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Aquatic Fungi Growing on the Hair of Wild and Domestic Animal Species in Diverse Water Bodies

B. Czeczuga, E. Muszyńska

Department of General Biology, Medical University, Kilinskiego 1, 15-230 Białystok, Poland

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Abstract

The mycoflora developing on the hair of wild and domestic animal species in the water of 6 limnologically different water bodies was investigated under laboratory conditions. 123 zoosporic fungus species were found to grow on the hair investigated, including 27 chytridiomycetes, 1 hypochytriomycetes, 93 oomycetes, and 1 zygomycetes fungus. The most common fungus species included *Rhizophydium keratinophilum, Rhizophydium nodulosum, Blastocladiopsis parva, Calenophlyctis variabilis, Aphanomyces irregularis, Aphanomyces kerathinophilus, Saprolegnia ferax,* and *Zoophagus insidians. Rhizophydium keratinophilum* and *Aphanomyces irregularis* were found on the hair of all the animals examined. The most fungi were noted to grow in water from lake Komosa (59), the fewest in water from spring Cypisek and spring Jaroszowka (each 49). Out of these 123 species, 33 are known as parasites or necrotrophs of fish. Twelve fungus species were recorded for the first time in Poland.

Keywords: zoosporic fungi, animals, hair, water bodies, hydrochemistry

Introduction

Animal's hair is one of the keratin-containing substrates which at least twice a year in the moulting period (spring and autumn) can be naturally found in the aquatic environment. Our preliminary studies have shown the growth of different substrate-specific keratinophilic fungus species on various keratin-containing substrates, influenced by water chemism [1]. Taking this into account we decided to examine the species composition of fungi found in the hair of wild and domestic animal species in the water of diverse types of water bodies. Fungus species of the genus *Pythium,* not investigated before, were included in the study.

Correspondence to: Prof. B. Czeczuga

Materials and Methods

The hair of wild and domestic animal species were investigated (Table 2). The hair was obtained in spring from dorsal and abdominal parts of animals in the Zoological Garden in Bialystok. The water for experiments was collected from six different water bodies:

- Cypisek Spring is located in the southern part of Knyszyn Forest, limnokrenic type, width 0.41 m, depth 0.17 m, discharge 0.6 1/sek.
- Jaroszowka Spring is located in the northern part of Bialystok, limnokrenic type, width 0.65 m, depth 0.12 m, discharge 2.4 1/sek.
- Suprasl River, length 106.6 km, this is the right-bank tributary of the middle part of the Narew River, flow ing through the Knyszyn Forest.
- Akcent Pond, 0.45 ha, max. depth of 1.50 m, is situated

Table 1. Chemical composition (in mg l^{-1}) of water from the different sites (n=3).

Specification	Cypisek Spring	Jaroszówka Spring	Supraśl River	Akcent Pond	Fosa Pond	Komosa Lake
Temperature, °C	6.8	5.7	5.4	7.0	7.2	6.5
pH	7.80	7.01	8.81	7.85	8.02	8.04
O_2	5.60	8.02	7.42	2.04	4.08	9.40
BOD_5	0.80	1.82	5.60	2.04	9.06	5.42
COD	3.40	3.44	8.03	17.92	22.62	8.04
CO_2	17.60	8.82	8.08	2.24	11.06	8.00
Alkalinity in $CaCO_3$ (mval l^{-1})	5.5	6.2	4.4	6.6	5.5	5.1
$N\text{-}NH_3$	0.03	0.01	0.14	2.65	0.68	0.10
$N\text{-}NO_2$	0.020	0.024	0.008	0.008	0.006	0.005
$N\text{-}NO_3$	2.508	2.176	0.012	0.044	0.040	0.014
$P\text{-}PO_4$	1.092	2.408	1.506	5.050	0.158	0.454
Sulphates	45.66	51.83	19.75	77.34	69.11	29.62
Chlorides	24.0	22.0	14.0	44.0	51.0	10.0
Total hardness in Ca	114.48	123.84	72.72	86.40	75.62	73.44
Total hardness in Mg	18.49	19.35	12.04	19.35	21.93	14.19
Fe	0.50	0.50	0.75	1.55	0.50	0.40
Dry residue	490.0	403.0	312.0	509.0	419.0	318.0
Dissolved solids	474.0	357.0	253.0	486.0	408.0	300.0
Suspended solids	16.0	46.0	59.0	13.0	11.0	18.0

