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Fungi and fungus-like organisms growing in selected lotic oxbow lakes and tributaries of the Narew River

by

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Abstract

Mycological and hydrochemical research was conducted in two different types of reservoirs connected with the Narew riverbed (three tributaries and three lotic oxbow lakes) in two growing seasons. The obtained results seem to indicate that more favorable conditions for the development of the analyzed microorganisms prevailed in the studied tributaries of the Narew. A total of 36 species of fungi and fungus-like organisms were identified in these tributaries in spring and 35 in autumn, while respectively 32 and 26 species in the lotic oxbow lakes. Six taxa not identified in the oxbow lakes were found only in the tributaries of the river. They were: *Alternaria alternata, Allomyces moniliformis, Catenaria anguillulae, Leptomitus lacteus, Rhipidium parthenosporum* and *Saprolegnia diclina*. On the other hand, only two species occurred only in the oxbow lakes (not recorded in tributaries) (i.e. *Catenophlyctis variabilis* and *Rhizophlyctis rosea*).

The differences observed in the microfungi species composition in the studied ecosystems are associated, among others, with the time of the year and physicochemical properties of the water. Hydrochemical parameters such as temperature, pH, Mg, N-NH_3, N-NO_3, P-PO_4 and suspended solids showed positive correlation, and sulfates, chlorides, Ca, Fe correlated negatively with the number of taxa observed.

Key words: aquatic fungi, physicochemical factors, water bodies, straminipilous organisms

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Introduction

Shallow water habitats such as river tributaries and oxbow lakes create favorable microhabitats for the development of different organisms (Shearer et al. 2007). Disruption of homeostasis and the exceeded threshold of self-regulation ability can cause disastrous effects in aquatic environments (Chróst & Siuda 2006; Gulis et al. 2006; Krauss et al. 2011; Kshirsagar 2013). Therefore, it seems important to monitor the level of pollution in tributaries and oxbow lakes of the Narew River, because the exchange of water with the main riverbed may alter their sanitary and epidemiological condition and the dynamics of processes occurring in the multi-species ecosystems of the river basin.

Previous results of hydromycological research related to selected tributaries of the Narew River indicate that the connection with the main riverbed largely determines the nature of their biotope. This connection affects, among others, the biodiversity of aquatic fungi and the physicochemical parameters of the waters (Czeczuga & Próba 1987; Muszyńska et al. 2009; 2014). In contrast, little is known about the hydromycological state of other types of reservoirs that are also connected with the main Narew riverbed, i.e. lotic oxbow lakes.

The objective of the study was to compare the species diversity of the fungal biota with the hydrochemical conditions of the waters in two different types of reservoirs connected with the main riverbed of the Narew, i.e. three similar lotic oxbow lakes and short tributaries of the river: the Strabelka, the Niewodnica and the Nereśl, taking account of the seasons of the year.

Materials and methods

The Narew River is a right tributary of the Vistula River. It is 455 km long (total length of 484 km) within the Polish territory. The sources of the river are in the swampy area of the Białowieża Forest in Belarus. The drainage basin of the upper Narew is located in a typically agricultural and relatively poorly industrialized region with large areas of forests. The Narew River flows through the Narew National Park and due to its high nature conservation values is referred to as “the Polish Amazon”. The Narew River belongs to the unique anastomosing river system in Europe. Hydrographic conditions in the valley of this river result from natural factors and human activity within the Park and in the whole Narew River basin (Czeczuga et al. 2011).

Water samples for mycological and hydrobiological analysis were collected in the spring and autumn of 2013 from the three tributaries, i.e. the Strabelka (site I), the Niewodnica (site II), and the Nereśl, (site III) entering the Narew River in such places as Strabla, Topilec and Tykocin and lotic oxbows located in the valley of the Narew River in the Narew National Park (site IV, site V and site VI) (Fig. 1).

Water samples for physicochemical and mycological analysis were collected approximately 2 m from the shore and at a depth of 50 cm, using a Ruttner water sampler (2 liter capacity). Water parameters in each reservoir were measured in a laboratory according to the methods recommended in Standard Methods for the Examination of Water and Wastewater (Eaton et al. 2005) (Table 1, 2).

