

POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	55	1	79–90	2007
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Regular research paper

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EPIPHYTIC PROTOZOA (TESTATE AMOEBAE AND CILIATES) ASSOCIATED WITH *SPHAGNUM* IN PEATBOGS: RELATIONSHIP TO CHEMICAL PARAMETERS

ABSTRACT: The composition and abundance of microorganisms (testate amoebae and ciliates) dwelling in the water in the patches of *Sphagnum palustre* L. in three peatbogs with different pH values of the Poleski National Park (Eastern Poland) and their relationship to chemical parameters were studied. From April to October 2005 from each peatbog twice a month, eight samples were collected by washing 10 g of a wet mass of plant material in 50 ml of distilled water. A total of 11 testate amoebae taxa and 32 ciliate taxa occurred among *Sphagnum palustre*. Testate amoebae and ciliates richness and abundance were significantly greater (33 taxa and > 15 ind. g⁻¹, respectively) in low pH (4.5) peatbog. Generally, the moss dwelling testacean fauna was dominated by cosmopolitan and ubiquitous taxa. Only four testate amoebae taxa (*Arcella vulgaris*, *Asulina muscurum*, *Hyalosphenia* sp. and *Euglypha* sp.) showed a clear preference for a low pH. Ciliate communities were dominated by Colpodea, Cyrtophorida, Scuticociliatida and Suctorida. In all peatbogs bacterivorous protozoa occurred in the highest numbers (up to 60%), while algivorous and mixotrophic in the lowest (range from 3 to 10%). Moisture conditions appeared to play a key role in determining the distribution pattern of testacean communities, while pH and the content of total organic carbon in water correlated positively with the total numbers or biomass of testate amoebae and ciliates.

KEY WORDS: peatbog, *Sphagnum*, testate amoebae, ciliates

1. INTRODUCTION

Since 1950 a lot of peatbog areas in Europe have been seriously damaged, destroyed and extincted. The decrease in the level of ground water caused the drying out and degradation of these habitats and their organogenic soils and increased their susceptibility to erosion processes. It also decreased their ability to retain water. In consequence, great amounts of nitrogen and carbon compounds are released during the process of organic substance mineralization (Flessa *et al.* 1998). Today the conservation of the remaining peatbogs has become a priority in many countries. The two main aims of such conservation measures are the preservation of biodiversity and of the carbon pool and sequestration functions of peatbog ecosystems (Kischiba and Mitchell 2005).

In *Sphagnum*-dominated peatbogs the animal communities, especially invertebrates are sufficiently known (Borcard and Vaucher von Ballmoos 1997). However, less is known about the protozoans and their relationships to environmental factors in

these specific ecosystems. These microorganisms are important consumers of bacteria, flagellates and algae; they also participate in the decompositions of the organic matter and nutrient cycling. Ciliates have been quite widely used for determination of water pollution (Slàdečková 1994). Many testate amoebae species have well-defined ecological preferences, and this stenotopy makes them very useful bioindicators (Lamentowicz and Mitchell 2005). In addition, testate amoebae produce shells, which are well preserved in peat and allow to reconstruct the paleoenvironments (Charman and Warner 1997). However, still more attention is paid to rhizopoda and ciliata of lake ecosystems (Moraczewski 1961, 1962, Biyu 2000, Sonntag 2002, Kalinowska 2004, Mieczan 2005) and soils (Mitchell *et al.* 2000, Vincke *et al.* 2004). Only a few publications are dealing with the abundance and taxonomic composition of protozoans living among mosses (*Sphagnum*) in peatbogs. The studies of Gilbert *et al.* (1998) indicate that Rhizopoda are important element in the food-web as well as they react rapidly to environmental changes. A few other publications dealing with rhizopods described mainly the taxonomic composition of the communities. Vincke *et al.* (2004) found 83 rhizopod species in Antarctic peatbogs. Kishaba and Mitchell (2005) analyzed the testate amoebae from two sets of moss samples of a peatbog of the Swiss Jura Mountains and found 33 species. Petz (1997) found only 5 rhizopod species in peatbogs from Wilkes Land (East Antarctica).

Previous studies have shown that the abundance of each taxon and hence the structure of communities are controlled by a set of environmental variables. Moisture conditions have been often identified as most important factor controlling testate amoebae community composition, the second important factor were pH of peatbogs (Mitchell *et al.* 2000). Petz (1997) demonstrated that the organic matter content played major role in the development of microbial communities.

In Poland, in recent years only one paper has been published concerning the relationship between testate amoebae communities and the water table depth, pH, conductivity

and microhabitat type in *Sphagnum* dominated peatbogs of north-western Poland (Lamentowicz and Mitchell 2005). The studies showed that testate amoebae community positively correlated with depth to water table and pH. Conductivity was not statistically significant as a third variable. Species growing in wet habitats were more sensitive to change in water table depth than the species growing in drier microhabitats.