within the Zoological Garden in Bialystok, in which swans are bred and to which wild ducks also come.
- Fosa Pond, 2.5 ha, max. depth of 1.75 m, is situated in the Palace Park in Bialystok, in which crucian carp and tench are bred.
- Komosa Lake, 12.1 ha, max. depth 2.25 m. is sur rounded by extensive coniferous woods of Knyszynska Forest.

Nineteen water parameters of the above sampling sites were determined (Table 1) according to the methods of Greenberg et al. [2].

For the determination of the presence of aquatic fungal species on the hair, the following procedure was employed: animal hairs were cut into small pieces and certain amount of pieces (100-200) of each species of animal were transfered to two samples for each water in an 1.0 litre vessel (together twelve vessels for each species) and placed in the laboratory (in glass thermostat) at ambient temperature. A part of the pieces of hair from each vessel was observed under a light microscope and the mycelium (zoosporic, oogonia and antheridia, and for *Saprolegnia parasitica* secondary cysts) [3] of aquatic fungi growing (produced of oogonia and antheridia) on the hair were recorded. The methods of the experiments are described in detail by Fuller and Jaworski [4]. The hair of the various animal species were observed under a light microscope for one and a half weeks. The length of time of the experiments was six weeks. For determination of the fungi the following keys were used: Johnson [5], Seymour [6], Batko [7], Karling [8], Dick [9] and Pystina [10].

Results

Hydrochemical data of water used for the experiment are presented in Table 1. The highest values of ammonium nitrogen, and phosphates were found in Akcent pond. Spring water appeared to be richest in nitrates and nitrites, as well as in calcium.

The growth of 123 zoosporic aquatic fungus species was found on the hair of wild and domestic animal species in the water of 6 limnologically different water bodies (Table 2, Fig. 1). The fewest fungi developed on the hair of red horse (8), the most on the hair of aurochs yak (25) and tarpan (25) (Table 3). The most common fungus species included *Rhizophydium keratinophilum, Rhizophydium nodulosum, Blastocladiopsis parva, Catenophlyctis variabilis, Aphanomyces irregularis, Aphanomyces keratinophilus, Saprolegnia ferax,* and *Zoophagus insidians. Rhizophydium keratinophilum* and *Aphanomyces irregularis* were found on the hair of all the animals examined.

The most fungi growing were noted in lake Komosa (59), the fewest in spring Cypisek (49) and spring Jaroszowka (49) (Table 4). Worth noting is the finding of 31 fungus species of the genus *Pythium,* of which 7 are new to Polish waters: *Pythium acanthophoron, Pythium ascophallon, Pythium cactacearum, Pythium cucur-*

Table 2. Occurrence of aquatic fungi on hairs of investigated animal species.

