ACTA MYCOLOGICA
Vol. 33 (1): 43 – 58
1988

Chitinophilic zoosporic fungi in various types of water bodies

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C z e c z u g a B., G o d l e w s k a A.: *Chitinophilic zoosporic fungi in various types of water bodies*. Acta Mycol. 33 (1): 43 – 58, 1998.

Chitinophilic fungi in various types of water bodies (slough, pond, beach pool, two lakes and two rivers) were studied. Samples of water were collected every other month for hydrochemical analysis and once a month (1992 – 1994) in order to determine the fungus content. The wings of dragonfly and flies, carapaces of crayfish and potato beetle and the fructification of two mushrooms were used as bait.

Thirty species of chitinophilic fungi were found in various types of water bodies. *Chytriomyces annulatus*, *Entophlyctis crenata*, *Obelidium megarrhizum*, *Rhopalophlyctis sarcoptoides*, *Achlya colorata*, *A. megasperma* and *Dictyuchus monosporus* represent new records as chitinophilic fungi. However, *Entophlyctis crenata*, *Obelidium megarrhizum* and *Podochytrium chitinophilum* reported for the first time from Poland.

Key words: zoosporic fungi, chitinophilic fungi.

INTRODUCTION

Zoosporic aquatic fungi (S p a r r o w 1960) and a few species of bacteria (B e n e c k e 1905; J e u n i a u x 1957; P a l u c h 1973) take part in the mineralization of chitin-containing substrates in water reservoirs. Due to the presence of the enzyme-chitinase, they transform this hardly available to other organisms polysaccharide into simpler elements, ready to be mineralized by subsequent decomposers. Chitinophilic fungi use these properties to prevent excessive accumulation of deposits made by „rain of corpses" of plancton crustaceans falling to the bottom as well as water insect exuvia (S p a r r o w 1937; D i c k 1970) and crayfish shell. This context, chitinophilic fungi play a significant role in aquatic ecosystems (R e i s e r t and F u l l e r 1962).

Our preliminary investigations in this field (Czeczuga and Godlewska 1994) revealed the species abundant occurrence of this group of aquatic fungi in NE Poland. Therefore, we undertake to make detailed studies on chitinophilic fungi in various limnological types of water bodies mainly with regard to new chitin-containing substrates and seasonality.

STUDY AREA

The following types of water bodies were investigated: a slough, 1 pond, 1 pool, 2 lakes and 2 rivers.

Sites: 1 – the slough – this is a mirey puddle, 1 × 0.5 m in dimensions, situated in the lower part of the Branicki Palace Park in which water overflowing from the fountains in the middle of the collects. Rain water from the palace roofs also collects here;

2 – the pond in the Palace Park (2.5 ha, max. depth to 1.75 m), in which swans are bred and here wild ducks also come. In addition, crucian carp and tench are bred for anglers;

3 – the beach pool (27.2 ha, max. depth 2.5 m), is located in the Dojlidy (district Białystok) and serves as a swimming pool in summer for the habitants of the city and for water sports. The samples were collected from the west side of this pool which the inhabitants use as a beach;

4 – Lake Białe (485 ha, max. depth 30 m), is surrounded by extensive coniferous woods of Augustów Forest. The western part of the lake is adjacent to Augustów Forest. The site for sampling was on the lake next to Recreation Centre;

5 – Lake Necko (area 518 ha, max. depth to 25 m). The northern shores of the lake adjoin Augustów Forest while the south-western shores border with the town of Augustów. For this reason most of the municipal and industrial wastes of the town are drained into the lake. The sampling site was on the eastern side of the lake next to the Polish Tourist Country-Lovers' Association Centre; the shore is sandy for 1.5 m;

6–8 – the River Biała (lenght 9.8 km) – left-bank tributary of the Supraśl River flowing through Białystok City. Three sites differing in the degree of pollution were chosen:

6 – the upper course of the Biała River, the water was the least polluted;

7 – middle of the river, the site situated in the centre Białystok – at this site numerous drains empty the municipal and industrial wastes into the river;

8 – lower course of Biała River below the city just were the Fish Processing Plant drains wasters rich in keratin into the river;

9–11 – the River Supraśl (length 106.6 km) – this is the right-bank tributary of the middle part of the Narew River, folowing through the Knyszyn Forest. The river is polluted with municipal wastes from the towns of Gródek, Michałowo, Supraśl and above all, from Białystok city (Lower course). Along a stretch of 1 km of the Supraśl River, 3 sites were chosen:

9 – above the municipal swimming pool at the sluice of an arm of the Supraśl River flowing just through the town of Supraśl;

10 – situated several score meters below Site 9 at the municipal swimming pool and the junction of two arms of the river above the main drain of Supraśl town;

11 – below the main drain of Supraśl town about 500 m away from Site 10.

