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ORIGINAL RESEARCH PAPER

Microscopic fungi on Nymphaeaceae plants of the Lake Płociczno in Drawa National Park (NW Poland)

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Abstract

The aim of this study was to determine the occurrence of micromycetes associated with disease symptoms on the leaves and flowers of three plant species, *Nymphaea alba* (NA), *Nymphaea candida* (NC), and *Nuphar lutea* (NL), forming nympheid phytocoenoses on Lake Płociczno in Drawa National Park during the years 2009 to 2012. From all collected plant specimens, an overall number of 38 distinct taxa of fungi and chromistan fungal analogues was isolated. The largest diversity of taxa was found on NL (37 taxa), the lowest was on NC (4 taxa), and NA contained 12 taxa.

Each year, anamorphic forms of Ascomycota were dominant in the taxonomic structure. For the first time in Poland, *Septoria nupharis* (NA, NL, NC) and *Colletotrichum nymphaeae* (NL, NC) were found on their spotted leaves. For both of the mentioned pathogens, *Nymphaea candida* is a new host plant in Poland. *Botrytis cinerea*, *Elongisporangium undulatum* (= *Pythium undulatum*), *Epicoccum nigrum*, *Fusarium incarnatum* (= *F. semitectum*), and *Gibberella avenacea* (= *Fusarium avenaceum*) were found each year in the studied phytocoenoses. The confirmation of NA and NL flower infections by *Botrytis cinerea*, which leads to gangrene, is an important aspect of the gray mold epidemiology. Until now, the occurrence of smut fungi on nympheids in Drawa National Park was not observed. The taxonomic structure and the predomination of asexual stages of fungi, as well as the similarity coefficients, suggest that the seasonal decomposition of nympheids run naturally and contribute to maintaining the stability of the lake ecosystem.

Keywords

fungal diversity; pathogenic fungi; *Nuphar*; *Nymphaea*; distribution

Introduction

Worldwide, Nymphaeaceae Salisb. consists of approx. 70 species from all over the world classified in six genera (*Barclaya* Wall., *Euryale* Salisb., *Nuphar* Sm., *Nymphaea* L., *Ondinea* Hartog., and *Victoria* Lindl.). Five taxa occur in the Polish natural habitats: *Nymphaea alba* L., *N. candida* C. Presl. and their hybrids *Nymphaea ×borealis* Camus, *Nuphar lutea* (L.) Sibth. & Sm., and *N. pumila* (Timm) DC. The plants inhabit chemically rich (= fertile), shallow, still and slow-flowing waters, mainly on lowlands. Phytocoenoses formed by these plants have been protected by the European Union Networking Programme Natura 2000 since 2010 as naturally valuable. Moreover, in accordance with the decree of the Polish Minister of Environment on 9 October 2014, *Nuphar pumila* is strictly protected while *Nymphaea alba* and *N. candida* have been

granted partial protection. The natural habitats of these plants are used, as well as others, to estimate the quality of surface waters in the ecological state macrophyte index [1]. Nymphaeaceae plants are an essential element in the process of creating an environment for other organisms. The plants health in ecosystems depends on the activity of pathogenic and saprotrofic mycobiota associated with the vegetation. In Poland, phytopathological studies on Nymphaeaceae plants in their natural ecosystems have so far been carried out only sporadically [2,3]. Taking into consideration the shortage of knowledge on the topic of microorganisms' participation in the functioning of valuable phytocoenosis within the nympheids, research has been set up to study the biodiversity of fungi and chromistan fungal analogues, which is crucial for the health of these plants in the protected area of Drawa National Park.

Material and methods

Field studies were carried out during four successive vegetation seasons (2009–2012) on fungi associated with plant species of the Nymphaeaceae family: *Nymphaea alba* L. (NA), *N. candida* C. Presl. (NC), *Nuphar lutea* (L.) Sibth. & Sm. (NL). Samples were collected twice during each vegetation season, depending on atmospheric conditions, i.e., at the turn of June and July and in the first decade of August from all five localities (1–5; Fig. 1). Each time up to 10 host plants (entire individuals when possible) with visible symptoms of diseases were collected (Fig. 2a). Plant nomenclature follows from Mirek et al. [4].

Characteristics of the studied area

The Lake Płociczno is a flow reservoir with the Płociczna River flowing through it (Fig. 1). For more than 20 years, the river's mouth has been blocked due to the increasing level of lake water forming a characteristic delta. In the 1980s, the delta of the Płociczna River was a candidate for ranking as a monument of inanimate nature [5].