Species of animal	Fungi (see Table 3)	Number of fungus species
1. *Alces alces* (L.) – elk	11,13,15,27,28,30,36,39,42,43,45,48,53,55,56,57,69,82,115,123	20
2. *Alopex lagopus* (L.) – polar fox	4,10,11,15,18,23,25,36,37,44,45,47,55,56,60,65,68,80,85,89	20
3. *Aumotragus lervia* (Pallas) – maned sheep	15,24,26,27,36,44,55,56,59,77,94,102,107,123	14
4. *Bison bonasus* (L.) – aurochs	13,15,16,23,28,30,32,35,45,47,51,55,56,60,63,68,76,77,79,97,98,104, 109,116,120	25
5. *Bos grunniens* (L.) – yak	7,11,15,18,23,28,30,35,39,40,47,48,51,55,56,65,66,76,85,88,97,109, 114,120,122	25
6. *Bos taurus* (L.) – cow	3,4,7,10,15,18,24,26,27,28,44,55,56,68,77,104	16
7. *Canis familiaris* (L.) – dog	5,11,15,16,21,24,26,27,28,44,52,55,59,62,68,77,80,94,105,111,119,121,123	23
8. *Canis lupus* (L.) – wolf	10,15,23,24,30,36,44,45,47,48,50,55,56,59,65,77,82,85,89,96,104,105, 122,123	24
9. *Capra hircus* (L.) – goat	16,18,23,24,25,27,36,44,55,56,77,80,94,117,123	15
10. *Capreolus capreolus* (L.) – roe-deer	15,16,20,23,30,40,45,50,51,55,60,68,79,85,91,113,116,119,123	19
11. *Castor fiber* (L.) – beaver	3,13,15,18,19,24,27,29,55,56,77,114,115,119	14
12. *Cervus dama* (L.) – fallow deer	12,15,17,19,23,27,45,46,47,55,56,65,66,68,69,70,75,77,85,114,115	21
13. *Cervus elaphus* (L.) – stag – male	8,10,11,14,18,23,25,26,28,39,40,44,45,49,51,55,56,63,97,99,103,109	22
13a. *Cervus elaphus* (L.) - stag – female	3,7,15,18,27,30,35,55,56,80,83,104	12
14. *Equus asinus* (Fitz.) – ass	3,4,10,15,18,19,20,22,23,24,28,44,50,51,55,56,59,65,72,85,97,109	22
15. *Equus caballus* (L.) – horse (black)	15,18,23,24,27,36,55,65,73,77,86,100,110	13
15a. *Equus caballus* (L.) horse (red)	11,15,18,23,55,58,118,123	8
16. *Equus gmelini* (L.) – tarpan	7,9,11,13,15,23,27,30,34,35,43,44,50,51,55,56,57,79,83,90,106,108,114, 115,116	25
17. *Felis catus* (L.) – cat	11,15,18,23,27,33,36,49,54,55,68,77,80,111,115,123	16
18. *Lama glama* (L.) – llama	11,18,23,24,25,27,28,44,45,55,77,102,111,123	14
19. *Lepus capensis* L. – hare	7,11,13,15,16,35,55,56,66,71,80,93,101,104	14
20. *Lutra lutra* (L.) – otter	15,18,19,27,38,55,61,68,74,89,95,114,123	13
21. *Lynx lynx* (L.) – lynx	7,10,13,15,16,22,24,27,31,44,45,50,51,55,56,60,61,65,68,80,84,97,115,116	24
22. *Mustela putorius* (L.) – polecat	2,14,15,18,23,24,27,28,36,55,57,59,77,90,92,111	16
23. *Ovis aries* (L.) – sheep	15,23,24,27,55,59,65,73,77,86,87,101,110,111,123	15
24. *Ovis musimon* (Pallas) – mouflon	3,4,7,11,15,18,35,41,55,56,57,78,83,97,99,104,123	17
25. *Panthera leo* (L.) – lion	8,15,18,23,24,25,30,39,40,42,43,44,47,48,55,56,59,70,111,112	20
26. *Procyan lotor* (L.) – racoon	1,6,7,15,23,30,34,35,40,46,47,49,50,55,56,61,68,70,83,96,120	21
27. *Rangifer tarandus* (L.) – reindeer	3,7,15,19,23,26,28,36,46,55,56,60,70	13
28. *Sus domesticus* (L.) – pig	4,10,15,18,23,28,55,56,58,59,70,85	12
29. *Sus scrofa* (L.) – wild	3,4,10,15,18,23,27,28,39,46,48,51,55,56,68,69,82,99,115,119	20
30. *Ursus arctos* (L.) – brown bear	4,11,13,15,18,27,30,31,45,51,55,56,77,85,101,116	16
31. *Vulpes vulpes* (L.) – fox	13,15,16,20,27,30,34,36,45,51,55,56,64,65,67,71,77,80,81,84,86,94,116,122	24

bitaceum, Pythium dichotomum, Pythium splendens, and *Pythium tardicrescens.*

Discussion

The colonization of the hair of the respective animals by aquatic fungi occurs in stages. Already after 3-6 days there appeared *Rhizophydium keratinophilum, Rhizophydium nodulosum, Blastocladiopsis parva* (the Chytridiales), *Aphanomyces irregularis,* and *Aphanomyces keratinophilus* (the Saprolegniales). Later other species could be observed, namely *Rhizophydium condylosum* (the Chytridiales), *Catenaria anguillulae,* and *Catenophlyctis variabilis* (the Blastocladiales); *Lagenidium*