MATERIALS AND METHODS

In order to determine the species composition chitinophilic fungi were collected once a month in the years (1992—1994). From each site one sample was taken for hydrochemical analysis (every other month) and two samples for the mycological studies. Water was collected in 5-litre Ruttner bucket from the depth at which the bucket was immersed. For the determinations of the different chemical elements in the water the methods recomended by Standard Methods (Golterman and Clymo 1969) were employed. For mycological analysis the water samples from each of the sites were transported in sterile glass containers of 1.5 l capacity. Subsequently, in the mycological laboratory, they were placed in sterilized beakers (capacity of 0.6 l), to which the appropriate baits were added in accordance with the general principles of culture (Fuller and Jaworski 1986). The wings of dragonflies (*Aeschna juncea*) and flies (*Sarcophaga carnaria*), carapaces of crayfish (*Orconectes limosus*) and potato beetle (*Leptinotarsa decemlineata*), and the fructification of two mushrooms (*Boletus edulis* and *Pleurotus ostreatus* were used as bait. The above materials were previously cut into small pieces, washed carefully and then boiled in a weak seap solution. Subsequently, they were rinsed thoroughly and boiled several times. The samples were kept in the laboratory for 1—2 months and precautions were taken to ensure that the thermo-lighting conditions were as close as possible to those prevalent outside the laboratory. The fungi species were distinguished by their morphological features, measurements being made of the shreds oogonia, and oospores. Species of the chitinophilic fungi were identied using mycological keys (Johnson 1956; Sparrow 1960; Seymour 1970; Batko 1975; Karling 1977).

In order to determine the relation between the number of species fungi at a given site and various factors in the aquatic environment, statistical calculations were made. For this purpose the multiple correlation coefficient was used (Czeczuga and Próba 1987). The regression programme with a choice of variables was applied on a ODRA-1204 digital computer. The water chemistry data and aquatic fungal flora of these water bodies were processed by the average linkage method (Hugh and Gauch 1982).

RESULTS

The results obtained indicated that the water bodies studied comprised very diversified habitats (Tab. 1). A comparative analysis of biogenic compounds (all forms of nitrogen and phosphorus) revealed the lowest

Table 1
Chemical concentration of properties of water (mean from 24) of the bodies of water investigated (in mg l^{-1})

Properties	Site										
	1	2	3	4	5	6	7	8	9	10	11
Temperature °C	9.15	9.18	10.29	8.20	8.45	9.10	8.79	8.42	8.40	8.69	8.62
pH	7.67	7.69	7.62	7.35	7.53	7.51	7.46	7.49	7.61	7.63	7.63
Oxidability	6.82	10.63	9.14	8.59	8.91	10.66	9.48	10.36	10.48	11.09	9.79
CO_2	39.74	42.42	27.13	33.28	32.18	43.31	54.18	52.48	32.72	32.03	28.05
Alkalinity in $CaCO_3$ (in $mval^{-1}$)	4.53	4.83	3.42	3.05	3.09	4.39	4.66	4.40	3.90	4.00	4.10
$N(NH_3)$	0.53	0.46	0.56	0.41	0.42	0.83	0.07	1.24	0.35	0.53	0.50
$N(NO_2)$	0.006	0.014	0.006	0.005	0.008	0.022	0.015	0.031	0.007	0.048	0.008
$N(NO_3)$	0.073	0.04	0.10	0.02	0.11	0.18	0.35	0.27	0.13	0.23	0.18
PO_4	2.16	1.09	0.77	0.21	0.45	0.67	1.08	1.22	0.70	1.03	1.12
Cl	42.00	75.81	45.88	29.63	38.55	59.38	80.56	78.94	35.81	39.25	42.00
Total hardness in Ca	96.93	84.96	58.23	55.26	66.96	86.94	94.50	105.12	77.04	69.84	76.77
Total hardness in Mg	23.13	30.91	21.77	21.82	21.82	21.45	22.47	20.64	19.56	19.61	19.14
SO_4	49.37	42.99	28.65	20.36	21.85	41.09	46.64	54.20	21.74	26.86	30.99
Fe	0.32	0.37	0.36	0.14	0.16	0.59	0.62	0.56	0.38	0.43	0.48
Mn	0.07	0.09	0.10	0.06	0.01	0.05	0.09	0.11	0.10	0.14	0.18
Dry residue	368.25	398.13	222.38	170.25	218.63	366.00	414.00	470.12	295.37	284.13	285.00
Dissolved solids	374.00	416.00	224.63	162.13	181.88	274.13	398.00	451.00	203.12	277.76	227.00
Suspended solids	41.25	29.12	67.25	12.86	39.00	92.25	16.00	22.62	92.25	18.87	63.37

