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ASSESSMENT OF THE DIVERSITY AND DENSITY OF GASTROTRICH FAUNA (GASTROTRICHA) IN BOTTOM SEDIMENTS OF RUNNING AND STANDING WATERS

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Summary. Species diversity and density of Gastrotricha in running and standing waters are compared in this paper. In total, 38 species of the families *Chaetonotidae* Zelinka and *Dasydytidae* Daday were found in bottom sediments of studied habitats. Bottom sediments gastrotrichs of the river were represented by only ten eurytopic species of the family *Chaetonotidae.* It should be noted that these species are also characteristic for gastrotrich communities from sphagnum peat-bogs. Low species diversity of the riverine gastrotrich fauna was confirmed by Shannon-Wiener index value of 1.91. The density of gastrotrichs in bottom sediments of studied water bodies ranged from 304 thousand indiv. m^{-2} in the Muchawka River (mean of three sites) to 2850 thousand indiv. m^{-2} in mid-meadow peat-hag. Density of Gastrotricha in the studied river was even 9 times lower than that in standing waters.

Key words: Gastrotricha, bottom sediments, lotic waters, standing waters

INTRODUCTION

Freshwater gastrotrich fauna is known better in Poland than in other countries of the world. This is true for both the species number and habitat diversity. Consecutive papers described the fauna of sphagnum peat-bogs, lakes (from oligotrophic to polytrophic and dystrophic), ponds and peat-hags, which allowed for collecting extensive data on the density, biomass and habitat preferences of particular species. It does not mean, however, that our knowledge of gastrotrichs is satisfactory. As compared with other representatives of Polish fauna, gastrotrichs of some habitats are still poorly recognized. For example, data on the occurrence of gastrotrichs in running waters are only from springs and brooks of

the Tatra and Karkonosze Mountains [Kisielewski and Kisielewska 1986]. Only 30 species of these animals have been described from running waters worldwide [Ricci and Balsamo 2000]. Data on the density of gastrotrichs in these habitats are still lacking.

Comparison of species diversity and density of gastrotrichs in bottom sediments of standing and running waters was the aim of the presented paper.

STUDY AREA, MATERIAL AND METHODS

Studies were carried out in the Muchawka River, a left side tributary of the Liwiec River, the main river of Siedlecka Upland (Południowopodlaska Lowland), and in the mesotrophic Lake Piaseczno (the buffer zone of the Poleski National Park). Results of earlier studies of bottom sediments of a eutrophic lake [Nesteruk 2007a] and mid-meadow peat hag [Nesteruk 2007b] near Siedlce, and data of Kisielewski and Kisielewska [1986] on the occurrence of gastrotrichs in springs and brooks of the Tatra and Karkonosze Mountains were also used in this paper.

The Muchawka River springs at an elevation of 165 m a.s.l., flows through Siedlecka Upland and discharges to the Liwiec River at 145 m a.s.l. The river length is 30 km and the surface area of its catchment basin is 300 km^2. The river valley is wide and bogged. Water flow is slow; the river heavily meanders and forms many stagnant water sites. River shore is usually steep and water depth reaches 1.5 m. Bottom is mostly of silt-sandy character. The river flows through agricultural lands and is not polluted by industrial or domestic waste waters. Annual assessment of water quality made by the Provincial Inspectorate of Environmental Protection showed that mean temperature, pH, conductivity, and concentrations of oxygen, nitrates and chlorides do not exceed standards of Class I of water quality. Only phosphate concentrations classify the river waters to Class II of water quality [Królak and Stańczykowska 1995].

Duckweeds (*Lemna* sp.), the narrow-leaved cattail (*Typha angustifolia* L.), reed (*Phragmites australis* Trin. ex Steudel), and water lily (*Nuphar luteum* (L.) Wahlb.) dominate among higher aquatic plants. Less numerous are the Canadian waterweed (*Elodea canadensis* Michx.) and floating pondweeds (*Potamogeton natans* L.).

