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Original Research

Aquatic Fungi and Heterotrophic Straminipiles from Fishponds

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Abstract

In our study we analyzed the species composition of fungi and heterotrophic straminipiles in four ponds of a fish farm in Popielewo and in four ponds in Poryta Jabłoń situated in the vicinity of Knyszyn, Poland. Samples of water were collected during the spring and autumn of 2009. Fourty-two species (11 fungi and 31 heterotrophic straminipiles) were recovered. We found some potential pathogens of economically valuable fish and fish spawn, such as *Achlya americana, Ac. polyandra, Saprolegnia ferax,* and *S. parasitica*. In addition, we found some common human pathogens such as *Aspergillus niger,* and *Candida tropicalis*. Some saprotrophs such as *Rhizophlyctis rosea, Nowakowskiella elegans, Olpidiopsis saprolegniae, Pythium debaryanum, Py. gracile, Py. hemmianum,* and *Py. inflatum* appeared to be relatively common.

Most species of fungi and straminipiles were recovered from ponds in Poryta Jabłoń (34), while the smallest number was found in Popielewo ponds (25). The physico-chemical analysis of water showed that ponds in Poryta Jabłoń were the least polluted with organic matter, whereas biogenic compounds were most abundant in Popielewo.

Keywords: fungi, heterotrophic straminipiles, ponds, physicochemical factors, Knyszyn

Introduction

Fungi and fungal-like organisms constitute a widespread and phylogenetically diverse component of aquatic ecosystems. They play key roles in matter circulation, energy flow, and biological balance. Most of them are saprotrophs that produce enzymes that facilitate mineralization of dead organic matter, both from plant and animal origin. By using the organic matter as a source of carbon and energy, aquatic fungi and fungal-like organisms contribute to water self-purification processes, and thus they naturally prevent eutrophization [1, 2]. Many authors have suggested that aquatic fungi act as bioindicators of pollutants and other organic substances that accumulate in surface waters [3-7].

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Some aquatic fungi are biotrophs of plants, animals, and humans, or act as facultative parasites when conditions are favorable for the development of pathogenesis [8].

Determination of respective aquatic fungi and straminipiles as bioindicators of water pollution against the background of environmental conditions is extremely important in hydrosphere monitoring [7, 9].

As part of our research on aquatic fungi and staminipiles in various types of water reservoirs, we investigated the species composition of the assemblages from the ponds of two fish farms in Popielewo and Poryta Jabłoń, which differ in their fish production intensity.

Material and Methods

Sampling dates were chosen according to water physical and chemical conditions in spring and autumn 2009.

Table 1. Physical and chemical water factors of each pond in Popielewo at each sampling date (mean of three samples).

Factor	Spring				Autumn			
	Popielewo Pond 1	Popielewo Pond 11	Popielewo Pond 12	Zygmunta Augusta Pond	Popielewo Pond 1	Popielewo Pond 11	Popielewo Pond 12	Zygmunta Augusta Pond
Temperature (ºC)	13.7	13.7	13.7	13.8	15.4	15.3	15.4	15.6
pH	7.33	7.42	7.38	7.35	7.6	7.92	8.0	8.1
O_2 (mg·l^{-1})	6.8	8.8	7.84	8.68	8.1	10.4	10.2	9.8
BOD_5 (mg·l^{-1})	1.10	0.20	0.90	1.80	1.20	0.30	1.10	2.60
COD (mg·l^{-1})	28.1	16.8	20.2	10.8	32.54	21.14	25.14	14.9
CO_2 (mg·l^{-1})	16.9	11.3	9.41	10.78	11.5	7.8	6.28	7.87
Alkalinity in $CaCO_3$ (mval·l^{-1})	2.43	2.32	2.58	2.93	3.29	3.11	3.36	3.96
N-NH_3 (mg·l^{-1})	0.324	0.312	0.615	0.410	0.676	0.792	1.18	0.845
N-NO_2 (mg·l^{-1})	0.006	0.007	0.006	0.003	0.009	0.008	0.008	0.005
N-NO_3 (mg·l^{-1})	0.17	0.11	0.008	0.052	0.44	0.17	0.21	0.094
P-PO_4 (mg·l^{-1})	0.23	1.26	1.14	0.92	0.11	0.408	0.82	0.55
Sulphates (mg·l^{-1})	20.18	23.18	23.54	19.14	32.50	38.26	32.64	30.68
Chlorides (mg·l^{-1})	52.9	44.0	15.28	11.3	32.0	30.24	26.89	24.5
Total hardness (mg Ca·l^{-1})	42.72	38.13	60.20	61.0	38.21	32.63	54.12	58.45
Total hardness (Mg·l^{-1})	20.17	12.4	10.96	13.7	18.10	11.16	10.98	11.2
Fe (mg·l^{-1})	1.12	0.71	2.12	0.85	0.67	0.64	1.06	0.65
Dry residue (mg·l^{-1})	496.5	287.2	5.20	358.12	310.18	176.4	342.0	282.5
Dissolved solids (mg·l^{-1})	397.22	214.86	496.0	264.0	324.54	148.1	255.6	213.8
Suspended solids (mg·l^{-1})	99.28	72.34	24.0	94.12	85.64	28.3	86.4	68.7