Table 2
Chitinophilic fungi found in particular bodies of water investigated

Fungi	Slough	Pond	Beach pool	Lake Białe	Lake Niecko	River Biała	River Supraśl
Chytridiomycetes							
Allomyces arbuscula Butler	x	x	x	x	x		x
Asterophlyctis irregularis Karling		x	x	x	x	x	x
Blastocladiella britannica Horenstein in Cantino	x	x	x	x	x	x	x
Blastocladiopsis parva (Whiffen) Sparrov	x	x	x	x	x	x	x
Catenaria anguillulae Sorokin	x	x	x			x	x
Catenophlyctis variabilis (Karling) Karling		x	x			x	x
* *Chytriomyces annulatus* Dogma		x	x			x	
Chytriomyces hyalinus Karling	x	x	x	x	x	x	x
* *Entophlyctis crenata* Karling			x			x	x
Karlingia chitinophila Karling	x	x	x	x	x	x	x
* *Obelidium megarrhizum* Willoughby	x		x		x		x
Phlyctochytrium aureliae Ajello	x	x			x	x	x
Phlyctorhiza endogena Hanson	x	x	x	x	x	x	x
Podochytrium chitinophilum Willoughby	x				x	x	x
Polychytrium aggregatum Ajello	x					x	
Rhizidium chitinophilum Sparrov	x	x	x	x	x	x	x
Rhizophlyctis petersenii Sparrov	x	x	x				x
Rhopalophlyctis sarcoptoides Karling		x	x	x	x		
Oomycetes							
* *Achlya colorta* Pringsheim		x	x		x	x	x
Achlya klebsiana Pieters		x	x			x	x
* *Achlya megasperma* Humphrey					x	x	x
Achlya oligacantha de Bary	x	x	x	x	x	x	x
Aphanomyces irregularis Scott	x	x	x	x	x	x	x
Aphanomyces laevis de Bary		x	x			x	x
Aphanomyces stellatus de Bary	x	x	x	x		x	x
Apodachlya brachynena (Hildbr.) Pringsh.	x	x	x			x	x
Cladolegnia unispora (Coker et Couch) Johannes			x			x	x
* *Dictyuchus monosporus* Leitgeb		x	x	x		x	x
Leptolegnia caudata de Bary	x	x	x	x	x	x	x
Saprolegnia ferax (Gruith) Thurnet	x	x	x	x	x	x	x
Number of species	19	24	26	15	18	26	27

* new records of chitinophilic fungi

Table 3

Seasonal changes in the occurrence of the various chitinophilic fungus in particular sites (s — spring, sr — summer, a — autumn, w — winter)