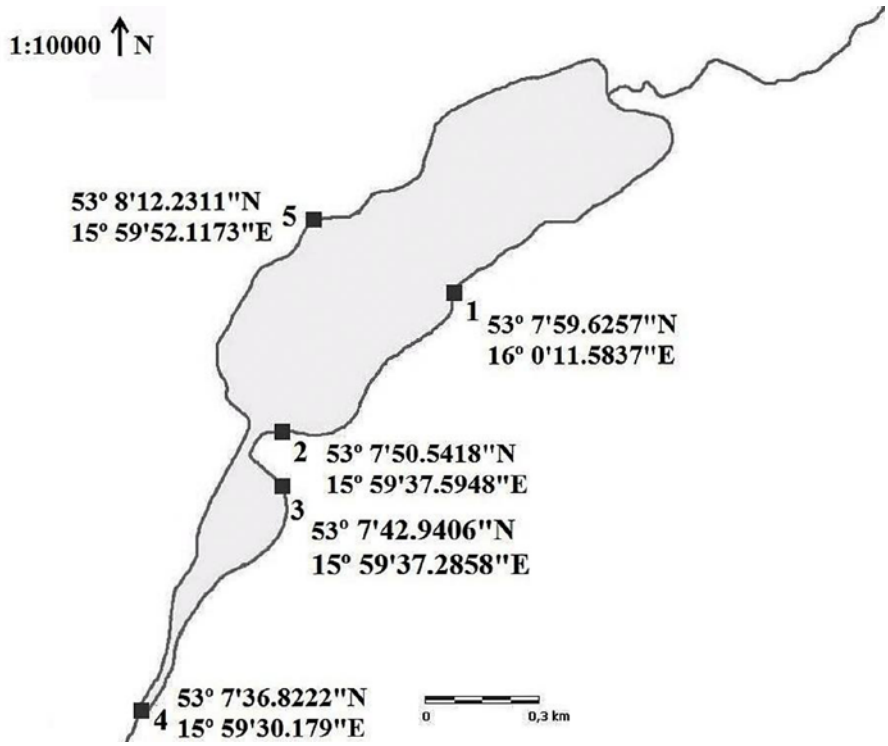

Fig. 1 The Lake Płociczno – localities (1–5). Source: http://geoportal.gov.pl, edit. Aleksandra Golianek.

The Lake Płociczno is shallow (average depth 2.7 m) and characterized by a high concentration of nutrients dissolved in the water (eutrophic lake, at the edge of hypertrophy). The lake water has a high level of nitrates (184.1 g m^2/year) and phosphates (17.0 g m^2/year), and its transparency is only 1.4 m. Due to the multiplicity of the water exchange (46 times a year), it is a polymictic lake [6]. An occurrence of phytocoenoses belonging to 17 plant associations was found in Lake Płociczno. Plants belonging to the *Nupharo-Nymphaeetum albae* and *Nymphaeetum candidae* associations form a wide belt at the opposite ends of the lake, grouped along the river banks and in the inflow and outflow areas, which are strongly shallowed by deposits of organic and inorganic matter [7].

Laboratory methods

During the laboratory tests, fresh parts of plants with disease symptoms on the leaves, flowers, and petioles were used for the isolation of microorganisms. Those plants were rinsed under cold tap water and then surface sterilized using 70% ethanol. Further analysis was carried out in sterile conditions. Fragments of 3 to 5 cm that contained areas of healthy tissue as well as areas with symptoms of diseases were cut from each plant. Between 10 to 15 samples were obtained from each plant, depending on the intensity and diversity of the symptoms. These samples were placed on a piece of sterile filter paper under Petri dishes (Ø 10 and 15 cm) in humidity chambers and incubated for 2 to 21 days at a temperature of 20 ±2°C. In the meantime, the humidity chambers were regularly moistened with sterile water aerosol, and the plant samples were screened daily under a stereoscopic microscope for primary etiological symptoms. Microscopic sections of infected plant tissues were prepared with lactic acid and dye methylene blue and observed under the Zeiss Axio microscope (125, 500, 825). In the absence of developed fungal structures, samples were transferred to plates with PDA, CDA, MEA, and Sabouraud media (MERCK). Fungal cultures, including single-spore cultures, were prepared using standard methods as listed by Waller et al. [8]. For the taxonomic identification of microscopic fungi and chromistan fungal analogues (directly from host plants as well as on artificially grown isolates) the keys by Skiergiełło [9], Borowska [10], Ellis and Ellis [11], Rietmüller [12], Kwaśna et al. [13], and Sutton [14] were used. Taxonomical system of Kirk et al. [15] was adapted, verifying their nomenclature with Index Fungorum [16]. The calculations of biocenotic factors, such as the diversity of microscopic fungi (Shannon–Wiener's coefficient – *H'*) according to Krebs [17], the structure based on taxonomic position, 5-degree frequency scale, and spatial structure [18,19] were used in the interpretation of the results. The Jaccard-Sörensen similarity coefficient was applied for microscopic fungi occurring on host plants and for NL in the individual years of research [17].

Results and discussion

On three plant species from the Nymphaeaceae family (NA, NC, and NL) that formed compact phytocoenoses on the Lake Płociczno in Drawa National Park, 38 taxa of microscopic fungi and chromistan fungal analogues were found. Among fungi ascomycetes were dominating group – 32 taxa (84.21%), while zygomycetes and basidiomycetes were represented by single species: *Mucor* sp. and *Athelia rolfsii* (= *Sclerotium rolfsii*), respectively. Disease symptoms were also caused by four taxa of chromistan fungal analogues from Oomycota (10.52% of total species number; Tab. 1). Among ascomycete anamorphs (30 taxa) were dominant and their teleomorphs were formed by two species (*Gibberella avenacea* and *Sordaria fumicola*; Fig. 2b). The dominant participation of anamorphic Ascomycota forms repeated itself in subsequent years of study with 16 taxa (88.89%) in 2009, 13 taxa (92.85%) in 2010, 16 taxa (84.21%) in 2011, and 25 taxa (89.28%) in 2012.