Three study sites were selected in the river:

Site 1 – situated in Wiśniew, c. 10 km from the river springs. The river is c. 3.5 m wide and 0.4 m deep there. River shore is high and the bottom is stone-sandy near the shore and turns into silt-sandy in deeper places.

Site 2 – situated in Wólka Wołyniecka c. 20 km from springs. River width is c. 3 m in this site. The bottom is composed of sand and silt.

Site 3 – localised at the outlet of the river to the Liwiec River. River shore is low there and overgrown by alder woods. River bottom is silty near the shore and silty with a thick layer of detritus in deeper places.

Lake Piaseczno, with an average depth of 38.8 m and surface area of 83.8 ha, is a mesotrophic reservoir without an outflow [Radwan and Kornijów 1998]. The lake is surrounded by a sandy beach, only its northern shallow part borders on transitional moor. Bottom sediments are rich in organic matter, the content of which in the lake littoral is 53%, and in the profundal 59% [Nesteruk 1996a].

Samples from three sites in the Muchawka River were collected four times in the vegetative season (April, June, August and October) in the year 2005 (12 samples in total). In Lake Piaseczno samples were taken in the year 2006 from three littoral sites in the same months as in the river. Twelve samples were taken in 2000 from a peat-hag and a pond. Samples were taken from April to October, because the fauna of Gastrotricha is most numerous from spring to autumn [Kisielewska 1982]. Samples were taken with the use of a tubular bottom corer [Kajak *et al.* 1965] with cross-section surface area of 10.4 cm^2. All the individuals were identified to species.

The density of Gastrotricha per m^2 of the bottom was determined using the method described by Nesteruk [1996a]. To analyse the species domination pattern, percentage contribution of individual species to the number of all gastrotrichs examined were calculated. The Shannon-Wiener species diversity index (*H'*) was calculated according to the formula given in Shannon and Weaver [1963]:

$$H' = -\sum n_i/N \ln n_i/N$$

where:

n_i – number of individuals of a species i,
N – total number of all gastrotrichs.

Similarity of gastrotrich fauna in river to that living in other habitats was expressed with the homogeneity coefficient after Riedl [1963]:

$$HD = \sum_{i=1}^{s} \left(\sum_{j=1}^{k} \frac{D_{ij}}{k} \right) \frac{D_{\min_i}}{D_{\max_i}}$$

where:

D_{ij} – the domination index of the *i-th* species at the *j*-th site with a total of species in *k* sites.

Mann-Whitney test was used to check the differences in gastrotrich density between river sediments and sediments from standing waters. Differences at $p < 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

Thirty eight gastrotrich species from two families: *Chaetonotidae* Zelinka and *Dasydytidae* Daday were found in bottom sediments of studied habitats. Only four species belonged to the latter family. No species of the family *Dasydytidae* were found either in the littoral of the mesotrophic lake (which confirms earlier observations [Nesteruk 1996b]) or in running waters. The number of spe-

Table 1. Species composition and percentage contribution of Gastrotricha in the studied habitats