humanum (the Lagenidiales); *Achlya colorata, Achlya klebsiana, Achlya megasperma, Achlya rodrigueziana, Leptolegnia caudata,* and *Saprolegnia ferax* (the Saprolegiales); and *Zoophagus insidians* (the Peronosporales). Then after 2-3 weeks some other species, particularly of the genus *Pythium* appeared on the animal hair. The growth of the respective species does not always occur in that order. We also observed successive colonization when studying the growth of fungi on dragon-flies [11] and benthos crustaceans [12].

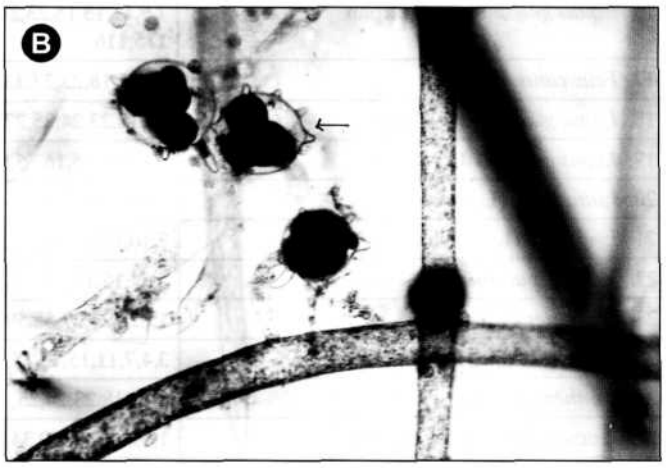
Interesting is also hair colonization of *Capreolus capreolus* in spring Jaroszowka by a sewage fungus *Leptomitus lacteus,* known mainly as a nitrophilous fungus growing in municipal sewage waters. Moreover, it has been known as a parasites offish [13,14] and spawn [15]. The water of spring Jaroszowka was found to have a high content of nitrate and nitrite nitrogen, but the lowest content of ammonium nitrogen.

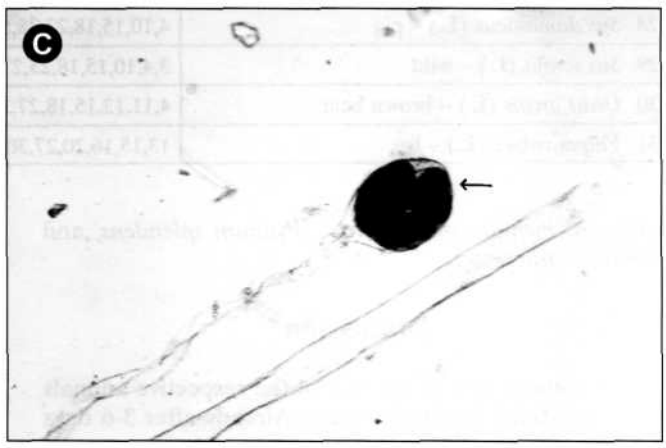
Species composition of fungi growing on animal hair is also substrate-dependent. This could explain qualitative and quantitative differences revealed in the experiment in the same conditions when examining the hair of *Cervus elaphus* of both sexes and of *Equus caballus* of different colours. In elk and horse, the differences could be explained by varied chemical composition of the substrate; hence, the number of fungus species and species composition differ so much. In elk only 3 species out of 31 colonized the hair of male and female, while in horse 4 species of 17 found to grow on horse hair were noted on the hair of black and red horses, the remaining being different. It is likely that the structure and chemical composition of the substrate affect the number of fungus species - the hair of ceratin animal species is colonized by a few tens of fungus species while the hair of others in the same condition shows only a few fungi.

