

DOI: 10.5586/am.1099

Publication history

Received: 2017-07-27

Accepted: 2017-11-23

Published: 2017-12-29

Handling editor

Maria Rudawska, Institute of Dendrology, Polish Academy of Sciences, Poland

Authors' contributions

KMZ: field research, identification of the micromycetes, writing the manuscript; AR: preparation of the results; ŁŁ: correction of the manuscript

Funding

Publishing of the manuscript was covered by the statutory funds of the Faculty of Food Sciences and Fisheries, West Pomeranian University of Technology Szczecin

Competing interests

No competing interests have been declared.

Copyright notice

© The Author(s) 2017. This is an Open Access article distributed under the terms of the [Creative Commons Attribution License](#), which permits redistribution, commercial and non-commercial, provided that the article is properly cited.

Citation

Mazurkiewicz-Zapałowicz K, Rybińska A, Łopusiewicz Ł. Microscopic fungi on *Schoenoplectus lacustris* in Płociczno and Płociowe lakes in Drawa National Park (northwest Poland). *Acta Mycol.* 2017;52(2):1099. <https://doi.org/10.5586/am.1099>

Digital signature

This PDF has been certified using digital signature with a trusted timestamp to assure its origin and integrity. A verification trust dialog appears on the PDF document when it is opened in a compatible PDF reader. Certificate properties provide further details such as certification time and a signing reason in case any alterations made to the final content. If the certificate is missing or invalid it is recommended to verify the article on the journal website.

ORIGINAL RESEARCH PAPER

Microscopic fungi on *Schoenoplectus lacustris* in Płociczno and Płociowe lakes in Drawa National Park (northwest Poland)

Kinga Mazurkiewicz-Zapałowicz^{1*}, Aleksandra Rybińska¹, Łukasz Łopusiewicz²

¹ Department of Hydrobiology, Ichthyology and Biotechnology of Reproduction, West Pomeranian University of Technology, Szczecin, Kazimierza Królewicza 4, 71-550 Szczecin, Poland

² Center of Bioimmobilisation and Innovative Packaging Materials, West Pomeranian University of Technology, Szczecin, Klemensa Janickiego 35, 71-270 Szczecin, Poland

* Corresponding author. Email: kmazurkiewicz@zut.edu.pl

Abstract

In the period 2009–2011, the micromycetes causing symptoms on the leaves of *Schoenoplectus lacustris* (SL) from Płociczno and Płociowe lakes in Drawa National Park (DNP) were investigated. A total of 39 taxa of microscopic fungi and chromistan fungi were found. The taxonomic structure of the mycobiota was dominated by anamorphs of Ascomycota. In each year of the study, the SL fungal species richness was higher in Płociowe Lake than in Płociczno Lake. In all the years of study in both lakes, the fungal community on SL was composed of the following six dominant species: *Alternaria alternata*, *Cladosporium herbarum*, *Fusarium incarnatum*, *F. sacchari*, *Gibberella avenacea*, and *Pleospora scirpicola*. The species occurring exclusively in Płociczno Lake were *Papulaspora immersa*, *Puccinia scirpi*, and *Trichothecium roseum*, and those found only in Płociowe Lake were *Acremoniella atra*, *Alternaria atra*, *Aspergillus niger*, *A. versicolor*, *Fusarium oxysporum*, *Gonatobotrys simplex*, *Massariosphaeria scirpina*, *Microascus brevicaulis*, *Penicillium chrysogenum*, and *Stagonospora aquatica*. Only one confirmation of the occurrence of *Puccinia scirpi* and the lack of other specialized obligate parasites indicate the good health of SL in DNP. The facultative parasites, inter alia, *Boeremia exigua*, *Chaetomium globosum*, *Fusarium culmorum*, *F. incarnatum*, *F. sacchari*, *Gibberella avenacea*, and *Stagonospora aquatica* that are present on plants as part of the natural process of apoptosis may influence the health of SL.

Keywords

biodiversity; microfungi; *Schoenoplectus*; Drawa National Park

Introduction

Plants of the genus *Schoenoplectus* (Rchb.) Palla (lake bulrush) belong to the family Cyperaceae and are represented by 77 species and subspecies of hydrophytes and helophytes [1]. In Poland, among the five species of *Schoenoplectus*, the most common and the only one not present on the red list is *Schoenoplectus lacustris* (L.) Palla (SL) [2]. In rush phytocoenoses, SL is a characteristic species of the *Scirpetum lacustris* (Allorge 1922) Chouard 1924 [3] community and is the belt of emergent macrophytes that extend the farthest from the shore. *Schoenoplectus lacustris* phytocoenoses are an important component of lake littoral zones and a cocreator of habitats for other hydrobionts. *Schoenoplectus* along with *Typha* and *Phragmites*, form one of the most productive zones in lake ecosystems [4,5]. This zone increased heterogeneity in water reservoirs, shaping the conditions for fishery exploitation. Many fish species from the families Cyprinidae, Esocidae, and Siluridae use bulrushes as substrate for spawned eggs and as nurseries for fry that cannot yet swim well. Like most macrophytes, SL

phytocoenoses facilitate the self-purification of waters. Therefore, they are increasingly used, for example, in the Netherlands to prevent the erosion of drained terrain [6]. In addition to its ecological significance, SL is also an important and increasingly popular natural raw material for construction and furniture manufacture. The quality and durability of the raw materials harvested from these plants are determined by the presence of the microorganisms accompanying SL vegetation [6]. In the context of the economic/utilitarian exploitation of SL, the occurrence of these microorganisms can also have significant health consequences because of the allergens, and frequently even toxins, produced by many microscopic fungi species co-occurring with plant vegetation. Among microorganisms that contribute to the health of macrophytes, phytopathogenic and saprotrophic mycobiota play significant roles, as they shorten plant vegetation. They initiate the decomposition of tissues, and their dominance, lasting for 1–4 days, can exceed by at least nine times greater biomass than that of bacteria [4]. Only after a time is the share of mycobiota suppressed by bacteria [7].

Microscopic mycobiota participate in the decomposition of plants and determine the release rate of soluble organic compounds, which modifies the hydrochemical conditions of lakes. However, knowledge about the diversity of these microorganisms remains fragmentary, and such studies of SL, both globally and in Poland, are sporadic; however, the few studies that have been published do provide interesting, often groundbreaking, information.

The aim of the study was to identify the microscopic fungi participating in the natural functioning of SL phytocoenoses in Płociczno and Płociowe lakes in Drawa National Park (DNP) and the frequency of their occurrence.

Material and methods

Description of the study area

Drawa National Park is located in the mesoregion of Drawsko Plain, northwestern Poland. Drawa National Park represents a young landscape of glacial outwash plains. The whole area (11 342 ha) is in the drainage basin of the Drawa River, one of the cleanest rivers in Poland. The Drawa River is also the only lowland Polish river, which in its course has over 20 km of rapid current, with the nature of the mountain river [8].