Ecology and spatial distribution of ciliates in *Sphagnum* have been studied only by Petz (1997) in east Antarctica and Foissner (1996) in the Gough and Marion Islands. In recent years the structure of microbial communities in *Sphagnum* has been studied by Mitchell *et al.* (2003). They indicate that heterotrophic organisms dominated the microbial communities and together represented from 78 to 97% of the total microbial biomass and that ciliates compose only a small proportion of the biomass. Up to the present, the research focused on ciliates in relation to chemical factors in peatbogs are not common.

In this study, I analyzed the structure of communities in relation to eight environmental variables (water table depth, pH, conductivity, N-NO₃, N-NH₄, PO₄, TP, TOC) in three types of peatbogs with different chemical values, which may affect habitat heterogeneity and community characteristics of both testate amoebae and ciliates. The detail aims of the present study were:

- identification of taxonomic and trophic diversity of the testate amoebae and ciliates communities occurring among *Sphagnum palustre* in three peatbogs of the Poleski National Park (Eastern Poland),
- to assess the effect of chemical factors on their distribution.

2. STUDY AREA

Poleski National Park was founded in May 1990, in the western part of the Łęczyńsko-Włodawskie Lakeland (Eastern Poland, 51°N, 23°E) and was the first National Park in Poland that was established with the mandate to protect peatbog and swamp areas. The Park area includes a unique territory, which is a miniature of tundra at its extreme southwest European location. Its borders encompass

the most precious parts of Polesie Lubelskie, including lakes and floodplains, as well as swamps and peatbogs, which survived until now in a relatively unaltered shape. In 1994, the Poleski National Park was extended to almost twice its previous size, reaching a total area of 9647.73 ha. The average air monthly temperatures of January and July are -4.1°C and $+17.9^{\circ}\text{C}$, respectively, and the average annual total rainfall in the Poleski National Park area is 551 mm (Kaszewski 2002).

Three types of peatbogs were selected to study: lowmoor peatbog "Lejno" (area 71.73 ha), highmoor peatbog "Durne Bagno" (213.2 ha) and carbonate peatbog "Bagno Bubnów" (2308.6 ha) (Fig. 1). In lowmoor peatbog the vegetation is dominated by graminoids such as *Eriophorum vaginatum* (L.), *Carex acutiformis* Ehrhart. and *Carex gracilis* Curt. In highmoor peatbog the vegetation is dominated by *Phragmites australis* (Car.), *Equisetum limosum* (L.), *Sphagnum palustre* L. and *Sphagnum squarrosum* Pers. The carbonate peatbog is colonized by *Phragmites australis* (Car.), *Typha latifolia* L. and *Carex acutiformis* Ehrhart.

The samples spanned a depth to water table gradient (measured with a tape gauge, and the zero level was defined as the top

of the mosses) from 53 to 58 mm (Table 1). From all the studied peatbogs, the highest pH values was noted in carbonate peatbog (pH = 7.6) and the lowest in lowmoor peatbog (pH = 4.5). The chemical properties of water were significantly different between peatbogs (ANOVA, $F = 21.07\text{--}30.27$, $P = 0.011\text{--}0.030$). Conductivity reached the highest values in carbonate peatbog, however the remaining factors (TP, P-PO_4 , N-NO_3^-) in lowmoor peatbog. Only content of ammonia-nitrogen reached the highest values in highmoor peatbog. The chemical characteristics of these peatbogs are summarized in Table 2.

3. MATERIAL AND METHODS

Microbial communities were examined in three peatbogs in the water between *Sphagnum palustre* beds. From April to October 2005 from each peatbog twice a month, eight samples were collected by washing 10 g of a wet mass of plant material in 50 ml of distilled water. All microorganisms were identified in four subsamples, each equal to 5% of the original sample. The abundance of microorganisms were calculated on 1 g wet weight of the plant material.

