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Aquatic fungi growing on dead fragments of submerged plants

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Abstract

The authors investigated the dead fragments of 22 species of submerged plants in the water from three limnological and trophical different water bodies (spring, river and pond). A total of 184 species of aquatic fungi, including 119 zoosporic and 65 conidial species were found on the fragments investigated plants. The most common fungus species were *Aphanomyces laevis, Saprolegnia litoralis, Pythium rostratum* (zoosporic fungi) and *Acrodictys elaeidicola, Anguillospora longissima, Angulospora aquatica, Lemonniera aquatica, Mirandina corticola, Tetracladium marchalianum, Tetracladium maxiliformis, Trinacrium subtile* (conidial fungi).

Most fungus species were observed on the specimens of *Elodea canadensis* (33 fungus species), *Hippuris vulgaris* f. *submersa* (33), *Myriophyllum spicatum* (34) and *Potamogeton crispus* (33), fewest on *Ceratophyllum demersum* (24), *Fontinalis dalicarlica* and *Potamogeton nitens* (each 25).

The most fungi were growing in the water from River Supraśl (107), the fewest in the water from Pond Dojlidy (99). Some aquatic fungus species were observed in the water of only one of the three water bodies – in Pond Dojlidy (30), in Spring Jaroszówka (32) and in the River Supraśl (39) species. Seventy-five species growing only on fragments of single submerged plants. A number of zoosporic and conidial species (22 and four, respectively) appeared new to Polish waters. Out of these 119 zoosporic species, some are known as parasites or necrotrophs of fish.

Keywords: Water zoosporic and conidial fungi; Submerged plants; Water bodies; Hydrochemistry

Introduction

In lakes with normally developed littoral zone, macrophytes form three characteristic zones. Starting from the bank, these are emergent plants, floating leaved plants and submerged plants (Bernatowicz & Wolny, 1974; Fare, Dutartre, & Rebillard, 2001; Hutchinson, 1975). Submerged plants frequently form extensive subaquatic meadows on the lower littoral floor of a lake-type reservoir (Jeppsen, Sondergaard, & Christofferson, 1997).

In the terminal phase of vegetation, representatives of submerged plants, just like ground herbaceous plants, die on a mass scale. Both bacteria and lower aquatic fungi are involved in their mineralization (Batko, 1975).

Parasitic fungi of aquatic plants, including Endomycetes, particularly species of the genus *Doassansia* and *Tracya*, are relatively well known (Batko, 1975). However, the knowledge of saprophytic mycoflora of this group of plants is only fragmentary (Voronin, 1992). Therefore, we decided to establish the species composition of both zoosporic and conidial

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fungi involved in the mineralization of dead fragments of plants, which form this ecological group of macrophytes.

Material and methods

The study included 22 species of submerged plants (Table 2) collected at the end of the vegetative season from water bodies of North East Poland. The water for experiments was collected from three different water bodies; two running (spring Jaroszówka and river Supraśl) and one stagnant (pond Dojlidy):

- Spring Jaroszówka, localized in the north part of Białystok: Limnokrenic type, width 0.65 m, depth 0.12 m, discharge $2.4\,l\,s^{-1}$, surrounding without trees. The spring is surrounded by cultivated fields. The bed is covered with sand. At bank grows *Nasturtium officinale* R. Br., *Veronica anagallis* L. and on bed *Fontinalis antipyretica* L.
- River Supraśl, right-bank tributary of the middle part of the Narew river flowing through the Knyszyńska Forest: Length 106.6 km. The samples were collected from the site above the muncipal swimming pool at the sluice of an arm of the Supraśl river flowing just through the town Supraśl. The sampling site is surrounded by meadows. The bed is muddy, at bank grows *Phragmites australis* (Cav.) Trien. ex Steudel, *Sagittaria sagittifolia* L. *Hydrocharis mersus-ranae* L., *Potamogeton natans* L. and *Elodea canadensis* Rich.
- Pond Dojlidy, localized in the near of Białystok: Area 34.2 ha, max. depth 2.85 m, its south shores border with coniferous woods and its western part with the town of Białystok. The samples were collected from the western part of this pond, which is used by the inhabitants of the town as a beach. Near this sites grows *Phragmites australis* (Cav.) Trien. ex Steudel, *Schoenoplectus lacustris* (L.) Pala, *Nuphar lutea* (L.) Sibth.et Sm., *Nuphar pumila* (Timm.) DC and *Lemna minor* L.

Samples of water were collected from the river and the pond with a 1 l Ruttner sampler, approximately 2 m from the shore and 50 cm under the surface. In the spring, samples were taken from surface. After collecting water at each field, 19 hydrochemical parameters of these water bodies were determined (Table 1) according to the methods recommended by Standard methods for the examination of water and wasterwater (Greenberg, Clesceri, & Eaton, 1995) (Table 2).

Water samples used for the experiment differed in nutrients. The water from spring Jaroszówka was the most abundant in nitrogen (sum of all three forms), while the samples from the river Supraśl had the lowest nitrogen content. The highest level of phosphates was also observed in the spring Jaroszówka, the lowest in pond Dojlidy. The largest amounts sulphates, chlorides, calcium and magnesium were noted in spring Jaroszówka, while their lowest content was found in the river Supraśl (Table 1). For the determination of the presence of aquatic fungal species on the submerged plants the following procedure was employed: a certain number of pieces (with carefully removed periphyton) about 2 mg of each plant species was transferred to two samples of water representing each site, in an $1.0\,dm^3$ vessel (all together six vessels for each species) and placed in the laboratory at ambient temperature. A part of pieces from each vessel was observed under a light microscope and the mycelium of aquatic fungi on the pieces of plant was recorded. The methods are described in detail by Seymour and Fuller (1987). The pieces of the various plant species were observed under a microscope for one and half weeks. The duration of the experiments was 4 weeks. Identification of fungi species was based on morphology and biometric data of antheridia and oogonia of the zoosporic fungi and conidiophores and conidia of the hyphomycetes.

Identification of the fungi was aided the following keys: Batko (1975), Dick (1990), Johnson (1956), Karling (1977), Pystina (1998), Seymour (1970), and for hyphomycetes – Carmichael, Kendrick, Conners, & Sigler (1980), Dudka (1974), Ingold (1975), Matsushima

Table 1. Chemical properties of water in particular water bodies

Specification	Spring Jaroszowka	River Suprasl	Pond Dojlidy
Temperature (°C)	5.7	5.4	6.2
pH	8.01	7.81	7.99
O_2 ($mg\,l^{-1}$)	8.0	7.4	11.0
BOD_5 ($mg\,l^{-1}$)	1.8	5.6	9.0
COD ($mg\,l^{-1}$)	3.4	8.3	12.5
CO_2 ($mg\,l^{-1}$)	8.8	8.8	4.4
Alkalinity in $CaCO_3$ ($mval\,l^{-1}$)	6.2	4.4	3.1
N-NH_3 ($mg\,l^{-1}$)	0.01	0.14	0.28
N-NO_2 ($mg\,l^{-1}$)	0.024	0.008	0.005
N-NO_3 ($mg\,l^{-1}$)	2.17	0.01	0.0
P-PO_4 ($mg\,l^{-1}$)	2.40	1.50	0.26
Sulphates ($mg\,l^{-1}$)	51.83	19.75	33.73
Chlorides ($mg\,l^{-1}$)	22.0	14.0	20.0
Total hardness (mg $Ca\,l^{-1}$)	123.84	72.72	50.40
Total hardness (mg $Mg\,l^{-1}$)	19.35	12.04	12.90
Fe ($mg\,l^{-1}$)	0.50	0.75	0.70
Dry residue ($mg\,l^{-1}$)	403	312	254
Dissolved solids ($mg\,l^{-1}$)	357	253	251
Suspended solids ($mg\,l^{-1}$)	46	59	3

Table 2. Occurrence of aquatic fungi on fragments of the investigated submerged plant species

