupta Ehrenb.							+			
Eunotia sp.			+	+	+					
Fragilaria arcus Ehrenb. Cleve	+	+	+	+	+	+	+	+	+	+
Fragilaria capucina Desm.			+		+		+	+	+	+
Fragilaria capucina var. *rumpens* (Kütz.) Lange-Bert.	+	+								
Fragilaria virescens Ralfs			+							
Fragilaria pinnata Ehrenb.					+					
Fragilaria ulna (Nitzsch) Lange-Bert.		+		+						
Gomphonema angustum C. Agardh	+	+								
Gomphonema clavatum Ehrenb.	+	+	+	+	+	+	+	+	+	+
Gomphonema olivaceum (Hornem.) Bréb.	+	+	+			+			+	+
Gomphonema parvulum (Kütz.) Kütz.							+		+	
Melosira varians C. Agardh		+								
Meridion circulare (Grev.) C. Agardh		+			+	+	+	+	+	+
Navicula angusta Grunow									+	
Navicula cryptocephala Kütz.							+			
Navicula gallica var. *perpusilla* (Grunow) Lange-Bert.				+			+	+	+	
Navicula pupula Kütz.							+			
Navicula sp.				+	+					
Nitzschia acidoclinata Lange-Bert.						+				

Table 3. continued

taxon	9.96	10.96	11.96	12.96	3.97	4.97	5.97	6.97	7.97	8.97
Nitzschia dissipata (Kütz.) Grunow										+
Nitzschia linearis (C. Agardh) W. Sm.	+									
Nitzschia palea (Kütz.) W. Sm.					+					
Nitzschia sp.				+				+		+
Pinnularia microstauron (Ehrenb.) Cleve							+			
Pinnularia subcapitata W. Greg.									+	
Pinnularia viridis (Nitzsch) Ehrenb.							+			
Stauroneis anceps Ehrenb.										+

Small euryecous species, such as *Aspidisca lynceus*, *Cinetochilum margaritaceum*, *Glaucoma scintillans*, as well as *Lithonotus alpestris* and *Loxophyllum meleagris* prevailed among the Infusoria. The seasonal dynamics of Infusoria was apparently strongly dependent on the type of substratum. They were most abundant, however, in all substrata in spring (April–May; Fig. 3) and autumn (September–November), with a shift of one month, depending on the type of substratum and water discharge regime. Abundance of Infusoria was relatively low and only very rarely exceeded 100 individuals. ml^{-1}. Abundance exceeded 100 individuals. ml^{-1} only in moss in riffles and was associated with degradation of autochthonous material during autumn. The low abundance observed was consistent with that expected in mountain oligotrophic streams.

Among the shredders in the macrozoobenthos (Table 5), *Protonemura nimborum* (Plecoptera) and *Potamophylax cingulatus* (Trichoptera) prevailed; gathering collectors were represented mainly by *Stylodrilus heringianus*, *Cognettia sphagnetorum* (Oligochaeta), *Leuctra armata*, *L. autumnalis* (Plecoptera), *Micropsectra* sp., and *Berdeniella unispinosa* (Diptera); scrapers mainly by *Rhithrogena loyolea*, *Baetis alpinus* (Ephemeroptera), *Tvetenia bavarica* gr. and *Eukiefferiella gracei* gr. (Diptera); filter feeders by *Prosimulium rufipes*, *Simulium monticola*, *S. maximum* (Diptera), *Philopotamus ludificatus* and *Drusus discolor* (Trichoptera); and predators by *Crenobia alpina* (Turbellaria), *Diura bicaudata*, *Perlodes intricatus*, *Isoperla sudetica* (Plecoptera), *Rhyacophila tristis* (Trichoptera) and *Dicranota* spp. (Diptera). Stoneflies (Krno 2002) and may-

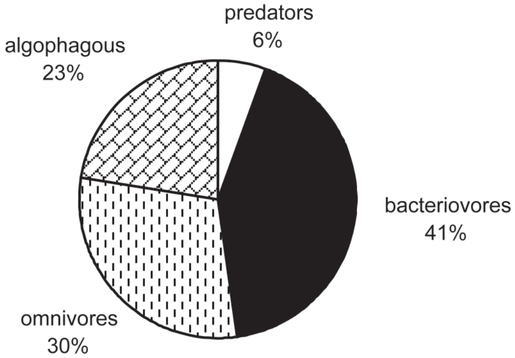

Fig. 4. Food guilds of Ciliophora.