Sustainability of these trends may indicate stability and a biocenotic balance of the analyzed biocenoses, which is also suggested by Mułenko [20] and Adamska [21]. Among all studied host plants, symptoms of disease occurred only on NL and were associated with the presence of a total of 37 taxa in each year of the study. In comparison with other phytopathological-mycological studies conducted in Western Pomerania, it is an impressive number. In earlier studies on NL from Lake Glinno, only 21 taxa were listed [2], whereas on Lake Sitno in Drawa National Park only 10 taxa were found [3]. On NA, the abundance of fungi and chromistan fungal analogues species in Drawa National Park showed smaller differences. In disease of this plant, a similar number of taxa, 12 and 14 taxa, were involved on Lake Płociczno and Lake Sitno, respectively [3]. These findings may not seem satisfactory in comparison with other regions of Poland, such as Lesser Poland and Subcarpathian voivodeships, where, on NA, 42 taxa fungi and chromistan fungal analogues were found [22,23]. However, it should be noted that many species were found on phyllospheres of NA grown in garden ponds. In these tanks, the cultivation of many varieties of water lilies is preferred, as they

are more impressive and decorative and also less resistant to pathogens, compared to their wild counterparts. In addition, in these artificial reservoirs, abiotic and biotic conditions are different from those in natural water ecosystems, which modifies the richness and species diversity of many organisms [24], including fungi and chromistan fungal analogues. The taxonomic diversity of mycobiota growing on nympheids in Lake Płociczno was primarily determined by a group of subrecedents (14 taxa), recedents (9 taxa), and dominants (9 taxa; Tab. 1). In this study, only four species, *Chaetomium globosum*, *Colletotrichum nymphaeae*, *Fusarium sporotrichioides*, *Septoria nupharis*, were found on NC. These findings are very valuable because NC is a new host for them in Poland. In all the years of the study, species diversity associated with the leaves of Nymphaeaceae plants was characterized by the presence of *Botrytis cinerea*, *Elongisporangium undulatum*, *Epicoccum nigrum*, *Fusarium incarnatum*, and *Gibberella avenacea*. Gray mold pathogen was also isolated from the flowers of NA and NL but was not found on NC (Tab. 1). These results confirm the causal effect of *B. cinerea* on NA and NL, which was first recognized earlier in other parts of Western Pomerania [2]. Kowalik [22,23] and Kowalik and Krasny [25] have emphasized similar threats in southern Poland. Their research confirmed the widespread distribution of *B. cinerea* on NA grown in garden ponds. This fact shows that the occurrence of gray mold on NA and NL in Poland is not just local. In many phytocoenoses, such as in these studies, it may appear as a dominant (Tab. 1). However, the current lack of gray mold on NC is probably associated with the far fewer occurrences of this host plant in nympheid communities. The reasons for this change are NC withdrawal from its habitats [26] as well as NA's and NC's ability to create hardly distinguishable hybrids. Similar to other plant species' hybrid genotypes, hybrids of NA and NC may have a temporary resistance to certain physiological strains of pathogens. In this case, only changes of the pathogen's virulence allow for the development of the disease and extend the range of host plants [27,28]. The results of this study indicate one more important aspect of the epidemiology of gray mold associated with the confirmed infection of flowers by *B. cinerea*. This particularly dangerous phase of the disease leads to generative organs' gangrene, which limits the landscape and decorative value of plants with extremely ornamental flowers. Another pathogen that regularly affects the health of Nymphaeaceae plants is *Elongisporangium undulatum* belonging to chromistan fungal analogues. This species and two others, *Septoria nupharis* and *Colletotrichum nymphaeae*, occur in large quantities and have the highest frequency (100%). *Elongisporangium undulatum* causes extensive brown spots on the leaves that form numerous oospores starting from mid-July (Fig. 2a,c). So far, this pathogen is isolated in Poland, not only from the Biebrza River [29], but also from NL growing in its natural habitats [2] and from NA grown in artificial ponds [22,23]. The occurrence of *E. undulatum* (previously *Pythium undulatum*) was also found in Europe in necrotic plant tissues of *Nymphaea* plants [30,31]. This fact shows that *E. undulatum*, like its relatives of the genus *Pythium*, is responsible for the decay of hydrophytes parenchymal tissues [32]. *Pythium marsipium* Drechsler, *P. pleroticum* T. Ito., and *P. diclinum* Tokunaga are also involved in the biological decomposition. These species were found on *Nymphoides peltata* [33], which forms floating leaves, similarly to *Nuphar* and *Nymphaea* plants.

Due to the occurrence on all examined host plants, three other species of fungi are noteworthy: *Chaetomium globosum*, *Fusarium sporotrichioides*, and *Septoria nupharis* (Tab. 1). Confirmation of occurrence of *S. nupharis* (Fig. 2d) is important, because it was probably isolated for the first time in Poland [34], but Brandenburger [30] mentions *S. nupharis* as potential pathogen of *Nuphar* in Europe. This pathogen also shows the largest share of more than 10% in the studied localities, which makes it the only eudominant in our studies (Tab. 1). The importance of *S. nupharis* increases due to its mass occurrence on Lake Płociczno at a 100% frequency. A similar maximum frequency also showed *Colletotrichum nymphaeae*, which was found for the first time in Poland on NL and NC [34] but not on NA (Tab. 1, Fig. 2e). The pathogen causes wide, soft, rotting brown spots on the edges and in the central part of the infected leaves. *Colletotrichum nymphaeae* is the earliest known pathogen of *Nymphaea* and *Nuphar*, observed in Portugal in 1899 and in England at the beginning of the twentieth century [35]. In 1997, *C. nymphaea* was confirmed as a factor contributing to the decomposition of nympheid's leaves in the Netherlands [36].