Species of plant	Fungi (see Table 3)	Number of fungus species
1. *Batrachium circinatum* (Sibth.) Fr.	36,38,39,40,46,49,51,54,65,105,111,114,122,127,130,137,142,150,153,156,158, 162,170,171,172,177,179	27
2. *Batrachium fluitans* (Lam.) Wimm.	45,48,53,54,70,72,77,78,100,102,103,114,124,125,127,129,137,139,150,153, 158,170,171,172,177,179	26
3. *Ceratophyllum demersum* L.	28,32,38,43,48,54,66,73,80,100,102,123,124,125,127,138,146,150,153,155,158, 170,171,177	24
4. *Ceratophyllum submersum* L.	22,31,41,50,55,66,72,78,84,85,99,101,111,125,127,133,134,138,153,156,158, 164,169,170,171,177,181	27
5. *Chara aspera* (Deth.) Willd.	12,14,35,45,60,81,97,112,114,122,125,127,134,136,138,146,148,150,151,153, 156,158,167,170,171,173,179	27
6. *Chara fragilis* Desv.	4,11,15,35,39,42,47,67,68,72,75,83,122,127,134,138,151,152,153,156,158,165, 167,168,170,171,173	27
7. *Chara vulgaris* L.	10,12,15,22,35,39,45,48,63,68,72,73,75,77,108,122,127,131,132,134,148,150, 153,158,159,165,168,170,173,179	30
8. *Elodea canadensis* Rich.	4,17,43,45,46,48,56,70,72,100,103,109,111,114,122,123,127,134,137,138,143, 150,153,157,158,159,163,170,171,173,177,180,182	33
9. *Fontinalis antipyretica* Hedw.	1,38,40,42,45,67,72,81,101,103,122,123,124,126,127,138,146,148,150,153,156, 158,170,171,173,174,178	27
10. *Fontinalis dalicarlica* Schimp.	46,47,53,65,67,72,97,108,114,117,120,122,126,127,134,137,146,150,153,156, 158,160,170,171,172	25
11. *Hippuris vulgaris* L. f. *submersa*	13,16,19,21,30,43,48,61,65,73,79,80,92,96,98,103,105,107,117,122,125,127, 137,146,148,150,153,156,158,170,171,177,179	33
12. *Myriophyllum spicatum* L.	4,7,21,34,37,44,48,57,66,67,72,76,80,95,97,111,114,117,122,125,127,137,138,146,148,149,150,153,156,158,170,171,177,179	34
13. *Myriophyllum verticillatum* L.	4,7,17,21,34,37,44,46,57,66,67,69,74,80,89,95,99,107,114,127,138,148,149,150,153,156,158,161,170,171,179	31
14. *Nitella mucronata* A. Br.	2,10,11,18,20,21,35,37,48,52,69,71,77,80,81,105,106,111,117,125,127,138,150, 153,158,170,177,179	28
15. *Potamogeton crispus* L.	6,16,21,26,36,42,60,66,67,85.90,95,97,107,113,119,122,124,125,127,146,147, 149,158,159,170,171,172,173,174,175,177,179	33
16. *Potamogeton densus* L.	16,23,24,25,42,48,57,62,72,92,93,95,97,113,114,124,125,127,137,144,149,153, 154,158,159,170,172,173,174,177	30
17. *Potamogeton filiformis* Pers	3,4,5,7,21,22,24,37,62,82,92,101,104,107,114,122,125,126,127,136,137,143, 146,153,158,162,170,171,172,179	30
18. *Potamogeton gramineus* L.	2,6,25,34,48,62,63,71,94,95,97,103,111,114,125,127,136,137,141,146,149,151, 153,158,162,170,171,172,179,181	30
19. *Potamogeton lucens* L.	8,16,23,25,55,58,59,87,88,91,94,103,104,114,117,119,124,125,127,137,146, 150,153,158,170,171,172,174,177,183	30
20. *Potamogeton nitens* Weber	24,29,48,60,63,85,92,94,104,115,117,118,124,125,126,127,150,153,158,161, 170,171,172,175,177	25
21. *Potamogeton perfoliatus* L.	4,5,16,25,27,34,48,62,63,67,94,95,97,104,114,117,118,122,124,125,127,135, 31 150,153,154,166,170,171,174,175,177	31
22. *Potamogeton rutilus* Wolfg.	4,9,16,24,26,33,47,60,86,104,107,114,116,117,125,127,136,140,145,150,153, 162,170,173,183,184	26

(1993), and works of the authors who were the first to describe the respective species.

Results

Chemical analysis of water used for the experiments (Table 1) revealed that the spring Jaroszówka was most abundant in nutrients; only the ammonium nitrogen content was the lowest there. The highest ammonium nitrogen concentration was found in pond Dojlidy, while he remaining nutrients in that pond occurred in trace amounts.

Zoosporic and conidial fungi growing on dead fragments of submerged plants have been presented in Table 3 and Fig. 1. Table 2 refers to the fungi found to grow on the respective plants. In total, 184 aquatic fungi, including 119 zoosporic and 65 conidial species were noted on the fragments of 22 species of submerged plants. A number of zoosporic and conidial species (22 and four, respectively) appeared new to the Polish waters. The most common zoosporic species included *Aphanomyces laevis* (11), *Saprolegnia litoralis* (9) and *Pythium rostratum* (13 plant species). Of the conidial fungi the most common were *Acrodictys elaeidicola* (12), *Anguillospora longissima* (15), *Angulospora aquatica* (22), *Lemonniera aquatica* (21), *Mirandina corticola* (20), *Tetracladium marchalianum* (22), *Tetracladium maxiliformis* (18) and *Trinacrium subtile* (on 13 fungus species). The largest number of aquatic fungus species developed on the fragments of *Myriophyllum spicatum* (34), *Elodea canadensis, Hippuris vulgaris* f. *submersa* and *Potamogeton crispus* (33 species on each), the fewest on *Ceratophyllum demersum* (24) and *Fontinalis dalicarlica* and *Potamogeton nitens* (25 on each).

With regard to the effectt of water on the growth of dead fragments of submerged plants, the most species were found to grow in the River Supraśl (107), the fewest in pond Dojlidy (99 species) (Table 4). Some aquatic fungus species were observed in the water of only one of the three water reservoirs – in pond Dojlidy (30), in spring Jaroszówka (32) and in the River Supraśl (39 species). Seventy-five species growing only on fragments of single submerged plants (Table 5).

Discussion

Submerged plants found in each water reservoir in varied amounts play a significant role in its functioning (Jeppsen et al., 1997). In the terminal phase of the vegetation period, huge masses of these plants die, especially in eutrophic lakes (Strand, 1999), constituting a substrate for the growth of varied species of microorganisms. The major role of bacteria in the mineralization of dead submerged plants has been emphasized (Karjalainen, Stefansdottir, Tuominen, & Kairesalo, 2001). Taking into consideration a large number of fungus species found on submerged plants in the present study, it can be assumed that also fungi play an important part in this process. The cells of fungus growing on a definite substrate are known to exploit its components by decomposition due to enzyme secretion onto the substrate (Howard & Gow, 2001). Both in zoosporic vegetable saprophytes (Bodeumann, Heininger, & Hohl, 1985) and conidial saprophytes (Abdullah & Taj-Aldeen, 1989; Zemek, Marvanová, Kuniak, & Kadlecikova, 1985) a number of hydrolases are involved in the substrate decomposition. A particularly large number of pectinases (Chamier & Dixon, 1982) and cellulases (Chamier, 1985) degrade cell-tissue structures of vegetable origin found in the respective aquatic environment (Chandrashekar & Kaveriappa, 1988). Pectinases decompose pectin which fuses cells and is found in the intercellular spaces, while cellulases affect the cellulose and lignin membranes of cells (Fisher, Davey, & Webster, 1983; Kirk & Obst, 1988; Zare-Maivan & Shearer, 1988) that built up a plant fragment. Once the cells have been decomposed, other enzymes get involved, including those of the protease group (Chamier & Dixon 1982), which degrade cytoplasmic proteins. At the final stage, specialistic enzymes which degrade chemical compounds characteristic of a particular plant are engaged (Singh, Sharma, Bhat, & Nats, 2001). In this way, the plant fragment as a substrate for lower aquatic fungi undergoes mineralization.