Water samples were collected from four ponds of a fish farm in Popielewo and from four ponds of a fish farm in Poryta Jabłoń, both near the town of Knyszyn. Although all these ponds have a thick layer of mud and they are used for breeding cyprinids, they differ in the intensity of fish production. In 2009 the productivity in Popielewo ponds was approximately 550 kg/ha, as compared to 700 kg/ha in Poryta Jabłoń.

The ponds in Popielewo were: Stanisław August Pond (450 ha), Popielewo Pond 1 (14.4 ha), Popielewo Pond 11 (2.2 ha), and Popielewo Pond 12 (5.6 ha), all arranged in a series.

In Poryta Jabłoń, the ponds were: Kajtek (10.5 ha), Moryś (5.5 ha), Aleksander (46 ha), and Fortuna (10 ha). The ponds in Poryta Jabłoń receive waters from the Jabłonka River and the clean Gać River. The Jabłonka is polluted with municipal and industrial sewage from the town of Zambrów. Before reaching the ponds, the waters of the two rivers mix in a common inflow canal.

For analysis of fungi and straminipiles three samples of water were collected from each sampling site. Water samples from each reservoir were poured into 0.6 l – capacity beakers and incubated in the laboratory under conditions resembling those of the natural environment. The baiting method described by Fuller and Jaworski [10] and Kiziewicz and Czeczuga [11] was used to isolate the fungi. The following baits were used: crustacean (*Gammarus pulex*); exoskeleton, snake (*Natrix natrix*) skin; seeds of *Trifolium repens*, *Cannabis sativa*, and *Fagopyrum esculentum*; and onion (*Alium cepa*) skin. All baits were boiled and rinsed with distilled water for a few times before use. After three days of incubation the baits were observed under the microscope (100 and 400x magnification) every 3-5 days for approximately a month. Fungi and fungus-like organisms were identified according to [1, 8, 12-18].

Water samples for physicochemical analyses were collected at a distance of approximately 2 m from the shore and 50 cm depth by means of a Ruttner apparatus (2 l capacity). Water parameters in each reservoir were measured in the labolatory (Tables 1-3) according to [19].

Results

The fishponds in Popielewo and Poryta Jabłoń showed differences in their physicochemical factors. The highest mean water temperature was found in autumn in Popielewo, whereas the lowest was in spring in Poryta Jabłoń.

Table 2. Physical and chemical water factors of each pond in Porta Jabłoń at each sampling date (mean of three samples).

