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SPECIES STRUCTURE, DENSITY AND BIOMASS OF GASTROTRICH FAUNA OF ELODEIDS IN TWO LAKES OF DIFFERENT TROPHY

Teresa Nesteruk

Department of Zoology, Universty of Podlasie
B. Prusa str. 12, 08-110 Siedlce, nesteruk.ap@wp.pl

Summary. Composition, density and biomass of gastrotrich communities on elodeids in mesotrophic and eutrophic lakes were compared. Gastrotricha were present at all studied sites. A total of 21 gastrotrich species belonging to the family *Chaetonotidae* were found. Elodeid fauna in the littoral of mesotrophic lake was represented by 18 species and in the littoral of strongly eutrophic lake by 15 species. Two species – *Heterolepidoderma macrops* Kisielewski 1981 and *Lepidodermella squamata* (Dujardin, 1841) amounted to 60% of the total abundance in the mesotrophic lake. The dominating species group of elodeid fauna in the eutrophic lake consisted of four species **(***Chaetonotus macrochaetus Zelinka* 1889, *H. macrops*, *H. ocellatum* (Mečnikow, 1865), *L. squamata* (Dujardin, 1841)**)** and amounted to 47% of the total abundance of Gastrotricha in that lake.

Species diversity index H' for elodeid fauna ranged from 2.01 (mesotrophic lake) to 2.54 (strongly eutrophic lake). Elodeid fauna of Gastrotricha in the littoral of the mesotrophic lake was similar in 34% to that in the littoral of the strongly eutrophic lake.

In the littoral of the lakes, mean density varied from 1240 10^3 indiv. m^{-2} in the mesotrophic lake to 2979 10^3 in the eutrophic lake. Mean biomass of fauna living on plants in the eutrophic Lake Bikcze (316.2 mg fresh wt. m^{-2}) was twice as high as that in the mesotrophic Lake Piaseczno (148.5 mg fresh wt. m^{-2}). Density and biomass of gastrotrich communities on elodeids were proved to be from 1.5 to 2.6 times greater than in the bottom sediments of the lakes.

Key words: Gastrotricha, density, biomass, lake, epiphytic fauna

INTRODUCTION

Gastrotricha are a constant component of aquatic ecosystems. They are especially numerous in organogenic bottom sediments of inland water basins and on submerged vegetation.

A majority of studies of gastrotrich fauna of bottom sediments helped to elucidate a number of issues connected with the ecology of Gastrotricha. The

species composition and dominance relations have been assessed in different types of waters [Kisielewski 1981, 1986, Kisielewska 1982, Nesteruk 1986, 1991, 1996b, Szkutnik 1986]. Analyses of the density and biomass of Gastrotricha have also been determined. In organic sediments of lakes and ponds gastrotrich fauna reach densities from 679.5 thousand to 2.6 million indiv. per m^2. In such water bodies their biomass ranges from 65.0 to 517 mg fresh weight per m^2 [Nesteruk 1996a].

Our knowledge of the ecology of epiphytic gastrotrich fauna is poor. Gastrotricha were also analysed [Nesteruk 1991, 1996a]. First data on the occurrence of Gastrotricha among aquatic vegetation were given by Kisielewski [1981] for peat-bogs, who distinguished three species groups associated with different plant communities. Data on species composition and domination structure in the epiphytic littoral fauna of a mesotrophic lake were given by Nesteruk [2000, 2004], who also described the species composition of epiphytic and sediment-fauna in the littoral of a eutrophic and a dystrophic lakes [Nesteruk 2007].

The aim of this study is to provide data on diversity, density and biomass of gastrotrich fauna living on elodeids in the littoral of a mesotrophic and a eutrophic lake.

STUDY AREA, MATERIAL AND METHODS

The studies were carried out in two lakes of different trophic status: Piaseczno (mesotrophic) and Bikcze (strongly eutrophic) [Radwan and Kornijów 1998, Radwan *et al*. 2003], situated in the region of Polesie Lubelskie (south-eastern Poland). Lake Piaseczno, has 38.8 m average depth and 8.5 ha surface area. The water pH ranged from 5.4 to 8.2, and 5.4 to13.2 mg l^{-1} of dissolved oxygen was found. The northern part of the lake is narrow and deep, the southern part is wide and shallow. The lake is surrounded by a sandy beach of a width of 20–30 m, and only its southern shallow part borders a transitional moor.

