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Effects of some abiotic factors on the occurrence of aquatic mycobiota in lakes of the Drawa National Park

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Key words: aquatic mycobiota, fungi, environmental factors, diversity indices, CCA ordination, Drawa National Park

Abstract

Effects of environmental factors, including acidity, temperature, oxygen, nitrogen, phosphate and total iron content, on the diversity of aquatic mycobiota in lake water were studied in two lakes in Northern Poland in 2005-2007. Fifty four species of fungi and fungus-like organisms were recorded in the sub-surface and benthic of both lakes. There were 36 and 45 species in Lakes Marta and Sitno, respectively. The greatest species diversity was observed with a higher content of oxygen and biogenic compounds in the surface water. Temperature and oxygen content were the most important factors affecting the distribution of mycobiota in lake water.

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INTRODUCTION

Understanding the effects of physicochemical factors of water on the occurrence of aquatic organisms is an important aspect of hydrobiological studies. Many published reports describe the situation concerning various systematic groups of hydrobionts. Such studies allow an approximate assessment of the dynamics of chemical and biological processes in aquatic ecosystems. Significant effects of the temperature, salinity level and pH on the morphometric variability of the crustacean *Artemia salina* (Branchiopoda) have been shown (Naceur et al. 2011). However, the authors found that there was no correlation between the dissolved oxygen and total nitrogen content in the water and the morphometry of *A. salina*.

Other studies on the effects of physicochemical factors of water and its trophic state on the abundance and biomass of microorganisms in the Vistula Lagoon showed significant effects of pH and the total phosphorus content on the abundance of zooplankton. The pH value, total phosphorus content, water temperature and dissolved oxygen concentration also significantly affected the zooplankton biomass. The total nitrogen content and trophic state of this body of water did not significantly affect the abundance and biomass of zooplankton (Paturej, Kruk 2011). Significant effects of chemical properties of water on the structure of zooplankton populations have been described (Kuczyńska-Kippen, Milecka 2009). There was a positive correlation between chlorophyll *a* concentration and densities of some zooplankton species, while a negative effect of concentration of nitrites was recorded for *Lecane quadridentata* (Rotifera) and *Alonella nana* (Cladocera). In other studies, the highest density and diversity of zooplanktonic Ciliata were noted at high pH (>6), higher conductivity and greater concentration of organic matter (Mieczan 2007). The total phosphorus level was less important.

A complete description of the chemical and biological properties of a body of water must include the group of aquatic decomposers consisting of aquatic microfungi (Ascomycota, mostly hyphomycete assemblages, and yeasts) and the fungus-like organisms (FLO) of the phylum Oomycota. The microbiological processes carried out by these groups are complex and differ significantly among individual taxa. These processes additionally include those that are miscellaneous, ubiquitous, unstable, and with physiological plasticity. The activity and significance of aquatic mycobiota are locally modified by additional abiotic factors, which often exert various and contradictory effects. Such effects can be demonstrated by studies on the effects of concentrations of inorganic nitrogen and phosphorus compounds on the diversity of aquatic mycobiota and the intensity of decomposition of organic matter by these microorganisms. According to Duarte et al. (2009), the greatest diversity of mycobiota was observed in mesotrophic conditions, while reduced biomass and diversity of mycobiota were noted in hypertrophic conditions. Chung and Suberkropp (2008) showed, however, that biomass, diversity and sporulation intensity were greater in water with higher nitrogen and phosphorus levels than in the control. These contradictions seem to result from the occurrence and contribution of additional physicochemical factors. Their complex action may determine and modify the local and unique relationships.

Temperature seems, however, to be the most important factor, apparently having the strongest effect on the structure of aquatic hyphomycetes communities (Ferreira, Chauvet 2011a) and fungus-like organisms (Salvin 1941, Koeypudsa et al. 2005). Higher nutrient levels in water were found to stimulate the growth, reproduction and activity of fungi more at a higher temperature (15°C, compared with 5°C). This was followed by stimulation of fungal respiration and increased litter decomposition. Synergistic interaction between the two factors, temperature and nutrient concentration, meant that increasing both of them stimulated all biological variables (Ferreira, Chauvet 2011b).