Factor	Spring				Autumn			
	Aleksander Pond	Fortuna Pond	Kajtek Pond	Moryś Pond	Aleksander Pond	Fortuna Pond	Kajtek Pond	Moryś Pond
Temperature (ºC)	13.2	13.2	13.3	13.3	14.8	14.8	14.9	14.7
pH	8.12	8.10	7.62	8.14	8.40	8.24	7.71	8.46
O_2 (mg·l^{-1})	16.2	16.9	15.4	17.8	19.4	18.3	16.6	19.0
BOD_5 (mg·l^{-1})	3.20	3.30	3.10	4.30	4.50	3.60	3.20	4.40
COD (mg·l^{-1})	17.18	17.16	16.87	17.26	23.16	22.58	18.56	23.14
CO_2 (mg·l^{-1})	6.8	3.7	10.3	4.1	3.6	2.8	8.4	2.9
Alkalinity in $CaCO_3$ (mval·l^{-1})	3.3	2.1	3.7	3.1	3.9	2.7	4.3	3.5
N-NH_3 (mg·l^{-1})	0.16	0.11	0.12	0.09	1.12	0.73	0.62	0.84
N-NO_2 (mg·l^{-1})	0.001	0.000	0.000	0.001	0.002	0.000	0.001	0.001
N-NO_3 (mg·l^{-1})	0.004	0.003	1.004	0.004	0.007	0.006	0.006	0.007
P-PO_4 (mg·l^{-1})	1.02	0.33	4.70	1.60	0.31	0.06	0.86	0.40
Sulphates (mg·l^{-1})	23.16	19.11	17.46	19.84	56.14	33.61	26.56	33.57
Chlorides (mg·l^{-1})	32.0	25.8	31.0	28.7	15.0	12.1	17.0	15.8
Total hardness (mg Ca·l^{-1})	48.12	38.2	57.67	32.84	37.32	32.78	52.33	29.18
Total hardness (Mg·l^{-1})	22.07	10.84	16.61	12.6	19.20	10.96	14.89	11.7
Fe (mg·l^{-1})	0.70	0.42	0.61	0.38	0.11	0.10	0.23	0.12
Dry residue (mg·l^{-1})	326.2	254.3	324.1	312.7	221.4	197.2	203.7	184.3
Dissolved solids (mg·l^{-1})	272.35	211.0	269.35	284.4	182.6	162.4	158.5	159.4
Suspended solids (mg·l^{-1})	53.85	43.0	54.75	28.5	38.8	34.8	45.2	24.9

The highest mean water temperature in Popielewo, in autumn, was 15.4ºC, with the maximum noted in Zygmunt August pond (15.6ºC). In the spring months the lowest mean water temperature in Poryta Jabłoń was 13.25ºC, with a minimum of 13.2ºC in the Aleksander and Fortuna ponds. Oxygen content was the highest in Poryta Jabłoń. In the ponds in Popielewo, the oxygen level was markedly lower than in Poryta Jabłoń and ranged from 8.03 (spring) to 9.63 mg·l^{-1} (autumn), with the minimum in Popielewo 1 (6.8 mg·l^{-1}). As a result, the content of carbon dioxide was higher in the ponds in Popielewo. The level of carbon dioxide was found to be much lower in the ponds in Poryta Jabłoń, being 4.4 (autumn) and 6.2 mg·l^{-1} (spring) on average. The content of nitrogen compounds (ammonium, nitrite, and nitrate) was relatively low in all the ponds in Popielewo and Poryta Jabłoń, whereas at the same time water in all the ponds showed high levels of absorbable phosphate salts. Pond water in Popielewo and Poryta Jabłoń was rich in calcium compounds. Their mean levels ranged between 45.85 and 50.51 mg·l^{-1} in Popielewo and from 38.0 to 44.20 mg·l^{-1} in Poryta Jabłoń. The content of iron was high in Popielewo and much lower in Poryta Jabłoń throughout the study period. Pond water in Popielewo was characterized by the highest content of dry residue and substances dissolved in water, whereas ponds in Poryta Jabłoń showed markedly lower levels of these parameters (Tables 1-3).

Fourty-two species consisting of 31 heterotrophic straminipiles belonging to Pernosporomycetes and 11 fungi belonging to the classes Chytridiomycetes (6), Blastocladiomycetes (1), Saccharomycetes (2), Ascomycetes (1), and Dothideomycetes (1) were recorded in the fishponds (Table 6). The largest number of species was recorded from the ponds in Poryta Jabłoń (34), particularly in Kajtek (16), whereas the smallest number of taxa was found in Popielewo (25), particularly in Popielewo 1 (9) (Tables 4-6, Fig. 1). All water reservoirs showed the greatest number of species belonging to the orders of Pythiales and Saprolegniales. Some of the taxa, such as *Aspergillus niger, Catenophlyctis variabilis, Rhizophlyctis rosea, Trichosporon cutaneum, Myzocytium zoophthorum, Pythium rostratum, Achlya debaryana, Ac. polyandra, Ac. treleaseana, Aphanomyces irregularis, Saprolegnia anisospora, S. ferax, S. glomerata, S. parasitica, S. torulosa,* and *Thraustotheca clavata* were found in the ponds of both Popielewo and Poryta Jabłoń fish farms.

Table 3. Mean values of physical and chemical factors of the fish farms in Popielewo and Poryta Jabłoń (the mean of three samples).