Table 4. Ciliophora of the brook Hincov; + frequency of Ciliophora 0–10%, ++ 11–50%, +++ 51–100%

Aspidisca cicada (Mueller, 1786)	+
Aspidisca lynceus (Mueller, 1773)	+++
Balanonema biceps (Penard, 1922)	+
Blepharisma hyalinum Perty, 1922	+
Bryophyllum tegularum Kahl, 1931	+
Chaenea limicola Lauterborn, 1901	+
Chaenea sp.	+
Chilodonella uncinata (Ehrenberg, 1838)	+
Chilodontopsis sp.	+
Chlamydonella alpestris Foissner, 1979	+
Chlamydonella rostrata (Vuxanovici, 1963)	++
Chlamydonelopsis plurivacuolata Blatterer et Foissner, 1990	+
Cinetochilum margaritaceum (Ehrenberg, 1831)	+++
Coleps hirtus (Mueller, 1786)	+
Colpoda steinii Maupas, 1883	+
Ctedoctema acanthocryptum Stokes, 1884	+
Cyclidium heptatrichum Schewiakoff, 1893	++
Cyrtolophosis elongata (Schewiakoff, 1892)	+
Cyrtolophosis muscicola Stokes, 1885	+
Dexiotricha tranquilla (Kahl, 1926)	+
Frontonia acuminata (Ehrenberg, 1833)	+
Frontonia angusta Kahl, 1931	++
Frontonia atra (Ehrenberg, 1833)	+
Glaucoma scintillans Ehrenberg, 1830	+++
Glaucoma reniformis Schewiakoff, 1893	+
Halteria grandinella (Mueller, 1773)	+
Hemisincirra gellerti (Foissner, 1982)	+
Holophrya discolor Ehrenberg, 1833	+
Holophrya teres (Ehrenberg, 1833)	+
Holosticha monilata Kahl, 1928	++
Holosticha multistillata Kahl, 1928	++
Lacrymaria filiformis Maskel, 1886	++
Lembadion bullinum (Mueller, 1786)	+
Litonotus alpestris Foissner, 1978	+++
Litonotus varsaviensis (Wrzesniowski, 1866)	+
Loxocephalus sp.	+
Loxophyllum helus (Stokes, 1884)	+
Loxophyllum meleagris (Mueller, 1773)	+++
Microthorax pusillus Engelmann, 1862	+
Nassula ornata Ehrenberg, 1833	+
Nassula picta Greeff, 1888	+
Oxytricha chlorelligera Kahl, 1932	+
Oxytricha ferruginea Stein,1859	++
Oxytricha haematoplasma Blatterer et Foissner, 1990	+
Oxytricha setigera Stokes, 1891	+
Oxytricha similis Engelmann, 1862	+
Paracolpidium truncatum (Stokes, 1885)	+
Placus luciae (Kahl, 1926)	+
Platyophrya spumacola Kahl, 1927	+
Platyophrya vorax Kahl, 1926	+
Pseudochilodonopsis fluviatilis Foissner,1988	+
Sathrophilus muscorum (Kahl, 1931)	++
Strobilidium caudatum (Fromentel, 1876)	+
Tachysoma pellionellum (Mueller, 1773)	++
Trachelophyllum apiculatum (Perty, 1852)	+
Trithigmostoma cucullulus (Mueller, 1786)	+
Trithigmostoma srameki Foissner, 1988	++
Trochilia minuta (Roux, 1899)	++
Trochiliopsis opaca Penard, 1922	+
Urosomoida agiliformis Foissner, 1982	+

flies were the most productive. On the other hand, the production of midges was surprisingly low (Table 2). This can be explained by low the temperature, which affects growth and life cycles, limited sources of food, refuges and relatively little cover provided by mosses and epilithic algae on the stony substratum.. The total production of macrozoobenthos peaked in May (Fig. 5) when discharge and benthic detritus were at maximum and there was a considerable increasing of temperature. The peak in Diptera occurred in June. Abiotic parameters were important for the production of filterers and scrapers (Fig. 6b, c). On the other hand, biotic parameters were crucial for shredders and predators (Fig. 6a, e). Total annual production of macrozoobenthos in Hincov potok was only 2.4 $g \times m^{-2} \times yr^{-1}$ dry matter.