A strong correlation has been observed between water acidity and density, diversity and biochemical activity of aquatic hyphomycetes and the litter decomposition rate (Baudoin et al. 2008). Fungal diversity was smaller at lower pH (pH = 4.3). There was, however, no effect of acidity on fungal biomass. The decomposition rate of leaves by these fungi decreased with increased acidity of water (lower pH). Similar observations were made on dead animal tissues, i.e. shrimp exoskeletons. The frequency of chitinolytic fungi in shrimp exoskeletons was greater compared to bacteria that hydrolyze chitin. The effect was associated with the activity of fungal chitinases, which was greatest at 50°C and pH = 5 (Swiontek-Brzezinska et. al. 2007).

A survey of the literature shows that data on the environmental preferences of aquatic fungus-like organisms (FLO) of the Oomycota are rare.

The objectives of this study were, therefore, to determine the effects of certain physicochemical factors on the occurrence of aquatic yeasts and fungus-like organisms in two lakes (Marta and Sitno) in the Drawa National Park.

Materials And Methods

Water samples for hydrochemical and microbiological analyses were collected every three months, in spring, summer, autumn and winter, in 2005-2007, from the sub-surface and near-bottom waters of Marta (53°18'N, 16°06'E) and Sitno (53°18'N, 16°02'E) Lakes in the Drawa National Park (DNP), Poland. The lakes are similar in size: Marta is 66.1 ha and Sitno is 67.2 ha. Other morphometric characteristics differ considerably. Lake Marta has submerged vegetation dominated by Charophyceae (green algae), has neither river inflow nor outflow, is mesotrophic and dimictic, and has maximum depth of 25 m (7.7 m on average). Lake Sitno has river flows, is eutrophic and polymictic, and has maximum depth of 7 m (4 m on average).

Temperature, pH and oxygen content of the water were determined in natural conditions, directly after collection of samples. Nitrate (NO_3^-) and phosphate (PO_4^{3-}) concentrations were determined in the laboratory using standard methods (Eaton et al. 2005). Mean values for physicochemical measurements were determined separately for the near-bottom and surface layers. The pH values were determined from mean concentration of the hydrogen ions.

Isolation and cultivation of mycobiota were carried out according to the standard bait methods used in hydromycology (Batko 1975, Riethmüller 2000). Baits used in the culture consisted of plant fragments (sesame and hemp seeds, onion brown hulls) and animal fragments (snake and insect exuviae, dead insects and crustaceans, fish muscles and spawn) and were maintained at 18-22°C. The baits allowed potential isolation of a broad spectrum of microbial species. Fungi and fungus-like organisms were identified successively on the basis of their morphology, anatomy and sporulation on baits according to Skirgiełło (1954), Batko (1975), Kreger-Van Rij (1984), Barnett et al. (1990), Dynowska (1995), Kurnatowska (1995), de Hoog et al. (2000), Riethmüller (2000), Khulbe (2001), Johnson et al. (2002) and Howard (2003).

The following indices were applied for statistical interpretation of the species diversity data :

- Shannon-Wiener's index

$$H = -\sum_{i=1}^{S}(p_i \log_2 p_i) \qquad (1)$$

where:
S – the number of species in a sample
p_i – the fraction of individuals in the i^{th} species
p_i (relative abundance) = n_i/N
where:
n_i – the number of individuals in the i^{th} species
N – total number of individuals in all species

- Pielou's evenness index

$$J = \frac{H}{H_{\max}} \qquad (2)$$

where:
H – Shannon-Wiener's index
H_{max} – the theoretical maximum value for H if all species in a sample were equally abundant

- Simpson's diversity index

$$D = \sum_{i=1}^{S}(p_i^2) \qquad (3)$$

where:
S – the number of species in a samples
p_i – the fraction of individuals in the i^{th} species

Microbial diversity in terms of species richness is also indicated by the number of species S.