Drawa National Park is a large abundance of ecosystems and plant communities. The area is dominated by forests (80%), but the distinguishing constituents of nature are mires, meadows, and aquatic ecosystems. In DNP, there are several lakes, differentiated in terms of trophies, physicochemical and morphic characteristics. Morphological differences are also observed in the Płociczno and Płociowe lakes, which are the subject of the study (Tab. 1) [8].

Płociczno Lake is a fluvial water body through which the Płociczna River flows (Tab. 1). The mouth of this river has been blocked for over 20 years by rising lake levels, which have resulted in the creation of a characteristic delta. In the 1980s, the Płociczna River delta was proposed for classification as a natural monument [9]. Among 17 plant communities in Płociczno Lake, the occurrence of phytocoenoses belonging to the community of *Scirpetum lacustris* was confirmed. Other plant communities of the lake phytolitoral include *Caricetum acutiformis* Sauer 1937, *Caricetum paniculatae* Wangerin 1916, *Caricetum ripariae* Soó 1928, *Caricetum vasicariae* Br.-Bl. et Denis 1926, *Carici remotae-Fraxinetum* Koch 1926 ex Faber 1936, *Phragmitetum australis* (Gams 1927) Schmale 1939, *Typetum latifoliae* Soó 1927, and *Typhetum angustifoliae* (Allorge 1922) Soó 1927 [3,10] (also, Kraska M, Piotrowicz R, 1998, unpublished data). These plant communities are composed of extensive vegetation beds at opposite ends of the lake concentrated in the river inflow and outflow zones, where there is heavy organic and mineral sedimentation, and along the lake shoreline [9,10] (also, Kraska M, Piotrowicz R, 1998, unpublished data).

Płociowe Lake (also called Rakowy Lake or Płocica Lake) is not a fluvial lake (Tab. 1). The vegetation in Płociowe Lake is composed of the phytocoenoses of 20 plant communities. Communities of lake bulrush, *Scirpetum lacustris*, form more or less dense beds that extend along the entire shoreline of the lake. Among other plant communities

Tab. 1 The most important features of Płociczno and Płociowe lakes [11–17].

Morphometric features and water exchange rate	Płociczno Lake	Płociowe Lake
Latitude (φ)	53°08.1' N	53°10.6' N
Longitude (λ)	16°00.2' E	16°03.1' E
Altitude (m)	59.4	71.4
Area (km ²)	0.561 km ²	0.353 km ²
Volume (thousand m ³)	1530.9	3620.0
Maximum depth (m)	5.2	25.0
Average depth (m)	2.7	10.3
Maximum length (m)	1800	1560
Maximum width (m)	500	310
Shoreline length (m)	5000	3450
Water supply	Flow-through lake	Closed lake
Trophy	Eutrophic	Mesotrophic
Nitrate content (g m ² year)	184.1	7.0
Phosphate content (g m ² year)	17.01	0.21
Water transparency – Secchi disk (m)	1.4	4.7
Water exchange (times/year)	46.0; polymictic	0.1; dimictic

of *Caricetum acutiformis*, *Caricetum elatae* Koch 1926, *Caricetum gracilis* (Graebn. et Hueck 1931) R. Tx. 1937, *Caricetum ripariae*, *Caricetum rostratae* Rübél 1912, *Caricetum vasicariae*, *Cladietum marisci* (Allorge 1922) Zobr. 1935, and *Phragmitetum australis* can be distinguished [3,10] (also, Kraska M, Piotrowicz R, 1998, unpublished data).

Field and laboratory study

Field studies were conducted in three subsequent vegetation seasons (2009–2011) in lake bulrush, *Schoenoplectus lacustris* (SL), that formed bulrush communities in lakes Płociczno and Płociowe in DNP. During each vegetation season, SL was collected twice from each lake, depending on weather conditions, in late June to early July and in the first 10 days of August (12 total field trips in three years). The SL plants with visible disease symptoms were collected from a boat alongside the shoreline (route method).

At each sampling, the collected material was composed of approximately 10 SL specimens exhibiting symptoms (Fig. 1a,b). As much as possible, the entirety of the SL specimen, including its submerged portions, was collected. The nomenclature of the host plant is provided in accordance with Mirek et al. [18].

Fresh parts of SL plants exhibiting disease symptoms were used in the laboratory studies

to isolate mycobiota. The samples were rinsed under running freshwater, and then their surfaces were disinfected (70% C₂H₅OH). Further procedures were conducted under sterile conditions. Cuttings (3–5 cm) were taken from each plant with disease symptom marks 3 to 15 mm in diameter. Five to 10 sections were obtained from each plant depending on the severity and variety of disease symptoms. The sections were placed on sterile paper in moist Petri dishes (Ø 10 and 15 cm) and incubated for 2 to 21 days at 20 ± 2°C. During incubation, the chambers were systematically moistened with sterile water aerosol, and the plant sections were examined daily under a stereo microscope to observe the morphological structure of the mycelium causing etiological symptoms. These structures were used to create microscope preparations in drops of lactic acid with dye (methylene blue), and they were observed under a Nikon Eclipse 200 at magnifications of 12.5×10, 40, and 66.

When fully formed fungi were not present and direct identification was not possible, they were moved to Petri dishes with PDA, CDA, MEA, and Sabouraud culture media (MERCK) with the addition of chloramphenicol. The preparation of fungal cultures and acquisition of single-spore cultures was performed using standard methods according to Waller et al. [19]. The microscopic fungi (fungi and fungus-like organisms) were identified (directly on host plants and in isolates cultured on media) using the following keys: Majewski [20], Sutton [21], Borowska [22], Kwaśna et al. [23], Ellis and Ellis [24], and Rietmüller [25]. The systematic framework used for the mycobiota was that of Kirk et al. [26], and the nomenclature was verified with Index Fungorum [27].

The results were interpreted by calculating biocenotic indexes such as the species richness and diversity of micromycetes according to Krebs [28] based on the taxonomic affiliation, frequency, and spatial structure of the mycobiota species [29,30]. Additionally, the Sørensen (SI) similarity index was calculated for species of microscopic fungi occurring on the SL in lakes Płociczno and Płociowe and in the different years of the study [28].