Factors	Spring		Autumn	
	Ponds in Popielewo	Ponds in Poryta Jabłoń	Ponds in Popielewo	Ponds in Poryta Jabłoń
Temperature (ºC)	13.7	13.25	15.4	14.8
pH	7.37	8.0	7.91	8.2
O_2 (mg·l^{-1})	8.03	16.6	9.63	18.33
BOD_5 (mg·l^{-1})	1.0	3.48	1.3	3.92
COD (mg·l^{-1})	19.0	17.12	23.4	21.86
CO_2 (mg·l^{-1})	12.1	6.2	8.4	4.4
Alkalinity in $CaCO_3$ (mval·l^{-1})	2.57	3.05	3.43	3.6
N-NH_3 (mg·l^{-1})	0.412	0.12	0.873	0.83
N-NO_2 (mg·l^{-1})	0.006	0.000	0.008	0.001
N-NO_3 (mg·l^{-1})	0.103	0.004	0.228	0.006
P-PO_4 (mg·l^{-1})	0.888	1.913	0.487	0.408
Sulphates (mg·l^{-1})	21.51	19.90	33.52	44.12
Chlorides (mg·l^{-1})	30.87	29.38	28.41	14.98
Total hardness (mg Ca·l^{-1})	50.51	44.20	45.85	38.0
Total hardness (Mg·l^{-1})	14.31	15.53	12.86	14.18
Fe (mg·l^{-1})	1.20	0.52	0.76	0.14
Dry residue (mg·l^{-1})	415.46	320.0	277.77	202.5
Dissolved solids (mg·l^{-1})	343.02	259.27	210.51	165.72
Suspended solids (mg·l^{-1})	72.44	45.03	67.26	35.93

Discussion

The present study describes the species composition of the assemblages of aquatic fungi and straminipiles from fishponds in Popielewo and Poryta Jabłoń. Most species (34) were isolated from the aquatic reservoirs in Poryta Jabłoń, particularly in Kajtek Pond (16 species). The physicochemical analysis of water from Poryta Jabłoń revealed high concentrations of oxygen, low content of carbon dioxide, high levels of biogenic compounds (especially calcium and phosphates), and low content of nitrogen and iron compounds. The total amount of organic matter was relatively low. As previously reported [1, 5], less polluted waters appeared to present a higher number of species and diversity than moderate to heavily polluted ones.

Physicochemical factors revealed that water was more eutrophized in fish ponds from Popielewo than from Poryta Jabłoń, which was reflected in the lower content of dissolved oxygen, higher content of carbon dioxide, and high levels of phosphates, calcium, and iron. In addition, the concentration of organic substances was generally high in Popielewo, which probably is the reason why the number of species of fungi and straminipilous organisms was low. The data obtained might indicate a decrease in the number of species due to high contents of organic matter as previously reported [5, 20, 21].

The greatest number of species belonged to the genera *Achlya* (9), *Pythium* (7), *Saprolegnia* (6), and *Aphanomyces* (3). In natural conditions, most of the species in these genera act as saprotrophs that contribute to water purification, and thus improve its quality [22-25], while some other species can be found, such as parasites of plants, animals, and humans. Some of the saprotrophic species can also act as facultative parasites under favourable conditions and thus being a potential source of infection [8]. The most common species found in these genera were *Achlya americana, Ac. polyandra, Aphanomyces irregularis, Saprolegnia ferax, S. glomerata,* and *S. parasitica*. *Achlya americana* and *Ac. polyandra* are known as parasites of economically valuable fish and fish spawn worldwide [26]. *Achlya polyandra* has been found growing on the spawn of the rainbow trout (*Oncorhynchus mykiss*) in Lake Sevan (Armenia) and on fish of the family Salmonidae in America [27]. In the present study, *Achlya americana* was found only in Popielewo (in spring from the ponds Popielewo 1 Zygmunt and in autumn in Popielewo 1 and Popielewo 11). *Achlya polyandra* was isolated only from the ponds in Poryta Jabłoń (in spring from the ponds Alexander, Fortuna, and Kajtek and in autumn from Alexander). These two taxa have been previously reported by Czeczuga et al. [28-30] on the spawn of fish belonging to various families in water reservoirs of Podlasie Province.

Table 4. Fungi and straminipiles found in ponds of the fish farm in Popielewo during the spring and autumn of 2009.