Chemical factors and numbers of fungal species

As revealed by the present study, the largest numbers of fungus species were found to grow on dead fragments of submerged plants in the River Supraśl. Some fungus species were noted only in this water reservoir. The analysis of water of the River Supraśl showed that its nutrient content ranges between the values noted for spring Jaroszówka and pond Dojlidy. However, in comparison to the other two reservoirs, the River Supraśl contained the lowest values of sulphates and chlorides known as chemical pollution indices. According to our previous studies, sulphates and chlorides delimit the occurrence of aquatic fungus species (Czeczuga, Kiziewicz, Godlewska, & Orłowska, 2002b; Czeczuga, Kiziewicz, & Orłowska, 2002c; Czeczuga, Kozłowska, & Godlewska, 2002d). However, certain zoosporic and conidial aquatic fungi may tolerate even high concentrations of chemical compounds, including nutrients (Czeczuga, 1993), and even toxins secreted by different species of cyanobacteria (Czeczuga & Orłowska, 2000; Czeczuga, Muszyńska, Mazalska, Godlewska, & Snarska, 2003c). Out of these 184 aquatic fungus

Table 3. Aquatic fungi found on submerged plants

Taxa	Plant (see Table 2)	Number of plants
Chytridiomycetes		
Olpidiales		
1. *Olpidium pendulum* Zop	9	1
Chytridiales		
2. *Blyttiomyces laevis* Sparrow	14,18	2
3. *Catenochytrium carolinianum* Berdan	17	1
4. *Chytridium xylophilum* Cornu	6,8,12,13,17,21,22	7
5. *Cladochytrium aneurae* Thirumalacher	17,21	2
6. *Cladochytrium aurantiacum* Richards	15,18	2
7. *Cladochytrium aureum* Karling	12,13,17	3
8. *Cladochytrium hyalinum* Berdan	19	1
9. *Cladochytrium taianum* Shen et Siang	22	1
10. *Diplophlyctis laevis* Sparrow	7,14	2
11. *Diplophlyctis nephrochytrioides* Karling	6,14	2
12. *Diplophlyctis verrucosa* Kobayashi et Ookubo	5,7	2
13. *Endochytrium digitatum* Karling	11	1
14. *Endochytrium ramosum* Sparrow	5	1
15. *Entophlyctis helioformis* (Dangeard) Ramsbottom	6,7	2
16. *Karlingia rosea* (de Bary et Woronin) Johanson	11,15,16,19,21,22	6
17. *Megachytrium westonii* Sparrow	8,13	2
18. *Nephrochytrium appendiculatum* Karling	14	1
19. *Nephrochytrium buttermerense* Willoughby	11	1
20. *Nephrochytrium stellatum* Couch	14	1
21. *Nowakowskiella elegans* (Nowakowski) Schroeter	11,12,13,14,15,17	6
22. *Nowakowskiella granulata* Karling	4,7,17	3
23. *Nowakowskiella hemishaeorospora* Shaneor	16,19	2
24. *Nowakowskiella macrospora* Karling	16,17,20,22	4
25. *Nowakowskiella profusa* Karling	16,18,19,21	4
26. *Phlyctochytrium aureliae* Ajello	15,22	2
27. *Phlyctochytrium reinboldtae* Persiel	21	1
28. *Podochytrium clavatum* Pfitzer	3	1
29. *Polyphagus euglenae* Nowakowski	20	1
30. *Rhizophydium ampullaceum* (Braun) Fischer	11	1
31. *Rhizophydium globosum* (Braun) Rabenhorst	4	1
Blastocladiales		
32. *Catenaria anguillulae* Sorokin	3	1
33. *Catenaria sphaerocarpa* Karling	22	1
Monoblepharidales		
34. *Gonapodya prolifera* (Cornu) Fischer	12,13,18,21	4
Hyphochytriomycetes		
Hyphochytriales		
35. *Hyphochytrium catenoides* Karling	5,6,7,14	4
Plasmodiophoromycetes		
Plasmodiophorales		
36. *Ligniera junci* (Schwartz) Maire et Tison	1,15	2
Oomycetes		
Saprolegniales		
37. *Achlya americana* Humphrey	12,13,14,17	4
38. *Achlya caroliniana* Coker	1,3,4,5,9	5
39. *Achlya colorata* Pringsheim	1,6,7	3
40. *Achlya debaryana* Humphrey	1,9	2

Table 3. (*continued*)

Taxa	Plant (see Table 2)	Number of plants
41. *Achlya flagellata* Coker	4	1
42. *Achlya klebsiana* Pieters	6,9,15,16	4
43. *Achlya orion* Coker et Couch	3,8,11	3
44. *Achlya polyandra* Hildebrand	12,13	2
45. *Achlya prolifera* Nees	2,5,7,8,9	5
46. *Achlya treleaseana* (Humphrey) Kauffman	1,8,10,13	4
47. *Aphanomyces irregularis* Scott	6,10,16,22	4
48. *Aphanomyces laevis* de Bary	2,3,7,8,11,12,14,16,18,20,21	11
49. *Aphanomyces parasiticus* Coker	1	1
50. *Aplanes androgynus* (Archer) Humphrey	4	1
51. *Aplanes turfosus* (Minden) Coker	1	1
52. *Brevilegnia unisperma* (Coker et Braxton) Coker et Braxton	14	1
53. *Calyptralegnia achlyoides* (Coker et Couch) Coker	2,10	2
54. *Dictyuchus sterilis* Coker	1,2,3	3
55. *Isoachlya anisospora* (de Bary) Coker	4,19	2
56. *Isoachlya curvata* (Minden) Cejp	8	1
57. *Isoachlya monilifera* (de Bary) Kauffman	12,13,16	3
58. *Isoachlya rhaetica* (Maurizio) Cejp	19	1
59. *Isoachlya toruloides* Kauffman et Coker	19	1
60. *Leptolegnia caudata* de Bary	5,15,20,22	4
61. *Protoachlya paradoxa* (Coker) Coker	11	1
62. *Protoachlya polyspora* (Lindstedt) Apinis	16,17,18,21	4
63. *Pythiopsis cymosa* de Bary	7,9,18,20,21	4
64. *Saprolegnia asterophora* de Bary	13	1
65. *Saprolegnia diclina* Humphrey	1,10,11	3
66. *Saprolegnia ferax* (Gruith) Thunet	3,4,12,13,15	5
67. *Saprolegnia furcata* Maurizio	6,9,10,12,13,15,21	7
68. *Saprolegnia glomerata* (Tiesenhausen)Lund	6,7	2
69. *Saprolegnia hypogyna* (Pringsheim) de Bary	13,14	2
70. *Saprolegnia irregularis* Johnson et Seymour	2,8	2
71. *Saprolegnia latvica* Apinis	14,18	2
72. *Saprolegnia litoralis* Coker	2,4,6,7,8,9,10,12,16	9
73. *Saprolegnia mixta* de Bary	3,7,11	3
74. *Saprolegnia monoica* Pringsheim	13	1
75. *Saprolegnia papillosa* (Humphrey) Apinis	6,7	2
76. *Saprolegnia torulosa* de Bary	12	1
77. *Saprolegnia turfosa* (Minden) Gauman	2,7,14	3
78. *Saprolegnia unispora* Coker et Couch	2,4	2
79. *Sommerstorffia spinosa* Arnaudow	11	1
80. *Thraustotheca clavata* (de Bary) Humphrey	3,11,12,13,14	5
Leptomitales		
81. *Apodachlya brachynema* (Hildebrand) Pringsheim	5,9,14	3
82. *Apodachlya pyrifera* Zopf	17	1
83. *Leptomitus lacteus* (Roth) Agardh	6	1
Lagenidiales		
84. *Lagenidium humanum* Karling	4	1
85. *Lagenidium marchalianum* de Wildeman	4,15,20	3
86. *Lagenidium podbielkowskii* Batko	22	1
87. *Lagenidium rabenhorstii* Zopf	19	1
88. *Myzocytium proliferum* Schenk	19	1
89. *Olpidiopsis achlyae* McLarty	13	1
90. *Olpidiopsis saprolegnia* (Braun) Cornu	15	1
Peronosporales		
91. *Pythiogeton autossytum* Drechsler	19	1
92. *Pythium afertile* Kanouse et Humphrey	11,16,17,20	4

Table 3. (*continued*)