Fungi	Site (see Study Area)
Chytridiomycetes	
Allomyces arbuscula	1w;2a;3s;4a,w;5sr;9w;10a,w
Asterophlyctis irregularis	2sr;3a,w;4a;5a;6a,w;7s;9sr,a;10a;11s
Blastocladiella britannica	1s,sr,a,w;2a,w;3sr,a,w;4a,w;5s,a,w;6s-w;7s-w;8s-w;9s,a,w;10s,a,w;11s-w
Blastocladiopsis parva	1s,a,w;2a;3s,a,w;4w;5sr;6a,w;7s,w;8s;9s;10a,w;11a
Catenaria anguillulae	1w;2a,w;3a,w;6a;7s,a;8a,w;9s;10a;11a,w
Catenophlyctis variabilis	2a;3a;6w;7s,w;8sr;9s,a,w;10a,w;11w
Chytriomyces annulatus	2a;3s,a;6a;7a;8w
Chytriomyces hyalinus	1s,sr,a,w;2w;3s-w;4s,w;5sr,a;6a,w;7s-w;8s-w;9s,a,w;10s,a,w;11s-w
Entophlyctis crenata	3w;6w;9w;10w;11w
Karlingia chitinophila	1sr;2s,sr,a,w;3s,a,w;4s;5s,sr;6s-w;7s,sr,w;8s,a,w;9s-w;10s,w;11a,w
Obelidium megarrhizum	1s;3w;5a;10s;11a
Phlyctochytrium aureliae	1a;2s,sr,w;5s;6a,w;7sr,w;8s,a;9sr,a;10s,a;11s,a
Phlyctorhiza endogena	1a,w;2a,w;3a,4s;5s,sr;6s,a;7a;8s,a;9s,a;10a;11sr
Podochytrium chitinophilum	1s;5s;7s-w;8s;9a;10w;11a,w
Polychytrium aggregatum	1sr;6a;7a;8a,w
Rhizidium chitinophilum	1a;2s;4w;5a,w;6s-w;7s-w;8s,a,w;9s-w;10s-a;11s-w
Rhizophlyctis petersenii	1s;2s,w;3s,w;9sr,w;10w
Rhopalophlyctis sarcoptoides	2a,w;3a;4a;5s,w
Oomycetes	
Achlya colorta	2s,w;3sr;5sr;6s;7s;8s;9s,a,w;10s,a;11s,w
Achlya klebsiana	2s,a;3a;6s,a;7s-a;8s;9a;10s,a;11w
Achlya megasperma	5w;6w;9w;10w;11w
Achlya oligacantha	1a;2w;3s;4w;5w;6w;7w;8a;9w;10w;11a
Aphanomyces irregularis	1s,sr,a;2s-w;3s-w;4s,sr,a;5a,w;6s-w;7s-w;8s-w;9s-w;10s-w;11s-w
Aphanomyces laevis	2a;3s;6sr,a,w;7s,a;8w;10s,sr;11sr
Aphanomyces stellatus	1a,w;2s,w;3w;4w;6s-w;7s-w;8sr,a;9a,w;10a,w;11w
Apodachlya brachynena	1s;2s,a;3s;6s;7s,a;8a;9s,a;10s,a;11s,a
Cladolegnia unispora	3s;6s,w;7s;8s;9s;10s;11s
Dictyuchus monosporus	2s,sr;3s,a;4a;6s,sr;7s-w;8sr;9s-a;10s,sr;11s,sr
Leptolegnia caudata	1s,sr,a,w;2s,a,w;3s-w;4s,a,w;5s,w;6s,a;7s-w;8s-w;9s,a,w;10s-w;11s-w
Saprolegnia ferax	1a;2s,a,w;3s-w;4sr;5s;6s-w;7s,a,w;8s-w;9s-w;10s-w;11s-w

concentrations of ammonium nitrogen in the water at Site 7 (middle course of the Biała), while the highest at Site 8 (lower course of the Biała). The phosphorus concentration was the lowest at the Site 4 (lake Białe) and the highest at Site 1 (slough). The remaining parameters also varied at the respective sites.

During the two years in investigations, 30 species were observed on chitin-containing substrates, including 18 *Chytridiomycetes* and 12 *Oomycetes* species. Most chitinophilic fungi species developed in the water of the River Supraśl, Biała and beach pool whilst the fewest in lake Necko and Białe (Tab. 2). The most common species were: *Blastocladiella britannica*, *Chytriomyces hyalinus*, *Karlingia chitinophila*, *Rhizidium chitinophilum*, *Aphanomyces irregularis*, *A. stellatus*, *Leptolegnia caudata* and *Saprolegnia ferax*. Rare species included: *Chytriomyces annulatus*, *Entophlyctis crenata*, *Olpidium megarrhizum*, *Polychytrium aggregatum*, *Rhopalophlyctis sarcoptoides*, *Achlya megasperma* and *Cladolegnia unispora* (Tab. 3).

Table 4

Number of fungi species found on particular baits in bodies of the water investigated

Reservoirs of water	*B. edulis*	*P. ostreatus*	*A. juncea*	*L. decemlineata*	*O. limosus*	*S. carnaria*
Slough	4	8	14	6	3	12
Pond	7	6	15	9	5	17
Beach pool	6	5	20	8	2	21
Lake Białe	3	2	10	2	1	6
Lake Necko	5	4	7	4	1	12
River Biała	16	11	23	11	7	21
River Supraśl	13	12	25	13	11	21

