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Habitat preferences of aquatic Oligochaeta (Annelida) in the Rokytná River, Czech Republic – a small highland stream

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Abstract

Research was carried out to determine aquatic oligochaete habitat preferences in the Rokytná River (Thaya River basin), a sixth order highland stream in the Czech Republic during the period of April 1999–April 2001. Quantitative samples were collected and current velocity and basic physico-chemical variables were measured monthly in four typical habitats in the Rokytná River. During this study, 28, 842 individuals representing 44 oligochaete species or higher taxa were collected. Temporal variability of proportional occurrence of trophic groups found on selected habitats (gathering collectors and grazers) was analysed. Habitat preferences of oligochaete species were evaluated by Canonical Correspondence Analysis (CANOCO). Biochemical oxygen demand (BOD) and nitrate (NO_3^-) ion concentration were the most important variables explaining the distribution of Oligochaeta along the first axis. Current velocity (at 40% of the depth) and presence of oligochaetes associated with the habitat where gravel bars never formed were the most important variables along the second axis. Both axes were correlated with the temperature, reflecting the sampling in summer along the first axis and sampling in late spring along the second axis. The amount of organic matter (BOD) and concentrations of NO_3^- ions represented both oligochaete food source and decomposition products contributing to the growth of algae. Current velocity and preferred habitat explained the spatial pattern of oligochaete distributions.

Introduction

A wide range of environmental factors permanently influences aquatic ecosystems. Major physico-chemical factors are mostly defined by geology, geomorphology, and climate, and aquatic ecosystems can also be affected significantly by human activity. The oligochaete community composition reflects the states and changes in these variables. Even under natural conditions, a dynamic process of disturbance and change in the community composition occurs continuously (Hynes, 1970; Williams, 1980). The influence of stream hydrology, and physical and chemical factors on aquatic Oligochaeta (Annelida) have been studied by many authors (e.g., Korn, 1963; Dumnicka & Pasternak, 1978; Prenda & Gallardo, 1992; Martínez-Ansemil & Collado, 1996; Verdonschot, 2001).

A moderately polluted highland stream was selected to study habitat preferences within the aquatic oligochaete community. The first objective was to follow the temporal variability of the community composition over a 2-year study. Oligochaete species were divided according to their feeding habits (Moog, 1995) into two groups – grazers and gathering collectors, and temporal variability in their proportional occurrence was evaluated. Such changes were followed separately on four dominant habitats differing from hydrological point of view.

The second objective was to evaluate, by means of multivariate analysis, environmental variables significant for the oligochaete distribution and thus to establish if selected habitats play an important role in oligochaete community composition.

Study area

The oligochaete fauna was studied in the Rokytná River (Thaya River basin, Czech Republic), a sixth order stream (Strahler, 1957). The Rokytná River is 89.3 km long, with a catchment area of 585.4 km^2; the mean annual discharge at the mouth is 1.27 m^3 s^{-1}. The present study was conducted in a 60 m reach of the river, located at river km 9, at an altitude of 220 m and a slope of 3.2 m km^{-1}.

The hydrology at the study reach is characterised by two (summer and winter) annual maximum discharge levels: 1999 (14.6 and 6.0 m^3 s^{-1} respectively), 2000 (3.8 and 24.3 m^3 s^{-1} respectively), and 2001 (2.2 and 7.5 m^3 s^{-1} respectively). Highly variable discharges are often associated with agricultural landscapes – the catchment area is not able to absorb either summer rainstorms or winter snow-melt. The substrate of the stream within this study area consists of pebbles, gravel, and small amount of sand. For the studied river stretch, an alternating of the straight and meander parts is typical.

On the gravel substratum, periphyton developed in spring, dominantly represented by Bacillariophyceae (Marvan, 1998), but the character of the river bottom did not enable a growth of macrophyta.

Materials and methods

Habitat types

Four major habitat types on two cross-sections were sampled monthly, from April 1999 to April 2001. One sample was taken at cross-section A, situated in the streamline. This part of the river was chosen, as a representative of the natural straight part of the river, where gravel bottom does not form either gravel bars or islands. Three samples were taken in a meander at cross-section B to include all different habitats of this river stretch. One in the littoral, drying up part (depositional zone indicated as B littoral), one on the gravel bar (indicated as B gravel bar) and one in streamline (erosional zone: B streamline), respectively (Fig. 1). Water depth, current velocity at the bottom and at 40% of the depth characterised selected habitats.