We recorded 163 brown trout *Salmo trutta fario* per km in Hincov potok. They were two to three years old and on an average 115 mm long. An earlier estimate (Kirka (1968) were 206 individuals per km.

DISCUSSION

The increased amount of NH_4 in spring and summer indicates some nutrient enrichment in the catchment, though not as high as that recorded by Kownacki (1977) and Bombowna (1997) in Rybí potok (the High Tatra Mts.) during the tourist season. A similar fluctuation in phosphorus and nitrogen (PO_4, NO_3) was also recorded in the Czarny creek (a high mountain stream) in the Polish Tatras (Kownacki et al. 1997).

Seasonal distribution of CPOM (Fig. 2a) differs considerably from seasonal dynamics of detritus in sub-mountain streams flowing through forests (Krno et al. 1996, 1997), where the amount of CPOM and wood increases in autumn (November and December). In Hincov potok CPOM increases after snowmelt and resultant increase in discharge during spring.

The two filamentous autotrophs – *Homoeothrix janthina* and *Hydrurus foetidus* which were numerous in Hincov potok, are characteristic of streams flowing through mountain forests (Kawecka, 1993). The other algae in the creek, mostly diatoms, are also typical of high mountain streams. Most of the species are indicators of high oxygen concentration and are sensitive to organic pollution. The algal communities of other mountain streams in the Tatras are similar (Kawecka 1981, 1982, 1993).

The feeding guilds of Ciliophora present (Fig. 4) suggest an increased proportion of algivorous and omnivorous as opposed to bactivorous species, compared to streams in Slovakia with a oligotrophic status, e.g. the upper sections of the Turiec river (Krno et al. 1997) and Javorník brook (Tirjaková 1997).

In these cases heavy shading of the stream and an increased supply of allochthonous material play a significant role. The increased proportion of algivorous species in Hincov brook is indicative of the original character streams of that flow through landscapes with little or very little tree cover. This observation corresponds with that of other authors e.g. Primc (1988).

Statzner (1987) reports that there are five important factors affecting lotic ecosystems: 1) temperature; 2) discharge and the character of the substratum (affected by the discharge regime), its stability, interactions between the aquatic environment and organisms, atmosphere, hyporheal and turbidity; 3) light; 4) nutrients which affect primary production; and 5) the input of allochtonous organic matter. Climatic, geological and hydrological conditions, tributaries, shore vegetation and geomorphology of the basin (macroenvironmental factors) are reported to control the

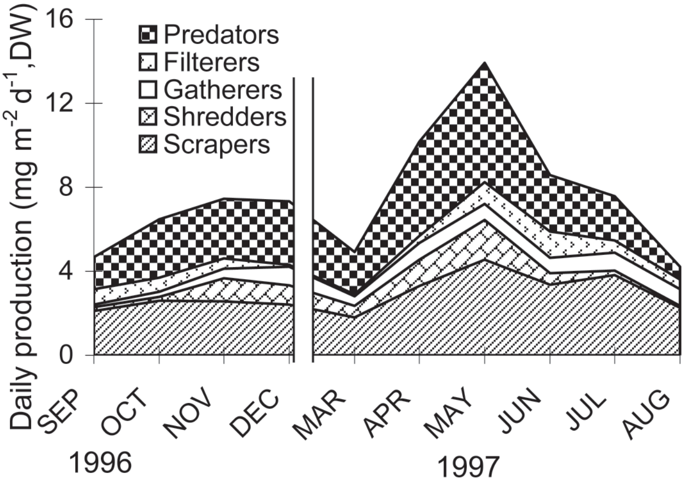

Fig. 5. Seasonal dynamics of of the production of the various guilds in the brook Hincov.