Lake Bikcze has 3.3 m maximum depth and 85 ha surface area. Water pH ranged from 8.0 (in spring) to 9.4 (in summer) whilst the dissolved oxygen content was found to vary from 9.0 mg/l (spring) to 13.4 mg/l (summer). The bottom of the lake is silted in its southern part and sandy in the eastern part. The lake is surrounded by a dense belt of *Scirpo-Phragmitetum* rushes. Southern and south-eastern parts of the belt are inhabited by the yellow water lily (*Nuphar luteum*), the hardy water lily (*Nymphaea candida*) and the floating-leaf pondweed (*Potamogeton natans*). The southern part of the lake is overgrown with clumps of bulrush (*Scirpus lacustris* L.). A common macrophyte in the lake littoral is the Canadian pondweed (*Elodea canadensis*) which forms a dense belt around the lake.

An abundant community with water soldier *(Stratiotes aloides* L.) develops in the western part of the lake. There is a cluster of common spike-rush (*Eleocharis palustris* (L.) Roem. et Schult.) on sandy bottom at the eastern shore.

Samples from three sites in the littoral of each lake were collected four times in two consecutive vegetative seasons (April, June, August and October) in the years 2008 and 2009.

The samples were taken from April to October because the fauna of Gastrotricha is most numerous from spring to autumn [Kisielewska 1982]. The study area comprised the littoral zone of the lakes, with depth from 0.5 to 1.2 m. During the whole study period 24 samples were collected from each lake, and all individuals of Gastrotricha were identified to species.

The plants from which the fauna was collected included: *Myriophyllum spicatum*, *Ceratophyllum demersum* and *Elodea canadensis* in Lake Piaseczno; *Elodea canadensis, Nuphar luteum, Potamogeton natans, Stratiotes aloides* in Lake Bikcze.

A square metal frame with sides half a meter long was placed at the bottom of the reservoir. Thus all the plants were collected from an area restricted to 0.25 m^2. The water was squeezed out from the plants into five containers with volume of 200 cm^3; the surfaces of yellow water lilies and water soldiers were scraped with a scalpel. Material collected in that way was mixed and used to determine species composition and percentage share of particular species in the total fauna of Gastrotricha, and to determine gastrotrich density and biomass. In order to compare the density and biomass of epiphytic fauna with that of bottom sediments, the latter should be related not only to the unit of weight, but also to the area of the bottom overgrown with elodeids.

The density was investigated in each container. From each container 5 thoroughly mixed portions of 2 cm^3 were taken. The number of specimens in 10 cm^3 was calculated in the whole volume of each of the five containers. With the known surface area of the square metal frame (0.25 m^2) and the number of individuals in five containers, the number of individuals per m^2 of bottom surface could be calculated. The plants which the fauna was selected from were weighed, dried and then weighed again in the laboratory. Then the density and biomass of Gastrotricha living on elodeids per 100 g of dry weight of plants was calculated.

A plasticine model of a gastrotrich was made in order to estimate the mass of an individual. The model was submersed into a graduated cylinder filled with water to determine its volume. Knowing the dimensions reported for particular species [Kisielewski 1998] and the average volume of gastrotrichs, the fresh weight of each species was calculated, assuming a density of 1.05 g cm^{-3} [Kajak *et al*. 1980]. This weight was multiplied by the mean density of each species to calculate the biomass of Gastrotricha living on elodeids in milligrams of fresh weight per square metre of the bottom area. The biomass was given also in mg of fresh weight per 100 g of dry weight of plants.

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 – the number of individuals of the *i-th* species,
N – total number of all gastrotrichs.

Similarity of elodeid gastrotrichs of the littoral in two lakes was expressed with the homogeneity coefficient after Riedl [1963]:

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

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

The significance of differences in mean species diversity indices, densities and biomass of fauna of elodeids and bottom sediments between the mesotrophic and the eutrophic lake were checked using the t-Student test.

RESULTS AND DISCUSSION

Gastrotricha were present in all studied sites. A total 21 gastrotrich species belonging to *Chaetonotidae* family were found. Elodeid fauna in the littoral of the mesotrophic lake was represented by 18 species and in the littoral of the strongly eutrophic lake by 15 species. Two species – *Heterolepidoderma macrops* Kisielewski 1981 and *Lepidodermella squamata* (Dujardin, 1841) – amounted to 60% of the total abundance of Gastrotricha in the mesotrophic lake. The dominating species group of elodeid fauna in the eutrophic lake consisted of four species (*Chaetonotus macrochaetus* Zelinka 1889, *H. macrops*, *H. ocellatum* (Mečnikow, 1865), *L. squamata* (Dujardin, 1841)) and amounted to 47% of the total abundance of Gastrotricha in the eutrophic lake (Tab. 1).