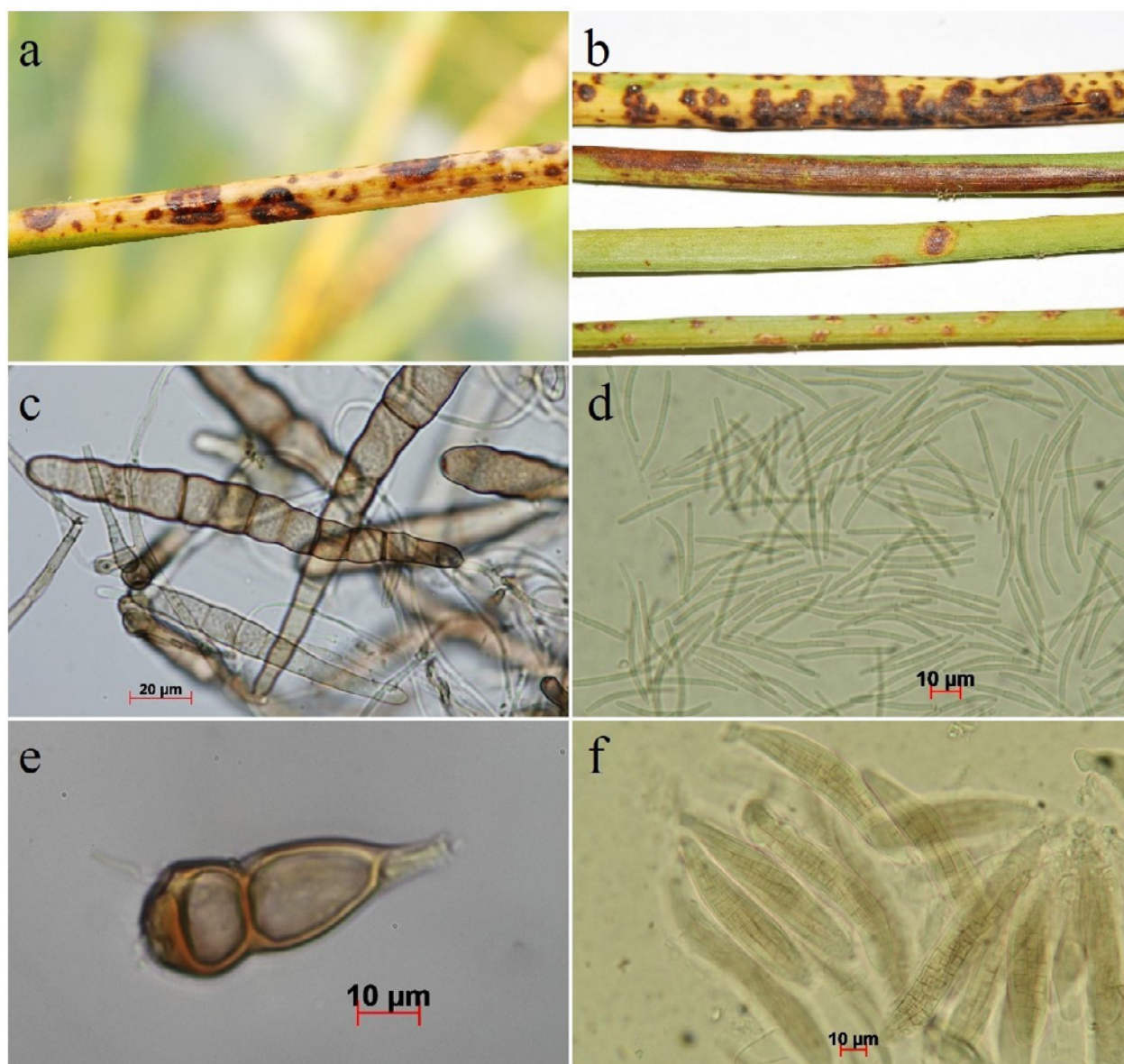


Fig. 1 a,b Disease symptoms on *Schoenoplectus lacustris* leaves. c Asexual spores of *Pyrenophora scirpicola*. d Asexual spores of *Pseudocercospora* sp. e Teliospore of *Puccinia scirpi*. f *Massariosphaeria scirpina* asci with ascospores. Photographs by Kinga Mazurkiewicz-Zapałowicz.

Results

The mycological and phytopathological studies conducted on SL collected from the littoral zone of the Płociczno and Płociowe lakes in DNP during 2009–2011 revealed the occurrence of 39 taxa of micromycetes. Ascomycota, with 37 taxa (95% of all identified), dominated the identified fungal community. Other true fungi were represented by one species from the division Basidiomycota (*Puccinia scirpi*), and one representative of chromistan fungi from the class Oomycota (*Pythium* sp.) was found on SL. Ascomycota was dominated by anamorphs, while only three species telemorphs (*Chaetomium globosum*, *Gibberella avenacea*, and *Massariosphaeria scirpina*) were identified. Of the 24 taxa confirmed on SL from Płociczno Lake, 23 were Ascomycota, while one was from the division Basidiomycota (*Puccinia scirpi*). Higher microscopic fungi species richness was noted on the SL from Płociowe Lake, where 35 taxa were identified, including 34 Ascomycota and one Oomycota (*Pythium* sp.) (Tab. 2).

In each year of the study, microfungi species richness was higher on the SL from Płociowe Lake than that from Płociczno Lake. The highest species richness on the SL from Płociowe Lake was 23 taxa (2010), while in Płociczno Lake it was 15 taxa

Tab. 2 Occurrence, frequency (f), and domination (D) of fungus species on *Schoenoplectus lacustris* in lakes Płociczno and Płociowe in 2009–2011.