Table 5. Macroinvertebrate of the brook Hincov; sum – sum of individuals

taxon	sum	taxon	sum
Turbellaria		**Trichoptera**	
Crenobia alpina (Dana, 1766)	18	*Rhyacophila glareosa* McLachlan, 1867	2
Oligochaeta		*Rhyacophila obliterata* McLachlan, 1863	9
Nais variabilis Piguet, 1906	4	*Rhyacophila tristis* Pictet, 1834	13
Stylodrilus heringianus (Claparede, 1862)	92	*Rhyacophila vulgaris* Pictet, 1834	2
Trichodrilus tatrensis (Hrabě, 1937)	1	*Wormaldia occipitalis* (Pictet, 1834)	28
Propappus volki Michaelsen, 1916	12	*Drusus annulatus* (Stephens, 1837)	3
Cognettia sphagnetorum (Vejdovsk7, 1877)	22	*Drusus biguttatus* (Pictet, 1834)	14
Cognettia glandulosa (Michaelsen, 1888)	1	*Drusus discolor* (Rambur, 1842)	71
Mesenchytraeus armatus (Levinson, 1883)	3	*Potamophylax cingulatus* (Stephens, 1837)	29
Eiseniella tetraedra tetraedra (Savigny, 1826)	1	*Acrophylax vernalis* Dziedzielewicz,1912	6
Haplotaxis gordioides (Hartmann, 1821)	6	*Halesus rubricollis* (Pictet, 1834)	3
Hirudinea		*Melampophylax nepos* (McLachlan, 1880)	4
Helobdella stagnalis (Linnaeus, 1758)	1	*Chaetopteryx polonica* Dziedzielewicz, 1889	2
Ephemeroptera		**Simuliidae**	
Ameletus inopinatus Eaton, 1887	7	*Prosimulium rufipes* (Meigen, 1830)	127
Baetis alpinus (Pictet, 1843–1845)	561	*Simulium cryophilum* (Rubtsov, 1959)	2
Baetis melanonyx (Pictet, 1845)	4	*Simulium argyreatum* Meigen, 1838	135
Baetis vernus Curtis, 1843	1	*Simulium maximum* (Knoz, 1961)	10
Electrogena lateralis Curtis, 1834	1	*Simulium monticola* Friederichs, 1920	101
Rhithrogena carpatoalpina Klonowska et al., 1984	5	**Chironomidae** *Brillia modesta* (Meigen, 1830)	7
Rhithrogena picteti Sowa, 1971	6	*Eukiefferiella brevicalcar* group	2
Rhithrogena gr *semicolorata*	1	*Eukiefferiella gracei* group	38
Rhithrogena puytoraci Sowa et Degrange, 1988	34	*Orthocladius* (*Eudactylocladius*) sp.	3
Rhithrogena loyolea Navás, 1922	94	*Orthocladius* (s.str.) *frigidus* (Zetterstedt, 1838)	2
Plecoptera		*Orthocladius* (s. str.) sp.	7
Brachyptera starmachi Sowa, 1966	2	*Parakiefferiella* sp.	4
Protonemura auberti Illies, 1954	6	*Parametriocnemus boreoalpinus* Gowin, 1942	1
Protonemura brevistyla (Ris, 1902)	2	*Paratrichocladius* sp.	3
Protonemura montana Kimmins, 1941	65	*Parorthocladius* sp.	2
Protonemura nimborum (Ris, 1902)	155	*Rheocricotopus effusus* (Walker, 1856)	1
Leuctra armata Kempny, 1899	254	*Thienemaniella* Pe 2b Langton, 1991	3
Leuctra autumnalis Aubert, 1948	282	*Tvetenia bavarica* group	37
Leuctra pseudosignifera Aubert, 1954	10	*Micropsectra atrofasciata* group	21
Leuctra pusilla Krno, 1985	43	**Other Diptera**	
Leuctra rosinae Kempny, 1900	1	*Dicranota* spp.	151
Capnia vidua Klapálek, 1904	72	*Eloeophila submarmorata* (Verrall, 1887)	5
Diura bicaudata (Linnaeus, 1758)	18	*Eloeophila* spp.	10
Isoperla sudetica (Kolenati, 1859)	66	*Tricyphona immaculata* (Meigen, 1804)	5
Perlodes intricatus (Pictet, 1841)	13	*Pedicia* (*Crunobia*) *straminea* (Meigen, 1838)	6
Siphonoperla neglecta (Rostock, 1881)	12	*Bazarella subneglecta* (Tonnoir, 1922)	5
Coleoptera		*Berdeniella manicata* (Tonnoir, 1920)	5
Elmis latreille (Bedel, 1878)	8	*Berdeniella unispinosa* (Tonnoir, 1919)	28
Hydraena excisa (Kiesenwetter, 1849)	2	*Berdeniella illiesi* Wagner, 1973	16
Wiedemannia spp.	11	*Liponeura cinerascens minor* Bischoff, 1922	4

character of the river continuum (they affect the input of nutrients, light and accumulation of detritus) (Minshall et al. 1983). Climate and changes in the substratum (local – microenvironmental factors) have a similar impact. Based on the proportional composition of organisms belonging to the various food guilds (Mackay 1987, Krno et al. 1996a), the high mountain Hincov potok can be considered a typical autotrophic ecosystem (Fig. 5, Table 2) in which consumers of primary production prevail over detritivores. The amount of organic matter and water temperature determine