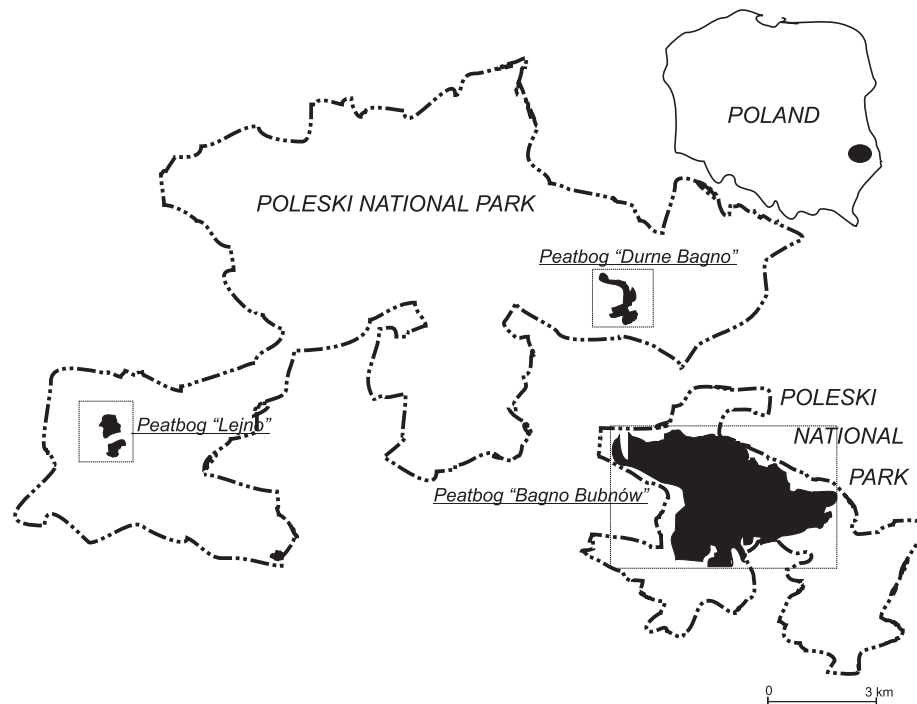


Fig. 1. Location of study area.

Table 1. Selected characteristics of the investigated peatbogs (*means April–October, 2005).

Peatbog	Area (ha)	Type of peatbogs	Water table* depth (mm)
LP ("Lejno")	71.73	lowmoore	58
DBP ("Durne Bagno")	213.2	highmoor	54
BBP ("Bagno Bubnów")	2308.6	carbonate	53

Table 2. Chemical characteristics of the water of investigated peatbogs (see Fig. 1) (average values \pm SD for period April–October 2005).

Peatbog	pH	Conductivity ($\mu\text{S cm}^{-1}$)	N-NO ₃ (mg dm^{-3})	N-NH ₄ (mg dm^{-3})	P-PO ₄ (mg dm^{-3})	TP (mg dm^{-3})	TOC (mg dm^{-3})
LP ("Lejno")	4.5	71.2	0.099	0.058	0.188	0.25	77.2
	± 0.61	± 24.4	± 0.03	± 0.02	± 0.06	± 0.12	± 8.4
DBP ("Durne Bagno")	5.5	187.3	0.031	0.100	0.003	0.02	68.5
	± 0.65	± 81.7	± 0.02	± 0.04	± 0.001	± 0.01	± 9.05
BBP ("Bagno Bubnów")	7.6	286	0.028	0.019	0.005	0.08	68.0
	± 0.83	± 144.8	± 0.05	± 0.01	± 0.003	± 0.10	± 2.40

In order to determine the rhizopods and ciliates four samples were preserved with Lugol solution. Observations *in vivo* were used for the taxonomic and trophic identification. Trophic identification was done using the method of Foissner and Berger (1996) and Clarke (2003). To isolate the carapaces of testate amoebae, the mosses were boiled in distilled water for 20 minutes, stirred and then sieved through a 300 μm mesh size to separate large particles. The samples with ciliates were condensed by the sedimentation method. Taxonomic identifications of the testate amoebae and ciliates were based on the keys in Odgen (1983), Foissner *et al.* (1994, 1999), Foissner and Berger (1996) and Clarke (2003).

Biovolumes of microorganisms were estimated assuming geometric shapes and converted to the carbon using the following conversion factor: $1\mu\text{m}^3 = 1.1 \times 10^{-7} \text{ mg C}$ (Gilbert *et al.* 1998).

The frequency of particular species of testate amoebae and ciliates was calculated. All the species found were classified into the four groups: very constant species (i.e. occurring in 61–100 per cent of the samples), constant species (i.e. occurring in 41–60 per

cent), accidental species (i.e. occurring in 21–40 per cent of the samples), accessory species (i.e. occurring in below 20 per cent of the samples).

Twice a month chemical factors (pH, conductivity, N-NO₃, N-NH₄, P-PO₄, TP, TOC) were examined in water in sites with *Sphagnum palustre* dominance. Conductivity and pH were determined *in situ* using the electrode JENWAY 3405, TOC was determined using the PASTEL UV and the remaining factors were analysed in the laboratory, according to Hermanowicz *et al.* (1976).

All data collected were analyzed statistically by means of GLM and CORR procedures of SAS Programme. The significance of differences between mean density and biomass values of testate amoebae and ciliates were verified by means of ANOVA. Correlation coefficients were calculated between pairs of variables in order to determine the relationships between testate amoebae and ciliates and chemical parameters.

4. RESULTS

The number of testate amoebae and ciliate taxa visibly differed in particular peat-

bogs. Generally the highest values were noted in lowmoor peatbog, the lowest in highmoor peatbog. The number of testate amoebae ranged from 4 to 6, ciliates from 15 to 26 taxa. In testate amoebae communities four taxa: *Arcella vulgaris*, *Diffugia oblonga*, *Nebela barbata* and *Euglypha* sp. were the most frequent species, however in epiphytic ciliate communities only two taxa: *Chlamydonella* spp. and *Gastronauta* spp. were very constant (Table 3).