No.	Fungi	Phyllum*	Number of records of fungi						f**	D***
			Płociczno Lake			Płociowe Lake				
			2009	2010	2011	2009	2010	2011		
1.	<i>Alternaria alternata</i> (Fr.) Keissl. 1912	A	1	1	1	1	1	1	M	Do
2.	<i>Cladosporium herbarum</i> (Pers.) Link 1816	A	1	1	1	1	1	1	M	Do
3.	<i>Fusarium incarnatum</i> (Desm.) Sacc. 1886 (syn. <i>Fusarium semitectum</i>)	A	1		1	1	1	1	M	Do
4.	<i>Fusarium sacchari</i> (E. J. Butler & Hafiz Khan) W. Gams 1971	A	1	1	1	1	1	1	M	Do
5.	<i>Gibberella avenacea</i> R. J. Cook 1967 (syn. <i>Fusarium avenaceum</i>)	A	1	1	1	1	1	1	M	Do
6.	<i>Pleospora scirpicola</i> (DC.) P. Karst. 1873 (syn. <i>Pyrenophora scirpicola</i>)	A	1	1	1	1	1	1	M	Do
7.	<i>Acremonium</i> sp. (syn. <i>Cephalosporium</i> sp.)	A			1		1	1	M	Sd
8.	<i>Alternaria tenuissima</i> (Kunze) Wiltshire 1933	A	1		1	1		1	M	Sd
9.	<i>Arthriniium</i> sp. Kunze 1817	A		1			1		M	Sd
10.	<i>Boeremia exigua</i> (Desm.) Aveskamp, Gruyter & Verkley 2010 (syn. <i>Phoma exigua</i>)	A		1				1	C	Sd
11.	<i>Chaetomium globosum</i> Kunze 1817	A	1		1			1	M	Sd
12.	<i>Chaetomium</i> sp. Kunze 1817	A				1	1		C	Sd
13.	<i>Chaetosphaeria vermicularioides</i> (Sacc. & Roum.) W. Gams & Hol.-Jech. 1976 (syn. <i>Chloridium chlamydosporum</i>)	A			1		1	1	C	Sd
14.	<i>Cladosporium cladosporioides</i> (Fresen.) G. A. de Vries 1952	A	1			1		1	M	Sd
15.	<i>Epicoccum nigrum</i> Link 1816	A			1		1		M	Sd
16.	<i>Fusarium culmorum</i> (Wm. G. Sm.) Sacc. 1892	A	1			1			M	Sd
17.	<i>Fusarium sporotrichioides</i> Sherb. 1915	A			1	1	1	1	M	Sd
18.	<i>Gibberella pulicaris</i> (Kunze) Sacc. 1877 (syn. <i>Fusarium sambucinum</i>)	A	1					1	M	Sd
19.	<i>Phaeosphaeria sowerbyi</i> (Fuckel) L. Holm 1957 (syn. <i>Leptosphaeria sowerbyi</i>)	A		1	1	1	1		M	Sd
20.	<i>Physalospora scirpi</i> (Gutner) Arx 1970 (syn. <i>Arthriniium curvatum</i>)	A			1	1	1	1	M	Sd
21.	<i>Pseudocercospora</i> sp. Deighton 1973	A	1	1		1	1		M	Sd
22.	<i>Acremoniella atra</i> (Corda) Sacc. 1886	A				1			C	R
23.	<i>Alternaria atra</i> (Preuss) Woudenb. & Crous 2013 (syn. <i>Ulocladium atrum</i>)	A						1	C	R

Tab. 2 Continued

No.	Fungi	Phyllum*	Number of records of fungi						f**	D***
			Płociczno Lake			Płociowe Lake				
			2009	2010	2011	2009	2010	2011		
24.	<i>Ascochyta</i> sp. Lib. 1830	A						1	C	R
25.	<i>Aspergillus niger</i> Tiegh. 1867	A					1		C	R
26.	<i>Aspergillus versicolor</i> (Vuill.) Tirab. 1908	A					1		C	R
27.	<i>Didymostilbe</i> sp. Henn. 1902	A					1		C	R
28.	<i>Fusarium oxysporum</i> Schltdl. 1824	A				1			C	R
29.	<i>Gonatobotrys simplex</i> Corda 1839	A				1			C	R
30.	<i>Massariosphaeria scirpina</i> (G. Winter) Leuchtm. 1984 (syn. <i>Leptosphaeria scirpinia</i>)	A				1			C	R
31.	<i>Microascus brevicaulis</i> S. P. Abbott 1998 (syn. <i>Scopulariopsis brevicaulis</i>)	A					1		C	R
32.	<i>Papulaspora immersa</i> Hotson 1912	A		1					C	R
33.	<i>Penicillium chrysogenum</i> Thom 1910	A					1		C	R
34.	<i>Penicillium</i> sp. Link 1809	A					1		C	R
35.	<i>Periconia</i> sp. Tode 1791	A			1				C	R
36.	<i>Puccinia scirpi</i> DC. 1805	B	1						C	R
37.	<i>Pythium</i> sp. Pringsh. 1858	Oo					1		C	R
38.	<i>Stagonospora aquatica</i> (Sacc.) Sacc. 1884	A					1		C	R
39.	<i>Trichothecium roseum</i> (Pers.) Link 1809	A	1						C	R
Number of records			14	10	15	18	23	17		
Total number of records			97							

*A – Ascomycota; B – Basidiomycota; Oo – Oomycota. ** C – common; M – in mass. *** Do – dominants; R – recedents; Sd – subdominants.

(2011). In Płociczno Lake, the lowest mycobiota species richness on SL was 10 taxa, while in Płociowe Lake, it was 17 taxa in both 2010 and 2011. During the study, only five fungal species occurred on SL every year and in both lakes: *Alternaria alternata*, *Cladosporium herbarum*, *Fusarium sacchari*, *Gibberella avenacea* (= *Fusarium avenaceum*), and *Pleospora scirpicola* (= *Pyrenophora scirpicola*) (Tab. 2, Fig. 1c). The species occurring exclusively in Płociczno Lake were *Papulaspora immersa*, *Puccinia scirpi*, and *Trichothecium roseum*, and those found only in Płociowe Lake were *Acremoniella atra*, *Alternaria atra*, *Aspergillus niger*, *A. versicolor*, *Fusarium oxysporum*, *Gonatobotrys simplex*, *Massariosphaeria scirpina*, *Microascus brevicaulis*, *Penicillium chrysogenum*, and *Stagonospora aquatic* (Fig. 2f, Tab. 2).

The frequency index of the micromycete species confirmed in both lakes indicated that in 2009–2011 the majority of them occurred abundantly (54%), while the remaining species occurred commonly (46%) (Tab. 2). No species were confirmed that occurred frequently, occasionally, or rarely.

The domination coefficient of species associated with SL in both lakes in 2009–2011 indicated that the most abundant group, comprising nearly half (46%) of all taxa noted, were recedents (18 taxa), 39% were subdominants (15 taxa), and 15% were dominants (six taxa) (Tab. 2). The domination coefficient for dominants was 5.15% and