"Freeze core" method (Bretschko & Klements, 1986) down to the depth of 0.1 m on each of the selected habitats was used for sediment structure evaluation twice – in October 2000 and June 2001. Detailed results of the sediment analysis including organic matter content down to the 0.7 m depth were published by Helešic et al. (2005). The sediment particles were sorted and percent representation of individual particle sizes was calculated. The roughness of the substrate of each habitat was expressed by the phi value (Cummins, 1962) for all selected habitats as a weighted average of phi values for each particle size. The smallest value (−3.5) and hence the highest roughness was found on B gravel bar, similar to that found on habitat A streamline (−3.2), habitats B littoral and B streamline had higher values (−2.4 and −2.5), all of them in October 2000. The bottom roughness almost did not change on habitats A streamline (−3.1), B gravel bar (−3.4) and B streamline (−2.6) while in B littoral the bottom roughness increased (−3.6) at the end of investigation in June 2001. Due to possible habitat damage it was refrained from more frequent sampling of the substratum.

Although the Rokytná River is quite a dynamic stream, the substratum did not change within a year except in one of the selected habitats. The substrate data were not included in analyses below, but were used to describe the characteristics of studied habitats.

Environmental variables

The following physico-chemical variables were recorded during each sampling period: water temperature, hydrogen ion concentration (as pH), dissolved oxygen, conductivity, current velocity at 40% of depth, current velocity at bottom, water depth, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia and nitrate nitrogen, and phosphate phosphorus (PO_4^{3-}). The values of physico-chemical variables measured were very similar between habitats, however, the current velocity differed considerably. Mean daily

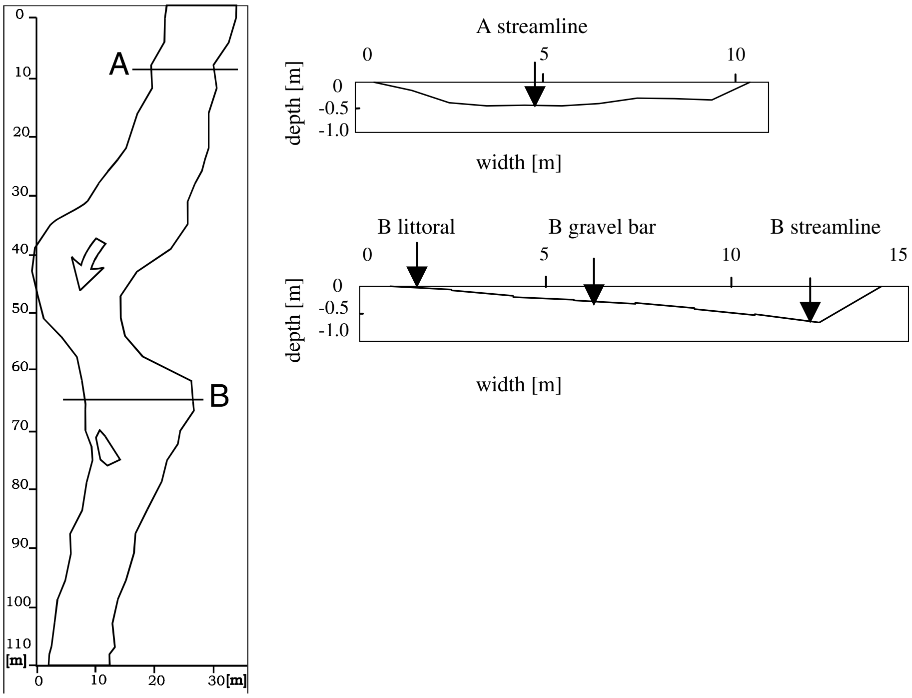

Figure 1. Cross-sections of habitats A and B on the Rokytná River, Czech Republic (5 April 2000), and the position of the sampling points: A streamline, B littoral, gravel bar and streamline (arrows).

discharge values of the sampling dates were obtained from the Czech Hydrometeorological Institute (Table 1). One value per sampling date was obtained, since the values did not differ among studied habitats.