The mean numbers of testate amoebae in lowmoor peatbog were about three times, and in the carbonate peatbog – two times lower as compared with highmoor peatbog (Fig. 2). The differences between the mean densities of testate amoebae were statistically significant (ANOVA, $F = 32.62$, $P = 0.015$). The biomass of testate amoebae was much higher in lowmoor peatbog and

differences between the mean values were statistically significant (ANOVA, $F = 30.27$, $P = 0.013$) (Fig. 3). During the study period the dominant species were *Arcella vulgaris*, *Diffugia oblonga*, *Nebela barbata* and *Hyalosphenia* sp., which represented from 19% to 43% of total testate amoebae numbers (Fig. 4).

The numbers and biomass of epiphytic ciliates in lowmoor and carbonate peatbogs were similar. The lowest density and biomass were observed in highmoor peatbog (Figs. 2 and 3). Differences between the mean values of ciliates numbers and biomass were statistically significant (ANOVA, $F = 9.07$, $P = 0.030$). The composition of ciliates changed in particular peatbogs. In lowmoor peatbog the most abundant were Colpodea (*Platophyra* sp.) and Scuticociliatida (*Cinetochilum margaritaceum*, *Cyclidium* sp.),

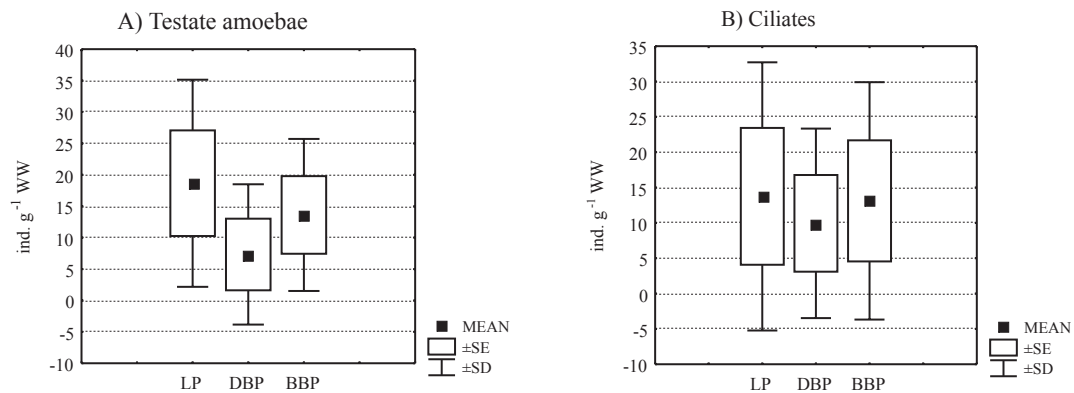


Fig. 2. Average (April–October 2005) density of testate amoebae and ciliates associated with *Sphagnum palustre* of peatbogs (LP "Lejno", DBP "Durne Bagno", BBP "Bagno Bubnów", see Fig. 1, Table 1).

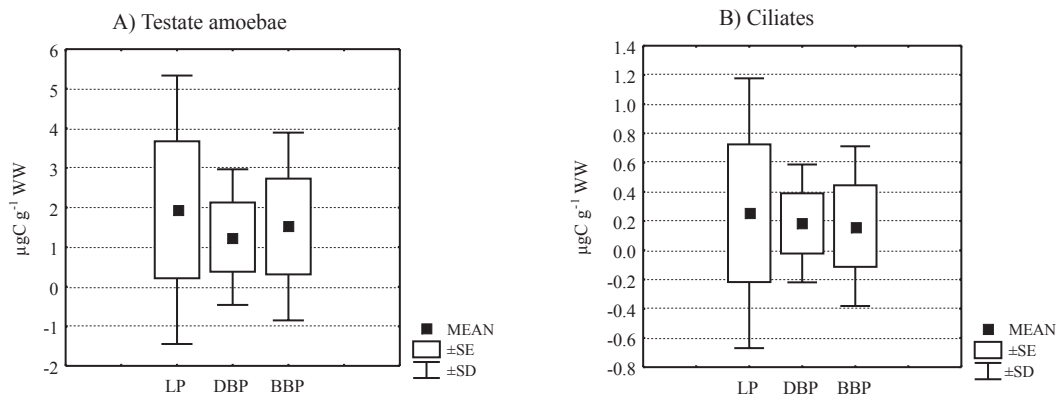
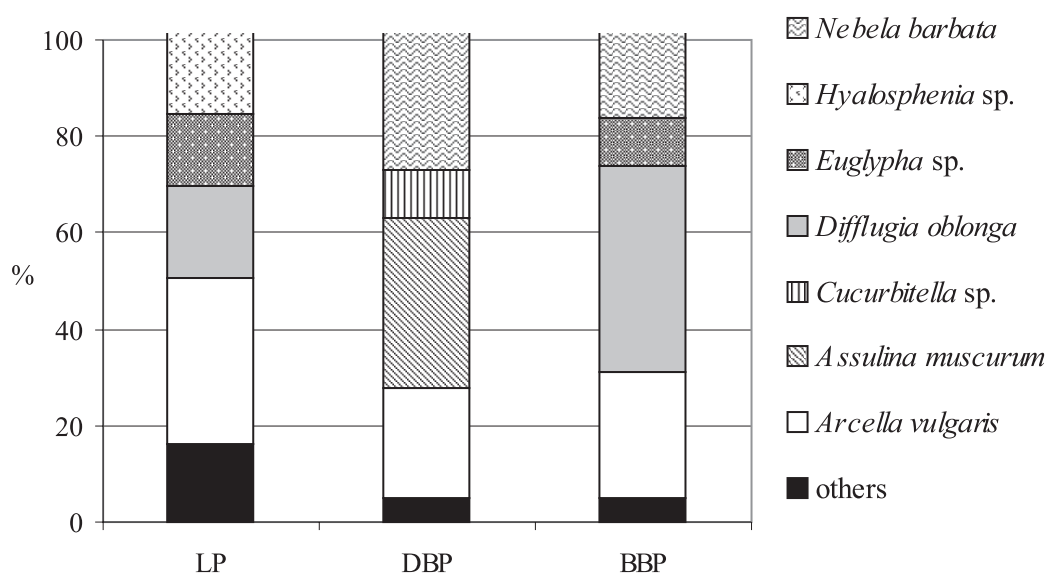