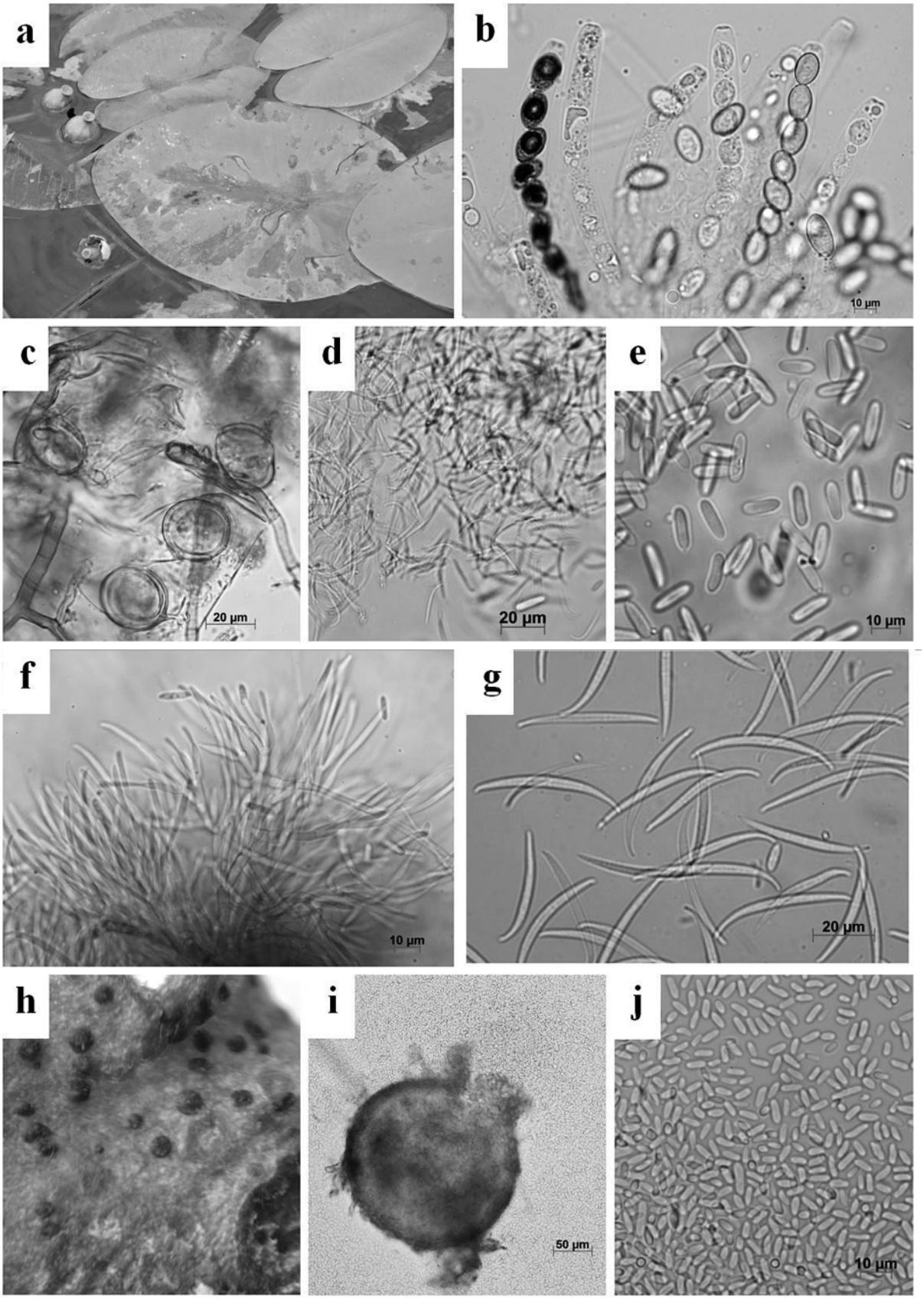

Fig. 2 **a** Disease symptoms on NL's leaves. **b** *Sordaria fimicola* asci with ascospores (NA). **c** Oospores of *Elongisporangium undulatum* (NL). **d** Asexual spores of *Septoria nupharis* (NA). **e** Asexual spores of *Colletotrichum nymphaeae* (NA). **f,g** Macroconidia of *Gibberella avenacea* (NL). **h,i** Picnidium of *Phyllosticta hydrophila*. **j** Picnospores of *Phyllosticta hydrophila* (NL). Photographs by Kinga Mazurkiewicz-Zapałowicz.

Tab. 1 Occurrence, frequency (*f*) and domination (*D*) of fungi species on Nymphaeaceae of the Lake Płociczno (in years 2009–2012).