Species	Studied habitats					
	river			lake littoral	peat-hag	pond
Sites	1	2	3	total	total	total
Chaetonotus acanthodes Valkanov, 1937						2.4
– *heideri Brehm*, 1917	11.8		3.8	2.1		4.2
– *heteracanthus* Remane, 1927				3.2	1.0	
– *m. macrolepidotus* Remane, 1927					0.6	0.8
– *macrolepidotus ophiogaster* Remane, 1927					3.6	
– *rectaculeatus* Kisielewska, 1981					0.8	
– *simrothi* Voigt, 1909					1.2	
– *disiunctus* Greuter, 1917	15.4	18.8	22.8	8.2	8.8	12.4
– *maximus* Ehrenberg, 1830		7.2	2. 8	3.8	0.1	1.1
– *parafurcatus* Nesteruk, 1991				0.8		
– *oculifer* Kisielewski, 1981		14.4	16.2	8.0		11.6
– *polyspinosus* Greuter, 1917	8.2	3.4	4.4	8.2	10.6	2.2
– *similis* Zelinka, 1889				7.2		
– *sphagnophilus* Kisielewski, 1981				2.2	2.2	
– *bisacer* Greuter, 1917					1.2	
– *hystrix* Mečnikow, 1865	30.4	10.2	9.0	5.8	2.1	2.8
– *succinctus* Voigt, 1904					4.2	2.1
– *macrochaetus* Zelinka, 1889	34.2	14.6	15.8	10.8		2.4
– *persetosus* Zelinka, 1889						0.6
– *octonarius* Stokes, 1887					3.4	
– *rafalskii* Kisielewski, 1979					0.8	
Lepidochaetus zelinkai (Grünspan, 1908)					2.0	
*Heterolepidoderma gracil*e Remane,1927		10.5	3.2	10.4	9.2	13.2
– *macrops* Kisielewski, 1981					3.8	2.6
– *majus* Remane, 1927				6.2	5.6	2.2
– *ocellatum* (Mečnikow, 1865)		12.4	12.2	3.8	2.2	1.8
Lepidodermella squamata (Dujardin, 1841)				8.4		
Aspidiophorus bibulbosus Kisielewski, 1981					1.6	1.2
– *oculifer* Kisielewski, 1981				2.1		3.4
– *paradoxus* (Voigt, 1902)				2.8	0.8	
Ichthydium forficula Remane, 1927		8.5	9.8	4.8	12.4	14.2
– *palustre* Kisielewski, 1981				1.2	2.2	4.2
Polymerurus nodicaudus (Voigt, 1901)					1.2	
– *rhomboides* (Stokes, 1887)					4.4	
Dasydytes ornatus Voigt, 1909					2.8	4.2
Setopus tongiorgii (Balsamo, 1983)					4.8	
Haltidytes festinans (Voigt, 1909)					3.8	
Stylochaeta fusiformis (Spancer, 1890)					2.6	10.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

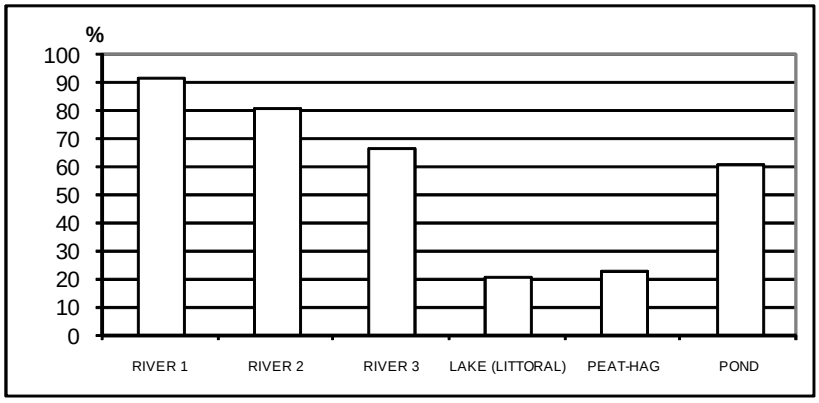

Fig. 1. Percentage contribution of eudominants to the total number of gastrotrich individuals in the studied habitats