Taxa	Plant (see Table 2)	Number of plants
93. *Pythium aquatile* Hohnk	16	1
94. *Pythium artotrogus* de Bary	18,19,20,21	4
95. *Pythium butleri* Subramaniam	12,13,15,16,18,21	6
96. *Pythium carolinianum* Matthews	11	1
97. *Pythium debaryanum* Hesse	5,10,12,15,16,18,21	7
98. *Pythium flevoense* Plaats-Niternik	11	1
99. *Pythium helicoides* Drechsler	4,13	2
100. *Pythium hypoandrum* Yu etWang	2,3,8	3
101. *Pythium indigoferae* Butler	4,9,17	3
102. *Pythium indicum* Balakrishnan	2	1
103. *Pythium inflatum* Matthews	2,3,8,9,11,18,19	7
104. *Pythium intermedium* de Bary	17,19,20,21,22	5
105. *Pythium myriotylum* Drechsler	1,11,14	3
106. *Pythium oedochilum* Drechsler	14	1
107. *Pythium palingenes* Drechsler	11,13,15,17,22	5
108. *Pythium paroecandrum* Drechsler	7,10	2
109. *Pythium periilum* Drechsler	8	1
110. *Pythium polysporum* Sorokin	20	1
111. *Pythium polypapillatum* T. Ito	1,4,8,12,14,18	6
112. *Pythium pulchrum* Minden	5	1
113. *Pythium pythioides* Roze et Cornu	15,16	2
114. *Pythium rostratum* Butler	1,2,5,8,10,12,13,16,17,18,19,21,22	13
115. *Pythium tenue* Gobi	20	1
116. *Pythium torulosum* Coker et Patterson	22	1
Zygomycetes		
Zoophagales		
117. *Zoophagus insidians* Sommerstorff	10,11,12,14,19,20,21,22	8
Endomycetes		
Endomycetales		
118. *Hansenula anomala* (Hansen) H. et P. Sydow	20,21	2
Ustiliginales		
119. *Doassansia martianoffiana* (Thüm.) Schroeter	15,19	2
Hyphomycetes		
120. *Acremonium grandisporum* Matsushima	10	1
121. *Acrodictys bambusicola* M.B. Ellis	14	1
122. *Acrodictys elaeidicola* M.B. Ellis	1,5,6,7,8,9,10,11,12,15,17,21	12
123. *Acrodictys martinii* Crane et Dumont	3,8,9	3
124. *Alatospora acuminata* Ing.	2,3,9,15,16,19,20,	8
125. *Anguillospora longissima(*Sacc. et Syd.) Ing.	2,3,4,5,11,12,14,15,16,17,18, 19,20,21,22	15
126. *Anguillospora pseudolongissima* Ranz.	9,10,17,2	4
127. *Angulospora aquatica* S. Nilss.	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	22
128. *Arborispora palma* Ando	16	1
129. *Arbusculina fragmentans* Marvanová et Marvan	2	
130. *Arthrobotrys ellipsoidea* Tubaki et Yamanaka	1	1
131. *Arthrobotrys* stilbacea Fres.	7	1
132. *Bacillispora aquatica* S. Nilss.	7	1
133. *Beverwykella pulmonaria* (v. Bever.) Tubaki	1,4	
134. *Calcarispora* hiemalis Marvanová et Marvan	4,5,6,7,8,10	6
135. *Camposporium pellucidum* (Grove) S. Hughes	21	1
136. *Canalisporium caribense* (Hol.-Jech. et Merc.) Now. et Kuth.	5,17,18,22	4

Table 3. (*continued*)

Taxa	Plant (see Table 2)	Number of plants
137. *Centrospora aquatica* Iqbal	1,2,8,10,11,12,16,17,18,19	10
138. *Centrospora filiformis* (Greath.) Petersen	3,4,5,6,7,8,9,12,13,14	10
139. *Ceratosporella basicontinua* Matsushima	2	1
140. *Cladosporium peruamazonicum* Matsushima	22	1
141. *Clavariopsis aquatica* de Wild.	18	1
142. *Colispora elongata* Marvanová	1	1
143. *Corynesporella simpliphora* Matsushima	8,17	2
144. *Curucispora ombrogena* Ando et Tubaki	16	1
145. *Dactylaria fusiformis* Shearer et Crane	22	1
146. *Dactylella submersa* (Ing.). Nilss,	3,5,9,10,11,12,15,17,18,19	10
147. *Filosporella exillis* Gulis et Marvanová	15	1
148. *FiagelIospora curvuIa* Ing.	5,7,9,11,12,13	6
149. *Heliscus lugdunensis* Sacc. et Therry	12,13,15,16,18	5
150. *Heliscus submersus* Hudson	1,2,3,5,7,8,9,10,11,12,13,14,19,20,21,22	16
151. *Kantospora halophila* Roland. et Honr.	5,6,18	3
152. *Kylindria keitae* Ramb. et Onofri	6,18	2
153. *Lemonniera aquatica* de Wild.	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22	21
154. *Lemonniera terrestris* Tubaki	16,21	2
155. *Leuliisinea amazonensis* Matsushima	3	1
156. *Lunulospora curvula* Ing.	1,4,5,6,9,10,11,12,13	9
157. *Microstella pluvioriens* Ando et Tubaki	8,13	2
158. *Mirandina corticola* G. Arnaud	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	20
159. *Paraarthrocladium amazoense* Matsushima	7,8,15,16	4
160. *Paradactylella peruviana* Matsushima	10	1
161. *Phaedodactylium acutisporum* Matsushima	13,20	2
162. *Phialogeniculata multiseptata* Matsushima	1,17,18,22	4
163. *Pithomyces obscuriseptatus* Matsushima	8	1
164. *Polycladium equiseti* Ing.	4	1
165. *Pseudohansfordia dimorpha* Matsushima	6,7	2
166. *Retiarius bovicornutus* Olivier	21	1
167. *Sigmoidea prolifera* (Peter.) Crane	5,6	1
168. *Speiropsis irregularis* Petersen	6,7	2
169. *Sporidesmium filisporum* Matsushima	4	1
170. *Tetracladium marchalianum* de Wild.	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22	22
171. *Tetracladium maxiliformis* (Rostr.) Ing.	1,2,3,4,5,6,8,9,10,11,12,13,15,17,18,19,20,21	18
172. *Tetracladium setigerum* (Grove) Ing.	1,15,16,17,18,19,20	7
173. *Tricellula aquatica* Webster	5,6,7,8,9,15,16,22	8
174. *Tricladium angulatum* Ing.	9,15,16,19,21	5
175. *Tricladium anomalum* Ing.	15,20,21	3
176. *Tricladium attenulatum* Iqbal	16	1
177. *Trinactrium subtile* Riess ap. Fres.	1,2,3,4,8,11,12,14,15,16,19,20,21	13
178. *Tripospermum variabile* Matsushima	9	1
179. *Triscelophorus monosporus* Ing.	1,2,5,7,11,12,13,14,15,17,18	11
180. *Vargamyces aquaticus* (Dudka)Tóth	8	1
181. *Varicosporium delicatum* Iqbal	4,18	2
182. *Varicosporium elodeae* Kegel	8	1
183. *Veronea bothryosa* Cif. et Montem.	19,22	2
184. *Ypsilina graminea* (Ing. et al.) Descals et al.	22	1

species, which were found to grow on the fragments of submerged plants, some species grew only in water from one water bodies. The largest number of fungal species occurred on submerged plants in the running waters (spring Jaroszówka, river Supraśl), there were fewer in the stagnant water (pond Dojlidy). Among the three water bodies included in the study, the water of Dojlidy pond has the smallest amounts of carbon dioxidae, nitrate and nitrite nitrogen, phosphates, calcium, dry residue, dissolved and suspended solids, but by the largest amounts of oxygen, BOD_5, COD and ammonium nitrogen. Water of this pond had the lowest