Three water samples from each selected site were collected for the analysis of fungi and fungus-like organisms. Water samples from the sites were transported in sterile containers of 2 dm^3 each. In the laboratory, samples were concentrated by filtration. They were poured into 0.6 dm^3 beakers and incubated in a laboratory under conditions resembling those of the natural environment. The baiting method is described by Batko (1975), Seymour & Fuller (1987), Riethmüller (2000). All baits were boiled and rinsed with distilled water several times prior to use. The

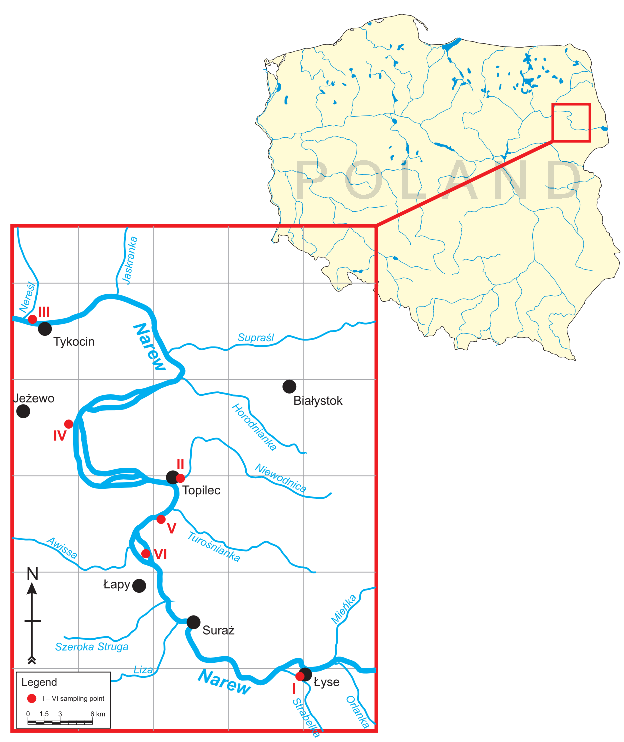

Figure 1

The study area and sampling sites at the lotic oxbow lakes and tributaries of the Narew River

Table 1

Physicochemical composition of water samples collected from the tributaries of the Narew River (I, II, III) and from the lotic oxbow lakes of the Narew River (IV, V, VI) in spring (n=3)

Specification	Unit	I	II	III	IV	V	VI
Temperature	°C	6	5	6	7	8	8
pH		7.60	7.74	7.64	7.10	7.21	7.13
O_2	mg dm^3	15.69	15.45	15.68	12.58	12.59	13.59
BOD_5		8.23	7.22	7.22	7.81	7.22	9.23
COD		9.05	14.64	14.64	9.02	7.00	9.05
CO_2		13.0	12.0	12.0	11.0	11.3	11.0
Alkalinity in $CaCO_3$	mval	4.5	4.3	4.2	4.4	4.1	4.5
$N\text{-}NH_3$	mg dm^3	0.770	1.071	0.970	0.770	0.720	0.760
$N\text{-}NO_2$		0.0236	0.0262	0.0236	0.0236	0.0236	0.0320
$N\text{-}NO_3$		0.360	0.460	0.460	0.220	0.460	0.230
$P\text{-}PO_4$		0.520	0.760	0.560	0.560	0.400	0.430
Sulfates		19.15	18.26	18.26	26.32	19.33	20.15
Chlorides		54	53	53	65	58	54
Total hardness	mg Ca dm^3	101.40	109.6	108.8	69.84	109.6	108.6
Total hardness	mg Mg dm^3	10.32	10.74	10.74	3.44	9.03	8.32
Fe	mg	0.90	1.40	1.40	0.90	0..40	0.95
Dry residue	mg dm^3	272	295	295	294	256	256
Dissolved solids		256	283	283	281	247	240
Suspended solids		16	12	12	13	9	16

Table 2

Physicochemical composition of water samples collected from the tributaries of the Narew River (I, II, III) and from the lotic oxbow lakes of the Narew River (IV, V, VI) in autumn (n=3)

Specification	Unit	I	II	III	IV	V	VI
Temperature	°C	12	14	12	18	16	19
pH		7.60	7.75	7.65	7.10	7.22	7.15
O_2	mg dm^3	15.68	15.66	15.67	14.66	14.67	14.68
BOD_5		7.81	7.21	9.22	8.22	8.22	8.22
COD		9.02	7.00	9.05	9.06	14.63	14.64
CO_2		13.0	12.2	10.0	12.0	12.0	12.0
Alkalinity in $CaCO_3$	mval	4.4	4.0	4.5	4.5	4.3	4.2
$N\text{-}NH_3$	mg dm^3	1.470	1.220	1.340	0.790	0.270	0.970
$N\text{-}NO_2$		0.0336	0.0330	0.0320	0.0236	0.0272	0.0336
$N\text{-}NO_3$		0.650	0.580	0.660	0.220	0.460	0.230
$P\text{-}PO_4$		0.620	0.760	0.760	0.560	0.500	0.673
Sulfates		20.15	38.26	38.26	26.32	19.33	20.15
Chlorides		65	58	54	54	53	53
Total hardness	mg Ca dm^3	72.00	72.00	69.84	100.30	107.50	104.70
Total hardness	mg Mg dm^3	3.44	9.03	8.32	10.25	10.16	10.22
Fe	mg dm^3	0.90	0..40	0.95	1.80	2.30	2.20
Dry residue		292	266	258	278	298	299
Dissolved solids		279	247	240	266	286	286
Suspended solids		13	19	18	12	12	13