For numerical analysis, the binary variables (values of 0 or 1 only) in samples were transformed to the ordinal scale according to van der Maarel (1979). Calculations of diversity indices were made with the MVSP package (Piernik 2008). Comparisons of mean values of indices were made with two-way analysis of variance (ANOVA). The first factor was the year of investigation (three levels: 2005, 2006 and 2007) and the second factor was the season (four levels: spring, summer, autumn and winter). Normality of distribution of each variable was verified with Shapiro-Wilk's test. Homogeneity of variance of the analyzed samples was checked with Leven's test. Homogeneous groups were formed using Tukey's multiple range test. All statistical hypotheses were verified at the significance level of 0.05.

Canonical Correspondence Analysis (CCA), which is a direct ordination technique and incorporates environmental data into ordination, was used to relate physicochemical factors to occurrence of microorganisms. The analysis used an environmental matrix (five physicochemical variables: pH, temperature, dissolved oxygen, nitrate (NO_3^-) and phosphate (PO_4^{3-}) concentration) and a dependent matrix (population estimates for microorganism species). Calculations were performed with a multivariate statistical package (MVSP).

Results And Discussion

Fifty four species of fungi and fungus-like organisms were recorded in the sub-surface and benthic waters of Lakes Marta and Sitno in Drawa National Park in Poland in 2005-2007 (Table 1). There were 36 and 45 species in Lakes Marta and Sitno, respectively. A broader spectrum of species was recorded in the eutrophic Sitno Lake in each of the three years of the study. Representatives of the order Saprolegniales predominated in both lakes. The increased diversity of mycobiota associated with the increased trophic state of the lake seems to be specific and local. There have been no similar correlations observed for other hydrobionts, e.g. zooplankton (Paturej, Kruk 2011). Other studies on the relationships between the trophic state of water bodies and diversity of aquatic hyphomycetes only partly support the present results. Chung and Suberkropp (2008) observed an increase in species diversity in water with a higher trophic index (TI), contrary to Duarte et al. (2009) who observed a decrease in fungal diversity.

The presence or absence of mycobiota in natural habitats depends on the dynamics of many interrelated factors. The data presented here show that the hydrological and physicochemical conditions of the two lakes determine their individual microbiological characters. The two water bodies were similar in the aspect that *Achlya americana, A. caroliniana, A. debaryana, Aphanomyces stellatus, Saprolegnia ferax* and *S. parasitica* occurred in both lakes and in each year of the study (Table 1). The common occurrence of these organisms indicates their capability of surviving under substantially different environmental conditions, characteristic of eurybionts.

Acidity of the water is a major factor affecting the presence and diversity of aquatic mycobiota (Batko 1975, Gadauho et al. 2005). It directly affects the physiology of mycobiota and indirectly changes other parameters of the water habitat. The pH values of the water were between 7.54 and 8.51 (Lake Marta), and 7.27 and 8.74 (Lake Sitno) (Table 2). These neutral to slightly alkaline conditions were apparently optimal for the growth of most of the fungus-like organisms (FLO). Our results confirmed other observations on most of the Oomycota species, particularly on *Achlya colorata* (Kiziewicz et al. 2006) and *Saprolegnia diclina* (Panchai et al. 2006). Acidic waters, with pH values 3.5-3.8, prevent the occurrence of *S. delica* and *S. parasitica* (Kitancharoen et al. 1996).

This study showed that the spectrum and species diversity of aquatic mycobiota was not affected by local, interannual and seasonal variations in weather or their consequences in Lake Sitno. In Lake Marta, however, diversity was significantly affected by interannual and seasonal changes in the weather. Significant differences in the spectrum of microbial species between summer and spring, and between summer and winter were supported by Shannon-Wiener index (*H*) values (Fig. 1).

These differences seemed to result from seasonal changes in the water temperature (Table 2). The results show that among the tested factors, water temperature was the most important one, which affects the diversity of mycobiota (Table 3). The seasonal occurrence of certain taxa shows that *Apodachlya pirifera, Thraustotheca clavata* and *S. monoica* are spring species and *A. prolifera*, *Candida krusei* and *C. parapsilosis* (Marta Like) are summer species. *Saprolegnia latvica* was recorded in Lake Marta only in autumn.