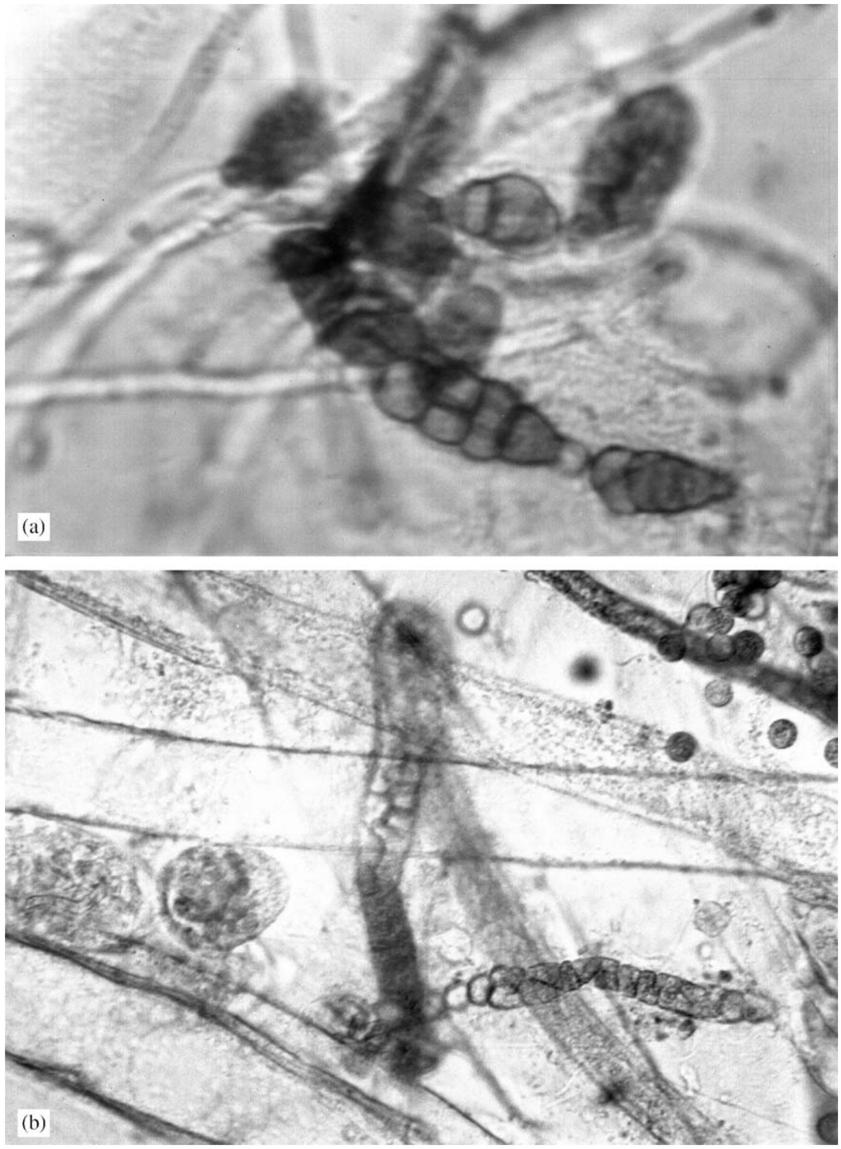

Fig. 1. Some fungus species growing on the specimens of submerged plants: (a) *Pithomyces sterilis* (Oomycetes)-hyphae from sporangia (280–24 μm). (b) *Dictyuchus obscuriseptats* (Hyphomycetes) – hyphae from conidia (18.5 × 12.5 μm).

alkalinity. Thus, the number of aquatic fungi in a water bodies depends not only on abiotic factors (water chemistry) but also on biotic properties, especially on a variety of positive or negative interactions within a group of hydrobionts inhabiting the water bodies (Czeczuga, Godlewska, Kiziewicz, Muszyńska, & Mazalska, 2005).

Fungi growing only on fragments of single plants

Most aquatic fungus species found on the fragments of submerged plants were found to grow on at least a few plant species. However, a 75 of zoosporic and conidial fungi were observed on single plant species. *Saprolegnia torulosa* was found only on *Myriophyllum spicatum* in water from pond Dojlidy. *Leptomitus lacteus* was found only on *Chara fragilis* in the River Supraśl, *Lagenidium podbielkowskii* on *Potamogeton rutilus* in pond Dojlidy. Six other fungus species were observed only on the fragments of that pond-weed. Fragments of *Ceratophyllum submersum* constituted a substrate for seven species, including the aero-aquatic species *Beverwykella pulmonaria*. This species was first described in overground conditions by Beverwijk van (1954). We found this fungus in rainwater flowing down from leaves of various tree species (Czeczuga & Orłowska, 1998) and from roofs in urban and rural areas (Czeczuga & Orłowska, 1997). A number of other zoosporic and conidial fungus species were noted only on single species

Table 4. Aquatic fungi found on submerged plants in different water bodies

Water from fungi species	Fungi (see Table 3)	Only in one water bodies	Total number
Spring Jaroszówka	2,4,5,8,10,16,17,21,23,24,27,31,38,39,43,44,45,46,47, 48,52,53,54,57,62,63,65,66,67,69,70,72,73,75,78,79, 81,88,89,90,92,94,95,97,98,99,100,101,103,104,105, 107,109,110,111,114,115,117,118,120,121,122,124, 125,126,127,129,131,134,136,137,138,139,142,143, 146,147,148,149,150,151,153,154,156,158,159,161, 162,164,166,167,170,171,172,173,174,175,177,179, 180,183	5,8,10,17,27,31,44,52,54,65,69,75,79,81,88, 89,90,98,104,109,110,118,120,121,139,142, 147,161,164,166,175,180	101
River Supraśl	1,2,3,4,9,11,12,15,16,19,20,21,22,23,24,25,28,29,30, 32,35,37,38,39,40,42,54,46,47,48,49,56,58,62,64,67, 70,71,72,73,74,77,78,80,83,85,87,92,94,95,96,97,99, 102,103,105,106,108,111,112,113,114,115,116,122, 123,124,125,126,127,128,129,133,135,136,137,138, 140,141,143,146,149,150,152,153,154,155,156,158, 159,160,162,163,165,167,168,169,170,171,172,173, 174,177,179,181,183,184	1,3,9,11,12,15,19,20,25,28,29,32,37,40,49,56, 58,64,71,74,83,85,87,102,106,113,116,123, 128,133,135,140,141,155,160,163,165, 168,169	107
Pond Dojlidy	4,6,7,13,14,18,21,22,26,30,33,34,35,36,39,41,42,43, 45,46,47,48,50,51,53,55,57,59,60,62,63,66,67,68,70, 72,73,76,77,80,82,84,86,91,92,93,94,95,96,97,100, 101,103,107,108,111,112,114,117,119,122,124,125, 126,127,130,131,132,134,136,137,138,144,145,146, 148,149,150,151,152,153,154,156,157,158,159,162, 167,170,171,172,173,176,177,178,179,181,182,184	6,7,13,14,18,26,33,34,36,41,50,51,55,59,60, 68,76,82,84,86,91,93,119,130,132,144,145, 157,176,178	99

Table 5. Fungi growing only on fragments of single plants

Species of plant	Fungi (see Table 3)	Number of fungus species
1. *Batrachium circinatum* (Sibth.) Fr.	49,51,130,142	4
2. *Batrachium fluitans* (Lam.) Wimm.	102,129,139	3
3. *Ceratophyllum demersum* L.	28,32,155	3
4. *Ceratophyllum submersum* L.	31,41,50,84,133,164,169	7
5. *Chara aspera* (Deth.) Willd.	14,112	2
6. *Chara fragilis* Desv.	83	1
7. *Chara vulgaris* L.	131,132	2
8. *Elodea canadensis* Rich.	56,109,163,180,182	5
9. *Fontinalis antipyretica* Hedw.	1,178	2
10. *Fontinalis dalicarlica* Schimp.	120,160	2
11. *Hippuris vulgaris* L. f. *submersa*	13,19,30,61,79,96,98	7
12. *Myriophyllum spicatum* L.	76	1
13. *Myriophyllum verticillatum* L.	64,74,89	3
14. *Nitella mucronata* A. Br.	18,20,52,106,121	5
15. *Potamogeton crispus* L.	90,147	2
16. *Potamogeton densus* L.	93,128,144,176	4
17. *Potamogeton filiformis* Pers	3,82	2
18. *Potamogeton gramineus* L.	141	1
19. *Potamogeton lucens* L.	8,58,59,87,88,91	6
20. *Potamogeton nitens* Weber	29,110,115	3
21. *Potamogeton perfoliatus* L.	27,135,166	3
22. *Potamogeton rutilus* Wolfg.	9,33,86,116,140,145,184	7
Total of fungus species		75

out of the 22 submerged plants examined. Out of these 75 fungus species, worthy of noting is the finding also of two such interesting fungal species as *Polyphagus euglenae* and *Curucispora ombrogena. Polyphagus euglenae* in literature it is described as a parasite of filiform green algae (Batko, 1975; Fuller & Jaworski, 1987; Karling, 1977). In our investigation, this fungus species was found on *Potamogeton nitens* in the water from the river Supraśl. *Curucispora ombrogena* was first described in rainwater flowing down from leaves of tree in Japan (Ando, 1992). In the present study *Curucispora ombrogena* was found to grow on fragments of *Potamogeton densus* in water from pond Dojlidy.