Oligochaeta

The macrozoobenthic populations were sampled using a Kubíček sampler (0.1 m^2, mesh size 0.5 mm) (Helan et al., 1973). Oligochaete specimens were fixed in formalin (4%) in the field, and sorted under the stereomicroscope in the laboratory. All oligochaete species were mounted in Canada Balsam (Cranston, 1982) and determined using keys by Hrabě (1954, 1981), Brinkhurst & Jamieson (1971), Sperber (1950), Timm (1999) and Kathman & Brinkhurst (1999). Identification of *Bythonomus lemani* was confirmed by microscopical examination of mounted specimens that had been embedded in paraffin, sectioned longitudinally, then stained in haematoxylin (Jírovec, 1958).

After the Oligochaeta were divided into trophic groups (Moog, 1995), the temporal variability in proportional occurrence of trophic groups found (gathering collectors and grazers) and their occurrence on selected habitats was evaluated.

Data processing

Habitat preferences of oligochaete trophic groups on selected habitats were compared using the Wilcoxon Matched pair test, because the measured data did not have normal distributions (Kolmogorov–Smirnov test) and were dependent on sampling date. The correlation of two trophic groups and two environmental variables (temperature and daily discharge) were evaluated using the Spearman rank correlation coefficient (Zar, 1984).

Faunistic and environmental data were analysed by Canonical Correspondence Analysis (CCA), CANOCO (Ter Braak & Schmilauer, 2002). This method permits the construction of theoretical variables (ordination axes) that best fit the species data according to a unimodal method

Table 1. Minimum, maximum, mean and median values of environmental variables of the Rokytná River over the period April 1999–April 2001

Variable	Min.	Max.	Mean	Median
Water temperature (°C)	−0.2	19.4	11.0	13.0
pH	4.4	9.0	7.6	7.7
O_2 [mg l^{-1}]	6.59	18.20	10.4	9.43
Conductivity [μS cm^{-1}]	453	725	615	615
Current velocity at bottom [m s^{-1}]	0	0.87	0.34	0.30
Current velocity at 40% of depth [m s^{-1}]	0	1.46	0.67	0.68
Mean daily discharge [m^3 s^{-1}]	0.13	3.95	1.36	1.08
Depth [m]	0.10	0.47	0.22	0.20
BOD [mg O_2 l^{-1}]	1.9	15.8	5.4	4.5
COD [mg O_2 l^{-1}]	26.1	51.1	27.8	32.2
NO_3^- [mg l^{-1}]	12.0	57.5	27.8	20.0
NH_4^+ [mg l^{-1}]	0.25	1.10	0.60	0.60
PO_4^{3-} [mg l^{-1}]	0.05	1.80	0.85	0.90

of ordination. In the canonical ordination these axes are a linear combination of environmental variables. The correlations between environmental variables and the ordination axes are derived and summarised in the eigenvalue of the ordination axis. The result of CCA is a set of scores for both sites and taxa, which can be presented as two-dimensional ordination diagram where points represent sites or taxa and lines outgoing from the origin expresses environmental variables (Ter Braak & Schmilauer, 2002). The length of the lines represents the importance of the respective variable.

The data were not transformed and species were not down-weighted. The statistical significance of the relationship between all species and all variables was tested by Monte Carlo permutation test using 9999 permutations (Ter Braak & Schmilauer, 2002).

Results

Oligochaeta

During this study, 28 842 individuals representing 36 species of the families Lumbriculidae, Naididae, Tubificidae, and Lumbricidae were collected and identified (Table 2). In addition, the family Enchytraeidae was represented by unidentified species in four genera. *Psammoryctides barbatus* and *Bothrioneurum vejdovskyanum* (Tubificidae) and *Nais elinguis* (Naididae) were the dominant species.

Trophic groups

Most of the recorded species belong to two trophic groups, gathering collectors and grazers. Species with more trophic adaptations (Moog, 1995), the dominant feeding habit was used for evaluating. The third group, predators (only within the genus *Chaetogaster*) represented only about 0.1% of the total number of individuals and therefore was omitted in the analyses. Though the proportion of trophic groups (gathering collectors and grazers) varied among habitats, these differences were insignificant ($p > 0.05$) (Wilcoxon Matched pair test).