following baits were used: snake and insect exuviae, dead crustaceans and insects, fish muscles and spawn, seeds of clover, hemp and buckwheat, onion brown hulls). After a three-day incubation, the baits were observed under a microscope. Fungi and fungus-like organisms were identified successively on the basis of their morphology, anatomy and sporulation on baits according to Batko (1975), Dick (1990), Pystina (1998), Riethmüller (2000), Khulbe (2001), Johnson et al. (2005). The systematics of the straminipilous organisms was defined according to Dick (2001 Johnson et al. (2005), James et al. (2006).

The results were considered statistically significant at $p<0.05$. For calculations, Statistica 10.0 (StatSoft) and PASW Statistics 17.0 (Predictive Solutions) were used.

Results

As indicated by most of the nineteen hydrochemical parameters studied, the water in the tributaries of the Narew was similar both in spring and autumn. In spring, statistically significant differences between site I and site II were determined for only four hydrochemical parameters, i.e. pH (p = 0.01), ammoniacal nitrogen (p = 0.01), phosphates (p = 0.02) and calcium (p = 0.02). Statistically significant differences at sites II and III were determined only for water temperature (p = 0.01). In autumn, the most statistically significant differences between the hydrochemical parameters were observed between site I and site III and they were related to pH (p = 0.01), CO_2 (p = 0.02), chlorides (p = 0.02), dry residue (p = 0.01) and dissolved solids (p = 0.01). Sites I and II differed in the ammoniacal nitrogen content (p = 0.02), magnesium (p = 0.02) and suspended solids (p = 0.01). In contrast, the content of BOD_5 at site III was significantly higher than at site II (p = 0.02).

The compared waters in the Narew oxbows were also similar in both study periods as indicated by most of the 19 analyzed hydrochemical parameters. In spring, statistical differences were observed only at sites IV and V and they were related to the content of nitrate nitrogen (p = 0.03), phosphates (p= 0.02), sulfates (p = 0.02), calcium (p = 0.01) and magnesium (p = 0.02), at sites V and VI in the content of BOD_5 (p = 0.02); COD (p = 0.02) ammoniacal nitrogen (p = 0.02), suspended solids (p = 0.01), at sites IV and VI in the content of nitrite nitrogen (p = 0.02) and chlorides (p = 0.02). In autumn, the differences in the quality of water in oxbow lakes were observed at sites IV and V in the values of five parameters (oxygen p = 0.02, nitrate nitrogen p = 0.03, sulfates p = 0.02, calcium p = 0.01 and magnesium p = 0.02), sites IV and VI in the values of two parameters (nitrite nitrogen p = 0.02 and dry residue p = 0.03) and sites V and VI only in the values of phosphate content p = 0.02 (Table 1, 2).

As for the mycological comparison of the tributaries of the Narew, slightly fewer taxa of fungi and fungus-like organisms in both study periods were observed in tributary III than in tributaries I and II. *Aspergillus fumigatus, A. colorata, Polyphagus euglenae, Pythium acanthicum* and *S. diclina* occurred only in tributary III (Table 3).

With regard to the oxbow lakes, most taxa of fungi and fungus-like organisms were recorded at site VI, in both study periods. *Achlya radiosa, Nowakowskiella elegans, Pythium afertile, Rhizophydium globosum* and *Saprolegnia glomerata* occurred only in this oxbow lake (Table 3).