Fish parasitic species growing on the fragments of submerged plants

Some aquatic zoosporic species grow only on vegetable substrates, while others leading a parasitic life cause great losses in the population of economically exploited fish (Schaperclaus, 1991). We frequently observed a number of zoosporic fungus species known as fish parasites on the fragments of certain species of submerged plants. Worth noting is the finding of such Oomycete species as *Achlya flagellata, Achlya prolifera, Aphanomyces laevis, Isoachlya anisospora, Saprolegnia diclina, Saprolegnia ferax, Saprolegnia mixta* and *Thraustotheca clavata. Achlya flagellata* was found to grow only on the fragments of *Ceratophyllum submersum* in pond Dojlidy, *Achlya prolifera* on five plant species in all the three water bodies, *Aphanomyces laevis* on the fragments of 11 plants also in the three water bodies. The three *Saprolegnia* species were observed in all the water bodies on a few species of submerged plants. *Isoachlya anisospora* was found on the fragments of *Ceratophyllum submersum* and *Potamogeton lucens* in both cases in pond Dojlidy. *Thraustotheca clavata* was found on the fragments of five plant species in the River Supraśl and pond Dojlidy. These fungus species are known to have caused great losses in hatcheries, in aquacultures (Dudka, Isayeva, & Davydov, 1989) and in lake fish stock (Meng, 1980). Their growth along with other species has been encountered on the eggs of various species (Czeczuga & Muszyńska, 1999), on hatch and on adult fish specimens (Czeczuga, Kiziewicz, & Danilkiewicz, 2002a).

New species to the Polish waters

In total, 22 zoosporic and four conidial fungus species found on the fragments of submerged plants are new to the Polish waters. Most of them have been already reported from other continents on different substrates.

For instance, in spring Jaroszówka on the fragments of *Potamogeton filiformis* and *Potamogeton perfoliatus*, we found *Cladochytrium aneurae*, which was once described in Mysore (India) to induce diseases in Bryophytes (Thirumalacher, 1947). In the River Supraśl, the fragments of Charales were colonized by three species of the genus *Diplophlyctis*, known as parasites of *Chara* and *Nitella* (Karling, 1967; Ookubo, 1954; Sparrow, 1939). In pond Dojlidy, we found *Endochytrium ramosum* on *Chara aspera* and *Endochytrium digitatum* on *Hippuris vulgaris* f. *submersa*. The former was described as a saprophyte (Sparrow, 1933), the latter on *Chara* and *Nitella* blades, both in the USA (Karling, 1937). *Entophlyctis helioformis*, known as a parasite of algae (Dangeard, 1888), was found to grow on two species of the genus *Chara* only in the River Supraśl. Sparrow (1933) described *Megachytrium westonii* as a parasite of *Elodea canadensis*. We found this fungus only in spring Jaroszówka also on the fragments of *Elodea canadensis* and on *Myriophyllum verticillatum.* In pond Dojlidy, on the fragments of *Nitella mucronata* we observed *Nephrochytrium appendiculatum*, which was also described as a saprophyte of *Chara* and *Nitella* species in North America (Karling, 1938). Another species of this genus, *Nephrochytrium stellatum*, also described in North America (Couch, 1938) was found to grow in pond Dojlidy on the fragments of *Nitella mucronata, Nowakowskiella granulata*, first reported from plant debris in Brasil (Karling, 1944), was found to grow in the River Supraśl and pond Dojlidy on the fragments of a few plants. *Ligniera junci* was reported by Schwartz (1910) as a parasite of Juncaceae roots, while its biology was investigated by Maire and Tison (1911). In our study, this fungus was found on the fragments of *Batrachium circinatum* and *Potamogeton crispus* only in pond Dojlidy. In the same water reservoir, on the fragments of *Batrachium circinatum* we found *Aplanes turfosus*, known as a soil and aquatic phytosaprophyte (Von Minden, 1916). *Isoachlya curvata* and *Isoachlya rhaetica* are also new to Polish waters. The former, known as a soil and aquatic zoosaprophyte (Von Minden, 1916; Cejp, 1959), was found to grow on the fragments of *Elodea canadensis* in the River Supraśl, the latter, referred to as a saprophyte (Maurizio, 1894; Cejp, 1959), on *Potamogeton lucens* in the same reservoir. Three *Pythium* species (Czeczuga & Snarska, 2001) and a representative of Pythiaceae – *Pythium autossytum* are also new to Polish waters. The latter species was described from a stalk of reed-mace *Typha latifolia* (Drechsler, 1932). In our study, it was found to grow on the fragments of *Potamogeton lucens* in the water of pond Dojlidy. We found *Pythium flevoense* of the genus *Pythium*, first described by van der Plaats-Niterink (1972) from a soil sample in Netherlands, on the fragments of *Hippuris vulgaris* f. *submersa* only in spring Jaroszówka. *Pythium hypoandrum* was found both in the spring and pond on the fragments of a few plants. It was previously described from China (Yong-Nian & Guo-Znong, 1989), from streams in the Crimea (Jacenko, 1992). *Pythium paroecandrum* was encountered in the water of the River Supraśl and pond Dojlidy on the fragments of *Chara vulgaris* and *Fontinalis dalicarlica*. It was first described by Drechsler (1930) from discolored roots of *Allium vineale* near McLean in the USA. Also *Doassansia martianoffiana*, a representative of Endomycetes appears new to Polish waters. We found its growth in pond Doilidy on the fragments of two pond-weed species *Potamogeton crispus* and *Potamogeton lucens*. In the literature of the subject it has been known as a parasite of leaves of the genus *Potamogeton* (Batko, 1975).

New species of Hyphomycetes included *Ceratosporella basicontinua*, *Paradactylella peruviana* and *Sporidesmium filisporum*, *Ceratosporella basicontinua* was found on the fragments of *Batrachium fluitans* only in water samples from spring Jaroszówka. *Paradactylella peruviana* was encountered on waters moss *Fontinalis dalicarlica* only in the River Supraśl. *Sporidesmium filisporum* was observed in the River Supraśl but only on the fragments of *Ceratophyllum submersum*. All these three species were first described from South America in the Amazon basin by Matsushima (1993) on fallen palm petioles; *Ceratosporella basicontinua* in the Rio Yuturi in Equador, *Paradactylella peruviana* in overground conditions in Tembopata reserve in Peru and *Sporidesmium filisporum* also in land conditions in Equador in Cuabeno National Park. For the latter two species, the River Supraśl is a new type of habitat.

Fungus species reported from distant continents

The present study has confirmed that aquatic fungi encounter no geographic barriers and environmental conditions play a decisive role in their occurrence; therefore, many species occur in waters of a similar hydrochemical type at various latitudes. Thus, the majority of species, both zoosporic and conidial, are cosmopolitan. A number of fungi reported from remote countries were found on the fragments of the submerged plants examined, e.g. Hyphomycete species which were first described from the Amazon basin in South America (Matsushima, 1993). The conidial fungi found in the present study include: *Acremonium grandisporum, Ceratosporella basicontinua, Cladosporium peruamazonicum, Corynesporella simpliphora, Leuliisinea amazonensis, Paraarthrocladium amazoense, Paradactylella peruviana, Phaedodactylium acutisporum, Phialogeniculata multiseptata, Pithomyces obscuriseptatus, Pseudohansfordia dimorpha* and *Sporidesmium filisporum*. We observed their growth on various species of submerged plants in the water of all three water bodies involved in the study. The spread of spores of zoosporic fungi and conidial Hyphomycetes at long distances is largely determined by air currents and waterfowl during autumn and spring flights (Wood-Eggenschwiler & Bärlocher, 1985; Czeczuga, 2004).

The occurrence of certain rare species

The fragments of certain species of submerged plants were colonized by rare and biologically interesting species. Of zoosporic species these were *Sommerstorffia spinosa* and *Leptomitus lacteus,* while the conidial fungi included *Arborispora palma, Calcarispora hiemalis, Filosporella exillis, Retiarus bovicornutus*, *Tripospermum variabile* and *Ypsilina graminea, Sommerstorffia spinosa*, a predacious species catching rotifers, occurs in soil (Czeczuga, Mazalska, & Orłowska, 2000) and as an aquatic epiphyte. To date it has been encountered in a few countries, including northeastern Poland. In Poland it was found in spring Jaroszówka, in polytrophic pond Fosa, in two rivers, two mesotrophic types and in oligotrophic Lake Białe (of Wigry) (Czeczuga, Orłowska, & Kozłowska, 2001). In the present study, *Sommerstorffia spinosa* was found to grow on the fragments of *Hippuris vulgaris* f. *submersa* in spring Jaroszówka. *Leptomitus lacteus* is not a rare species but its biology is interesting as it is able to grow on liquid substrates with no contact with a solid substrate (Batko, 1975). This nitrophilous species is a mycoflora representative found in waters severely polluted with municipal sewage. Later studies have, provided data indicating that this fungus may lead a parasitic life on eggs of fish (Czeczuga & Woronowicz, 1993) and on adult fish (Czeczuga et al., 2002a). In the present study, *Leptomitus lacteus* was found to grow of the fragments of *Chara fragilis* in the River Supraśl.