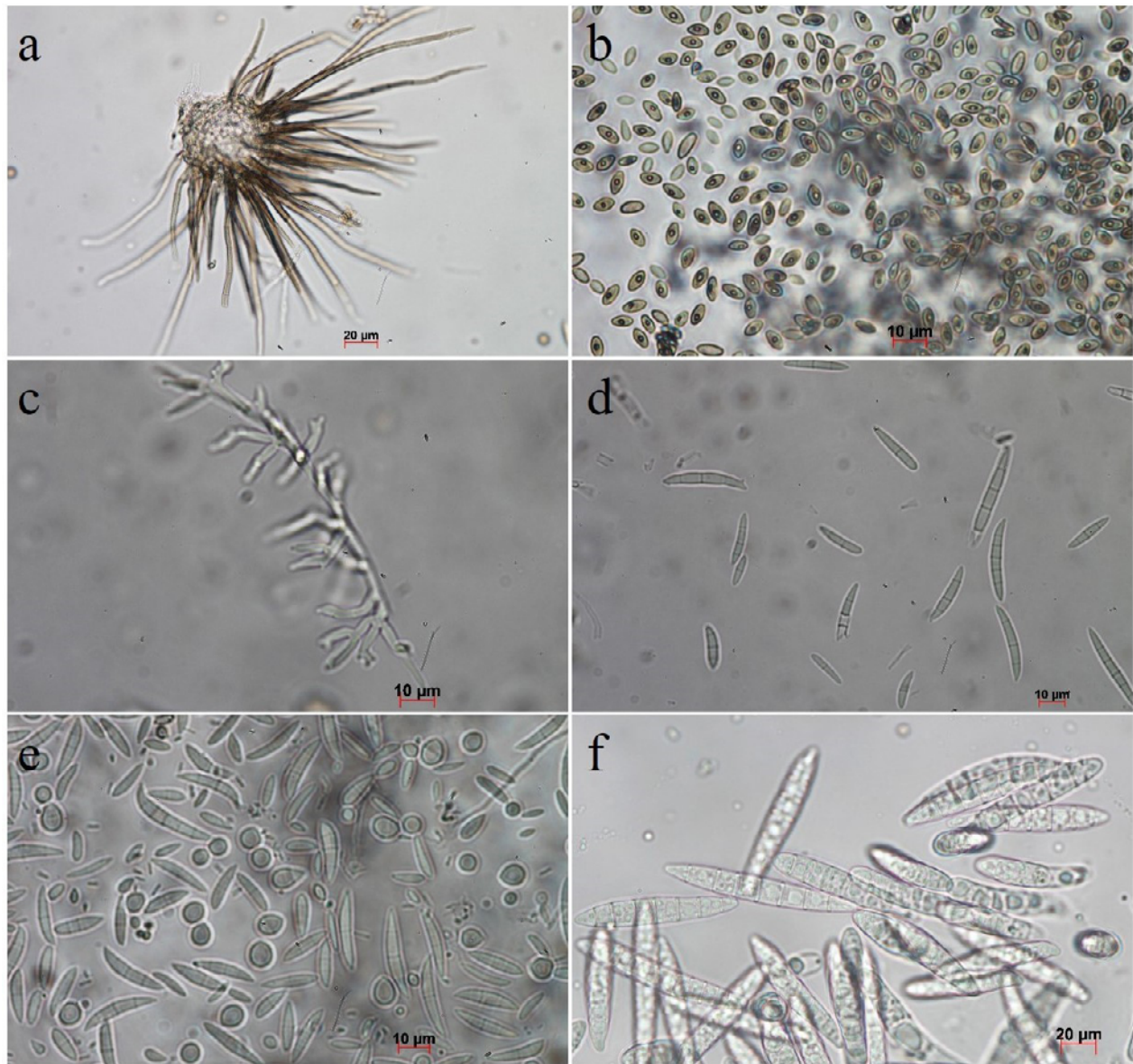


Fig. 2 a Perythecium of *Chaetomium globosum*. b Ascospores of *Chaetomium globosum*. c,d Conidiophore and micro- and macroconidia of *Fusarium incarnatum*. e Micro- and macroconidia of *Fusarium sporotrichioides*. f Conidia of *Stagonospora aquatica*. Photographs by Kinga Mazurkiewicz-Zapałowicz.

6.19%, for subdominants 2.06%, 3.09%, and 4.12%, and for recedents 1.03%. Among all the species noted, none was confirmed to belong to the classes of eudominants or subrecedents. In Płociczno Lake, the majority of fungal taxa on SL was represented by the class of subdominants (14 taxa), while the rest was from the class of dominants (six taxa) and recedents (four taxa) (Tab. 2). The most abundant group noted on SL in Płociowe Lake was also that of subdominants (15 taxa), and the least abundant was that of dominants (six taxa), while the remaining 14 taxa belonged to the class of recedents (Tab. 2).

The comparison of the mycobiota species richness on SL in lakes Płociczno and Płociowe indicated that throughout the 3-year study, the degree of species similarity was 67.8%, which corresponded to 20 common taxa that were confirmed on this host plant in both lakes (Tab. 3). The microfungi species similarity for SL in both lakes varied depending on the year of the study and fluctuated from 48.5% (eight common taxa) to 75% (12 common taxa) in 2010 and 2011, respectively. However, lesser differences in the coefficient of mycobiota species similarity on SL were confirmed in the two

Tab. 3 Number of common fungal taxa found on *Schoenoplectus lacustris* from lakes Płociczno and Płociowe and Sørensen similarity index between lakes in years 2009–2011.

	No. of taxa in common
2009	10 taxa; 62.5%
2010	8 taxa; 48.5%
2011	12 taxa; 75%
2009–2011	20 taxa; 67.8%

Tab. 4 Number of common fungal taxa found in years 2009–2011 on *Schoenoplectus lacustris* and Sørensen similarity index between years for lakes Płociczno and Płociowe.

	Płociczno Lake			Płociowe Lake		
	2009	2010	2011	2009	2010	2011
2009	×	6 taxa	8 taxa	×	11 taxa	10 taxa
2010	50%	×	6 taxa	53.7%	×	10 taxa
2011	55.2%	48%	×	57.1 %	50%	×

lakes separately in the different years of the study (Tab. 4). In Płociczno Lake, this coefficient fluctuated from 48% (in 2010 and 2011) to 55.2% (in 2009 and 2011), while in Płociowe Lake, the SI index ranged from 50% (in 2010 and 2011) to 57.1% (in 2009 and 2011) (Tab. 4).