The occurrence of grazers was positively correlated (Spearman rank correlation coefficient, $p < 0.05$) with the discharge and negatively with temperature on habitat A streamline (Fig. 2a). The grazers were also negatively correlated with temperature habitat B streamline (Fig. 2b) and gathering collectors were positively correlated with temperature on habitat A streamline (Fig. 2c), (Spearman rank correlation coefficient, $p < 0.05$).

Table 2. List of oligochaete taxa recorded, taxon code, frequency of occurrence, percentage of occurrence and trophic group (gat – gathering collector, gra – grazer and pre – predator)

Taxon	Abbreviation	No. of individuals	%	Trophic group
Lumbricidae				
Allolobophora chlorotica Savigny, 1826)	Allo chl	28	0.10	gat
Eiseniella tetraedra (Savigny, 1826)	Eise tet	26	0.09	gat
Enchytraeidae				
Enchytraeus g. sp. div.	Ench sp	64	0.22	gat
Fridericia g. sp. Div.	Frid sp	54	0.19	gat
Cernosvitoviella g. sp. div.	Cern sp	3	0.01	gat
Cognettia g. sp. div.	Cogn sp	32	0.11	gat
Tubificidae				
Aulodrilus pluriseta (Piguet, 1906)	Aulo plu	2	0.01	gat
Bothrioneurum vejdovskyanum Štolc, 1886	Both vej	2604	9.03	gat
Limnodrilus claparedeanus Ratzel, 1868	Limn cla	3	0.01	gat
Limnodrilus hoffmeisteri Claparede, 1862	Limn hof	167	0.60	gat
Limnodrilus udekemianus Claparede, 1862	Limn ude	6	0.02	gat
Limnodrilus g. sp. div. juv.	Limn sp	2292	7.95	gat
Moraviodrilus pygmaeus Hrabě, 1935	Mora pyg	386	1.34	gat
Potamothrix hammoniensis (Michaelsen, 1901)	Pota ham	7	0.02	gat
Psammoryctides barbatus (Grube, 1861)	Psam bar	5482	19.01	gat
Psammoryctides moravicus (Hrabě, 1934)	Psam mor	5	0.02	gat
Rhyacodrilus coccineus (Vejdovský, 1875)	Rhya coc	41	0.14	gat
Rhyacodrilus falciformis Bretscher, 1901	Rhya fal	1395	4.84	gat
Rhyacodrilinae juv. with hair chaetae	Rhya juv	1634	5.67	gat
Spirosperma ferox Eisen, 1879	Spir fer	1	0.003	gat
Tubifex tubifex (O. F. Műller, 1774)	Tubi tub	50	0.17	gat
Tubificidae juv. with hair chaetae	Tubi juv	957	3.32	gat
Naididae				
Chaetogaster diaphanus (Gruithuisen, 1828)	Chae dip	21	0.07	pre
Chaetogaster diastrophus (Gruithuisen, 1828)	Chae dis	7	0.02	pre, gat, gat
Nais alpina Sperber, 1948	Nais alp	461	1.60	gra, gat
Nais barbata O. F. Műller, 1773	Nais bar	108	0.37	gra, gat
Nais bretscheri Michaelsen, 1899	Nais bre	857	2.97	gra, gat
Nais communis Piguet, 1906	Nais com	144	0.50	gra, gat
Nais elinguis O. F. Műller, 1773	Nais eli	5580	19.34	gra, gat
Nais pardalis Piguet, 1906	Nais par	6	0.02	gra, gat
Nais pseudobtusa Piguet, 1906	Nais pse	48	0.17	gra, gat
Nais simplex Piguet, 1906	Nais sim	20	0.07	gra, gat
Nais variabilis Piguet 1906	Nais var	1	0.003	gra, gat
Ophidonais serpentina O. F. Műller, 1773	Ophi ser	4	0.01	gra, gat
Pristina aequiseta Bourne, 1981	Pris aeq	56	0.19	gra, gat
Pristina bilobata (Bretscher, 1903)	Pris bil	19	0.07	gra, gat
Pristina rosea (Piguet, 1906)	Pris ros	323	1.12	gra, gat
Stylaria lacustris (Linnaeus, 1767)	Styl lac	2	0.01	gra, gat
Vejdovskyella intermedia (Bretscher, 1896)	Vejd int	22	0.08	gra, gat