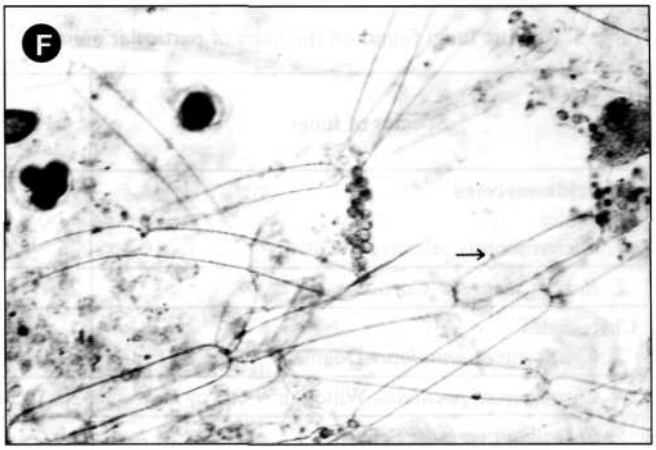
The fewest fungi were noted to grow in spring Cypisek and spring Jaroszowka. The water at both these springs had the highest nitrites, nitrates and calcium, and minimal content of ammonium nitrogen and the lowest ratio of BOD_5 and oxidability (COD).

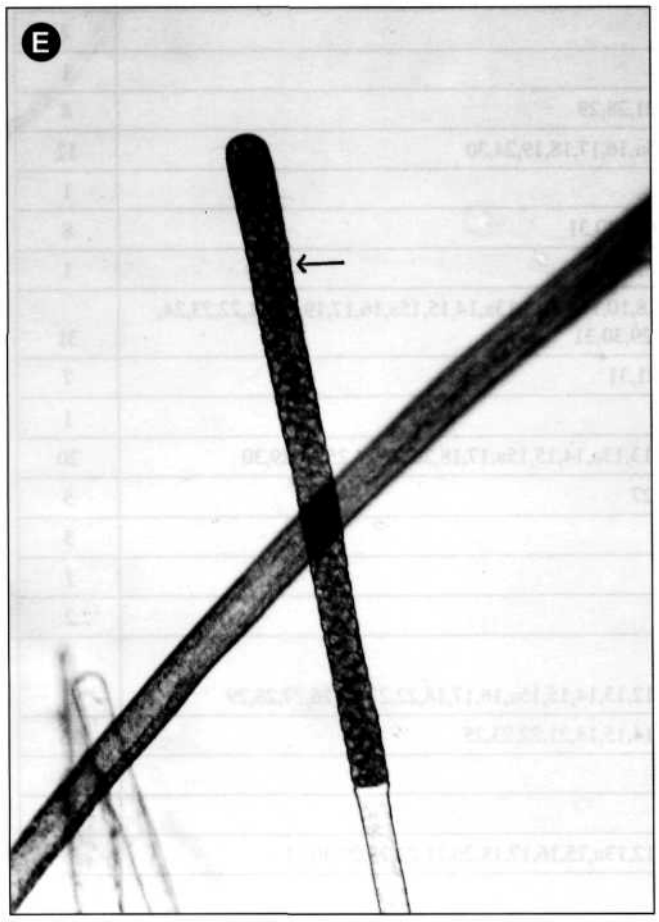
The present study has shown that chemical composition of water influences the occurrence of certain aquatic fungus species on animal hair. This is indicated by the number of species growing on the hair in the respective water bodies and by the fact that some species were observed only in the water of one water body, out of six from which samples were collected for the experiment. We observed such a phenomenon when studying fungi on keratin-containing substrates other than hair [1], such as chitinophilic fungi [16, 17] and fungi growing on the eggs of various freshwater fish species [18, 19]. Some studies [20-23] revealed the growth of species-specific flora of keratinophilic fungi in waters of varied pollution degree. Environmental factors may cause a particular fungus species in a definite environment to change from saprophyte to parasite or to grow on different substrates.