Fig. 3. Average (April–October 2005) biomass of testate amoebae and ciliates associated with *Sphagnum palustre* of peatbogs (LP "Lejno", DBP "Durne Bagno", BBP "Bagno Bubnów", see Fig. 1, Table 1).

A) Testate amoebae



B) Ciliates

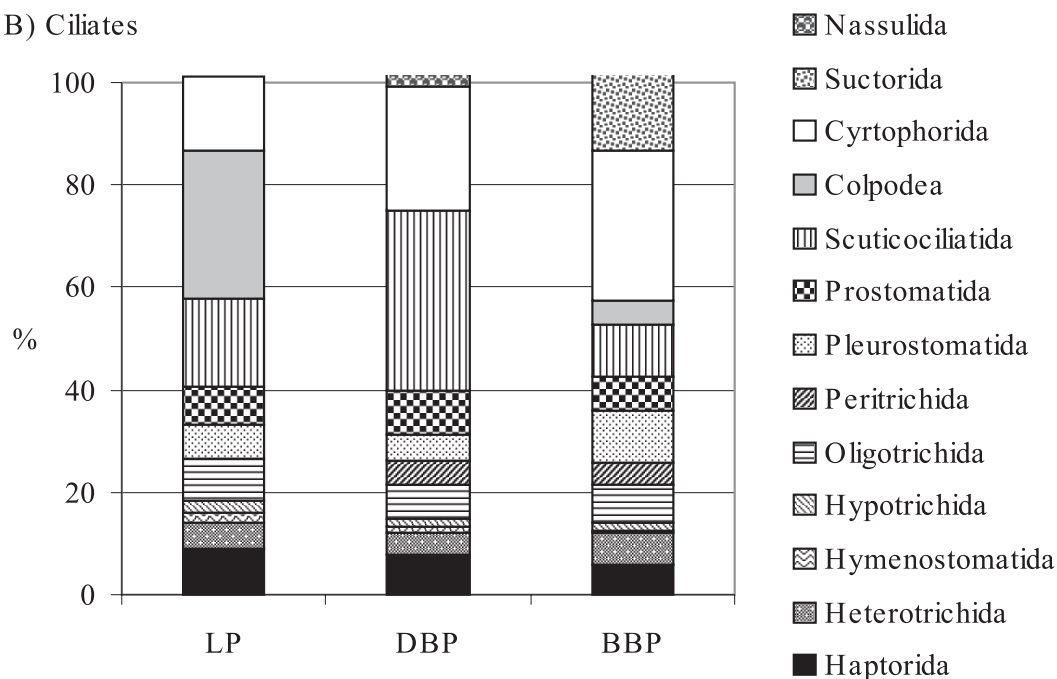


Fig. 4. Dominance structure of Testate amoebae and Ciliata associated with *Sphagnum palustre* of peatbogs (% in total numbers) (LP "Lejno", DBP "Durne Bagno", BBP "Bagno Bubnów", see Fig. 1, Table 1).

in highmoor peatbog two orders Scuticociliatida (*Cinetochilum margaritaceum*) and Cyrtophorida (*Chlamydonella* spp.) and in carbonate peatbog – Cyrtophorida (*Gastronauta* spp., *Chlamydonella* spp.) and Suctorida (*Enchelyomorpha vermicularis*) (Fig. 4).