cies found in particular habitats varied from 10 to 29, being 29 in the mid-meadow peat-hag, 21 in the eutrophic pond, 19 in the littoral of the mesotrophic lake and 10 in the river. Gastrotrichs of the Muchawka River were poorly diversified and the number of species changed with the type of substratum. The highest species diversity was noted in the outlet river stretch (site 3) with silty bottom covered by a thick layer of detritus. In the middle part of the river, where the bottom was covered with more stones (apart from sand and silt), gastrotrichs were distinctly less numerous and represented by only five species. Gastrotrich fauna of the studied water bodies differed also in the domination structure (Tab. 1). The number of eudominants (percentage share exceeding 10%) ranged from 2 (littoral of the mesotrophic lake and mid-meadow peat-hag) to 5 species in the eutrophic pond to 7 species in the river. Ten species were the eudominants, including one (*Heterolepidoderma gracile*) in three water bodies, four (*Chaetonotus disiunctus, Ch. macrochaetus, Ch. oculifer* and *Ichthydium forficula*) in two water bodies and five other species (*Ch. heideri, Ch. hystrix, Ch. polyspinosus, H. ocellatum* and *Stylochaeta fusiformis*) in one water reservoir. Combined domination of eudominants in particular river sites varied from 67% (site 3) to 91.8% (site 1). In other water bodies the combined domination ranged from 21% in the littoral of the mesotrophic lake to 62% in the eutrophic pond (Fig. 1).

Performed analysis clearly shows the differences in species composition of gastrotrichs in bottom sediments of running *versus* stagnant waters. The occurrence of Gastrotricha in water bodies is affected by the type of bottom sediments. Gastrotrichs prefer soft, silty substratum. Therefore, it is no surprise that the fauna is most diverse in standing waters (lakes, ponds, peat-hags). Habitats of that type are present in running waters only at low water velocity. The Muchawka River is characterised by slow water flow. Moreover, abundant vas-

cular aquatic plants hamper water flow, which stabilises bottom sediments. However, silt-sandy sediments are not preferred by gastrotrichs. In mountain springs and streams of high river gradient and usually low water temperature the gatrotrich fauna is poor in both the number of species and densities. Only six species (*Ch. hystrix, Ch. disiunctus, Ch. macrochaetus, Ch. maximus, Ch. oculier* and *H. ocellatum*) were found in these habitats [Kisielewski and Kisielewska 1986]. Species that have so far been recorded in Polish running waters are eurytopic and belong to the *Chaetonotidae* family. Interestingly, species composition of gastrotrichs from the Muchawka River and from springs and streams of the Karkonosze Mountains is similar to that of the fauna from sphagnum peat-bogs. From among 10 species found in those habitats, one (*Ch. macrochaetus*) is considered characteristic for the community *Heterolepidoderma ocellatum f. sphagnophilum* and four other (*Ch. acanthodes, Ch. oculifer, H. ocellatum* and *Ichthydium forficula*) – for the community *I. forficula*. *Ch. heideri, Ch. polyspinosusi* and *H. majus* are species characteristic for the community *H. majus.* The three mentioned gastrotrich communities are common in sphagnum peat bogs [Kisielewski 1981]. Similarity of gastrotrich fauna in running waters and peat-bogs might result from peat forming processes in the area.

Table 2. Number of species, density (thousand indiv. m^{-2}) and diversity index H' (average values ±SD; n = 12) for Gastrotricha in the studied habitats

Specification	Studied habitats							
	river (total)	lake littoral	peat-hag	pond	Tatra		Karkonosze	
					springs	streams	springs	streams
Number of species	10	19	29	21	2	1	3	2
Density (thousand indiv.m^{-2})	304 ±116	1020 ±215	2850 ±409	855 ±228	42*	108*	66*	174*
Diversity index (H')	1.91 ±0.95	2.77 ±0.59	2.94 ±0.68	2.67 ±0.71	no data		no data	

*Gastrotrich abundance expressed as the number of individuals in 1 cm^3 of sediment was converted to Gastrotrich density per 1 m^2 of the bottom area [Nesteruk 1993]

The density of gastrotrichs (±SD, n = 12) in bottom sediments of studied water bodies ranged from 304 ±116 thousand indiv. m^{-2} in the Muchawka River (mean of three sites) to 2850 ±409 thousand indiv. m^{-2} in mid-meadow peat-hag (Tab. 2). In bottom sediments of the studied river the density was 3 times lower than in the eutrophic pond and 9 times lower than the density in the mid-meadow peat-hag, but 7 times higher than in the springs and streams of the Tatra Mountains. Statistical analysis with the Mann-Whitney test showed significant differences in the gastrotrich density between the river and standing waters ($p < 0.001$).