According to Roberts (1963) and Batko (1975), the temperature preferences of the species listed above, as well as their seasonal occurrence, indicate that they are characterized by the increased biochemical and physiological activity (i.e. formation of generative organs) in their preferred season. In Lake Sitno, which is much shallower and less heterogeneous than Lake Marta, the spectrum of microbial species was not related to seasonal changes in climate and weather, including temperature. No significant differences in microbial composition between years or seasons were indicated by Shannon-Wiener index (*H*).

The dynamics of water conditions may periodically result in persistent conditions that are favorable for certain groups of microorganisms resulting in their unique and sporadic occurrence and activity (Table 1). The occurrence of particular species is often determined by complex interactions and relationships. In lentic waters of botanical gardens in Iran, *S. ferax* was recorded only in spring and autumn, and *A. colorata* and *S. litoralis* only in summer (Nejadsattari 2000). Similar seasonal phenology was observed in our study. This may have resulted not only from the specific temperature but also from oxygen content preferences. The amount of oxygen dissolved in pure water is inversely proportional to its temperature. Colder water (e.g. in spring and autumn) has more dissolved oxygen needed by microorganisms. In water of Lake Sitno, where the oxygen content was between 6.7 and 15.0 mg l^{-1}, the mycobiota included nine additional species (Table 2). In Lake Marta, where the oxygen content was lower, the species diversity was smaller. The microbiological diversity of each lake was also related to its morphometric characteristics, particularly depth of water. The spectrum of mycobiota species decreased with depth, which seemed to result from lower temperature and oxygen content in the benthic water. The factors affected mycological diversity similarly in the sub-surface and benthic water in lakes studied by Silicki (2008). The observations are consistent with suggestions made by Suzuki (1960) about uniform distribution of mycobiota during water circulation and stratified distribution of mycobiota during its stagnation in summer and winter.

Most species of Oomycota that are present in water reservoirs throughout the year, can occur there in various forms, including non-persistent and persistent organs and structures, depending on environmental conditions. All of them are useful for identification. Usually, however, the presence of the

Table 1

Mycobiota isolated in Lakes Marta and Sitno in Drawa National Park in years 2005 – 2007.