The protozoan community was numerically dominated by bacterivorous taxa (40–60% of the total numbers), which occurred in the greatest proportion in lowmoor and highmoor peatbogs. Omnivorous species (known to feed on autotrophs, other pro-

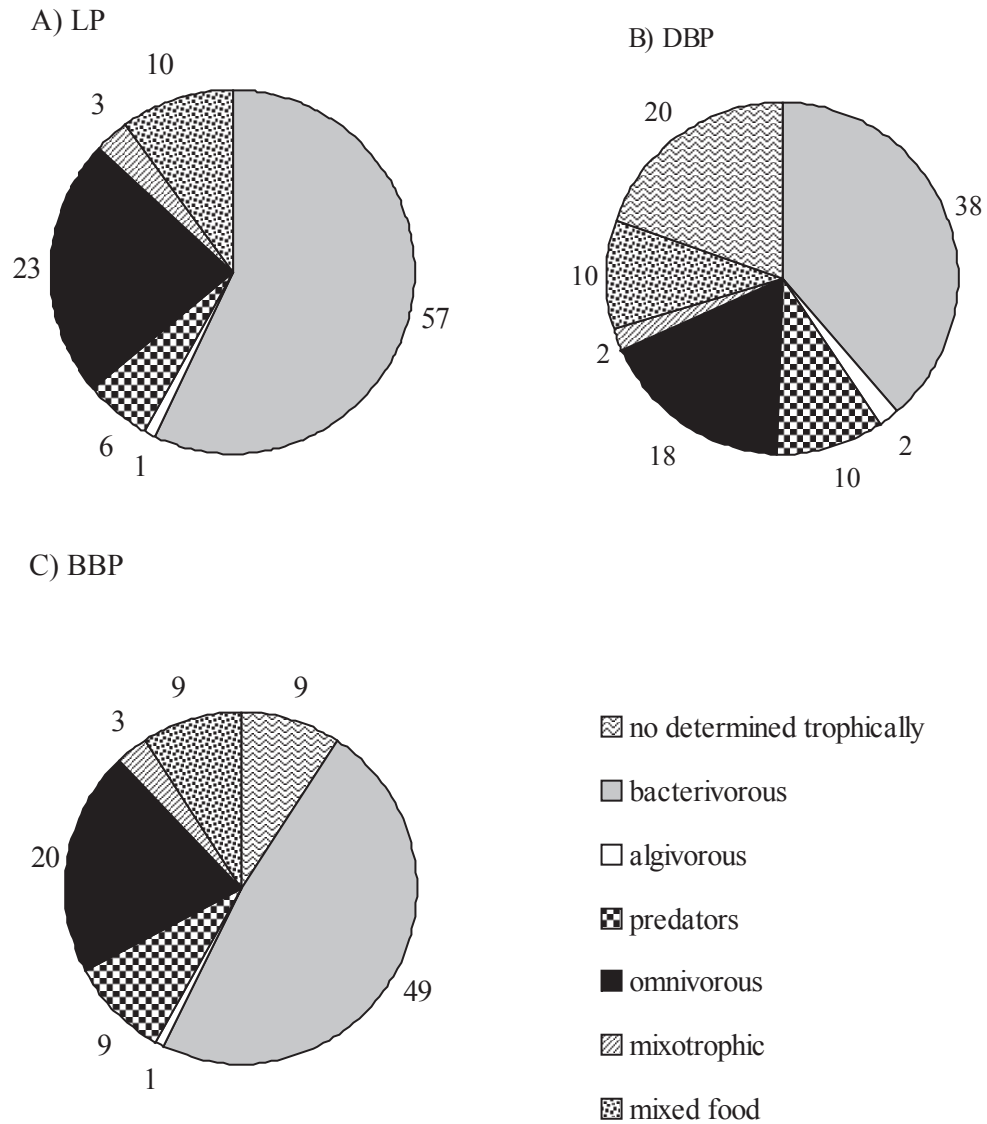


Fig. 5. Mean annual percentage share of trophic groups of protozoa associated with *Sphagnum palustre* of peatbogs (LP "Lejno", DBP "Durne Bagno", BBP "Bagno Bubnów", see Fig. 1, Table 1).

tozoans and even on small metazoans) also occurred in greater numbers constituting 18-23% of the total numbers of protozoa. Microorganisms feeding on mixed food (bacteria, flagellates and algae), predatory, mixotrophic and algivorous constituted from 10 to 3% (Fig. 5).

Certain chemical properties of water and depth to water table had a clear effect on the community structure of microorganisms. In all of the studied peatbogs testate amoebae densities were correlated with the water table depth (from $r = 0.43$ to $r = 0.55$, $P \leq 0.01$). Significant and positive linear correlations occurred between protozoa

densities and pH ($r = 0.39$, $P \leq 0.05$, $r = 0.49$, $P \leq 0.01$). In moss in all of the studied peatbogs the content of total organic carbon (TOC) in water correlated positively with the total numbers and biomass of testate amoebae and ciliates density. Correlation coefficients reached the values from 0.33, ($P \leq 0.05$) to 0.46, ($P \leq 0.01$). Only in low-moor peatbog the content of total phosphorus in the water correlated with the numbers of ciliates ($r = 0.41$, $P \leq 0.05$). In three types of peatbogs conductivity was not significantly correlated with the total numbers and biomass of testate amoebae and ciliates (Table 4).

Table 3. The composition and frequency (% of samples) of the majority of testate amoebae and ciliates taxa found among *Sphagnum palustre* in investigated peatbogs (see Fig. 1).