The results of the research related to hydrochemical parameters of the studied reservoirs indicate significant statistical differences between the quality of water in the tributaries and in the lotic oxbow lakes in both study periods. Significant temperature differences were observed in spring (p = 0.0002) and autumn (p = 0.009), with much lower temperature observed in the tributaries. The water in the tributaries was more oxygenated (p = 0.0003) and contained more biogenic compounds than in the oxbow lakes. It has been observed that the tributaries contained higher amounts of ammoniacal nitrogen (p = 0.003) and nitrate nitrogen (p = 0.006) in spring and ammoniacal nitrogen (p = 0.004) in autumn. In autumn, the amount of phosphates was also significantly higher in the tributaries (p = 0.006). As regards the content of mineral substances, statistically significant differences were observed in the values of most of the studied parameters. Only the amount of calcium ions and suspended solids did not differ significantly in the analyzed reservoirs of the Narew (see Table 1 and Table 2).

Thirty six species of fungi and fungus-like organisms were observed in the water collected for mycological analysis from the three selected tributaries of the Narew: the Strabelka, the Niewodnica and the Nereśl and the three lotic oxbow lakes. They belonged to two kingdoms: Fungi (15) and Stramenompila (21), five classes: Ascomycota (3), Blastocladiomycota (5), Chytridiomycota (6), Zygomycota (1) and Oomycota (21) (Table 3).

Significant statistical differences were observed between the number of fungi identified in the oxbow lakes and tributaries of the Narew in spring (p = 0.03) and autumn (p = 0.002). In both study periods, more species of fungi and fungus-like organisms were observed in the waters of the three tributaries of the Narew (Figs 2, 3).

Five taxa were found only in the tributaries, while they were absent in the oxbow lakes: (*Allomyces moniliformis, Catenaria anguillulae, Leptomitus lacteus, Rhipidium parthenosporum* and *Saprolegnia diclina*). In contrast, only two species were found in the oxbow lakes (i.e. *Catenophlyctis variabilis* and *Rhizophlyctis rosea*).

During the research conducted in both types of the reservoirs, greater species diversity of micromycetes was observed in spring. The following species occurred only in spring: *Geotrichum candidum, Allomyces moniliformis, Catenaria. verrucosa, Chytridium*

Table 3

Fungi and straminipilous organisms found in water collected from the tributaries and from the lotic oxbow lakes of the Narew River in spring and autumn (a – autumn, s – spring)

Kingdom, class, order and species	Water sites					
	Narew-tributaries (N_t)			Narew-oxbow lakes (N_o)		
	I	II	III	IV	V	VI
Fungi						
Ascomycota						
Pleosporales						
1. *Alternaria alternata* (Fr.) Keissl.	s					
Eurotiales						
2. *Aspergillus fumigatus* Fresen.			a		s	s
Saccharomycetales						
3. *Geotrichum candidum* Link	s				s	s
Blastocladiomycota						
Blastocladiales						
4. *Allomyces moniliformis* Coker & Braxton	s					
5. *Blastocladiopsis parva* (Whiffen) Sparrow	a	a	s, a	a	a, s	s, a
6. *Catenaria anguillulae* Sorokin	a		a	a		
7. *C. verrucosa* Karling	s				s	
8. *Catenophlyctis variabilis* (Karling) Karling				s	s	s
Chytridiomycota						
Chytridiales						
9. *Chytridium xylophilum* Cornu	s					
10. *Chytridium schenkii* (P.A. Dang.) Scherff						
Spizellomycetales						
11. *Rhizophlyctis rosea* (de Bary et Woronin) A. Fisch				s		
Cladochytriales						
12. *Nowakowskiella elegans* (Nowakowski) Schröter	s, a	a	a			a
13. *Polyphagus euglenae* Nowakowski			a	s	s, a	
14. *Rhizophydium globosum* (Braun) Rabenhorst	s	s	s			s
Zygomycota						
Zoopagales						
15. *Zoophagus insidians* Sammerst.	a		s, a		s	s
Stramenopila						
Oomycota						
Monoblepharidiales						
16. *Monoblepharis brachyandra* Lagerheim	s, a	s, a	s, a			s, a
17. *Monoblepharis macrandra* (Lagerheim) Woronin	s, a	s, a	s, a			s, a
Leptomitales						
18. *Leptomitus lacteus* C. Agardh		s	s			
Pythiales						
19. *Pythium acanthicum* Drechsler			s, a		a	
20. *P. afertile* Kanouse et Humphrey	a	s	s			a
21. *Globisporangium debaryanum* (R. Hesse) Uzuhashi, Tojo & Kakish.	a			a	a	
22. *P. myriotylum* Drechsler		s, a	s, a			
Rhipidiales						
23. *Rhipidium parhtenosporum* Kanouse	a	a	a			
Saprolegniales						
24. *Achlya americana* Humphrey	s			a, s		s
25. *A. ambisexualis* Raper		a	s		a	s
26. *A. debaryana* Humphrey	a	s, a				a
27. *A. colorata* Pringsheim			s	s, a	s	s
28. *A. flagellata* Coker				s, a		
29. *A. radiosa* Maurizio		s	s			s
30. *Aphanomyces irregularis* Scott	s, a	s, a	s, a	a	a	a
31. *Newbya oligocantha* Spencer, Vick & Dick		s			s	
32. *Saprolegnia diclina* Coker			s			
33. *S. ferax* (Gruith.) Thur.	s, a	s, a	s, a	s, a	s, a	s, a
34. *S. glomerata* (Tiessnh.) A. Lund	a	s, a	a			a
35. *S. mixta* de Bary	s		s	s, a		a
36. *Scoliolegnia asterophora* (de Bary) M.W. Dick	s	s			s	
Total number	14s/13a	15s/13a	9s/9a	8s/9a	11s/7a	13s/10a