Nearly all species occurred in throught the year, while such as *Entophlyctis crenata* and *Achlya megasperma* were found only in winter months. Some fungi as *Catenaria anguillae*, *Chytriomyces annulatus*, *Obelidium megarrhizum*, *Rhopalophlyctis sarcoptoides*, *Achlya oligacantha*, *Apodachlya brachynema* and *Cladolegnia unispora* were not observed in summer. In all the water bodies studied most fungi developed on the wings of the dragonfly and the fly, the fewest on the shell of the crayfish (Tab. 4). Such species as *Catenaria anguillulae*, *Catenophlyctis variabilis* and *Phlyctorhiza endogena* were found only on the wings of dragonflies while *Blastocladiella britannica*, *Chytriomyces hyalinus*, *Achlya klebsiana*, *A. oligacantha*, *Aphanomyces irregularis*, *A. stellatus*, *Dictyuchus monosporus*, *Leptolegnia caudata* and *Saprolegnia ferax* were observed on all the substrates used analysis (Tab. 5).

Table 5

Attractive substrate for particular of the chitinophilic fungi in particular sites

Fungi	*B. edulis*	*P. ostreatus*	*A. juncea*	*L. decemlineata*	*O. limosus*	*S. carnaria*
Chytriomycetes						
Allomyces arbuscula			9–11	2, 4, 5	1	3, 4, 9–11
Asterophlyctis irregularis			3, 4, 6–8	5, 9–11	9–11	2, 3, 6–8
Blastocladiella britannica	3, 6–11	1, 3, 4, 9–11	1–11	1, 2, 6–11	3, 9–11	1–3, 5–11
Blastocladiopsis parva	6–8	1	1–11	1, 3		1–3
Catenaria anguillulae			1–3, 6–11			
Catenophlyctis variabilis			2, 3, 6–11			
Chytriomyces annulatus			3, 6–8			2, 3
Chytriomyces hyalinus	1, 2, 5–11	1, 2, 6–8	1–4, 6–11	1, 6–8	1, 3, 6–11	1–11
Entophlyctis crenata			3			4, 6–11
Karlingia chitinophila	6–11	6–11	1, 3, 6–11	1–3, 6–11		2–11
Obelidium megarrhizum				3, 9–11		1,5
Phlyctochytrium aureliae	6–11	1, 2, 6–11	5, 6–11		2, 6–11	2, 6–11
Phlyctorhiza endogena			1–11			
Podochytrium chitinophilum			6–11			1, 5–11
Polychytrium aggregatum	6–8		1, 6–8			6–8
Rhizidium chitinophilum			1–11	6–11		1–3, 5–11
Rhizophlyctis petersenii	9–11		6–8			1–3
Rhopalophlyctis sarcoptoides			2, 4	5		3, 5
Oomycetes						
Achlya colorta	2, 5–11	2, 5–11	2, 9–11	3, 6–11		3, 5–11
Achlya klebsiana	2, 3, 6–11	6–11	3, 6–11	3, 6–11	9–11	3, 6–11
Achlya megasperma	5–11	5–11			9–11	3, 9–11
Achlya oligacantha	1–4, 6–11	1, 2, 4, 6–11	6–8	2, 3, 6–8	2, 9–11	2, 5
Aphanomyces irregularis	3, 4, 9–11	1	1–11	1–11	2, 6–11	1–11
Aphanomyces laevis			1, 2, 6–11	2, 6–8	2, 3, 6–11	
Aphanomyces stellatus	6	1, 3	1–3, 6–11	2, 6–11	2, 4, 6–11	2, 3, 6–11
Cladolegnia unispora	6–8	9–11	3, 6–11	9–11		6–11
Dictyuchus monosporus	2, 4, 6–11	2, 3, 6–11	6–11	6–11	6–11	2, 3, 6–11
Leptolegnia caudata	1, 5–8	3, 5–11	1–3, 6–11	1, 2, 6–8	6–8	1–11
Saprolegnia ferax	1–3, 5–11	1–3, 6–11	1–4, 6–11	2, 3, 6–11	1, 2, 5–11	2–11

DISCUSSION

A comparative analysis of the fungi found on various vegetable and animal chitin-containing substrates and chitinophilic fungi listed in the monography by Sparrow (1960) revealed that except *Chytriomyces hyalinus*, *Phlyctochytrium aureliae*, *Polychytrium agregatum*, *Rhizidium chitinophilum* and *Rhizophlyctis petersenii*, the remaining species complete this list. Moreover, the present data indicated the presence of fungi that grow on chitin-containing substrates and which had already been found in the waters of northeastern Poland (Czeczuga and Godlewska 1994, Czeczuga et al. 1998). The include *Chytriomyces annulatus*, *Entophlyctis crenata*, *Obelidium megarrhizum*, *Podochytrium chitinophilum*, *Rhopalophlyctis sarcoptoides*, *Achlya colorata*, *A. megasperma* and *Dictyuchus monosporus*.