Species diversity index H' for elodeid fauna, which includes the number of species and their percentage contribution indices, ranged from 2.01 (mesotrophic lake) to 2.54 (strongly eutrophic lake). Species diversity index for Gastrotricha in the strongly eutrophic lake was significantly higher than that in the mesotrophic lake ($p < 0.01$). Elodeid fauna in the littoral of the mesotrophic lake was similar in 34% to that in the littoral of the strongly eutrophic lake (Tab. 2). Low values of similarity of epiphytic fauna in studied lakes of different trophic status at a similar vegetation structure allows for concluding that the trophic status of the lakes exerts an important effect on the development of a given community of epiphytic Gastrotricha. The character of vegetation is, however, not the main factor determining the settlement and diversity of gastrotrich communities, which was also shown for peat-bogs by Kisielewski [1981].

Table 1. Species composition and percentage contribution of Gastrotricha of elodeid fauna in the littoral of a mesotrophic and a eutrophic lake (average values, n = 24)

Species	Mesotrophic Lake Piaseczno	Strongly eutrophic Lake Bikcze
Aspidiophorus squamulosus Roszczak, 1936		5
Chaetonotus insigniformis Greuter, 1917	1	
Ch. brevispinosus Zelinka, 1889	1	
Ch. oculifer Kisielewski, 1981	1	5
Ch polyspinosus Greuter, 1917	3	6
Ch. similis Zelinka, 1889	1	7
Ch. sphagnophilus Kisielewski, 1981	5	9
Ch. hystrix Mećnikow, 1865	2	7
Ch. macrochaetus Zelinka, 1889	7	12
Ch. octonarius Stokes, 1887	1	
Ch. persetosus Zelinka, 1889	2	2
Ch. spinulosus Stokes, 1887	1	
Ch. acanthodes Stokes,1887		2
Ch. heideri Brem, 1917	7	
Heterolepidoderma gracile Remane, 1927	1	1
H. macrops Kisielewski 1981	28	11
H. majus Remane, 1927	4	4
H. ocellatum (Mečnikow, 1865)		13
I. podura (Müller, 1773)	1	
Lepidodermella minor (Remane, 1935)	2	5
L. squamata (Dujardin, 1841)	32	11
Total	100.0	100.0

Table 2. Number of species, diversity index H' (average values, n = 24) and homogeneity index (HD) for epiphitic fauna of Gastrotricha of littoral in studied lakes

Parameters	Mesotrophic Lake Piaseczno	Eutrophic Lake Bikcze
Number of species	18	15
Diversity index (H')	2.01	2.54
Homonogeity index HD, %	34	
Years of research	2008–2009	2008–2009

Mean density of Gastrotricha per 100 g of dry weight of plants in the eutrophic lake amounted to 200.6 10^3 indiv. and was more than twice as high ($p < 0.05$) as that in the mesotrophic lake (102 10^3 indiv.). Mean density of gastrotrich fauna living on elodeids per m^2 of the bottom area overgrown by the studied plants depended on the biomass of these plants. In the mesotrophic lake it amounted to 1240 10^3 indiv. m^{-2} and was more than two times lower ($p < 0.02$) than in the eutrophic lake (2979 10^3 indiv. m^{-2}).

Mean value of gastrotrich biomass per 100 g of dry weight of plants in the eutrophic lake amounted to 15.4 mg of fresh weight and was 1.8 times higher ($p < 0.05$) than in the mesotrophic lake (8.34 mg of the fresh weight). The value

of biomass per m^2 of the bottom surface area in the mesotrophic lake was more than two times lower than in the eutrophic lake and amounted to 148.5 and 316.2 mg of fresh weight, respectively (Tab. 3).