Classification (kingdom, class, order, and species)	Water sites							
	Popielewo 1		Popielewo 11		Popielewo 12		Zygmunta Augusta	
	spring	autumn	spring	autumn	spring	autumn	spring	autumn
Fungi								
Ascomycetes								
Eurotiales								
1. *Aspergillus niger* Thieghem			x					
Blastocladiomycetes								
Blastocladiales								
2. *Catenophlyctis variabilis* (Karling) Karling	x	x	x	x	x	x	x	x
Chytridiomycetes								
Chytridiales								
3. *Rhizophlyctis rosea* (de Bary et Woronin) Johanson					x			
4. *Phlyctochytrium aureliae* Ajello				x	x			
Saccharomycetes								
Saccharomycetales								
5. Trichosporon cutaneum (de Bermann, Gougrot et Vaucher) Ota				x				
Straminipila (Chromista)								
Peronosporomycetes								
Olpidiopsidiales								
6. *Olpidiopsis saprolegniae* Cornu			x					
Pythiales								
7. *Myzocytium zoophthorum* Sparrow			x	x				
8. *Py. debaryanum* Hesse					x		x	
9. *Py. inflatum* Matthews	x							
10. *Py. rostratum* Butler						x		
Saprolegniales								
11. *Achlya americana* Humphrey	x	x		x			x	
12. *Ac. debaryana* Humphrey							x	x
13. *Ac. klebsiana* Pieters						x		
14. *Ac. oblongata* de Bary				x				
15. *Ac. polyandra* Hildebrand	x			x			x	x
16. *Ac. treleaseana* (Humphr.) Kauffman		x						
17. *Aphanomyces daphniae* Prowse.								x
18. *Ap. irregularis* Scott	x			x	x	x		x
19. *Ap. laevis de* Bary								x
20. *S. anisospora* de Bary						x		
21. *S. ferax* (Gruith) Thuret		x	x	x	x	x	x	x
22. *S. glomerata* (Tiesenh.) Lund							x	
23. *S. parasitica* Coker	x	x	x	x	x	x	x	
24. *S. torulosa* de Bary						x		
25. *Thraustotheca clavata* (de Bary) Humphrey		x						
Total number of species in spring and autumn	6	6	6	10	7	8	8	7
Total number of species	9		11		11		10	

Table 5. Fungi and straminipiles found in ponds of the fish farm in Poryta Jabłoń during the spring and autumn of 2009.

Classification (kingdom, class, order, and species)	Water reservoirs							
	Aleksander		Fortuna		Kajtek		Moryś	
	spring	autumn	spring	autumn	spring	autumn	spring	autumn
Fungi								
Ascomycetes								
Eurotiales								
1. *Aspergillus niger* Thieghem					x	x		
Blastocladiomycetes								
Blastocladiales								
2. *Catenophlyctis variabilis* (Karling) Karling	x	x	x	x	x	x	x	x
Chytridiomycetes								
Chytridiales								
3. *Chytridium xylophilum* Cornu	x		x					
4. *Rhizophlyctis rosea* (de Bary et Woronin) Johanson				x				
5. *Nowakowskiella elegans* (Nowak.) Schröt		x						
6. *N. macrospora* Karling				x	x			
7. *Phlyctochytrium aureliae* Ajello						x		
8. *Polychytrium aggregatum* Ajello							x	
Pleosporales								
9. *Alternaria alternata* (Fr.) Keissl.				x				
Saccharomycetes								
Saccharomycetales								
10. *Candida tropicalis* (Castell.) Berkhot	x		x		x			
11. *Trichosporon cutaneum* (de Bermann, Gougrot et Vaucher) Ota							x	
Straminipila (Chromista)								
Peronosporomycetes								
Pythiales								
12. *Myzocytium zoophthorum* Sparrow		x			x			
13. *Pythiogeton nigricans* Batko			x					
14. *Pythium elongatum* Matthews	x	x					x	x
15 *Py. gracile* Schenk								x
16. *Py. hemmianum* Takahashi						x		
17. *Py. tardicrescens* Vanterp							x	x
Saprolegniales								
18. *Achlya apiculata* de Bary						x		
19. *Ac. debaryana* Humphrey	x	x						
20. *Ac. dubia* Coker				x				
21. *Ac. orion* Coker							x	x
22. *Ac. polyandra* Hildebrand	x	x	x		x			
23. *Ac. treleaseana* (Humphr.) Kauffman					x	x		
24. *Aphanomyces irregularis* Scott	x	x				x	x	x
25. *Ap. laevis* de Bary				x		x		

Table 5. Continued.