Chytriomyces annulatus was described in the United States from the vicinity of Lake Douglas by Dogma (1969). In our case, it grew in the pond-moat, in the bathing pond and in the River Biała on the wings of dragonflies and flies. It has been hitherto found in Lakes near Ełk, Sejny, in the River Narew and in forest lakes called Suchary (Czeczuga 1995a, b, c; 1996 a, b). *Entophlyctis crenata* was described as an epidermal parasite of cells of an aquatic plant *Vallisneria* sp. in New Zealand (Karling 1967). We found it on the wings on dragonflies and flies in the bathing pond in the upper course of the River Biała and at all sites of the River Supraśl, only in winter months. *Obelidium megarrhizum* was observed to grow in the waters of the slough, bathing pond, Lake Necko and at Site 10 in the River Supraśl. It was first described by Willoughby (1961a) in England in the vicinity of Lake District. The above author described *Podochytrium chitinophilum* from bottom sediment samples on a chitin-containing substrate. We observed *P. chitinophilum* on the wings of dragonflies and flies in the waters of the slough, Lake Necko, the River Biała and Supraśl. Among the representatives of *Chytridiomycetes*, a new chitinophilic fungus *Rhopalophlyctis sarcoptoides*, described from the waters of Brazil (Karling 1945). We found it to occurring on the wings of dragonflies, flies and potato beetle in the waters of both ponds and lakes. In our hitherto studies *Rhopalophlyctis sarcoptoides* only found in the waters of Suchar II in Suwałki province (Czeczuga 1995b).

Three species of *Oomycetes* i. e. *Achlya colorata*, *A. megasperma*, and *Dictyuchus monosporus*, were recognized for the first time as chitinophilic fungi. *Achlya colorata* developed in the ponds, Lake Necko and in the two rivers on all the substrates used for analysis, except *Orconectes limosus*, *A. megasperma* was observed only in winter months in the water of Lake Necko and in both rivers on all the substrates except dragonflies and potato beetle. These *Achlya* species are quite frequently encountered in inland waters (Johnson 1956).

Dictyuchus monosporus, a new species of the *Oomycetes* was noted on all the substrates in the ponds, rivers and in Lake Białe. It is common in the waters of the northeastern part of Poland, both in running waters and in lakes of various size (C z e c z u g a 1991 a, b; C z e c z u g a et al. 1997). It is recognized as a fish parasite (C z e c z u g a et al. 1995). Three species from this chitinophilic fungi, namely *Entophlyctis crenata*, *Obelidium megarrhizum* and *Podochytrium chitinophilum* turned of to be new to the water bodies of Poland (Fig. 1).

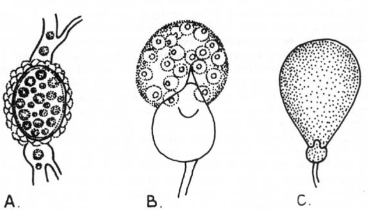

Fig. 1. Chitinophilic fungi new for Poland
A – *Entophlyctis crenata* – mature resting spore with a hyaline crenate wall; B – *Obelidium megarrhizum* – swarming of planospores; C – *Podochytrium chitinophilum* – full grown zoosporangium with a sterile basal cell (after Karling 1977)

While studying chitinophilic fungi for the two-year period (1992–1994) at one-month intervals in seven types of water reservoirs, we did not find *Aphanomyces astaci*, a fungus known to cause the so-called "plague" of crayfish (S c h i k o r a 1922; U n e s t a m 1965). However, we found it in the years 1986–87 in Lake Białe (C z e c z u g a 1994 a) and in 1990–91 in the River Biebrza and Ełk (C z e c z u g a and G o d l e w s k a 1994), as well as in Suchar II in the Suwałki National Park (C z e c z u g a 1995b). In all the these the aforementioned species was reported from the wings of dragonflies. *Aphanomyces staci* is known to grow in the nervous system and limb joints of the crayfish (K o s s a k o w s k i 1966) and in the carapace and muscles (C z e c z u g a et al. 1998). This may explain why, despite possessing the chitin-decomposing enzyme-chitinase (S ö d e r h ä l l et al. 1978), this fungus is not attracted by the chitinous shell of *Orconectes limosus*. In addition