Continued on p. 122

Table 2. (Continued)

Taxon	Abbreviation	No. of individuals	%	Trophic group
Lumbriculidae				
Bythonomus lemani (Grube, 1879)	Byth lem	1401	4.86	gat
Lumbriculus variegatus O. F. Műller, 1774	Lumb var	14	0.05	gat
Stylodrilus parvus (Hrabě & Černosvitov, 1927)	Styl par	813	2.82	gat
Stylodrilus heringianus Claparede, 1862	Styl her	49	0.17	gat
Stylodrilus g. sp. div. juv.	Styl juv	3647	12.64	gat
Total		28 842	100.00	

Habitat preferences

Canonical correspondence analysis (Fig. 3) was used to extract species–environment relationships; 44 taxa and 13 environmental variables and 8 nominal variables in 84 samples were evaluated. Four nominal variables represented selected habitats – A streamline, B littoral, B gravel bar, and B streamline, and four nominal variables represented seasons – spring (March–April), spring/summer (May–June), summer (July–August), and autumn/winter (September–February). These sampling periods correspond more closely with temporal changes in oligochaete community composition than the four 'standard' seasons (e.g., winter = 21 December through 20 March). The statistical significance of environmental variables was assessed by Monte Carlo permutation test. Ranked from the most to the least: BOD, temperature, habitat A streamline, NO_3^-, current velocity at 40%, habitat B streamline, summer sampling and conductivity were significant.

The eigenvalues for the four axes are 0.325, 0.171, 0.084, and 0.075, respectively. According to the weighted correlation matrix, the first axis (40.8% variance of the species–environment relation) is related to BOD (0.592) and NO_3^- (0.350) and thus represents the food source (NO_3^- as indicator of a nutrient source for algae and diatoms). The second axis (21.6% of variance) is correlated with current velocity at 40% of the depth (0.400) and presence on habitat A streamline (−0.408), explained spatial variability. Both axes are negatively correlated with temperature (−0.334, −0.396 respectively), which reflects the summer sampling along the first axis (−0.518) and the spring/summer sampling (−0.421) along the second axis respectively (Fig. 3). The third ordination axis (10.6% of variance) is positively correlated with the presence of oligochaetes on habitat B streamline (0.391), BOD (0.376), temperature (0.360) and negatively with NO_3^- (−0.401).

In the ordination diagram representatives of the family Naididae were in right upper corner showing development at lower temperatures, in spring. Most of Tubificidae representatives were negatively correlated with current velocity in 40% of the depth and occurred on habitat A streamline.

Discussion

Most oligochaete species found in the Rokytná River occurred within a wide range of environmental conditions, demonstrating a large temporal and spatial variability. Oligochaete composition on four selected habitats did not differ significantly when comparing proportion of two feeding groups. We suggest that density changes of grazers, which were negatively correlated with the temperature and positively with discharge, were directly caused by periphyton growth. The grazers represented by members of the family Naididae have maximal development in winter and spring (Pfannkuche, 1981) when sufficient light enables the development of periphyton, also Šporka (1996) have found that the abundance of the family Naididae is dependent on the quantity of periphyton. The positive correlation of gathering collectors and the temperature again correspond with availability of food sources. They reach maximal densities in summer (Lazim & Learner, 1986), when decaying organic matter is available. Most significant relationships were associated with a very stable habitat A; the fact that gravel bars never form there enhance oligochaete growth.