No.	Fungi	Phylum*	Number of records of fungi			*f* (%)	*D* (%)**	
			NL	NA	NC			
1	*Achlya androgyna* (W. Archer) T.W. Johnson & R.L. Seym. (syn. *Aplanes androgynus*)	O	1			20	0.64	Sr
2	*Acremoniella atra* (Corda) Sacc.	A	1			20	0.64	Sr
3	*Acremonium* Link (syn. *Cephalosporium*)	A	3			40	1.92	R
4	*Alternaria alternata* (Fr.) Keissl.	A	8	1		80	5.77	Do
5	*Alternaria tenuissima* (Kunze) Wiltshire	A	2			40	1.28	R
6	*Apodachlya pirifera* Zopf (syn. *Apodachyla pillulifera*)	O	1			20	0.64	Sr
7	*Aspergillus* P. Micheli ex Haller	A	1			20	0.64	Sr
8	*Athelia rolfsii* (Curzi) C.C. Tu & Kimbr. (syn. *Sclerotium rolfsii*)	B	1			20	0.64	Sr
9	*Bipolaris* Shoemaker	A	3			40	1.92	R
10	*Botrytis cinerea* Pers.	A	8	2		80	6.41	Do
11	*Chaetomium globosum* Kunze	A	8	1	1	80	8.97	Do
12	*Chaetosphaeria vermicularioides* (Sacc. & Roum.) W. Gams & Hol.-Jech. (syn. *Chloridium chlamydosporum*)	A	1			20	0.64	Sr
13	*Cladosporium cladosporioides* (Fresen.) G.A. de Vries	A	7			80	4.49	S
14	*Cladosporium herbarum* (Pers.) Link	A	2	1		60	1.92	R
15	*Clasterosporium* Schwein.	A	1			20	0.64	Sr
16	*Colletotrichum nymphaeae* (Pass.) Aa	A	9		1	100	6.41	Do
17	*Elongisporangium undulatum* (H.E. Petersen) Uzuhasi, Tojo & Kakish. (syn. *Pythium undulatum*)	O	8	1		100	5.77	Do
18	*Epicoccum nigrum* Link	A	5			60	3.21	S
19	*Fusarium culmorum* (Wm.G. Sm.) Sacc.	A		1		20	0.64	Sr
20	*Fusarium incarnatum* (Desm.) Sacc. (syn. *Fusarium semitectum*)	A	10	2		60	7.69	Do
21	*Fusarium oxysporum* Schltdl.	A	4			60	2.56	S

Tab. 1 Continued

No.	Fungi	Phylum*	Number of records of fungi			*f* (%)	*D* (%)**	
			NL	NA	NC			
22	*Fusarium sporotrichioides* Sherb.	A	5	1	1	80	7.05	Do
23	*Gibberella avenacea* R.J. Cook (syn. *Fusarium avenaceum*)	A	7	1		80	5.13	Do
24	*Gibberella pulicaris* (Kunze) Sacc. (syn. *Fusarium sambucinum*)	A	4			60	2.56	S
25	*Gliomastix murorum* (Corda) S. Hughes	A	1			20	0.64	Sr
26	*Globisporangium ultimum* (Trow) Uzuhashi, Tojo & Kakish. (syn. *Pythium ultimum*)	O	3	1		80	2.56	S
27	*Melanospora damnosa* (Sacc.) Lindau (syn. *Gonatobotrys simplex*)	A	3			60	1.92	R
28	*Microascus brevicaulis* S.P. Abbott (syn. *Scopulariopsis brevicaulis*)	A	1			20	0.64	Sr
29	*Mucor mucedo* Fresen.	Z	2			40	1.28	R
30	*Periconia byssoides* Pers.	A	2			40	1.28	R
31	*Phoma glomerata* (Corda) Wollenw. & Hochapfel	A	2			40	1.28	R
32	*Phyllosticta hydrophila* Speg.	A	7	1		80	5.13	Do
33	*Pithomyces* Berk. & Broome	A	1			20	0.64	Sr
34	*Septoria nupharis* Ranoj.	A	10	1	1	100	10.90	Eu
35	*Sordaria fimicola* (Roberge ex Desm.) Ces. & de Not.	A	1			20	0.64	Sr
36	*Trichocladium asperum* Harz	A	1			20	0.64	Sr
37	*Trichoderma koningii* Oudem.	A	1			20	0.64	Sr
38	*Ulocladium chartarum* (Preuss) E.G. Simmons	A	3			40	1.92	R
Number of records			138	14	4			
Total number of records		156						

* A – Ascomycota; B – Basidiomycota; O – Oomycota; Z – Zoomycota. ** Do – dominants; Eu – eudominants; R – recedents; S – subdominants; Sr – subrecedents.

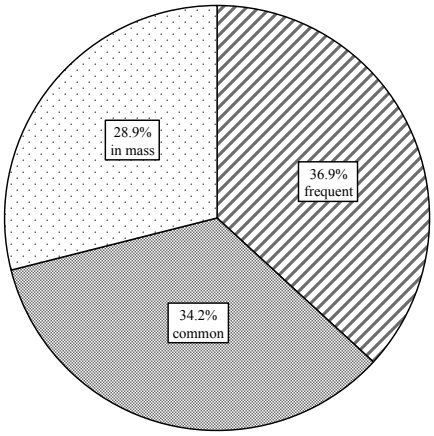

Fig. 3 Participation of frequency types of fungi on Nymphaeaceae plants of the Lake Płociczno (in years 2009–2012).