Table 3. Mean density and biomass (n = 24) of Gastrotricha colonizing elodeids in lakes Piaseczno and Bikcze. April-October 2008, 2009. The density is given in: A – thousand indiv.m^{-2}, B – thousand indiv. $100g^{-1}$ d.w. of plants; and the biomass in: A – mg fresh weight m^{-2}, B – mg fresh weight $100g^{-1}$ d.w. of plants

Lakes	Density		Biomass	
	A	B	A	B
Mesotrophic Lake Piaseczno	1240	102	148.5	8.34
Eutrophic Lake Bikcze	2979	201	316.2	15.4

In both studied lakes the number of species on elodeids was lower than in bottom sediments [Nesteruk 2009]. Epiphytic fauna consists of the same systematic groups as bottom fauna, but the species composition and dominance structure of both assemblages differ from each other [Kornijów 1988, 1989a, b, 1994]. This applies to the studied gastrotrich fauna. The assemblage of *Gastrotricha* living on plants is dominated by a small number of species. The decided eudominants and dominants in this habitat in both lakes include: *Chaetonotus macrochaetus* Zelinka 1889 *Heterolepidoderma macrops* Kisielewski 1981, *H. ocellatum* (Mečnikow, 1865) and *Lepidodermella squamata* (Dujardin, 1841). Some *Gastrotricha* species find the most convenient conditions for living in bottom sediments as well as on the plants. These species are *Ch. macrochaetus* and *L. squamata*. The first of the species mentioned was once considered to be mainly a peat-bog species [Kisielewski 1981], in the bottom sediments of the mesotrophic lake it belongs to eudominants (dominance 15%), and on the plants it belongs to dominants (dominance 7%). Earlier studies [Nesteruk 1996b] show that it is a eurythopic species and common in all types of lakes. It lives in slime and on water plants, and also in sand [Kisielewski 1998]. *L. squamata* is a lacustrine species. It is abundant in mountain lakes, littoral lakes and in lakes with different trophy [Nesteruk 1996b]. It is found in all types of substrate: in slime, on plants and in sand. In bottom sediments of the littoral of the studied lakes it belongs to dominants, and on plants it belongs to eudominants.

Analysing the values of species diversity index H' for gastrotrich fauna living on elodeids in the studied lakes (2.54 eutrophic lake and 2.01 mesotrophic lake) it is worth mentioning the values of this index for fauna of bottom sediments which for the eutrophic and mesotrophic lakes amount 2.67 and 2.58, respectively [Nesteruk 2004, 2009]. The results of statistics test show that the different values of these indices are not statistically significant ($p > 0.05$). In turn, comparison of the values of species diversity indices for fauna of bottom sediments with those for elodeid fauna in the studied lakes shows that for both gastrotrich

assemblages in the eutrophic lake (2.67 and 2.54) they are higher than in the mesotrophic lake (2.58 and 2.01). The statistical analysis of diversity indices for elodeid fauna and that of bottom sediments in the studied lakes demonstrated that they differ significantly only in the mesotrophic lake ($p < 0.01$).

Comparative studies of the mesotrophic and eutrophic lakes located near each other show two times higher density of gastrotrich fauna on elodeids in the lake with higher trophy ($p < 0.02$). It is hard to compare the results of density of gastrotrichs present in this study with literature data, because these last are connected only with bottom sediments of lakes. The only data about density of gastrotrichs living on water plants are given by Kisielewski [1981] for the fauna of peat-bogs counted per 1 g of dry weight of plants (in this case *Sphagnum*). Density of Gastrotricha counted per 1 g of dry weight of plants in the studied mesotrophic lake amounted to 1020 individuals and was ten times higher than the mean values noted on sphagnum peat-bogs, and in the eutrophic lake more than twenty times higher. Density of gastrotrichs in bottom layers of littoral of lakes with different trophy [Nesteruk 1996a] grows together with the growth of trophy of a reservoir. The majority of groups of meiofauna, depending on trophy and other features of a reservoir, reveal differences in density up to a few orders of magnitude [Strayer 1985]. It is possible to suppose that higher trophy of a reservoir influences higher fauna number and biomass. Analysis of the values of gastrotrich biomass in relation to the bottom area for elodeid fauna showed that in the eutrophic lake it is two times higher than in the mesotrophic lake and amounts to 316.2 and 148.5 mg of fresh weight m^{-2}. The values of biomass are usually proportional to fauna density in a reservoir. Dependence of density and biomass on the trophy of a reservoir was noted also for macrofauna of elodeids in mesotrophic and eutrophic lakes [Kornijów 1989a].

Density of gastrotrichs living on elodeids in the mesotrophic lake has been proved to be from 1.5 to 1.8 times higher than in the bottom sediments of the lake. In the eutrophic lake the density of gastrotrichs living on elodeids has been proved to be from 1.9 to 2.6 times higher than in the bottom sediments of the lake [Nesteruk 1996a, 2007]. Differences of density in both habitats are statistically significant.