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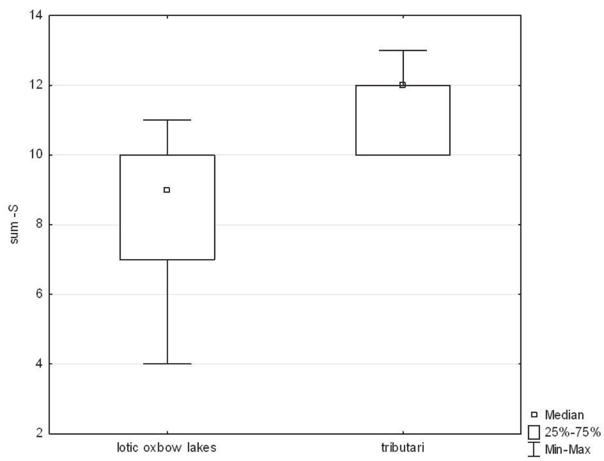

Figure 2

Significant statistical differences between the number of fungi and fungus-like organisms identified in the oxbow lakes and tributaries of the Narew in spring

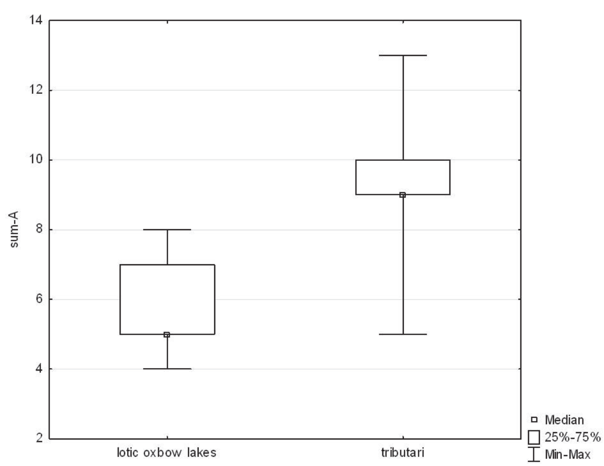

Figure 3

Significant statistical differences between the number of fungi and fungus-like organisms identified in the oxbow lakes and tributaries of the Narew in autumn

xylophilum, Rhizophlyctis rosea, Rhizophydium globosum, Leptomitus lacteus, Nowbya oligocantha, A. radiosa, Scoliolegnia asterophora and *S. diclina*. Only two taxa were observed in autumn: *Catenaria anguillulae, Rhipidium parthenosporum*.

In both research periods, i.e. in spring and in autumn, statistically significant correlations were determined between the number of taxa identified in the studied waters and some of the hydrochemical parameters. In spring, there was a positive correlation between the number of microfungi and temperature, pH, CO_2 and Mg, and a negative correlation between the number of microfungi and sulfates and chlorides (Fig. 4). The research revealed that a large number of the analyzed hydrochemical parameters affected the species diversity of micromycetes in autumn than in spring (Fig. 5).

A positive correlation with the number of fungi and fungus-like organisms was observed for such parameters as pH, biogenic compounds (ammoniacal nitrogen, nitrate nitrogen and phosphates) and suspended solids, while negative correlation was observed for mineral compounds, i.e. ions of calcium, magnesium, iron and dissolved solids.

Discussion

The obtained results of the hydrochemical and mycological analysis of water collected from the tributaries and the lotic oxbow lakes of the Narew during the two study periods, i.e. spring and autumn, indicate some differences between these reservoirs. The differences are related to, among others, the physicochemical parameters and the species diversity of microfungi in the analyzed waters.