In our study also other species of fungi were isolated from the decaying tissues. Among them were numerous facultative pathogens determining the phytosanitary condition of plants, such as: the group of species occurring in mass (frequency of 61–100%): *Alternaria alternata*, *Chaetomium globosum*, *Cladosporium cladosporioides*, *Gibberella avenacea* (Fig. 2f,g), *Fusarium sporotrichioides*, and *Phyllosticta hydrophila* (Fig. 2h–j) as well as 13 common species (frequencies of 31–60%; Tab. 1, Fig. 3). Species occurring commonly and in large numbers are mainly polyphagic, among which the representatives of the genus *Fusarium* deserve special attention. These fungi are nonspecialized, facultative pathogens commonly found on weakened or damaged plants [13]. Their ecosystemic importance is associated with diverse chemical activity that accelerates the natural course of organic matter decomposition. Previous studies indicate that more and more species previously associated with a tropical climate are involved in this process. It is evidenced by the common occurrence of *Fusarium incarnatum* on the rotting leaves of NA and NL. This pathogen is a thermophilic organism [13] that is found more and more often in Poland, especially on greenhouse grown plants [37]. It is worth mentioning that another thermophilic species, *Athelia rolfsii*, takes part in the decomposition of leaves of NL and its distribution and host plant number is probably extending due to global warming. Such correlations have already been proven for other pathogenic species [38]. In this context, a systematic and constant monitoring of phytosanitary condition of Nymphaeaceae plants for another thermophilic species, mainly smut fungi, should be carried out. So far, their presence has only been observed in tropical and subtropical climate zones. It has been confirmed by numerous data since 1912, when *Doassansia nymphaea* was described in India as the cause of the discoloration of the petioles of *Nymphaea nauchali* (= *N. stellata*) [39]. Other studies on the spot disease (on floating leaves) of *Nymphaea nauchalii* have documented the presence of *Doassansiopsis tomasii* in Ethiopia [40], Uganda [41], and Cameroon [39]. Another thermophilic species of smut fungi, *Doassansiopsis nymphoides*, previously only occasionally recorded on *Nymphoides rautaneni* in Kenya [42] and Zimbabwe [43], has recently been discovered in Zambia in an epidemic form [44]. Affinity to the subtropical climate zone has also been showed in case of *Doassansiopsis ticonis*, isolated from *Nymphaea blanda* in Costa Rica [45] and *Entyloma nymphaeae* (Cunn.) Setch. (= *Rhamphospora nymphaeae* Cunn.), which attacked *Nymphaea tetragoni* grown in a garden pond in Korea [46]. However, hitherto known distribution of these pathogens can shift due to the global warming trends promoting their spread in other climate zones. There is no data on *Entyloma nymphaeae* or other smut fungi species occurring on plants of natural or artificial localities in Poland. Therefore, the suggestion made by Kochman and Majewski [47] that these species may one day be found in Poland still awaits confirmation. Despite the common occurrence of potential host plants for *Entyloma nymphaeae*, this species has not yet been found in

Tab. 2 Similarity coefficients of fungi and chromistan fungal analogues on NL of the Lake Płociczno in years 2009–2012.

Nuphar lutea		Years of research			
		2009	2010	2011	2012
Years of research	2009		8 species	11 species	14 species
	2010	50.0%		11 species	13 species
	2011	59.5%	66.7%		14 species
	2012	60.9%	61.9%	59.7%	

Tab. 3 Similarity coefficients of fungi and chromistan fungal analogues on host plants of the Lake Płociczno in years 2009–2012.

Years of research (2009–2012)		Host plant		
		Nymphaea alba	*Nuphar lutea*	*Nymphaea candida*
Host plant	*Nymphaea alba*		11 species	3 species
	Nuphar lutea	44.9%		4 species
	Nymphaea candida	37.5%	19.5%	

Poland [34]. The lack of smut fungi pathogens in naturally valuable phytocoenosis of protected Nymphaeaceae suggests the potential extension of the plants' vegetation period and the delay of their decomposition. However, in natural ecosystems, the lack of one group of pathogens promotes the development of another. For instance, in the presented studies, a mass occurrence of *Colletotrichum nymphaeae* and *Septoria nupharis* was observed and played a significant role in the process of plant tissue destruction.

In our research the Jaccard-Sörensen similarity coefficient of phytopathogens associated with NL has been estimated between 50% for the years 2009 and 2010 and 66.67% for the years 2010 and 2011 (Tab. 2). The coefficient for taxa associated with particular pairs of Nymphaeaceae plants is even lower at about 19.5% for NC and NL to 44.89% for NA and NL (Tab. 3). The similarity is low despite the fact that the three studied plant species are potential hosts for the same pathogens and grow in dense patches. This is probably due to the domination of one species (NL) in the plant communities and the abundance of fungi and chromistan fungal analogues associated with this exact host plant. Low species similarity of associations of the same plant species enhances the diversity of their phytocoenoses. The similarity coefficient and a high frequency of particular pathogenic/saprotrophic species are essential for the stability of ecosystems [19]. In this context, it may be said that taxonomic structure, the asexual/sexual morphs and species frequency influence the correct natural course of the seasonal decomposition of Nymphaeaceae plants and contribute to the ecological balance of the whole lake ecosystem.