Definitely higher density of gastrotrichs on elodeids than in bottom sediments of the studied lakes can result from a good food base among plants. Research carried out in an oligotrophic Lake Pääjärvi (southern Finland) revealed that both the total density and biomass of all animal communities (zoobenthos, epiphytic fauna and nekton) were positively related to the biomass of *Elodea canadensis* [Kornijów and Kairesalo 1994]. Water plants represent food base for a majority of epiphytic fauna. Tissues of the plants contain bacteria which get into the diet of a majority of gastrotrichs .

Abundance of bacteria, root secretions and decaying plant tissue also make good food conditions for nematodes [Prejs 1988]. The author concluded significant correlation between the density and the level of destruction of the rhizones of pondweed. Usually the density of nematodes living in rhizones of decaying pondweeds is many times higher than in rhizones of healthy plants.

Over the past, few researches carried on the bottom and epiphytic fauna show that the density and biomass of elodeid fauna are equal and even higher than the fauna of bottom sediments [Kajak 1988, Kornijów and Kairesalo 1994]. Analysis of the density and biomass of gastrotrichs living on elodeids in the studied lakes shows that they are more abundant on water plants than in the bottom sediments of the lakes. It is possible to suppose that epiphytic fauna living on water plants plays a significant role in the food chain of the water reservoirs.

CONCLUSIONS

1. Density and biomass of gastrotrichs living on elodeids in meso- and eutrophic lakes is from 1.5 to 2.6 times greater than in the bottom sediments of the lakes.

2. Gastrotrich fauna on elodeids in the studied lakes with different trophy shows low similarity as measured by the homogeneity index.

3. Species diversity index of Gastrotrich elodeid fauna in the eutrophic lake was significantly higher than that in the mesotrophic lake.

4. Epiphytic fauna of gastrotrichs in lakes of different trophy status shows low similarity at a similar species structure of elodeids in the lakes. The development of a definite Gastrotrich community on elodeids is mainly affected by the trophy status of lakes and not by the character of vegetation.

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STRUKTURA GATUNKOWA, ZAGĘSZCZENIE I BIOMASA BRZUCHORZĘSKÓW ELODEIDÓW W DWÓCH JEZIORACH O RÓŻNEJ TROFII

Streszczenie. Badano skład gatunkowy, zagęszczenie i biomasę brzuchorzęsków żyjących na elodeidach w dwóch jeziorach: mezotroficznym i eutroficznym. Brzuchorzęski występowały na wszystkich badanych stanowiskach. Łącznie stwierdzono 21 gatunków brzuchorzęsków należących do rodziny *Chaetonotidae* Zelnika 1889. Brzuchorzęski elodeidów w litoralu jeziora mezotroficznego były reprezentowane przez 18 gatunków, a w litoralu jeziora eutroficznego przez 15 gatunków. W jeziorze mezotroficznym pośród elodeidów dominowały dwa gatunki: *Heterolepidoderma macrops* Kisielewski 1981 i *Lepidodermella squamata* (Dujardin, 1841), których łączny

udział w całości fauny brzuchorzęsków w tym jeziorze wynosił 60%. Grupę gatunków dominujących w jeziorze mezotroficznym stanowiły cztery gatunki: *Chaetonotus macrochaetus* Zelnika 1889, *H. macrops*, *H. ocellatum* (Mečnikow, 1865) i *L. squamata*, a ich łączny udział w całości fauny brzuchorzęsków elodeidów w tym jeziorze wynosił 47%.

Wskaźnik różnorodności gatunkowej H' dla fauny brzuchorzęsków elodeidów w jeziorze mezotroficznym wynosił 2,01, a w jeziorze eutroficznym 2,54. Różnica wartości tych wskaźników była istotna statystycznie. Podobieństwo fauny elodeidów w badanych jeziorach było niskie i wynosiło 34%.

Średnie zagęszczenie brzuchorzęsków na powierzchnię dna w jeziorze eutroficznym było ponad 2-krotnie większe niż w jeziorze mezotroficznym i wynosiło odpowiednio: 2979 10^3 i 1240 10^3 osobników m^{-2}. Średnia wartość biomasy brzuchorzęsków elodeidów w jeziorze eutroficznym była również większa niż w jeziorze mezotroficznym i wynosiła odpowiednio: 316,2 i 148,5 mg świeżej masy na 1 m^2 powierzchni dna. Wartości zagęszczenia i biomasy brzuchorzęsków elodeidów były od 1,5 do 2,6 razy wyższe niż w osadach dennych tych jezior.

Słowa kluczowe: Gastrotricha, jeziora, zagęszczenie, biomasa, fauna elodeidów