Discussion

The results of the current study that revealed 39 fungal taxa associated with the SL in lakes Płociczno and Płociowe in DNP are impressive compared with other previous studies conducted in Poland. In the Masurian Lake District, Durska [31] noted one species, *Myrioconium scirpi*, on SL, which infected 50% of the plants. Rather modest data are also reported for Glinno Lake (Western Pomerania), where the occurrence of *Epicoccum nigrum* was only noted on SL [32], while two species, *Phyllosticta scirpi* and *Stagonospora schoenoplecti*, caused disease symptoms on SL in Czarne Sosnowickie Lake (Łęczna-Włodawa Lake District) [33]. Low species richness of microfungi associated with SL in Poland from studies cited above could arise from what they primarily refer to as pathogenic species, while the study discussed in the current paper focused on all the micromycete species associated with SL vegetation. Species isolated from SL in England also include *Coleosperma lacustrae* Ingold, *Trichobelonium questphalicum* Rehm, *Hypoderma scirpinum* DC. [34], and *Physalospora aquatica* [35], while in Ukraine, the SL species richness is characterized by the occurrence of other micromycete species such as *Niptera melanosphaera* Rehm., *N. pilosa* (Cross & Boudier), *Lasiosphaeria* sp., *Lophiotrema culmifraga* Speg., *Leptosphaeria clavicularpa* Ev. [36], species which seem to be of highly local significance. In contrast, according to Nannfeldt [37], *Belonopsis mediella* (P. Karst.) Aebi is characterized by a much wider range of occurrence and is confirmed on SL in England, Finland, France, Germany, Ireland, Sweden, and Switzerland. This author also reports the occurrence of *Niptera lacustris* (Fr.) in Scandinavia. The current study has not verified the occurrence of the species mentioned above in DNP or in Poland. Literature data indicate that the only other location where a similarly wide-ranging study was conducted is Hong Kong, China, where 39 taxa of these microorganisms were identified on SL [38]. Despite the approximate mycobiota species richness noted on SL from Hong Kong and in lakes Płociczno and Płociowe, there are notably distinct qualitative differences in their species diversity. Just six taxa [*Alternaria alternata*, *Cladosporium cladopsorioides*, *Fusarium incarnatum* (= *F. semitectum*) (Fig. 2c,d), *Periconia* sp., *Pseudocercospora* sp. (Fig. 1d), and *Trichotecium roseum*] that are associated with SL are common in the areas discussed. Wong et al. [38] report 27 taxa on SL that were not noted in our study. None of these species was confirmed in the present study, and they are also lacking from the report by Ellis and Ellis [24], in which they identified 13 micromycete species that are potentially linked to *Schoenoplectus* in Europe. Among these, the occurrence of the following seven taxa was confirmed on SL in the present study: *Alternaria* sp., *Puccinia scirpi* (Fig. 1e) *Massariosphaeria scirpina* (= *Leptosphaeria scirpina*), *Pleospora scirpicola* (= *Pyrenophora scirpicola*) (Fig. 1c), *Phaeosphaeria sowerbyi* (= *Leptosphaeria sowerbyi*), *Pseudocercospora* sp. (Fig. 1d), and *Stagonospora aquatica* (Fig. 2f). In the research by Wong et al. [38] and in each year of the current study, the species confirmed on SL were dominated by anamorphs of Ascomycota, which occurred in mass and commonly. The constancy of these tendencies is evidenced by the biocoenotic stability of the phytocoenoses studied, which is also a suggested point by Subramanian [39] and Adamska [40]. Teleomorphs rarely occur in Europe. They have been described in Mecklenburg – West Pomerania, where only *Coronellaria pulicaris* s. l. (P. Karsten) Sacc. [= *Peziza palustris* (P. Karst.)] was observed [41].

Most of micromycete taxa found on SL are facultative parasites and saprotrophic fungal species. Such trophic groups of fungi on other host plants with similar ecological requirements include *Alternaria*, *Cladosporium*, and *Fusarium*, which were previously identified in Drawa National Park [42] and in Słowiński National Park [40].

Our and other authors' previous studies indicate that microfungi species richness and diversity on host plants are specific to vegetation regions, and their occurrence is shaped by local environmental conditions. These environmental differences result in low mycobiota species similarity coefficient values at different times and from different areas of occurrence of given host plant species. In the present study, these relationships were confirmed by the SI index of less than 60%, which expressed the mycobiota species similarity on SL in each of the lakes (Płociowe and Płociczno) in comparable years of the study (Tab. 4). Mycological diversity in different years of the study could arise from different weather conditions, which, depending on the year of the study, facilitated the development of other microorganisms [43]. However, during each vegetation season, the microscopic fungi diversity coefficient may be affected by specific local abiotic and biotic conditions in addition to weather factors like element accessibility and plant vulnerability [44,45]. The significance of these conditions is confirmed by the wide range of the SI index of mycobiota species similarity (48.5–75%), which indicates the share of common micromycetes on SL in the lakes compared in the same year of the study (Tab. 3). Lower SI index values for the microorganisms occurring on the same host plant determine increases in the diversity of the phytocoenoses created by these microorganisms.

Among the fungi that determine the health of SL, the *Pleospora rubelloides*, associated with *Schoenoplectus tabernaemontani* [24], and *P. scirpicola* (Fig. 1c), which were confirmed in the current study on SL, are noteworthy. In DNP, the significance of *P. scirpicola* is confirmed by its presence on SL in both lakes in all years of the study and by the fact that it is one of six representatives of the dominants class (Tab. 2) alongside with such abundant polyphagous species as *Alternaria alternata*, *Cladosporium cladosporioides*, *Fusarium incarnatum*, *F. saccharii*, and *Gibberella avenacea*. *Pleospora scirpicola* appears to have a significant impact on the health of SL in Europe, which is confirmed by its wide range of distribution extending from England [35] to Ukraine (the former USSR) [36].

Nevertheless, it is noteworthy that in the current study the occurrence of telial stage (stage III) of *Puccinia scirpi* was confirmed on SL in Płociczno Lake (Tab. 2, Fig. 1e). This is the first confirmed occurrence of this stage on SL since the nineteenth century, when, according to Majewski [46], this species was described on Wolin Island, in Kołobrzeg, near Legnica and Ścinawa, and in the vicinity of Cracow and Międzyrzec Podlaski. The rare occurrence of this rust may be associated with the equally sporadic, though dispersed, occurrence of *Nymphoides peltata*, its ecidial host (stage 0; I), in its natural habitats [47]. However, in Europe, the telial stage of *P. scirpi* has also been noted on other species from the family Cyperaceae, including *Bolboschoenus maritimus* and *Blysmus compressus* (in the former Czechoslovakia) [46]. Increasing host range is often associated with changes in the epidemiology of pathogenic factors [48]. In the context of the possibility of increasing pathogen host range, information about two new fungus species of Ustilaginales confirmed by Vánky and Shivas [49] on representatives of the genus *Schoenoplectus* in the subtropical zone of Australia is important. This refers to *Dermatosorus schoeoplecti* associated with *Schoeoplectus mucronatum* and *Dermatosorus thirumalachari* confirmed on *Scirpus supinus* (= *Schoenoplectus supinus*). In Taiwan, in addition to the well-known *Pestalotia palmarum*, two new species of mycobiota, *Hyalotia lateripes* and *Polyschema olivacea*, were also described on *S. tiquer* [50]. Most probably, SL is also a potential host of these and other phytopathogens, which will certainly appear in Polish latitudes, which is just a question of time. Evidence of this fact is found in the Netherlands, where recent studies describe the new species *Bloxamia hesteriae* M. Spooren sp. nov. that was first noted on *Schoenoplectus tabernaemontani* and SL and then on other representatives of the family Cyperaceae (i.e., *Eleocharis palustris*) [51].

Climate change plays a significant role in the dynamics of widening the spectrum of hosts, often associated with the widening of the range of microorganisms [52]. Such dependencies, related to, i.a., higher temperatures, are explained by the increased intensity of the powdery mildew (*Erysiphe flexuosa*) epidemic in urban areas [53]. The dynamics of the emergence of one species and the withdrawal of other species of micromycetes can affect the stability of the ecosystem. This is manifested by the predominant role of saprotrophs and facultative pathogens that guarantees the natural course of seasonal decomposition of host plants.