No.	Species	Marta Lake			Sitno Lake		
		2005	2006	2007	2005	2006	2007
1.	*Achlya americana* Humphrey (1892)	+	+	+	+	+	+
2.	*Achlya apiculata* de Bary (1888)				+	+	+
3.	*Achlya caroliniana* Coker (1910)	+	+	+	+	+	+
4.	*Achlya colorata* Pringsheim (1882)	+		+	+	+	
5.	*Achlya debaryana* Humphrey (1893)	+	+	+	+	+	+
6.	*Achlya dubia* Coker (1923)				+		
7.	*Achlya flagellata* Coker (1923)				+	+	+
8.	*Achlya klebsiana* Pieters (1915)		+		+	+	+
9.	*Achlya megasperma* Humphrey (1892)				+	+	+
10.	*Achlya oligocantha* de Bary (1888)						+
11.	*Achlya polyandra* Hildebrand (1867)	+	+	+			
12.	*Achlya prolifera* Nees (1823)		+	+			
13.	*Achlya racemosa* Hildebrand (1867)	+		+	+	+	+
14.	*Achlya spinosa* de Bary (1882)				+	+	+
15.	*Anguillospora pseudolongissima* Ranzoni (1953)				+	+	
16.	*Aphanomyces astaci* Schikora (1903)		+	+		+	+
17.	*Aphanomyces irregularis* Scott (1961)		+	+	+	+	
18.	*Aphanomyces laevis* de Bary (1860)	+		+	+	+	+
19.	*Aphanomyces stellatus* de Bary (1860)	+	+	+	+	+	+
20.	*Aplanes androgynus* (Archer) Humphrey (1892; 1893)	+		+			+
21.	*Aplanes treleaseanus* (Humphrey) Coker (1923)	+		+		+	+
22.	*Apodachlya pirifera* Zopf (1888)		+				+
23.	*Candida krusei* Berkhout (1923)		+				
24.	*Candida parapsilosis* Langeron & Talice (1932)		+			+	
25.	*Candida pelliculosa* Redaelli (1925)		+	+			
26.	*Composporium aquaticum* Dudka				+		
27.	*Debaryomyces hansenii* Lodder & Kreger-van Rij (1952)					+	
28.	*Debaryomyces polymorphus* Price & Phaff (1979)					+	+
29.	*Dictyuchus sterile* Coker (1969)		+	+	+	+	
30.	*Isoachlya monilifera* (de Bary) Kauffman (1921)	+		+	+	+	
31.	*Kluyveromyces polysporus* van der Walt (1956a)					+	
32.	*Leptolegnia caudata* de Bary (1888)						+
33.	*Leptomitus lacteus* (Roth) Agardh (1824)				+	+	
34.	*Metschnikowia pulcherrima* Pitt & Miller (1968)		+				
35.	*Pichia guilliermondii* Wickerham (1966) = *Candida guilliermondii* Langeron & Guerra (1938)			+ $^{1)}$		+ $^{2)}$	
36.	*Pichia membranaefaciens* Hansen (1904)		+				
37.	*Pythiogeton utriforme* Minden (1916)				+	+	
38.	*Pythium intermedium* de Bary (1881)				+	+	+
39.	*Pythium proliferum* de Bary (1860)				+	+	+
40.	*Pythium rostratum* Butler (1907)						+
41.	*Saccharomyces cerevisiae* Meyen & Hansen (1883)			+			
42.	*Saprolegnia delica* Coker (1923)				+	+	+
43.	*Saprolegnia diclina* Humphrey (1892)		+	+		+	
44.	*Saprolegnia ferax* (Gruith.) Thuret (1821)	+	+	+	+	+	+
45.	*Saprolegnia glomerata* (Tiesenhausen) Lund (1934)		+		+	+	+
46.	*Saprolegnia lapponica* Gäuman (1918)	+		+	+	+	+
47.	*Saprolegnia latvica* Apinis (1930)		+				
48.	*Saprolegnia litoralis* Coker (1923)	+	+		+	+	+
49.	*Saprolegnia mixta* de Bary (1883)		+	+			
50.	*Saprolegnia monoica* Pringsheim (1858)		+	+	+	+	+
51.	*Saprolegnia parasitica* Coker (1923)	+	+	+	+	+	+
52.	*Saprolegnia torulosa* de Bary (1956)	+		+	+	+	+
53.	*Thraustotheca clavata* (de Bary) Humphrey (1893)			+		+	
54.	*Zoophagus insidians* Sommerstorff (1911)		+	+	+	+	+
	Total in year	16	25	27	31	38	30
	Total in years 2005-2007		36			45	

$^{1)}$ – anamorphic state; $^{2)}$ – teleomorphic state

Table 2

Average values of the parameters studied in Lakes Marta and Sitno in 2005-2007.

Parameter	Spring			Summer			Autumn			Winter		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
	Marta Lake											
pH	7.62	7.64	7.76	8.51	7.54	7.99	8.48	8.48	8.09	7.62	7.99	7.98
Temp. (°C)	14.4	15.5	13.1	20.4	24.7	18.5	16.9	18.1	9.9	4.0	6.5	4.7
O_2 (mg l^{-1})	10.8	10.5	11.1	10.5	7.6	8.0	10.4	8.8	7.4	9.4	8.8	9.2
NO_3 (mg l^{-1})	8.7	8.7	8.8	8.3	8.2	5.4	8.3	7.9	6.3	4.8	8.9	7.2
PO_4 (mg l^{-1})	0.31	0.35	0.65	1.49	0.38	0.79	0.49	0.50	2.31	0.16	1.69	2.31
	Sitno Lake											
pH	7.83	7.49	7.90	8.74	7.27	7.90	8.04	8.05	7.87	8.07	8.09	8.00
Temp. (°C)	14.2	14.2	12.3	19.1	24.3	17.4	9.4	17.3	8.5	2.6	6.4	5.0
O_2 (mg l^{-1})	13.1	12.1	12.0	15.0	7.9	7.0	8.1	7.2	6.7	11.3	9.9	9.0
NO_3 (mg l^{-1})	7.4	9.4	12.0	1.4	10.7	10.1	7.9	5.4	6.6	5.1	10.3	9.8
PO_4 (mg l^{-1})	0.38	0.35	1.18	0.57	0.84	1.76	0.43	0.36	0.32	0.73	0.77	0.78