The water in the tributaries had lower temperature, was more oxygenated and richer in nitrogen compounds than the water in the lotic oxbow lakes of the studied river (Tables 1 and 2).

The research showed a strong positive correlation between the number of the identified taxa and the temperature of their habitat in spring. The temperature of the analyzed water at this time of the year was not very high and varied between 5°C and 8°C. It is generally known that microfungi develop more efficiently in cooler waters, they produce more spores and are more likely to outcompete bacteria and zooplankton (Batko 1975). However, some authors claim that it is the higher temperature that stimulates the development of fungus-like organisms (Watanabe et al. 2008).

In cooler water, the solubility of oxygen is increased, which causes the increase in the diversity of mycobiota in surface water (Mazurkiewicz-Zapałowicz et al. 2012).

Another important factor in our study limiting the occurrence of fungi and fungus-like organisms was the oxygen content in the water. More oxygenated waters of the tributaries of the Narew had a larger number of microfungi than the less oxygenated oxbow lakes. Similar results were obtained by Misra (1982) who analyzed water in ponds in India and Mazurkiewicz-Zapałowicz et al. (2012) who studied the influence of abiotic factors on the development of fungi and fungus-like organisms in the lakes of the Drawa National Park in Poland. Other authors studying

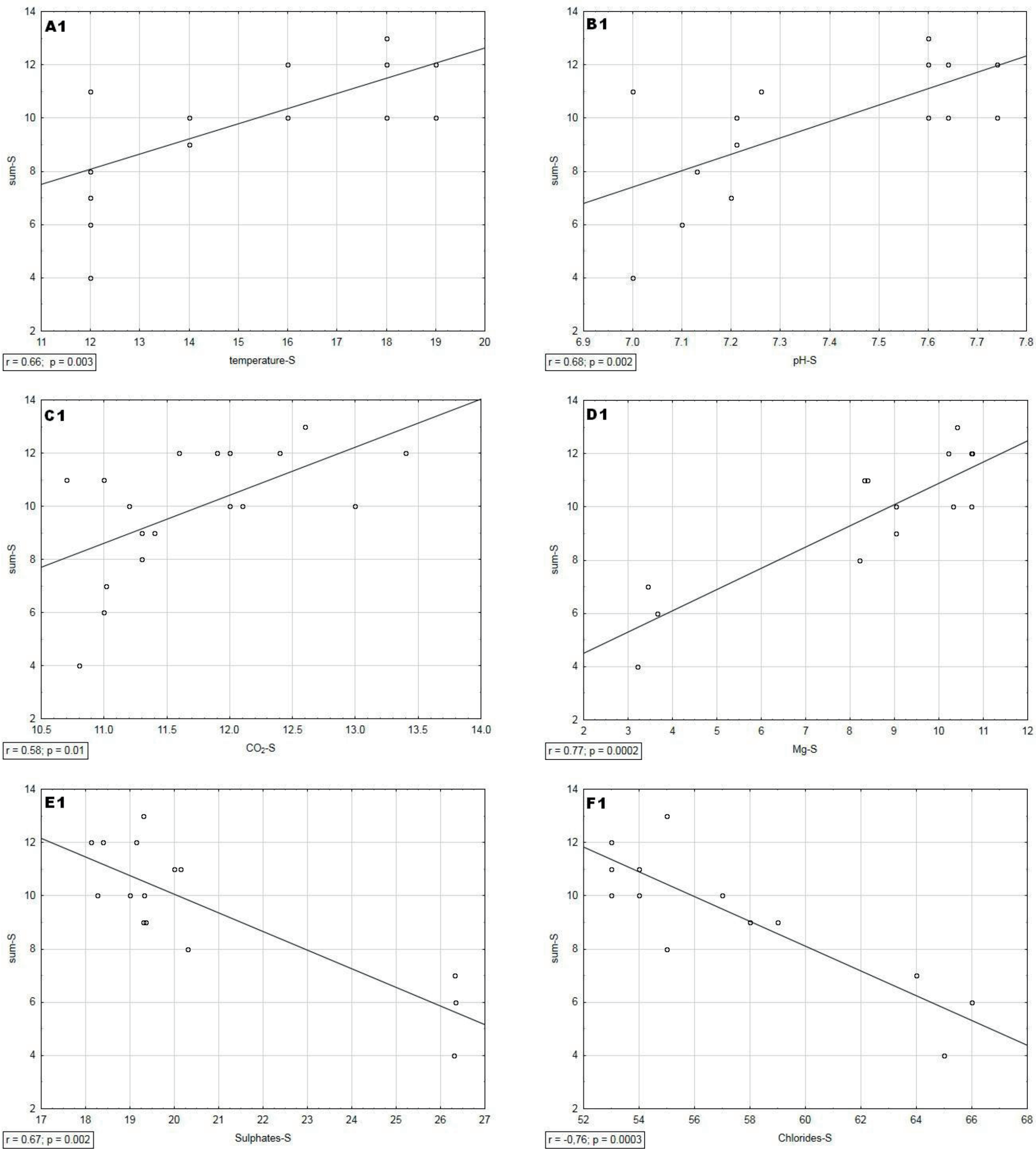

Figure 4

Statistically significant correlations between the number of fungi and fungus-like organisms identified in spring in the studied waters and the values of hydrochemical parameters: A1 – temperature, B1 – pH, C1 – carbon dioxide, D1 – magnesium, E1 – sulphates, F1 – chlorides

the species diversity of mycobiota inhabiting fish spawn and various mollusk species in well-oxygenated spring water have also confirmed this relationship (Czeczuga & Muszyńska 1997a,b; Czeczuga & Kiziewicz 1999; Czeczuga 2000). In our research, we found *Monoblepharis brachyandra* and *Monoblepharis macrandra* in all three tributaries of the Narew, whose water was rich in oxygen and only one oxbow lake

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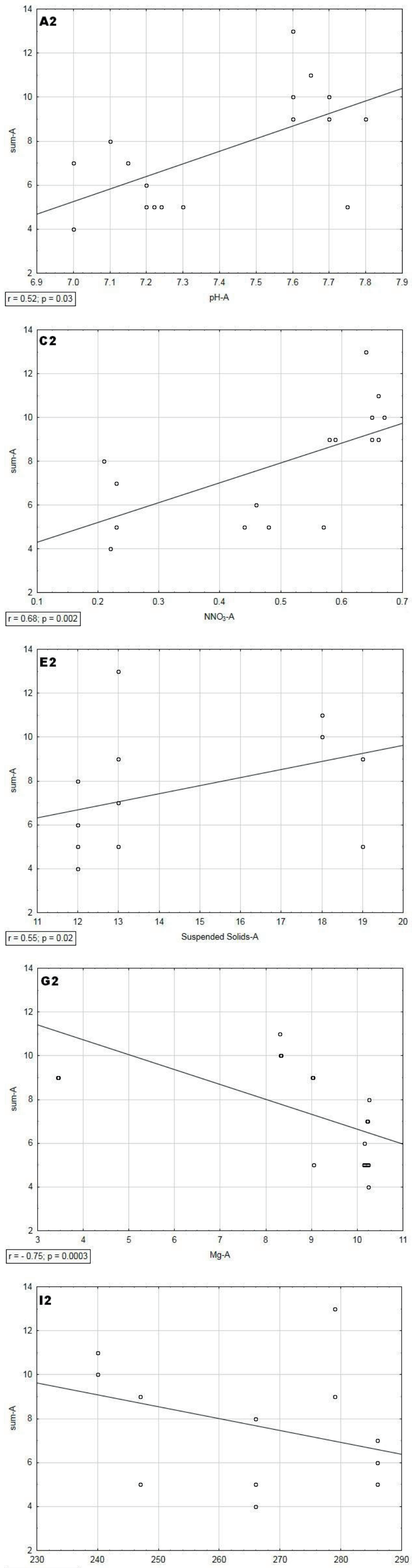