Conclusions

- The abundance and species diversity of microscopic fungi on *Schoenoplectus lacustris* differ depending on the study area.
- Anamorphic forms dominate between micromycetes associated with *S. lacustris*.
- The dominant trophic and ecological group of micromycetes isolated from *S. lacustris* are saprobionts and facultative parasites.
- In Poland, the presence of *Puccinia scirpi* on *S. lacustris* was observed and confirmed for the first time since the nineteenth century.

Acknowledgments

The authors would like to express their sincere thanks to the Regional Director for Environmental Protection and the Drawa National Park management for giving their consent for carrying out examinations, as well as to all park employees for their assistance during the execution of field work.

References

1. Smith SG. *Schoenoplectus*. In: Flora of North America Editorial Committee, editors. Flora of North America North of Mexico. Vol. 23: Magnoliophyta: Commelinidae (in part): Cyperaceae. New York, NY: Oxford University Press; 2002. p. 44–60.
2. Kopeć D, Michalska-Hejduk D. How threatened is the Polish wetland flora? *Oceanol Hydrobiol Stud.* 2012;41(3):79–89. <https://doi.org/10.2478/s13545-012-0030-2>
3. Matuszkiewicz W. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Warszawa: Wydawnictwo Naukowe PWN; 2002.
4. Gessner M, Gulis V, Kuehn K, Chauvet E, Suberkropp K. Fungal decomposers of plant litter in aquatic ecosystems. In: Kubicek C, Druzhinia I, editors. Environmental and microbial relationships. Berlin: Springer; 2007. p. 301–324. (Mycota; vol 4). <https://doi.org/10.1007/978-3-540-71840-6>
5. Wurzbacher CM, Bärlocher F, Grossart HP. Fungi in lake ecosystems. *Aquat Microb Ecol.* 2010;59:125–149. <https://doi.org/10.3354/ame01385>
6. Szwedler I, Sobkowiak M. Spotkania z przyrodą. Rośliny. Warszawa: Oficyna Wydawnicza Multico; 1998.
7. Fischer H, Mille-Lindblom C, Zwirnmann E, Tranvik LJ. Contribution of fungi and bacteria to the formation of dissolved organic carbon from decaying common reed (*Phragmites australis*). *Arch Hydrobiol.* 2006;166(1):79–97. <https://doi.org/10.1127/0003-9136/2006/0166-0079>
8. Kujawa-Pawlaczyk J, Pawlaczyk P. Drawieński Park Narodowy. Warszawa: Oficyna Wydawnicza Multico; 2002.
9. Kucharski B, Pawlaczyk P. Drawieński Park Narodowy i okolice: przewodnik turystyczny. Warszawa: Wydawnictwo PTTK “Kraj”; 1997.
10. Kraska M. Jeziorne kompleksy roślinne Drawieńskiego Parku Narodowego. In: Agapow L, Jasnowski M, editors. Przyroda projektowanego Drawieńskiego Parku Narodowego. Gorzów Wielkopolski: Gorzowskie Towarzystwo Naukowe; 1986. p. 157–162.
11. Jańczyk J. Atlas jezior Polski. Jeziora Pojezierza Wielkopolskiego i Pomorskiego w granicach dorzecza Odry. Poznań: Bogucki Wydawnictwo Naukowe; 1996.
12. Kraska M. Jeziora Drawieńskiego Parku Narodowego. In: Agapow L, editor. Drawieński Park Narodowy. Gorzów Wielkopolski: Wojewódzki Fundusz Ochrony Środowiska i Gospodarki Wodnej; 1998. p. 125–145. (Przyroda Województwa Gorzowskiego).
13. Choiński A. Katalog jezior Polski. Poznań: Fundacja Warta; 1992.
14. Piotrowicz R, Kraska M, Klimaszuk P, Szyper H, Joniak T. Vegetation richness and nutrient loads in 16 lakes of Drawieński National Park (northern Poland). *Pol J Environ Stud.* 2006;1(3):467–478.
15. Klimaszuk P, Gancarczyk A. Ekosystemy wodne Drawieńskiego Parku Narodowego. In: Joniak T, editor. Bezkręgowce denne wód parków narodowych Polski. Poznań: Zakład