Table 3

Correlations between diversity of mycobiota and environmental variables in Lakes Marta and Sitno.

Parameter	Marta Lake	Sitno Lake
pH	-0.1957	-0.2858
Temp. (°C)	**0.5458***	**0.4728***
O_2 (mg l^{-1})	-0.3112	-0.3457
NO_3 (mg l^{-1})	0.0173	-0.1433
PO_4 (mg l^{-1})	-0.1788	0.3209

*Significant at $P \leq 0.05$)

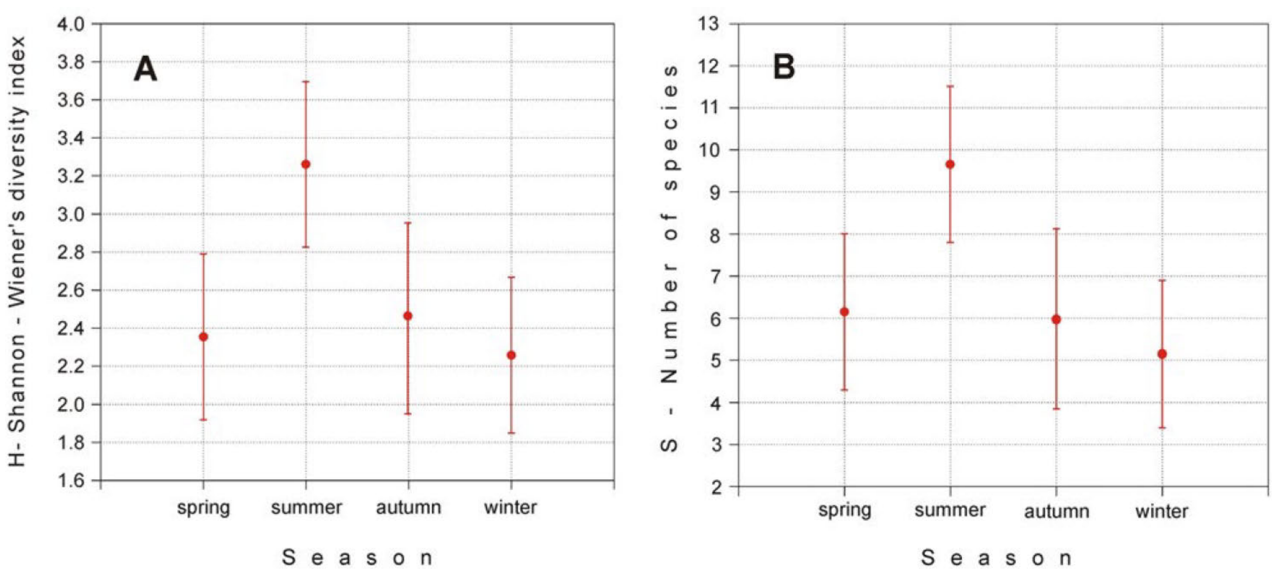

Fig. 1. Significance of differences in the mycobiota occurrence in Lake Marta in four seasons; A - Shannon-Wiener diversity index, B – the number of species. Bars represent 95% confidence intervals for means.

generative organs helps to identify aquatic Oomycota.