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References

1. Dyrektywa Wodna 2000/60/WE [Internet]. 2000 [cited 2016 Jul 5]. Available from: http://geoportal.pgi.gov.pl/css/powiaty/prawo/ue_ramowa_dyrektywa_wodna
2. Mazurkiewicz-Zapałowicz K, Wróbel M, Wolska M, Silicki A. Phytopathogens and saprotrophic fungi of *Nuphar lutea* (L.) Sibth. et Sm. in *Nupharo-Nymphaeetum albae* Tomasz. 1997 plant association of Lake Glinno. Polish Journal of Environmental Studies. 2006;15(5d):283–287.
3. Mazurkiewicz-Zapałowicz K, Wróbel M, Wolska M. Species diversity of mycobiota on nympheids of the Sitno Lake in the Drawno National Park. In: Bajkiewicz-Grabowska E, Borowiak D, editors. Anthropogenic and natural transformations of lakes. Vol. 2. Gdańsk: Department of Limnology, University od Gdańsk, Polish Limnological Society; 2008. p. 123–126.
4. Mirek Z, Piękoś-Mirkowa H, Zając A, Zając M, editors. Flowering plants and pteridophytes of Poland – a checklist. Kraków: W. Szafer Institute of Botany, Polish Academy of Sciences; 2002. (Biodiversity of Poland; vol 1).
5. Kucharski B, Pawlaczyk P. Drawieński Park Narodowy i okolice: przewodnik turystyczny. Warszawa: Wydawnictwo PTTK "Kraj"; 1997.
6. Kraska M. Jeziora Drawieńskiego Parku Narodowego. In: Agapow L, editor. Przyroda województwa gorzowskiego. Gorzów Wielkopolski: Drawieński Park Narodowy; 1998. p. 125–145.
7. Kraska M, Piotrowicz R. Roślinność jezior Drawieńskiego Parku Narodowego. Suplement [Manuscript]. Poznań: Operat Ochrony Ekosystemów wodnych Drawieńskiego Parku Narodowego; 1998.
8. Waller JM, Ritchie BJ, Holderness M. Plant clinic handbook. Oxon: CAB International; 1998. (IMI Technical Handbooks; vol 3).

9. Skiergiełło A. Grzyby niższe. Pragrzyby i glonowce. Warszawa: Państwowe Wydawnictwo Naukowe; 1954.
10. Borowska A. Grzyby niedoskonałe (deuteromycetes), strzępczakowe (hyphomycetes), ciemnobarwnikowe fialidowe (Dematiaceae, Phialoconidae). Warszawa: Państwowe Wydawnictwo Naukowe; 1986. (Flora Polska. Rośliny Zarodnikowe Polski i Ziem Ościennych; vol 16).
11. Ellis MB, Ellis JP. Microfungi on land plants. An identification handbook. Slough: Richmond Publishing Co.; 1997.
12. Rietmüller A. Morphologie, Ökologie und Phylogenie aquatischer Oomyceten. Berlin: J. Cramer; 2000. (Bibliotheca Mycologica; vol 185).
13. Kwaśna H, Chełkowski J, Zajkowski P. Sierpik (*Fusarium*). Warszawa: Państwowe Wydawnictwo Naukowe; 1991. (Flora Polska. Rośliny Zarodnikowe Polski i Ziem Ościennych; vol 22).
14. Sutton BC. The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stromata. Kew: Commonwealth Mycological Institute; 1980.
15. Kirk PM, Cannon PF, Minter DW, Stalpers JA. Dictionary of the fungi. 10th ed. Wallingford: CABI Europe; 2008.
16. Index Fungorum [Internet]. 2016 [cited 2016 Jul 5]. Available from: http://www.indexfungorum.org
17. Krebs CJ. Ekologia: eksperymentalna analiza rozmieszczenia i liczebności. Warszawa: Wydawnictwo Naukowe PWN; 2001.
18. Mułenko W. A review of the methods used for studies on parasitic fungi in natural plant communities. Acta Mycol. 1997;32(2):323–346. http://dx.doi.org/10.5586/am.1997.029
19. Ruszkiewicz-Michalska M. Mikroskopijne grzyby pasożytnicze w zbiorowiskach roślinnych Wyżyny Częstochowskiej. Łódź: Polskie Towarzystwo Botaniczne; 2006. (Monographiae Botanicae; vol 96). http://dx.doi.org/10.5586/mb.2006.001
20. Mułenko W. Mikroskopowe grzyby fitopatogeniczne w strukturze naturalnych zbiorowisk leśnych. Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej; 1998. (Rozprawy Habilitacyjne – Uniwersytet Marii Curie-Skłodowskiej. Wydział Biologii i Nauk o Ziemi; vol 62).
21. Adamska I. Zróżnicowanie zbiorowisk grzybów mikroskopowych w odniesieniu do zróżnicowania zbiorowisk roślinnych w Słowińskim Parku Narodowym. Szczecin: Wydawnictwo Uczelniane ZUT w Szczecinie; 2013.
22. Kowalik M. Phyllosphere mycobiota on garden pond plants. Acta Mycol. 2012;47(1):11–19. http://dx.doi.org/10.5586/am.2012.002
23. Kowalik M. Fungi and chromistan fungi associated with plants white water lily *Nymphaea alba* L. during the vegetation season. Acta Scientiarum Polonorum. Hortorum Cultus. 2012;11(2):167–172.
24. Brucet S, Poikane S, Lyche-Solheim A, Birk S. Biological assessment of European lakes: ecological rationale and human impacts. Freshw Biol. 2013;58(6):1106–1115. http://dx.doi.org/10.1111/fwb.12111
25. Kowalik M, Krasny M. Fungi occurring on garden pond plants. Phytopathologia. 2009;51:21–26.
26. Kaźmierczakowa R, Zarzycki K, editors. Polska czerwona księga roślin. Paprotniki i rośliny kwiatowe. Kraków: Instytut Botaniki im. W. Szafera, Polska Akademia Nauk; 2001.
27. Kozłowska M, Konieczny G. Biologia odporności roślin na patogeny i szkodniki. Poznań: Wydawnictwo AR-Poznań; 2003.
28. Berger S, Sinha AK, Roitsch T. Plant physiology meets phytopathology: plant primary metabolism and plant – pathogen interactions. J Exp Bot. 2007;58(15–16):4019–4026. http://dx.doi.org/10.1093/jxb/erm298
29. Czeczuga B, Kiziewicz B, Mazalska B. Further studies on aquatic fungi in the river Biebrza within Biebrza National Park. Polish Journal of Environmental Studies. 2003;12(5):531–543.
30. Brandenburger W. Parasitische Pilze an Gefäßpflanzen in Europa. Stuttgart: Gustav Fischer Verlag; 1985.
31. van der Plaats-Niterink AJ. Monograph of the genus *Pythium*. Baarn: Centraalbureau voor Schimmelcultures; 1981. (Studies in Mycology; vol 21).
32. Hendrix FF, Campbell WA. Pythiums as plant pathogens. Annu Rev Phytopathol. 1973;11:77–98. http://dx.doi.org/10.1146/annurev.py.11.090173.000453