As for the conidial species, *Arborispora palma* was described from overground environment (Ando, 1992), from rainwater flowing down oak-tree leaves (Ando & Kawamoto, 1986), from building roofs (Czeczuga & Orłowska, 1997) and from melting snow collected from trees (Czeczuga & Orłowska, 1998). It was found to grow in the River Supraśl on the fragments of *P. densus*. According to Marvanová & Bärlocher (2001), *Calcarispora hiemalis* and *Ypsilina graminea* are also rare conidial species, although the former fungus is not rare any more in northeastern Poland (Czeczuga et al., 2001, 2002b; Czeczuga, Kiziewicz, & Mazalska, 2003b). In our study, *Calcarispora hiemalis* was found on the fragments of six plant species in all the three water bodies, while *Ypsilina graminea* only on *Potamogeton rutilus* in the River Supraśl and pond Dojlidy.

Worth noting is the finding of *Filosporella exillis* on the fragments of *Potamogeton crispus* in water samples from spring Jaroszówka. Until now, this fungus has been known only from three sites – one in Belarussia and two in Poland. It was first described by Gulis and Marvanová (1998) from river water in Belarussia and then in the River Biebrza within the Biebrza National Park (Czeczuga et al., 2003b) and in the water of the River Bug within Podlasie stretch (Czeczuga et al., 2002c). *Retiarus bovicornutus* is known from literature to inhabit peatbogs (Ando, 1992); it has been encountered in rainwater in Japan (Ando, 1992) and in melting ice from the River Supraśl (Czeczuga & Orłowska, 1999). In the present study, *Retiarus bovicornutus* was found to grow on the fragments of *Potamogeton perfoliatus* only in the water of spring Jaroszówka. *Tripospermum variabile* was observed on the fragments of aquatic moss *Fontinalis antipyretica* only in pond Dojlidy. It was first described from decaying fruit of *Disporis discolor* on Taiwan (Matsushima, 1980). We found it in oligo-mesotrophic Lake Hańcza, being the deepest lake in the European Lowland (Czeczuga, Kozłowska, & Kiziewicz, 2003a).

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References

Abdullah, S. K., & Taj-Aldeen, S. J. (1989). Extracellular enzymatic activity of aquatic and aero-aquatic conidial fungi. *Hydrobiologia*, *174*, 217–223.

Ando, K. (1992). A study of terrestrial aquatic Hyphomycetes. *Transactions of the Mycological Society of Japan*, *3*, 15–425.

Ando, K., & Kawamoto, J. (1986). *Arborispora*, a new genus Hyphomycetes. *Transactions of the Mycological Society of Japan*, *27*, 119–128.

Batko, A. (1975). *Zarys hydromikologii (An outline of hydromycology)*. Warszawa: PWN [In Polish].

Bernatowicz, S., & Wolny, P. (1974). *Botanika dla limnologów i rybaków [Botany for limnologist and fishermen]*. Warszawa: PWRiL [In Polish].

Beverwijk van, A. L. (1954). Three new fungi *Helicoon pluriseptatum* n. sp., *Papulospora pulmonaria* n. sp. and *Tricellula inaequalis* n. gen., n. sp. *Antonie van Leeuwenhoek*. *Journal of Microbiology and Serology*, *20*, 10–16.

Bodeumann, J., Heininger, V., & Hohl, H. R. (1985). Extracellular enzymes of *Phytophthora infestans*: endocellulase, B-glucosidase and 1,3-B glucanases. *Canadian Journal of Microbiology*, *31*, 75–83.

Carmichael, J. W., Kendrick, W. B., Conners, I. L., & Sigler, L. (1980). *Genera of Hyphomycetes*. Edmonton: Alberta Press.

Cejp, K. (1959). Oomycetes. I. In *Flora CSR* (pp. 1–168). Praha: Cesk. Acad. Ved.

Chamier, A.-C. (1985). Cell-wall degrading enzymes of aquatic hyphomycetes: A review. *Botanical Journal of the Linnean Society*, *91*, 67–81.

Chamier, A.-C., & Dixon, P. A. (1982). Pectinases in leaf degradation by aquatic hyphomycetes: The enzymes and leaf maceration. *Journal of General Microbiology*, *128*, 2469–2483.

Chandrashekar, K. R., & Kaveriappa, K. M. (1988). Production of extracellular enzymes by aquatic hyphomycetes. *Folia Microbiologica (Prague)*, *33*, 55–58.

Couch, J. N. (1938). A new chytrid on *Nitella*: *Nephrochytrium stellatum*. *American Journal of Botany*, *25*, 507–511.

Czeczuga, B. (1993). Aquatic fungi of the Gorbacz and Ostrówki peatbogs. *Acta Mycologica*, *28*, 9–75.

Czeczuga, B. (2004). Dissemination of microfungi in the aquatic environment. *Recent Research Developments in Microbiology*, *4*, 121–130.

Czeczuga, B., Godlewska, A., Kiziewicz, B., Muszyńska, E., & Mazalska, B. (2005). Effect of aquatic plants on the abundance of aquatic zoosporic fungus species. *Polish Journal of Environmental Studies*, *14*, 149–158.

Czeczuga, B., Kiziewicz, B., & Danilkiewicz, Z. (2002a). Zoosporic fungi growing on the specimens of certain fish species recently introduced to Polish waters. *Acta Ichthyologica et Piscatoria*, *32*, 117–125.

Czeczuga, B., Kiziewicz, B., Godlewska, A., & Orłowska, M. (2002b). Further studies on aquatic fungi in the River Narew within the Narew National Park. *Annales Academiae Medicae Bialostocensis*, *47*, 58–79.

Czeczuga, B., Kiziewicz, B., & Mazalska, B. (2003b). Further studies on aquatic fungi in the River Biebrza within Biebrza National Park. *Polish Journal of Environmental Studies*, *12*, 531–543.

Czeczuga, B., Kiziewicz, B., & Orłowska, M. (2002c). Zoosporic and conidial fungi within the Podlasie stretch of the River Bug. *Annales Academiae Medicae Bialostocensis*, *47*, 40–57.

Czeczuga, B., Kozłowska, M., & Godlewska, A. (2002d). Zoosporic aquatic fungi growing on dead specimens of 29 freshwater crustacean species. *Limnologica*, *32*, 180–193.

Czeczuga, B., Kozłowska, M., & Kiziewicz, B. (2003a). Hyphomycetes of a deep, oligo-mesotrophic lake Hańcza (north east Poland). *Ecohydrology and Hydrobiology*, *3*, 435–443.

Czeczuga, B., Mazalska, B., & Orłowska, M. (2000). New aquatic sites of the fungus *Sommerstorffia spinosa* Arnaudow. *Acta Mycologica*, *35*, 261–268.

Czeczuga, B., & Muszyńska, E. (1999). Aquatic fungi growing on the eggs of fishes representing 33 cyprinid taxa (Cyprinidae) in laboratory conditions. *Acta Ichthyologica et Piscatoria*, *29*, 53–72.

Czeczuga, B., Muszyńska, E., Mazalska, B., Godlewska, A., & Snarska, A. (2003c). Joint occurrence of cyanobacteria and zoosporic fungi in water of various origin in laboratory conditions. *Ecohydrology and Hydrobiology*, *3*, 425–433.

Czeczuga, B., & Orłowska, M. (1997). Hyphomycetes fungi in rainwater falling from building roofs. *Mycoscience (Tokyo)*, *38*, 421–424.

Czeczuga, B., & Orłowska, M. (1998). Hyphomycetes in rain water draining from intact trees. *Annales Academiae Medicae Bialostocensis*, *43*, 66–84.

Czeczuga, B., & Orłowska, M. (1999). Hyphomycetes in rain water, melting snow and ice. *Acta Mycologica*, *34*, 183–202.

Czeczuga, B., & Orłowska, M. (2000). Investigations on the joint occurrence of *Anabaena spiroides* Klebahn and Hyphomycetes in various types of water bodies. *Acta Hydrochimica et Hydrobiologica*, *28*, 162–165.

Czeczuga, B., Orłowska, M., & Kozłowska, M. (2001). Hyphomycetes of lakes of varied trophic state in the Wigry National Park (north-eastern Poland). *Polish Journal of Ecology*, *49*, 201–213.

Czeczuga, B., & Snarska, A. (2001). *Pythium* species in 13 various types of water bodies of N-E Poland. *Acta Societatis Botanicorum Poloniae*, *70*, 7–17.