Table 6

The coefficients of correlation beetwen of the environmental factors and number of chitinophilic fungus species in particular of the sites (level of significance 0.04; italic — statisticaly credible)

Specification	Site										
	1	2	3	4	5	6	7	8	9	10	11
Temperature °C	0.6721	*−0.7893*	−0.6359	−0.2811	0.1432	−0.6852	0.1075	−0.3830	*−0.7970*	−0.5208	−0.4461
pH	0.0104	−0.5864	−0.2713	−0.1328	0.5412	−0.5156	0.1926	0.0795	−0.3502	−0.2716	−0.1916
Oxidability	0.3041	0.2992	−0.4579	0.0907	0.0067	0.5369	−0.5871	*0.8252*	*0.9005*	0.3006	0.5718
CO_2	−0.1633	0.3827	*0.7894*	0.4024	0.2678	0.5734	−0.4478	−0.0266	0.4035	0.2329	0.0187
Alkalinity in $CaCO_3$ (in $mval^{-1}$)	−0.6060	−0.2564	0.0396	0.0299	0.4081	−0.0085	−0.1286	*−0.8537*	−0.4555	−0.1359	−0.6882
$N(NH_3)$	0.3485	0.2665	−0.2364	*0.9062*	0.0441	−0.3253	0.4978	−0.3521	0.2305	0.4684	0.2015
$N(NO_2)$	0.2728	0.3552	0.4477	0.3088	−0.4511	−0.2463	0.4231	0.0716	0.7005	0.5741	0.3480
$N(NO_3)$	−0.4731	−0.1619	0.5915	−0.3294	−0.1246	*0.7144*	0.2842	−0.2880	0.6084	*0.8689*	0.5129
PO_4	*−0.8701*	0.0191	0.0931	0.1962	−0.6395	0.1593	0.0180	0.2784	0.2850	−0.1084	−0.3178
Cl	−0.4521	−0.3904	−0.5557	−0.0561	0.0949	−0.6000	0.3049	−0.2925	0.2071	−0.1398	*0.7787*
Total hardness in Ca	−0.4822	−0.3533	−0.1282	0.5464	−0.2149	0.0735	−0.1943	*−0.7477*	−0.0506	−0.1524	−0.4522
Total hardness in Mg	−0.1174	−0.1575	−0.0262	0.3255	−0.3485	−0.3492	−0.3182	−0.6281	−0.5114	−0.1812	−0.4600
SO_4	*−0.7727*	0.4349	0.2957	−0.0561	0.6572	*0.8747*	−0.1847	0.4239	*0.7370*	0.0729	*0.8110*
Fe	0.1285	−0.6946	−0.5770	0.5755	*0.7767*	−0.0036	−0.0499	−0.0397	0.0497	0.0089	0.0376
Dry residue	−0.6214	*−0.9022*	−0.2608	0.1525	0.6892	−0.5662	0.0233	−0.5033	−0.5975	−0.2362	−0.2067
Dissolved solids	−0.4177	*−0.8765*	−0.0815	0.1349	*0.7901*	0.4653	0.1653	−0.4190	−0.4054	0.1345	−0.0547
Suspended solids	0.2740	−0.1465	−0.0863	−0.1392	−0.7352	−0.0571	−0.2870	−0.4372	0.0155	−0.1928	−0.1435

to chitinophilic fungi, crustaceans can also house a number of parasitic species (Gaertner 1962; Unestam 1966; Tracy and Vallentyne 1969; Söderhäll and Dick 1991), including a common fish parasite — *Saprolegnia parasitica*.

Statistic elaboration of the results enabled determination of the relationships between hydro-chemical parameters at the respective sites and the number of species found at a particular site (Tab. 6). The mycoflora of the slough was affected by considerably the levels of phosphates and sulphates, showing a negative correlation. In the pond-moat, water temperature and substances dissolved in the water differed from each other significantly demonstrating a negative correlation. In the bathing pond, a positive correlation was revealed in the case of amonium nitrogen concentration, while in Lake Niecko in the case of iron and substances disolved in water, while a negative influence was exerted by the suspended material. In the rivers invesigated, different hydrochemical parameters affected the number of species at various sites of the same river. Thus, in the upper part of the River Biała, the concentrations of nitrate nitrogen and sulphates influenced the occurrence of species, demonstrating a positive correlation, while in the lower part a positive correlation was exhibited by oxidability and a negative one by alkalinity and the level of calcium significant. In the River Supraśl at Site 9 a negative correlation was displayed in the case of temperature, and a positive one with the case of oxidability and sulphates. However, at Site 10, the greatest statistically effect was exerted by sulphates and chlorides (positive correlation). At Site 11, only the effect of nitrate nitrogen was cinsiderable, which indicated