- Ochrony Wód UAM w Poznaniu; 2010. p. 11–18.
16. Klimaszuk P, Kraska M, Joniak T, Piotrowicz R. Jezioro meromiktyczne, unikatowy ekosystem wodny w Drawieńskim Parku Narodowym – funkcjonowanie i ochrona. In: Grzeskowiak A, Nowak B, editors. Dynamika procesów przyrodniczych w zlewni Drawy i Drawieńskim Parku Narodowym. Poznań: Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy; 2010. p. 47–53.
 17. Drawieński Park Narodowy [Internet] 2017 [cited 2017 Jul 5]. Available from: <http://www.dpn.pl>
 18. Mirek Z, Piękoś-Mirkowa H, Zając A, Zając M, editors. Flowering plants and pteridophytes of Poland – a checklist. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2002. (Biodiversity of Poland; vol 1).
 19. Waller JM, Ritchie BJ, Holderness M. Plant clinic handbook. Oxon: CAB International; 1998. (IMI Technical Handbooks; vol 3).
 20. Majewski T. Grzyby (Mycota). T. 11. Podstawczaki (Basidiomycetes), rdzawnikowe (Uredinales). II. Warszawa: Państwowe Wydawnictwo Naukowe, Instytut Botaniki im. W. Szafera Polskiej Akademii Nauk; 1979. (Flora Polska. Rośliny Zarodnikowe Polski i Ziemi Ościennych).
 21. Sutton BC. The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stromata. Kew: CMI; 1980.
 22. Borowska A. Grzyby (Mycota). T. 16. Grzyby niedoskonałe (Deuteromycetes), strzępczakowe (Hyphomycetes), ciemnobarwnikowe fialidowe (Dematiaceae, Phialoconidae). Warszawa: Państwowe Wydawnictwo Naukowe, Instytut Botaniki im. W. Szafera Polskiej Akademii Nauk; 1986. (Flora Polska. Rośliny Zarodnikowe Polski i Ziemi Ościennych).
 23. Kwaśna H, Chelkowski J, Zajkowski P. Grzyby (Mycota). T. 22. Grzyby niedoskonałe (Deuteromycetes), strzępczakowe (Hyphomycetales), gruzelkowate (Tuberculariaceae), sierpik (Fusarium). Warszawa: Państwowe Wydawnictwo Naukowe, Instytut Botaniki im. W. Szafera Polskiej Akademii Nauk; 1991. (Flora Polska. Rośliny Zarodnikowe Polski i Ziemi Ościennych).
 24. Ellis MB, Ellis JP. Microfungi on land plants. An identification handbook. London: The Richmond Publishing Company Ltd.; 1997.
 25. Rietmüller A. Morphologie, Ökologie und Phylogenie aquatischer Oomyceten. Berlin: J. Cramer; 2000. (Bibliotheca Mycologica; vol 185).
 26. Kirk PM, Cannon PF, Minter DW, Stalpers JA. Dictionary of the fungi. 10th ed. Wallingford: CABI Europe; 2008.
 27. Index Fungorum [Internet]. 2017 [cited 2017 Jul 5]. Available from: <http://www.indexfungorum.org>
 28. Krebs CJ. Ekologia: eksperymentalna analiza rozmieszczenia i liczebności. Warszawa: Wydawnictwo Naukowe PWN; 2001.
 29. Mułenko W. A review of the methods used for studies on parasitic fungi in natural plant communities. Acta Mycol. 1997;32(2):323–346. <https://doi.org/10.5586/am.1997.029>
 30. Ruskiewicz-Michalska M. Mikroskopijne grzyby pasożytnicze w zbiorowiskach roślinnych Wyżyny Częstochowskiej. Łódź: Polskie Towarzystwo Botaniczne; 2006. (Monographiae Botanicae; vol 96). <https://doi.org/10.5586/mb.2006.001>
 31. Durska B. Studies on parasitic fungi of plants occurring in the lake littoral of the Masurian Lakeland. Acta Mycol. 1974;10(1):73–141. <https://doi.org/10.5586/am.1974.002>
 32. Mazurkiewicz-Zapałowicz K, Wróbel M, Silicki A, Wolska M. Studies on phytopathogenic and saprotrophic fungi in rush associations of Lake Glinno (NW Poland). Acta Mycol. 2006;41(1):125–138. <https://doi.org/10.5586/am.2006.016>
 33. Mułenko W. Mikroskopowe grzyby fitopatogeniczne Pojezierza Łęczyńsko-Włodawskiego. II. Acta Mycol. 1988;24(2):125–171. <https://doi.org/10.5586/am.1988.010>
 34. Ingold CT. Aquatic Ascomycetes: Discomycetes from lakes. Transactions of the British Mycological Society. 1954;37:1–18. [https://doi.org/10.1016/S0007-1536\(54\)80059-3](https://doi.org/10.1016/S0007-1536(54)80059-3)
 35. Ingold CT. Aquatic Ascomycetes: further species from the English Lake district. Transactions of the British Mycological Society. 1955;38:157–168. [https://doi.org/10.1016/S0007-1536\(55\)80026-5](https://doi.org/10.1016/S0007-1536(55)80026-5)
 36. Dudka IO. Data on the flora of aquatic fungi of the Ukrainian SSR. II. Aquatic Hyphomycetes of Kiev Polesse. Ukraine Botanical Journal. 1963;20:86–93.

37. Nannfeldt JA. *Niptera*, *Trichobolonium* und *Belanopsis*, drei noch zu erläuternde Gattungen der mollisioiden Discomyceten. Sydowia. 1985;38:194–215.
38. Wong MKM, Hyde KD. Diversity of fungi on six species of Gramineae and one species of Cyperaceae in Hong Kong. Mycol Res. 2001;1485–1491. <https://doi.org/10.1017/S0953756201004695>
39. Subramanian CV. Hyphomycetes. Taxonomy and biology. London: Academic Press; 1983
40. Adamska I. Zróżnicowanie zbiorowisk grzybów mikroskopowych w odniesieniu do zróżnicowania zbiorowisk roślinnych w Słowińskim Parku Narodowym. Szczecin: Wydawnictwo Uczelniane ZUT w Szczecinie; 2013.
41. Richter T, Baral HO. *Coronellaria pulicaris*, *Mollisia luctuosa* und *Marasmius cornelii* – selten Saprobiten an Cyperaceen. Boletus. 2008;31(1):45–63.
42. Mazurkiewicz-Zapałowicz K, Golianek A, Łopusiewicz Ł. Microscopic fungi on Nymphaeaceae plants of the Lake Płociczno in Drawa National Park (NW Poland). Acta Mycol. 2016;51(1):1079. <https://doi.org/10.5586/am.1079>
43. Desprez-Loustau ML, Coutrecuisse R, Robin C, Husson C, Moreau PA, Blancard D, et al. Species diversity and drivers of spread of alien fungi (sensu lato) in Europe with a particular focus on France. Biol Invasions. 2010;12:157–172. <https://doi.org/10.1007/s10530-009-9439-y>
44. Dłużniewska J. Występowanie chorób powodowanych przez grzyby na wierzbie (*Salix* sp.) w zależności od wieku roślin. Progress in Plant Protection. 2011;51(3):1146–1149.
45. Dłużniewska J, Nadolnik M, Kulig B. Choroby rzepaku ozimego w zależności od poziomu zaopatrzenia roślin w azot i siarkę. Progress in Plant Protection. 2011;51(4):1811–1815.
46. Majewski T. Analiza geograficzna flory Uredinales Polski. Acta Mycol. 1978;14(1–2):13–107. <https://doi.org/10.5586/am.1978.002>
47. Gdaniec M. Nowe stanowisko *Nymphoides peltata* (S. G. Gmel.) Kuntze w Borach Tucholskich. Acta Botanica Cassubica. 2010;7–9:243–245.
48. Koralewski Z, Werner M, Andrzejak R, Kosiada T. Rozprzestrzenianie mączniaka prawdziwego (*Erysiphe flexuosa* U. Braun & S. Takamatsu) na kasztanowcach w Wielkopolsce. Progress in Plant Protection. 2010;50(4):1797–1800.
49. Vánky K, Shivas RG. Further new smut fungi (Ustilaginomycetes) from Australia. Fungal Divers. 2003;14:243–264.
50. Wu CG, Tseng HY, Chen ZC. Fungi inhabiting on *Schoenoplectus triqueter* (L.) Palla (I). Taiwan. 1982;27:35–38.
51. Sporeen M. A new species of *Bloxamia* from freshwater in the Netherlands. Mycosphere. 2014;5(2):346–349. <https://doi.org/10.5943/mycosphere/5/2/8>
52. Glawe AD. The powdery mildews: a review of the world's most familiar (yet poorly known) plant pathogens. Annu Rev Phytopathol. 2008;46:27–51. <https://doi.org/10.1146/annurev.phyto.46.081407.104740>
53. Stankeviciene A, Snieskiene V, Lugauskas A. *Erysiphe flexuosa* – the pathogen of *Aesculus hippocastanum* in Lithuania. Phytopathologia. 2010;56:67–71.