33. Jacobs RP. Pythiaceous fungi associated with the decomposition of *Nymphoides peltata*. Antonie Van Leeuwenhoek. 1982;48(5):433–445. http://dx.doi.org/10.1007/BF00448415
34. Mułenko W, Majewski T, Ruszkiewicz-Michalska M, editors. A preliminary checklist of micromycetes in Poland. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2008. (Biodiversity of Poland; vol 9).
35. van der Aa HA. A leaf spot disease of *Nymphaea alba* in the Netherlands. Netherlands Journal of Plant Pathology. 1978;84:109–115. http://dx.doi.org/10.1007/BF01981538
36. Vergeer LHT, van der Velde G. Phenolic content of daylight-exposed and shaded floating leaves of water lilies (Nymphaeaceae) in relation to infection by fungi. Oecologia. 1997;112(4):481–484. http://dx.doi.org/10.1007/s004420050335
37. Marcinkowska J. Oznaczanie rodzajów grzybów ważnych w patologii roślin. Warszawa: Fundacja Rozwój SGGW; 2003.
38. Koralewski Z, Werner M, Andrzejak R, Kosiada T. Rozprzestrzenienie epidemii mączniaka prawdziwego (*Erysiphe flexuosa* U Braun & S. Takamatsu) na kasztanowcach w Wielkopolsce. Progress in Plant Protection. 2010;50(4):1797–1800.
39. Piątek M, Vánky K, Mossebo DC, Piątek J. *Doassansiopsis caldesiae* sp. nov. and *Doassansiopsis tomasii*: two remarkable smut fungi from Cameroon. Mycologia. 2008;100(4):662–672. http://dx.doi.org/10.3852/07-189R
40. Vánky K. Taxonomic studies on Ustilaginomycetes 26. Mycotaxon. 2006;95:1–65.
41. Piątek M. *Doassansiopsis tomasii*, an aquatic smut fungus new to Uganda. Pol Bot J. 2006;51(2):173–176.
42. Nattrass RM. Host list of Kenya fungi and bacteria. Mycological Papers. 1961;81:1–46.
43. Whiteside JO. A revised list of plant diseases in Rhodesia. Kirkia. 1966;5:87–196.
44. Vánky K. Taxonomic studies on Ustilaginomycetes 22. Mycotaxon. 2002;81:367–430.
45. Pipenbring M. Taxonomic studies on Ustilaginales from Costa Rica. Mycol Res. 1995;99(7):783–788. http://dx.doi.org/10.1016/S0953-7562(09)80726-0
46. Park MJ, Denchev CM, Han KS, Shin HD. Occurrence of *Rhamphospora nymphaeae* on *Nymphaea tetragona* in Korea. Plant Pathol J. 2010;26(3):293. http://dx.doi.org/10.5423/PPJ.2010.26.3.293
47. Kochman J, Majewski T. Podstawczaki (Basidiomycetes), głowniowe (Ustilaginales). Warszawa: Państwowe Wydawnictwo Naukowe; 1973. (Flora Polska. Rośliny Zarodnikowe Polski i Ziem Ościennych; vol 5).