Our study provides data that indicate interrelationships between the content of biogenic compounds in water and mycobiota species diversity. The content of biogenic compounds was greater in Lake Sitno NO_3^- at concentrations up to 12.0 mg l^{-1}) than in Lake Marta (NO_3^- at concentrations up to 8.9 mg l^{-1}), and was associated with the development of greater species diversity (Table 2). A similar relationship was observed with phosphates (Table 2). These relationships seemed to result from long-lasting anthropopressure (human-related disturbance). Oomycota, including *Achlya flagellata, A. megasperma, Anguillospora pseudolongissima*, representatives of *Pythium* (*P. intermedium*, *P. proliferium*), *Pythiogeton utriforme* and *S. delica*, which were continuously present in Lake Sitno and absent from Lake Marta, can be considered as indicators of the increased trophic state (Table 1). A higher content of biogenic compounds in water may, however, inhibit the growth of microorganisms with particularly low ecological tolerance. The Ascomycota yeasts recorded, including *Candida parapsilosis*, *Debaryomyces hansenii*, *Pichia guilliermondii* (= *Candida guilliermondii*) and *P. membranaefaciens*, are important stenobionts and indicators of good water quality (Dynowska et al. 2000). Two of the Ascomycota yeasts recorded, *D. hansenii* and *P. membranaefaciens*, are species that help to clean the water (Dynowska 1995, Biedunkiewicz et al. 2007). Apart from these Ascomycota yeasts, the oomycetous *Leptomitus lacteus* acts as a bioindicator (Batko 1975, Czeczuga et al. 2002). It prefers habitats with higher concentrations of biogenic compounds, gaining the status of 'sewage fungus'. *Leptomitus lacteus* was recorded in the surface water only in Lake Sitno (Table 1). The data presented, supported by statistical analyses, show that environmental factors are undoubtedly important determinants of mycobiota species diversity in natural water reservoirs. Interannual variability of environmental factors was significant only in Lake Marta (Fig. 2); this was supported by Shannon-Wiener index *H*, Simpson's index *D* and species richness S. There were significant differences in the diversity indices between 2005 and 2007.

It is difficult to prove effects of interannual and seasonal variability of parameters in water of natural reservoirs on species diversity of aquatic mycobiota, because of the changing and complex dynamics of the hydrochemical processes that occur in water.