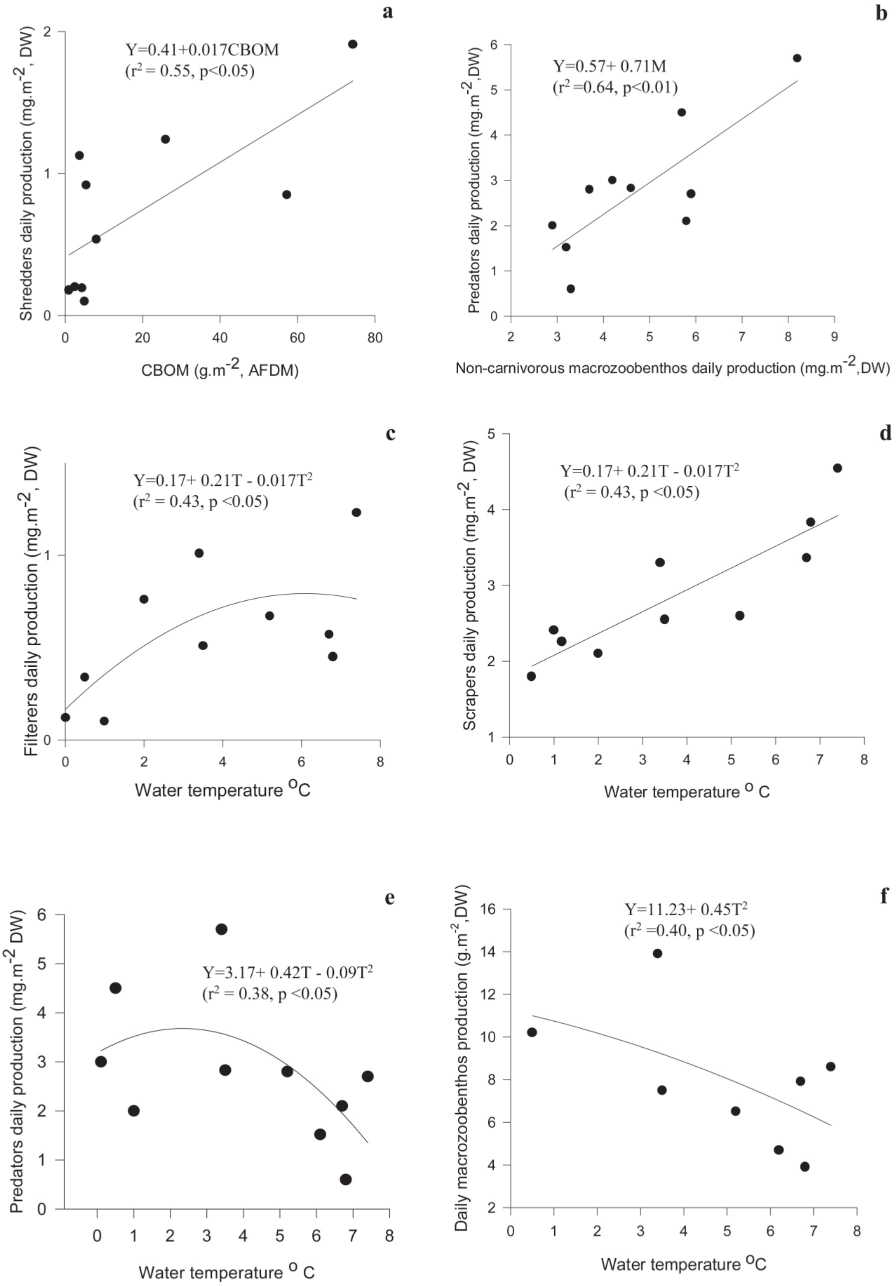

Fig. 6. Relationships between macrozoobenthos production and some environmental variables; CPOM, M – macrozoo-benthos production, T – temperature.