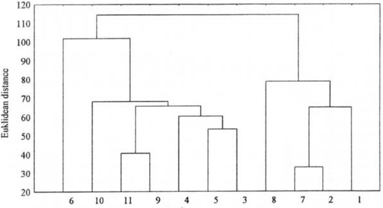

Fig. 2. Clustering of sites (1 – 11) according to number species of aquatic fungi

that the number of fungi increased together with the concentration of this from of nitrogen. The tree diagram method showed that the number of chitinophilic fungus species in the two-year studies was the closest to oxidability of the sites investigated (Fig. 2).

The results obtained indicate that in every water body of water various hydrochemical factors affect significantly the occurrence of chitinophilic fungi, which also refered to different sites of the same water body. We noted this phenomenon while investigating phytosaprotrophes in the lakes and in the River Narew and its tributaries (C z e c z u g a and P r ó b a 1987), in the lakes (C z e c z u g a 1994 b). Similar results were obtained in the case of keratynophilic fungi in different types of water bodies (C z e c z u g a and M u s z y ń s k a 1994) and *Hyphomycetes* in different types of springs (C z e c z u g a and O r ł o w s k a 1996). This was also confirmed by data obtained with the method of clustering water bodies according to water chemistry data (Fig. 3). These data showed that the same number of chitinophilic fungus species occurred at sites that differed in the chemistry of water (Fig. 4). Thus, the development of mycoflora especially chitinophilc fungi inclusive, depended on the number of environmental factors. The number of fungus species in a given water body was influenced by two groups of factors: chitinous substrate and its availability on the one hand, and chemical composition of water on the other. In the former case, the proportion of the respective parameters of water in each body of water were in constant dynamic balance. Thus, the lack of chitin-containing substrates despite favourable

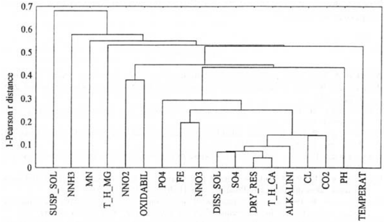

Fig. 3. Clustering of sites according to water chemistry data

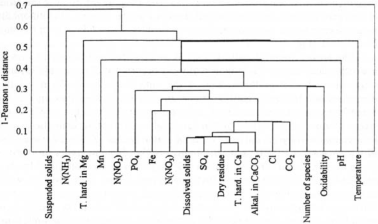

Fig. 4. Clustering of sites according to water chemistry data and to number species of aquatic fungi

aquatic conditions will limits the growth and activity of chitinophilic flora and fungi. On the other hand, environmental influence unfavourable conditions (large amount and diversity of chitin substrate) will have a negative effect on the occurrence of aquatic fungi of a given physiological group. The species composition and the activity of chitinophilic flora at a particular site in a water body is, therefore, determined by of substrate type-related factors and chemical properties of water.

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Chitynofilne grzyby pływkowe w zbiornikach wodnych różnego typu

Streszczenie

Autorzy w latach 1992–1994 co miesiąc badali na tle chemizmu środowiska występowanie chitynofilnych grzybów pływkowych w młaku, stawie–fosie, stawie kąpieliskowym, w 2 jeziorach oraz 2 rzekach. Jako przynęty używano owocników 2 gatunków grzybów kapeluszowych, pancerza raka oraz skrzydeł muchy, ważki i stonki ziemniaczanej. Na wymienionych substratach zawierających chitynę obserwowano rozwój 30 gatunków grzybów pływkowych.

Chytriomyces annulatus, *Entophlyctis crenata*, *Obelidium megarrhizum*, *Rhopalophlyctis sarcoptoides*, *Achlya colorata*, *A. megasperma* oraz *Dictyuchus monosporus* dopełniają istniejącą listę grzybów chitynofilnych. Dwa z nich, *Entophlyctis crenata*, *Obelidium megarrhizum*, a także *Podochytrium chitinophilum* są gatunkami zarejestrowanymi po raz pierwszy w Polsce.