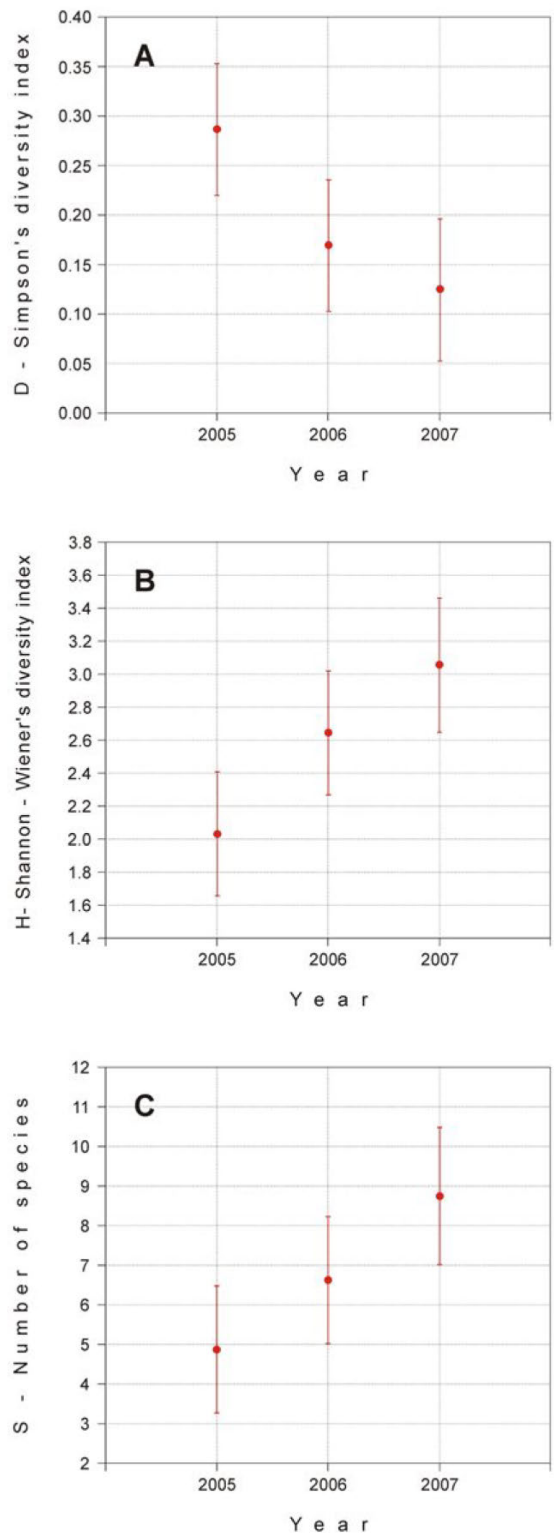

Fig. 2. Significance of differences in the mycobiota occurrence in Lake Marta in 2005-2007; A - Shannon-Wiener diversity index, B – Simpson'`s diversity index, C – the number of species. Bars represent 95% confidence intervals for means.

The distribution of species across the ordination space is presented in Figure 3 (Lake Marta) and Figure 4 (Lake Sitno). Small eigen values of the first two ordination axes (<0.5) indicate the linear structure of the primary data and little separation of the objects. In Figure 3, vectors representing the

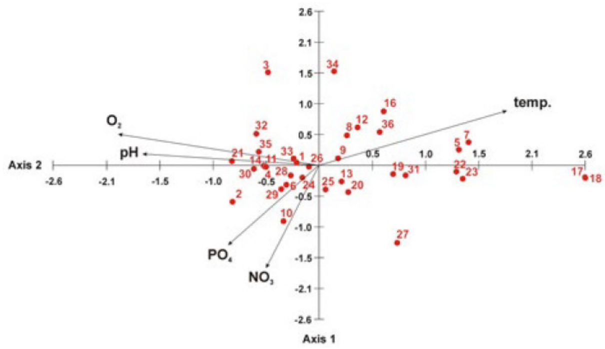

Fig. 3. Effects of environmental variables on species composition under different conditions of Lake Marta across the ordination scale.

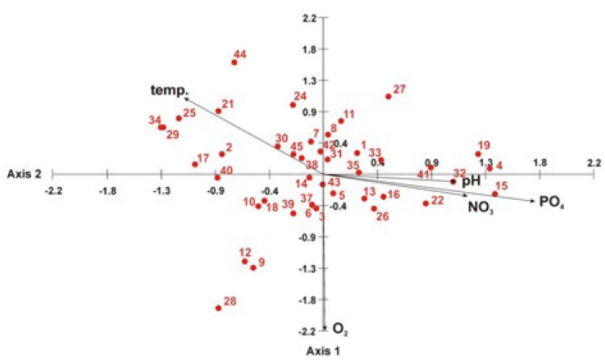

Fig. 4. Effects of environmental variables on species composition under different conditions of Lake Sitno across the ordination scale.

variables temperature and oxygen content are the longest and strongly correlated with the first ordination axis, which is evidenced by a small angle between these vectors and the axis. The values of the variable temperature on the diagram increase from the left side of the ordination space to the right, while values of the variable oxygen content take the opposite direction. Both variables explain 30% of the direct variation. The second ordination axis is optimized by the vectors of the variables nitrate (NO_3^-) and phosphate (PO_4^{3-}) content.

In Figure 4, the vectors of biogenic compounds are strongly correlated with the first axis. The variable nitrate (NO_3^-) content explains approximately 19% of the mycobiota dispersion and the variable phosphate (PO_4^{3-}) content explains 40% of the species variation. The oxygen content has a strong negative effect on the second ordination axis. This environmental variable explains 60% of the species distribution across the ordination space.

CONCLUSIONS

1. High values of correlation between environmental variables and species indices are evidence of a strong association between the oxygen content and temperature in Lakes Marta and Sitno and the content of biogenic compounds in Lake Sitno, and mycobiota species found in samples.
2. Temperature, among other physicochemical factors, significantly increased the diversity of mycobiota in two lakes in Northern Poland.

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