Classification (kingdom, class, order, and species)	Water reservoirs							
	Aleksander		Fortuna		Kajtek		Moryś	
	spring	autumn	spring	autumn	spring	autumn	spring	autumn
Saprolegniales								
26. *Dictyuchus monosporus* Leitg				x				
27. *Isoachlya monilifera* (de Bary) Kauffman			x					
28. *Saprolegnia anisospora* de Bary							x	
29. *S. ferax* (Gruith) Thuret	x	x	x		x	x	x	x
30. *S. glomerata* (Tiesenh.) Lund	x	x			x		x	x
31. *S. hypogyna* (Pringsh.) de Bary						x		
32. *S. parasitica* Coker	x	x	x	x		x	x	x
33. *S. torulosa* de Bary					x			x
34. *Thraustotheca clavata* (de Bary) Humphrey				x			x	
Total number of species	12		15		16		14	

Saprolegnia ferax and *S. parasitica* are the main etiological factors of the mycotic fish disease called saprolegniosis [31, 32], which causes considerable losses in hatcheries, as well as ponds, lakes, and fish farms [33-36]. Throughout the study period, these two species were detected in all ponds from both Popielewo and Poryta Jabłoń. These species have been reported to cause the deaths of more than half the population of silver salmon (*Oncorhynchus kisutch*) in fish farms in Japan [37] and brown trout (*Salmo trutta*) in England [38].

It is worth noting that *Catenophlyctis variabilis* (Blastocladiomycetes) was frequently recovered in the ponds from Popielewo and Poryta Jabłoń. This species has been described in literature as a widely spread saprotroph found on keratin substrates [38] such as human skin, hair, and nails, as well as fur and nails of the hooves, and has been frequently found in various aquatic reservoirs and watercourses [40-42].

Rare species found in the ponds include *Alternaria alternata*, *Aspergillus niger*, *Candida tropicalis*, *Rhizophlyctis rosea*, *Nowakowskiella elegans*, *Olpidiopsis saprolegniae*, *Pythium debaryanum*, *Py. gracile*, *Py. hemmianum*, *Py. inflatum*, and *Trichosporon cutaneum*.

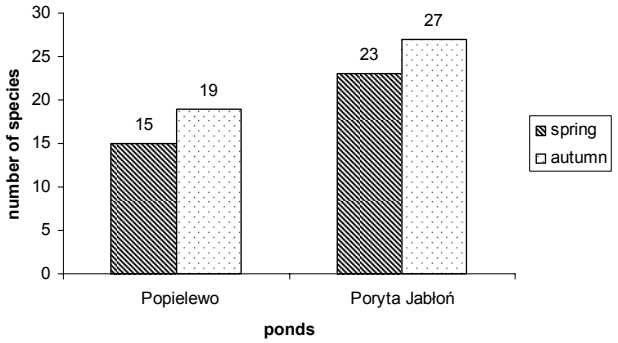

Fig. 1. Number of species of fungi and straminipiles recovered from each fish farm at the sampling dates (spring and autumn).

Alternaria alternata is responsible for several diseases affecting plants, animals, and humans [43, 44]. In the current study, this fungus was only isolated in autumn from Fortuna Pond in Poryta Jabłoń.

Some of these species, such as *Aspergillus niger*, *Candida tropicalis*, and *Trichosporon cutaneum,* are commonly saprotrophs but can be pathogenic to humans, inhabiting the human skin, alimentary tract, genitourinary system, and other tissues and organs. They produce the most toxic substances, namely mycotoxins that have mutagenic, carcinogenic, and teratogenic effects [45-49]. These species were isolated mainly from the ponds in Poryta Jabłoń.

The remaining species of rare fungi isolated in the ponds, such as *Rhizophlyctis rosea*, *Nowakowskiella elegans*, *Olpidiopsis saprolegniae*, *Pythium debaryanum*, *Py. gracile*, *Py. hemmianum*, and *Py. inflatum,* were found only once during the study period both in Popielewo and Poryta Jabłoń. These species produce numerous pectinolytic and cellulolytic enzymes that decompose pectin and cellulose found in seeds, fruits, flower petals, leaves, stems and other parts of plants submerged in water. Due to enzymatic capabilities, they contribute to mineralization of vegetable debris [50-56].