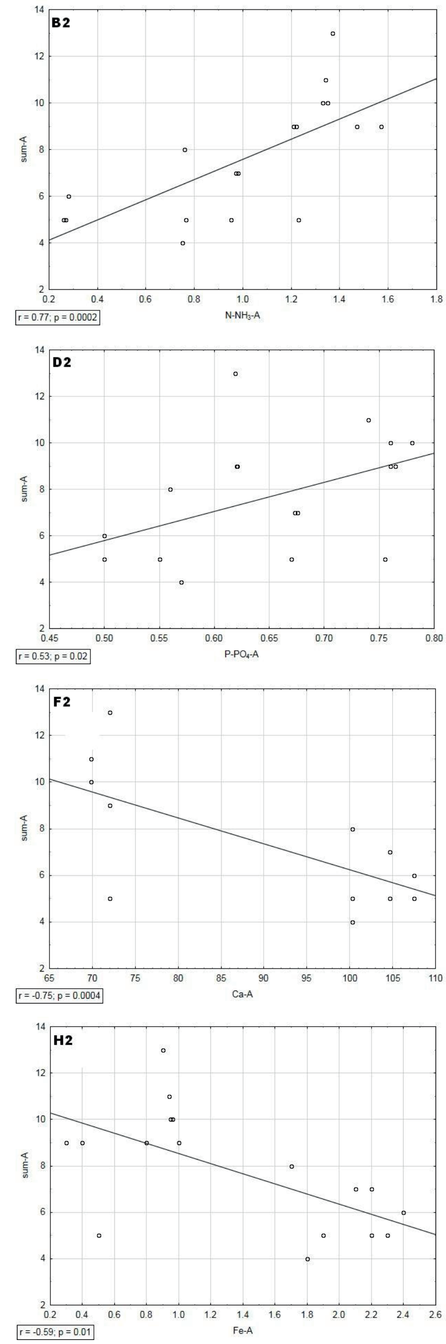

Figure 5

Statistically significant correlations between the number of fungi and fungus-like organisms identified in autumn in the studied waters and the values of hydrochemical parameters: A2 – pH, B2 – ammoniacal nitrogen, C2 – nitrate nitrogen, D2 – phosphates, E2 – suspended solids, F2 – calcium ions, G2 – magnesium, H2 – iron, I2 – dissolved solids contained lower concentrations of this element (Table 1). These species were already observed in the basin of the Narew River during our previous studies (Muszyńska et al. 2014). According to Batko (1975), these taxa are characterized by high oxygen demands. Lower concentration of this element in the oxbow lakes was probably due to the fact that the water of oxbow lakes was mostly directly adjacent to drifting, decaying organic substrates coated with clusters of bacteria.

Statistically significant positive correlations between the number of species of fungi and parameters such as ammoniacal nitrogen, nitrate nitrogen and phosphates were found in the studied reservoirs in autumn. Mazurkiewicz-Zapałowicz et al. (2012) also showed a positive effect of biogenic compounds on the development of aquatic mycobiota in the surface waters of lakes. An opposite phenomenon was observed when conducting research on fungi developing on the pollen of plants where an increase in levels of phosphorus compounds and nitrogen compounds in waters would limit the development of these microfungi (Czeczuga & Muszyńska 2004).

Some authors point out that any enrichment of water with organic matter results in an increase in the number and changes in the species composition of microfungi (Dynowska 1998; Godlewska et al. 2009; 2012; 2013; Czeczuga et al. 2014; 2015). Our study demonstrates greater diversity of microfungi, both in spring and autumn, in waters containing higher concentrations of nutrients. In mycological terms, water becomes a liquid source of nutrients for common saprotrophs characterized by high ecological plasticity, as it is becomes contaminated by organic compounds. These include e.g. *Saprolegnia ferax* and *Aphanomyces irregularis*, observed in both types of the investigated watercourses. This is probably due to the wide range of tolerance of these taxa to various impurities. Through trapping organic substances and their metabolization, the fungi play an important role in self-purification of these waters (Czeczuga et al. 2005; 2010; Kiziewicz & Nalepa 2008; Muszyńska et al. 2014). Research conducted by Ferreira & Chauvet (2011) indicates that the rate of decomposition of organic matter by fungi belonging to Hyphomycetes depends on i.a. temperature and nutrients in their habitat. An increase in temperature and the amount of nutrients stimulates, among others, their sporulation.

The obtained results indicate that the researched mycobiota showed greater species diversity in spring than in autumn. This was probably related to the chemistry of the surveyed waters. In autumn characterized by smaller species diversity of microfungi, statistical calculations confirmed the dominant negative correlations between the number of these microorganisms and the values of as many as five indicators such as: COD, Ca, Mg, Fe and dissolved solids. Czeczuga et al. (1990) also observed fewer species of fungi and fungus-like organisms during the mycological research in the Biebrza River at a low concentration of magnesium.

Conclusions

Mycological research conducted in spring and autumn in the reservoirs connected with the main Narew riverbed revealed that fungi and fungus-like organisms had more favorable conditions for the development in the tributaries than in the lotic oxbow lakes of the river. It was probably due to the fact that the waters of the investigated tributaries were cooler, more oxygenated and richer in organic matter.

Hydrochemical parameters such as temperature, pH, Mg, $N\text{-}NH_3$, $N\text{-}NO_3$, $P\text{-}PO_4$ and suspended solids showed positive correlation, and sulfates, chlorides, Ca, Fe correlated negatively with the number of taxa observed.

The species diversity of microfungi in both oxbow lakes and tributaries of the studied river was greater in spring than in autumn.

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