Czeczuga, B., & Woronowicz, L. (1993). Aquatic fungi developing on the eggs of certain fresh-water fish species and their environment. *Acta Ichthyologica et Piscatoria*, *23*, 39–57.

Dangeard, P. A. (1888). Les Peridiniens, et leurs parasites. *Bulletin de Botanique*, *2*, 126–132.

Dick, M. W. (1990). *Keys to Pythium.* Reading: College Estate Managament Witheknights.

Drechsler, C. (1930). Some new species of *Pythium*. *Journal of the Washington Academy Science*, *20*, 398–418.

Drechsler, C. (1932). A species of *Pythiogeton* isolated from decaying leaf-sheaths of the common cat-tail. *Journal of the Washington Academy Science*, *22*, 421–449.

Dudka, I. O. (1974). *Wodni hifomiceti Ukraini (Aquatic Hyphomycetes of Ukraine)*. Kiev: Naukova Dumka.

Dudka, I. A., Isayeva, N. M., & Davydov, O. N. (1989). Saprolegniaceae inducing fish mycosis. *Mycological Phytopathology*, *23*, 488–498.

Fare, A., Dutartre, A., & Rebillard, J.-P. (2001). *Les principaux végétaux aquatiques du sud-ouest de la France*. Toulouse: Agence de I'Eau Adour Garonne.

Fisher, P. J., Davey, R. A., & Webster, J. (1983). Degradation of lignin by aquatic and aero-aquatic hyphomycetes. *Transactions of the British Mycological Society*, *80*, 106–168.

Fuller, M. S., & Jaworski, A. (1987). *Zoosporic fungi in teaching and research*. Athens: Southeastern Publishing.

Greenberg, A. E., Clesceri, L. S., & Eaton, A. D. (1995). *Standard methods for the examination of water and wastewater*. Washington: American Public Health Association.

Gulis, V., & Marvanová, L. (1998). *Filosporella exilis* sp. nov. on submerged plant debris from Belarus. *Mycotaxon*, *68*, 313–320.

Howard, R. J., & Gow, N. A. R. (2001). *Biology of the fungal cell*. Berlin, Heidelberg: Springer.

Hutchinson, G. E. (1975). *A treatise of Limnology, Limnological Botany*, Vol. III. New York: Wiley.

Ingold, C. T. (1975). An illustrated guide to aquatic and water born hyphomycetes (Fungi imperfecti) with notes on their biology. *Freshwater Biological Association Scientific Publication*, *30*, 1–96.

Jacenko, T. A. (1992). Oomicety wodojomow i wodotokow Kryma. *Gidrobiologicheskij Zurnal*, *28*, 32–38 [In Russian].

Jeppsen, E., Sondergaard, M., & Christofferson, K. (1997). *The structuring role of submerged Macrophytes in lakes*. Berlin: Springer.

Johnson, T. W. (1956). *The genus Achlya: Morphology, taxonomy*. Ann Arbor: University of Michigan Press.

Karjalainen, H., Stefansdottir, G., Tuominen, L., & Kairesalo, T. (2001). Do submersed plants enhance microbial activity in sediment? *Aquatic Botany*, *69*, 1–13.

Karling, J. S. (1937). The structure, development, identify and relationship of *Endochytrium*. *American Journal of Botany*, *24*, 352–364.

Karling, J. S. (1938). A new chytrid genus: *Nephrochytrium*. *American Journal of Botany*, *25*, 211–215.

Karling, J. S. (1944). Brazylian chytrids. I. Species of *Nowakowskiella*. *Bulletin of the Torrey Botanical Club*, *71*, 374–385.

Karling, J. S. (1967). Some zoosporic fungi of New Zealand. VI. *Entophlyctis*, *Diplophlyctis*, *Nephrochytrium* and *Endochytrium*. *Sydowia*, *20*, 109–118.

Karling, J. S. (1977). *Chytridiomycetarum Iconographia. An illustrated and brief descriptive guide to the chytridiomycetous genera with supplement of the Hypochytriomycetes*. Vaduz: Lubrecht & Cramer.

Kirk, T. K., & Obst, J. R. (1988). Lignin determination. In W. A. Wood, & S. T. Kellogg (Eds.), *Methods in enzymology-biomass, Part B. Lignin, pectin, and chitin* (pp. 87–101). San Diego: Academy Press.

Maire, R., & Tison, A. (1911). Sur quelques Plasmodiophoracées non hypertrophicantes. *Bulletin L'Academie Sciences, Paris*, *152*, 206.

Marvanová, L., & Bärlocher, F. (2001). Hyphomycetes from Canadian streams. VI. Rare species in pure cultures. *Czech Mycology*, *53*, 1–28.

Matsushima, T. (1980). *Saprophytic microfungi from Taiwan, Part: Hyphomycetes. Matsushima Mycological Memoirs No. 1*. Kobe: Author.

Matsushima, T. (1993). *Matsushima Mycological Memoirs No. 7*. Kobe: Author.

Maurizio, A. (1894). Zur Entwicklungsgeschichte und Systematik der Saprolegnieen. *Flora*, *79*, 109–158.

Meng, H. Y. (1980). *Über die Ursachen von Saprolegniosen in schweizerischen Gewaessern*. Zuerich, Eidgenoes. Technische Hochschule.

Von Minden, M. (1916). Beiträge zur Biologie und Systematik einheimischer submerser Phycomyceten. In Flack (Ed.), *Mykologische Untersuchungen und Berichte*, Vol. 2 (pp. 146–255).

Ookubo, M. (1954). Studies on the aquatic fungi in the moors and ponds of Hakkoda. *Nagava*, *4*, 48–60.

van der Plaats-Niterink, A. J. (1972). The occurrence of *Pythium* in the Netherlands. 3. *Pythium flevoense* sp. n. *Acta Botanica Neerlandica*, Vol. 21 (pp. 633–639).

Pystina, K. A. (1998). Genus *Pythium Pringsh*. Sankt Petersburg: Nauka [In Russian].

Schäperclaus, W. (1991). *Fish diseases*. New Delhi: Oxonlan.

Schwartz, E. J. (1910). Parasitic root diseases of the Juncaceae. *Annals of Botany, London*, *24*, 511–522.

Seymour, R. L. (1970). The genus *Saprolegnia*. *Nova Hedwigia*, *19*, 1–124.

Seymour, R. L., & Fuller, M. S. (1987). Collection and isolation of water molds (Saprolegniaceae) from water and soil. In M. S. Fuller, & A. Jaworski (Eds.), *Zoosporic fungi in teaching and research* (pp. 125–127). Athens: Southeastern Publishing.

Singh, A., Sharma, O. P., Bhat, T. K., & Nats, S. K. (2001). Fungal degradation of lantadene A, the pentacyclic triterpenoid hepatotoxin on Lantana plant. *International Biodetergents and Biodegradation*, *47*, 239–242.

Sparrow, F. K. (1933). Observations on operculate chytridiaceous fungi collected in the vicinity of Ithaca, New York. *American Journal of Botany*, *20*, 63–77.

Sparrow, F. K. (1939). Unusual chytridiaceous fungi. *Paper of the Michigan Academy of Science Arts and Letters*, *24*, 121–126.

Strand, J. A. (1999). *Submerged macrophytes in shallow eutrophic lakes – regulating factors and ecosystem effects*. Lund: Lund University Press.

Thirumalacher, M. J. (1947). Some fungal diseases of Bryophytes in Mysore. *Transactions of the British Mycological Society*, *31*, 7–12.

Voronin, L. (1992). Fungal complexes on dead macrophytes in Estonian lakes. *Izwestia Akademii Nauk Estonii, Biologia*, *41*, 77–85.

Wood-Eggenschwiler, S., & Bärlocher, F. (1985). Geographical distribution of Ingoldian fungi. *Verhandlungen Internationale Vereinigung Limnology*, *22*, 2780–2785.

Yong-Nian, Y. U., & Guo-Znong, M. A. (1989). The genus *Pythium* in China. *Mycosystema*, *2*, 1–110.

Zare-Maivan, H., & Shearer, C. A. (1988). Extracellular enzyme production and cell wall degradation by freshwater lignicolous fungi. *Mycologia*, *80*, 365–375.

Zemek, J., Marvanová, L., Kuniak, L., & Kadlecikova, B. (1985). Hydrolytic enzymes in aquatic hyphomycetes. *Folia Microbiologica (Prague)*, *30*, 363–372.