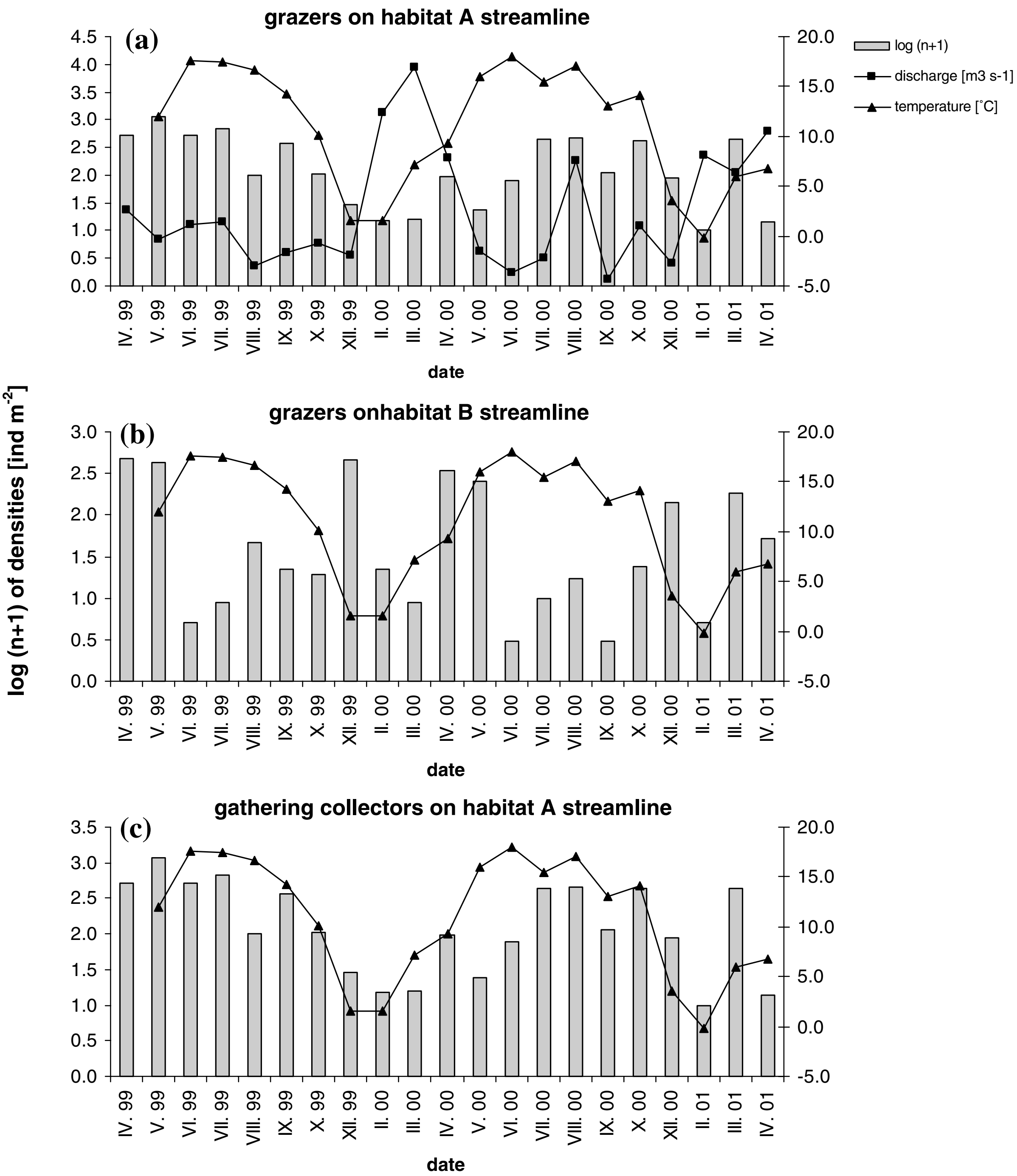

Figure 2. The temporal variability of grazers on habitat A streamline, positively correlated with the discharge and negatively with temperature (a) The temporal variability of grazers on habitat B streamline, negatively correlated with temperature (b) The temporal variability of gathering collectors on habitat A streamline, positively correlated with temperature (c) (Spearman rank correlation coefficient, $p < 0.05$).