Taxon	% of samples		
	LP ("Lejno")	DBP ("Durne Bagno")	BBP ("Bagno Bubnów")
TESTATE AMOEBAE			
<i>Arcella vulgaris</i> (Ehrenberg, 1830)	75	16	77
<i>Assulina muscurum</i> (Greeff, 1888)	5	24	
<i>Cucurbitella</i> sp.	6	33	
<i>Centropyxis</i> sp.	4		
<i>Diffflugia oblonga</i> (Ehrenberg, 1838)	89		90
<i>Diffflugia</i> sp.	8		
<i>Euglypha strigosa</i> (Ehrenberg, 1872)	23		
<i>Euglypha</i> sp.	93		80
<i>Hyalosphenia</i> sp.	3		
<i>Nebela barbata</i> (Leidy, 1874)	90	54	75
<i>Nebela</i> sp.	3	43	
No. of taxa: 11	11	5	4
CILIATES			
CYRTOPHORIDA			
<i>Chlamydonella</i> spp.	41	17	13
<i>Gastronauta</i> spp.		56	89
<i>Trochilia</i> sp.	15		8
COLPODEA			
<i>Platophrya</i> sp.	5		
HAPTORIDA			
<i>Askenasia volvox</i> (Kahl, 1930)	1		
<i>Didinium</i> sp.	2		
<i>Enchelys</i> sp.	9	7	6
<i>Monodinium</i> sp.	11	3	3
<i>Spathidium sensu lato</i>	15		
HETEROTRICHIDA			
<i>Caenomorpha</i> spp.			2
<i>Stentor multiformis</i> (Mueller, 1786)	2	1	2
HYMENOSTOMATIDA			
<i>Frontonia leucas</i> (Ehrenberg, 1833)	9	1	1
<i>Paramecium bursaria</i> (Ehrenberg, 1831)	17	14	12
<i>Paramecium putrinum</i> (Claparede, 1859)	18		10
SCUTICOCILIATIDA			
<i>Cinetochilum margaritaceum</i> (Ehrenberg, 1831)	23	14	12
<i>Cyclidium</i> sp.			15
HYPOTRICHIDA			
<i>Euplotes</i> sp.	4	4	20
<i>Holosticha pullaster</i> (Mueller, 1773)			5
<i>Stylonychia mytilus</i> -Komplex	15	4	
<i>Urostylla grandis</i> (Ehrenberg, 1830)		3	3

Taxon	% of samples		
	LP ("Lejno")	DBP ("Durne Bagno")	BBP ("Bagno Bubnów")
OLIGOTRICHIDA			
<i>Codonella cratera</i> (Leidy, 1877)	4	5	
<i>Halteria gradinella</i> (Mueller, 1773)			8
<i>Strombidium viride</i> (Stein, 1867)	14	3	11
<i>Strombidium humile</i> (Penard, 1922)			16
PLEUROSOMATIDA			
<i>Amphileptus pleurosigma</i> (Stokes, 1884)	33		
<i>Amphileptus</i> sp.	5	1	1
PROSTOMATIDA			
<i>Coleps hirtus</i> (Mueller, 1786)	24	23	20
<i>Holophrya</i> sp.			23
<i>Prorodon</i> sp.	3		
<i>Urotricha</i> spp.	15		8
NASSULIDA			
<i>Chilodontopsis depressa</i> (Perty, 1852)		3	
SUCTORIDA			
<i>Enchelyomorpha vermicularis</i> (Smith, 1899)			21
No. of taxa: 32	22	15	23

Table 4. Linear correlation coefficients (r) ($n = 46$) between testate amoebae and ciliates density and biomass and chemical factors of the investigated peatbogs (see Fig. 1). $P \leq 0.01^{**}$, $P \leq 0.05^*$, – not significant.

Variable	Testate amoebae						Ciliates					
	Density			Biomass			Density			Biomass		
	LP ("Lejno")	DBP ("Durne Bagno")	BBP ("Bagno Bubnów")	LP ("Lejno")	DBP ("Durne Bagno")	BBP ("Bagno Bubnów")	LP ("Lejno")	DBP ("Durne Bagno")	BBP ("Bagno Bubnów")	LP ("Lejno")	DBP ("Durne Bagno")	BBP ("Bagno Bubnów")
Water table depth	0.55**	0.43**	0.45**	-	-	-	-	-	-	-	-	-
pH	0.40*	0.39*	0.41*	-	-	-	0.49**	0.43**	0.45**	-	-	-
Conductivity	-	-	-	-	-	-	-	-	-	-	-	-
N-NO ₃	-	-	-	-	-	-	-	-	-	-	-	-
N-NH ₄	-	-	-	-	-	-	-	-	-	-	-	-
PO ₄	-	-	-	-	-	-	-	-	-	-	-	-
TP	-	-	-	-	-	-	0.41*	-	-	-	-	-
TOC	0.48**	0.43**	0.43**	0.33*	0.51**	0.43**	0.46**	0.40*	0.43**	0.43**	0.45**	-

5. DISCUSSION

The data referring to testate amoebae associated with *Sphagnum* have been little studied. The species diversity in the studied peatbogs is generally much lower than that reported in literature (Gilbert *et al.* 1998, Vincke *et al.* 2004, Lamentowicz and Mitchell 2005). The dominant species *Arcella vulgaris* in lowmoor peatbog is characteristic of very wet microhabitats such as minerotrophic pools (Mitchell *et al.* 2000). The highmoor peatbog was colonized mostly by *Assulina muscorum* – species located at the dry end of the water table gradient. In carbonate peatbog amoebae species characteristic of wet conditions belonging to the genus *Diffflugia* were recorded in high numbers. Many *Diffflugia* taxa have been found in the aquatic habitats of South Georgia (Beyens *et al.* 1995). Smith (1992) classified *Diffflugia* taxa as hydrophilic species associated with mosses and algae in less acid freshwater habitats.