Comparison of the species diversity indices demonstrates very similar attractiveness of bottom sediments of the mesotrophic lake and mid-meadow peat-hag for

gastrotrichs, and slightly lower attractiveness of the eutrophic pond (Tab. 2). Obtained H' values for these water bodies were high and similar. The least attractive were bottom sediments in the river. Low number of species and unevenness of their domination were reflected in low value of the H' index equalling 1.91.

Gastrotrich fauna from the river showed a low similarity (measured with the homogeneity index) to the fauna from standing waters (Fig. 2). Most different was the fauna found in the mid-meadow peat-hag which was similar to that in riverine sediments in only 20%.

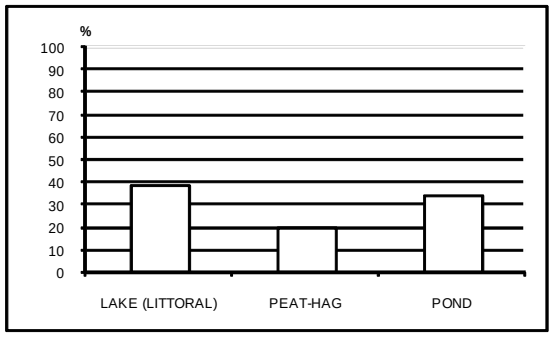

Fig. 2. Similarity of the river fauna to that from the littoral of mesotrophic lake, peat-hag and the fauna of eutrophic pond expressed as homogeneity index

Results of performed studies showed that the abundance and species diversity of gastrotrichs in running waters was markedly lower than those in standing waters. The fauna in particular river sites, particularly near-shore sites, is exposed to water flow fluctuations. Even small raising of the water table (in spring) or its decline (in summer) may change the site location or cause mechanical destruction of the fauna typical for a definite habitat.

CONCLUSIONS

1. Gastrotrichs of running waters are present in muddy stagnant sites or among aquatic vegetation. The abundance and species diversity of gastrotrichs in running waters is definitely lower than that in standing waters.
2. Density and species diversity of Gastrotricha in running waters is affected by the type and stability of substratum – gastrotrichs prefer soft and silty substrata.
3. *Chaetonotidae* species recorded in the river belong to eurytopic species and are characteristic for gastrotrich communities found in sphagnum peat-bogs.

4. No species of the family *Dasydytidae* were found in the running waters.

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OCENA RÓŻNORODNOŚCI I LICZEBNOŚCI FAUNY BRZUCHORZĘSKÓW (GASTROTRICHA) W OSADACH DENNYCH CIEKÓW I WÓD STOJĄCYCH

Streszczenie. Porównano zróżnicowanie gatunkowe i liczebność brzuchorzęsków (Gastrotricha) w ciekach i wodach stojących. W osadach dennych badanych środowisk stwierdzono łącznie 38 gatunków brzuchorzęsków, należących do dwóch rodzin: *Chaetonotidae* Zelnika i *Dasydytidae* Daday. Brzuchorzęski osadów dennych rzeki reprezentowane były tylko przez 10 gatunków eurytopowych, należących do rodziny *Chaetonotidae*. Należy dodać, że gatunki te są charakterystyczne również dla zgrupowań brzuchorzęsków występujących na torfowiskach sphagnowych. Małą

różnorodność gatunkową fauny Gastrotricha w badanej rzece potwierdza wartość wskaźnika Shannona-Wienera, która wynosi 1,91. Zagęszczenie brzuchorzęsków w osadach dennych badanych środowisk wynosiło od 304 tys. osobn. m^{-2} w rzece do 2850 tys. osobn. m^{-2} w śródłąkowej torfiance. Zagęszczenie brzuchorzęsków w badanej rzece jest nawet 9-krotnie niższe od ich zagęszczenia w wodach stojących.

Słowa kluczowe: brzuchorzęski, osady denne, cieki, wody stojące