As observed in the current study, the number of species of fungi and straminipiles was generally lower in fish ponds overloaded with organic matter. However, when the content of biogenic compounds in water is within the limit of tolerance for a particular species, it has a stimulatory effect on fungal growth.

Conclusions

The fishponds in Popielewo and Poryta Jabłoń showed differences in the physicochemical parameters, which had an effect on the occurrence and species composition of aquatic fungi and straminipiles. The high levels of organic

Table 6. Fungi and straminipiles found in ponds of the fish farms in Popielewo and Poryta Jabłoń during spring and autumn 2009.

Classification (kingdom, class, order, and species)	Ponds in Popielewo		Ponds in Poryta Jabłoń	
	spring	autumn	spring	autumn
Fungi				
Ascomycetes				
Eurotiales				
1. *Aspergillus niger* Thieghem	x		x	x
Blastocladiomycetes				
Blastocladiales				
2. *Catenophlyctis variabilis* (Karling) Karling	x	x	x	x
Chytridiomycetes				
Chytridiales				
3. *Chytridium xylophilum* Cornu			x	
4. *Rhizophlyctis rosea* (de Bary et Woronin) Johanson	x			x
5. *Nowakowskiella elegans* (Nowak.) Schröt				x
6. *N. macrospora* Karling			x	x
7. *Phlyctochytrium aureliae* Ajello	x	x		x
8. *Polychytrium aggregatum* Ajello			x	
Dothideomycetes				
Pleosporales				
9. *Alternaria alternata* (Fr.) Keissl.				x
Saccharomycetes				
Saccharomycetales				
10. *Candida tropicalis* (Castell.) Berkhot			x	
11. *Trichosporon cutaneum* (de Bermann, Gougrot et Vaucher) Ota		x	x	
Straminipila (Chromista)				
Peronosporomycetes				
Olpidiopsidiales				
12. *Olpidiopsis saprolegniae* Cornu	x			
Pythiales				
13. *Myzocytium zoophthorum* Sparrow	x	x	x	x
14. *Pythiogeton nigricans* Batko			x	
15. *Pythium debaryanum* Hesse	x			
16. *Py. elongatum* Matthews			x	x
17. *Py. gracile* Schenk				x
18. *Py. hemmianum* Takahashi				x
19. *Py. inflatum* Matthews	x			
20. *Py. rostratum* Butler		x	x	x
21. *Py. tardicrescens* Vanterp				
Saprolegniales				
22. *Achlya americana* Humphrey	x	x		
23. *Ac. apiculata* de Bary				x
24. *Ac. debaryana* Humphrey	x	x	x	x

Table 6. Continued.

Classification (kingdom, class, order, and species)	Ponds in Popielewo		Ponds in Poryta Jabłoń	
	spring	autumn	spring	autumn
Saprolegniales				
25. *Ac. dubia* Coker				x
26. *Ac. klebsiana* Pieters		x		
27. *Ac. oblongata* de Bary		x		
28. *Ac. orion* Coker			x	x
29. *Ac. polyandra* Hildebrand	x	x	x	x
30. *Ac. treleaseana* (Humphr.) Kauffman		x	x	x
31. *Aphanomyces daphniae* Prowse		x		
32. *Ap. irregularis* Scott	x	x	x	x
33. *Ap. laevis* de Bary		x		x
34. *Dictyuchus monosporus* Leitg				x
35. *Isoachlya monilifera* (de Bary) Kauffman			x	
36. *Saprolegnia anisospora* de Bary		x	x	
37. *S. ferax* (Gruith) Thuret	x	x	x	x
38. *S. glomerata* (Tiesenh.) Lund	x		x	x
39. *S. hypogyna* (Pringsh.) de Bary				x
40. *S. parasitica* Coker	x	x	x	x
41. *S. torulosa* de Bary		x	x	x
42. *Thraustotheca clavata* (de Bary) Humphrey		x	x	x
Total number of species in spring and autumn	15	19	23	27
Total number of species	25		34	

substances and the low oxygen content in water might have limited the occurrence of these organisms. The high level of biogenic compounds (which was, however, within the limit of tolerance for a particular species) as well as the high oxygen concentration stimulated the growth of fungi and straminipiles.

The ponds of the fish farm in Popielewo presented high amounts of organic matter and low oxygen content; hence the lowest number of species. In contrast the ponds of the fish farm in Poryta Jabłoń showed lower concentrations of these parameters, low content of organic matter, and high concentrations of oxygen, hence a greater number of species.

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