The number of ciliate taxa was similar to those noted in other parts of the world (Petz 1997). In this study ciliates communities were mainly composed of Colpodea (*Platophyra* sp.), Scuticociliatida (*Cinetochilum margaritaceum*, *Cyclidium* sp.), Cyrtophorida (*Chlamydonella* spp.) and Suctorida (*Enchelyomorpha vermicularis*). The most of these species were found in various trophic types of lakes (Beaver *et al.* 1988, Carrías *et al.* 1994, Wickham 1995, Nauwerck 1996, Biyu 2000, Mieczan 2005). The species belonging to Suctorida and Cyrtophorida has also been observed in the pelagial of small and large water bodies, occasionally in running waters and were also fairly often found in strongly contaminated waters in habitats rich in detritus (Reck 1987, Foissner *et al.* 1994, Lavrentyev *et al.* 1995, Mieczan 2005). The dominance of Colpodea was observed in moss in the Gough and Marion Islands (Foissner 1996). The domination of these orders could have resulted from its wide ecological tolerance. According to Vincke *et al.* (2004), the moss is dominated by cosmopolitan and ubiquitous taxa. The studied peatbogs contained the greatest number of bacterivorous taxa while the smallest of algivorous and

mixotrophic ones. During the spring and late autumn the *Sphagnum* were characterized by the presence of a considerable amount of decaying plant remains. Such a type of environment could enhance a massive development of bacteria and therefore small-sized bacterivorous protozoan. A slight proportion of algivorous taxa may be explained by the fact that protozoans are selective to algal food. Similar relations were observed in lakes of different trophic status in Poland (Kalinowska 2000, Mieczan 2004) and in moss samples from Gough and Marion Islands (Foissner 1996). However, Gilbert *et al.* (1998) demonstrated that the biomass of ciliates was closely correlated with the biomass of cyanobacteria and Bacillariophyceae in a *Sphagnum magellanicum* peatbogs in France.

Certain chemical properties of water in the peatbogs had a clear effect on the structure of microorganisms. The richest taxonomic composition was found in low pH peatbog. This phenomenon was described earlier by Mitchell *et al.* (2000), who demonstrated that the number of testate amoebae taxa increased in more acid microhabitats. However, studies performed by Beaver and Crisman (1981) in acid lakes indicate that with increased acidity the species richness of ciliates decreased. Probably in peatbog ecosystems the major role in development of microorganisms communities play the high concentration of organic carbon. In studied peatbogs only four testate amoebae taxa (*Arcella vulgaris*, *Assulina muscorum*, *Hyalosphenia* sp. and *Euglypha* sp.) showed a clear preference for a low pH. According to Lamentowicz and Mitchell (2005) the pH optima for these taxa range from 3.30 to 4.69. The content of total organic carbon in water correlated positively with the total numbers and biomass of testate amoebae. Similar relations have been shown to exist in the *Sphagnum*-dominated peatbogs in Europe (Mitchell *et al.* 2000). In all of the studied peatbogs testate amoebae were correlated with a depth to water table and with pH. This study showed that testate amoebae respond to the same major environmental gradients as in other parts of the world (Charman and Werner 1992, Vincke *et al.* 2004). The strongest relationship has been found between testate

amoebae communities and both a depth to water table and pH in north-western Poland in the Tuchola Pinewoods region (Lamentowicz and Mitchell 2005). Conductivity was not significantly correlated with the total numbers and biomass of microorganisms. These results are in good agreement with the statement of Lamentowicz and Mitchell (2005). In the studied peatbogs pH and the concentration of total organic carbon correlated positively with the numbers of ciliates. Only in lowmoore peatbog the content of total phosphorus correlated with the biomass and density of ciliates. In literature, data on the relationship between ciliates in *Sphagnum palustre* and chemical parameters are lacking. Beaver and Crisman (1981) have shown a positive relationship between pH and ciliates numbers in dystrophic lakes. Beaver *et al.* (1988), Sarvala *et al.* (1999), Mieczan (2005), Mieczan and Radwan (2005) demonstrated that both total phosphorus and organic matter concentrations are significantly related to ciliate abundance in lakes of different trophic status.

ACKNOWLEDGEMENTS: I thank my colleagues Katarzyna Pikunas and Andrzej Różycki for their invaluable technical assistance during sampling. I am very grateful to prof. dr. Ryszard Kornijów for valuable comments.

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(Received after revising May 2006)