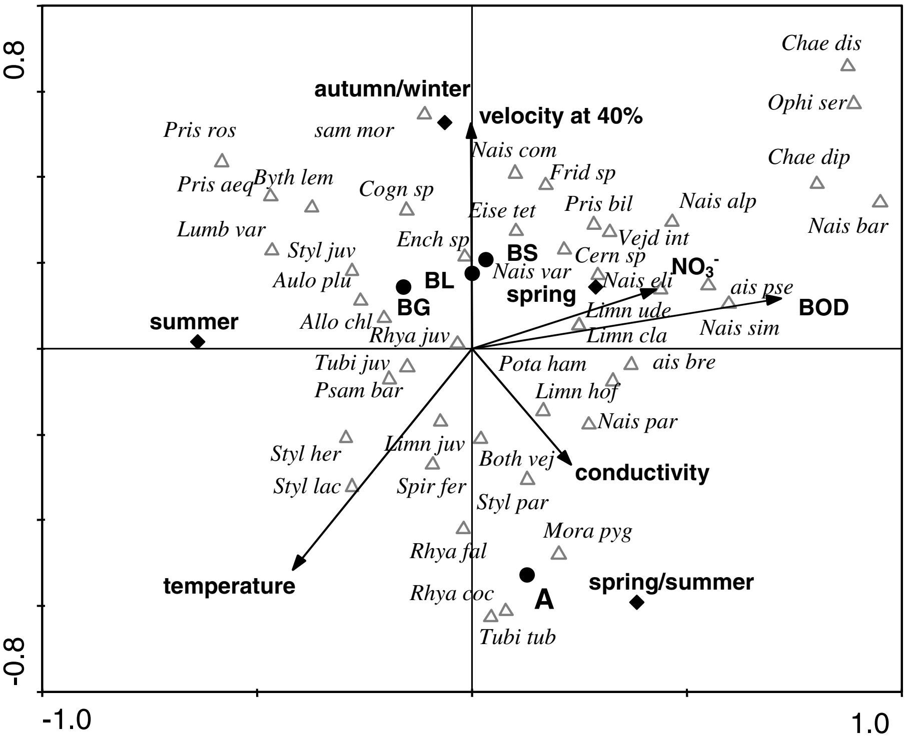

Figure 3. CCA diagram of the axis 1 and 2 of oligochaete taxa (for abbreviations see Table 2) in relation to environmental variables (arrows), seasons (diamonds) and sampled habitats (points): A = A streamline, BL = B littoral, BG = B gravel bar, BS = B streamline – recorded in the Rokytná River.

Variability of current velocities in different habitats of cross-section B resulted in either the movement of worms between habitats or their downward burrowing into hyporheic layers.

Habitat preferences of various species were evaluated using CANOCO. Oligochaete community composition was dependent upon organic matter input (BOD) and sources of inorganic ions NO_3^- (aerobic degradation product and secondary periphyton nutrient source) along the first axis. The second axis was correlated with current velocity and presence on habitat A streamline. The most important variable determining oligochaete community composition in habitats assessed during this study was habitat A streamline in which little if any shifting of substrate occurred – it offered stable conditions for oligochaete occurrence, especially permanent availability of organic matter in substratum. Both axes, however, were also correlated with temperature and seasons of sampling, thus representing temporal variability. The values for chemical variables monitored during this study indicate that the Rokytná River varies from slightly to strongly polluted stream within a year. Detecting the habitat preferences of species in polluted waters is problematic. Some authors (Dumnicka & Pasternak, 1978; Culp et al., 1983; Prenda & Gallardo, 1992) showed that certain oligochaete species were not habitat selective. In CCA analysis, two of the four selected habitats (B littoral and B gravel bar) showed only small reaction with the oligochaete distribution. Although both were differing in environmental conditions with respect to velocity and depth, the oligochaete composition was quite similar there. The position of these environmental variables is similar in the diagram (Fig. 3), although they are not correlated. CCA analysis showed that certain habitats are vital for oligochaete occurrence (habitat A streamline was the third most important environmental variable); other variables were less important. Results were significantly influenced by temporal variability – oligochaete community composition differed both in time and in space.

We conclude that, at least in the lower reaches of a highland stream, habitats do not play as an important role as has been demonstrated in high order streams (Korn, 1963; Montanholi-Martins & Takeda, 1999, 2001). Although some authors (Montanholi-Martins & Takeda, 1999) applied a very similar sampling scheme, they found spatial distribution to prevail over the temporal one. Our conclusions are similar to those of Verdonschot (2001), who studied the influence of different substrates in lowland rivers. There were no significant relationships with the habitats if the most of the study streams included them. According to Verdonshot (2000) the disturbance caused by agricultural activities in the catchment area can cause that only ubiquists without habitat preferences settle the bottom. Most of the oligochaete species show wide ecological valences and habitat preferences are not significant when comparing relatively close sampling points in streams particular in agricultural areas. Relatively natural character of the stream is why we found two (stable) habitats important for oligochaete occurrence. On the other hand, the impact of agriculture causes extreme discharges and this promotes ubiquist species whose community composition and abundance, therefore, varies with time rather than with habitat.

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