seasonal production of the macrozoobenthos (Fig. 6). In spite of the ultraoligotrophic conditions, high mountain ecosystems situated above the upper timberline (Tables 1 and 2) retain their autotrophic nature. The main food chain of these ecosystems (Fig. 2b), depends on primary producers, which is similar to the conditions that prevail in larger sub-mountain rivers, e.g. Turiec (Krno et al. 1996). To some extent, this crucial deviation of the structure of the macrozoobenthos trophic guilds from the RCC (Vannote et al. 1980) is similar to thattowards autotrophy in streams, as reported by Minshall et al. (1985) for semi-desert areas. The departure from the River Continuum Concept observed in Hincov potok is due to the high exposure of this stream to light, which results from its being above the timberline. According to Peckarska (1983), the impact of abiotic factors predominates in habitats with harsh conditions (homogenous substratum, high fluctuation in current velocity, temperature, depth and width of the stream). For these habitats, a lower input of nutrients (both allochthonous and autochthonous – oligotrophy), lower species diversity, high index of taxa domination, and low number of predators and predominance of trout is characteristic. On the other hand, it is also reported that in such biotopes, A-strategists, characterised as species with a wide ecological niche, long developmental cycle, low fecundity, high mortality in all stages, and low diversity and productivity, are common (Williams & Felmate 1994). A-strategists live in biotopes with predictable and extreme environmental factors, where interspecific competition is weak, and predators and species with a long diapause during embryonic and larval development predominate. A similar situation was found in Hincov potok. In this creek, unlike the springs studied by Krno et al. (1997; also Fig. 5, Table 2), predatory invertebrates are very abundant even in the presence of an abundance of trout . The total production of macroinvertebrates in Hincov potok (2.4 g×m^{-2} dry matter) is much lower than in mountain and sub-mountain (7.3–19.9 g×m^{-2} dry matter) streams, such as those investigated by Šporka & Krno (2003). I addition, in their study a very low production of filter feeders were found (Table 2). According to Benke et al. (1998) this is typical of ultraoligotrophic conditions with extremely low alkalinity. Therefore, production by macrozoobenthos in high-mountain streams is affected by the sum of the mean daily temperatures, altitude and slope. At higher altitudes, production is lower because of low temperatures and hydraulic stress (steep slope).

In comparable Pyrenean biotopes without fish (Lavandier & Décamps 1984), the yearly production of macrozoobenthos is double (4.9–7.0 g×m^{-2} dry matter) that recorded in this study. The ultraoligotrophic biotope studied thus offered an opportunity to observe the impact of trout predation on macrozoobenthos (Allan 1982). Richardson (1993) analysed the data in the literature on the interaction between macroinvertebrates and fish, but did not come to any conclusion. Allan (1982) found that the removal of trout from a river had no significant affect on the prey and offered two explanations . It is likely that his experimental site, a 1220 m section, was too short for such an experiment. Our hypothesis is supported by a phenomenon that is very unusual in high-mountain ecosystems: a decrease in the production of macrozoobenthos (excluding scrapers) with increase in temperature (Fig. 6d), which contrast with what occurs in Pyrenean streams without fish where the production of macrozoobenthos peaked when temperature were highest(Lavandier 1975, 1981, 1982). This may be explained by an increase the voracity of the trout with increase in temperature. Although brown trout is a cold-water fish, its optimum for spawning and development of embryos and larvae is above 5 °C. Cold-water salmonid fish are known to increase their feeding with increasing temperature. Alabaster & Lloyd (1994) and Elliott & Hurley (2000) showed that feeding activity in trout starts at 5 °C and that the daily energy intake increases with increasing water temperature. Maximum growth and gross efficiency in the conversion of energy intake into growth in brown trout occurred at 9.3 °C. At 2–3 °C, trout do not feed or take food only sporadically. There is a relatively high abundance of brown trout in this ultraoligotrophic stream compared to other sub-mountain streams in the Váh River basin (Kirka 1968, Holčík et al. 1976). This is probably because from the fact that the location is close to the mesotrophic Lake Popradské which is well populated with brown trout, partly from hatcheries. The part of Hincov potok studied here is connected with Lake Popradské via Krupá brook. This is probably the reason for the high abundance of brown trout in this part of the creek compared to the River Estibere in Pyrenees (Lavandier & Décamps 1984).

The metabolism, retention, and organic matter turnover time in Hincov potok (Table 2) correspond to those recorded for small streams and springs (Minshall et al. 1992, Krno et al. 1997). In contrast, transport of organic matter and the length of turnover of organic matter are similar to those recorded in larger streams. This is specific for high-mountain streams and is different from the concept of the river continuum, which is more applicable to streams originating in woodland areas (Vannote et al. 1980).

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