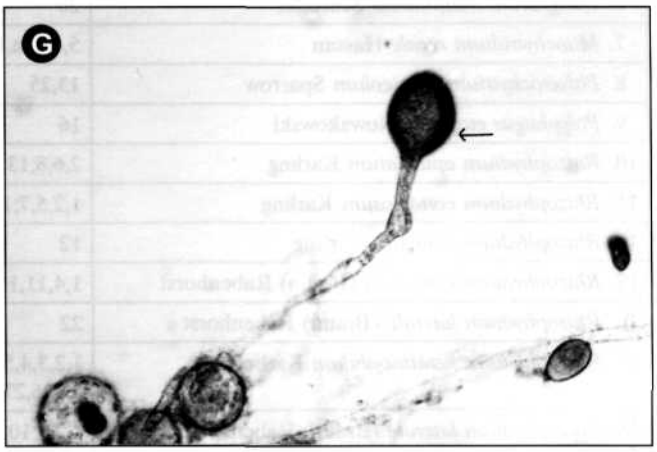
The specificity of the keratin-containing substrate exerts an effect on the number of colonizing fungus species. For instance, *Aphanomyces helicoides* was found only on the hair of *Felis catus* while in the case of feathers, being another keratin-containing substrate, it colonized 23 bird species [24]. This also refers to some other zoosporic aquatic fungus species.











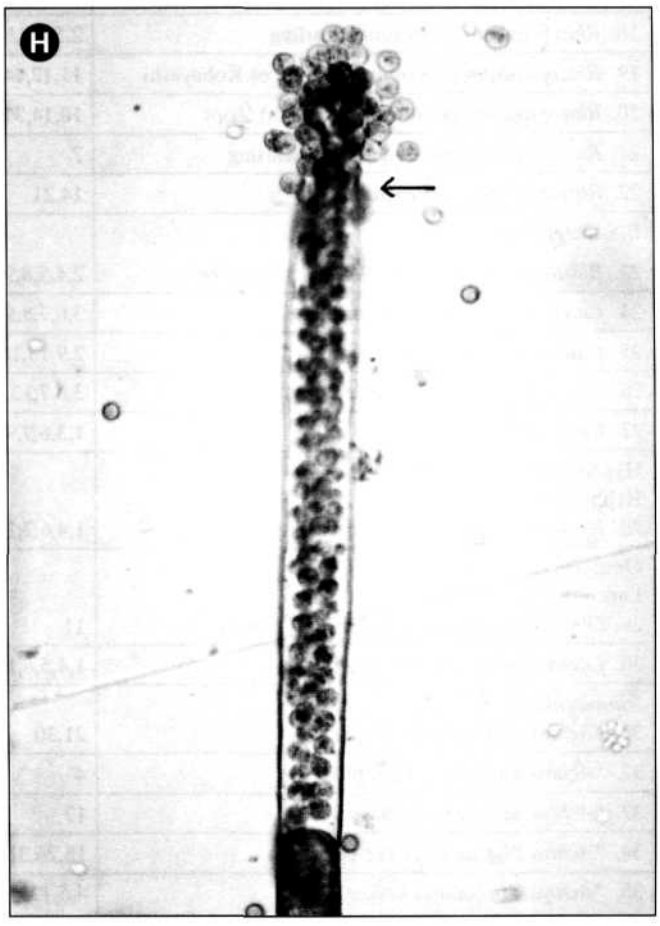


Fig. 1. Some non-keratinophilic fungus species growing on hair (x 200)
A – *Achlya americana* – oogonia (30-102 µm)
B – *Achlya colorata* – oogonia (40-115 µm)
C – *Achlya orion* – oogonia (24-81 µm)
D – *Cladolegnia unispora* - gem (24-75 µm)
E – *Dictyuchus sterile* – sporangium
F – *Leptomitus lacteus* – segment of the hyphae (to 400 µm length)
G – *Saprolegnia eccentrica* – oogonia (50-100 µm)
H – *Saprolegnia ferax* – discharge sporangium

Table 3. Aquatic fungi found on the hairs of particular animals.

Species of fungi	Animal (see Table 2)	Number of animals species
Chytridiomycetes Olpidiales 1. *Micromycopsis intermedia* Coker	26	1
2. *Rozella septigena* Cornu	22	1
Chytridiales 3. *Chytriomyces annulatus* Dogma	6,11,13a,14,24,27,29	7
4. *Chytriomyces poculatus* Willoughby et Townley	2,6,14,24,28,29,30	7
5. *Chytridium versatile* Scherffel	7	1
6. *Dangeardia mammilata* Schroder	26	1
7. *Mitochytridium regale* Hassan	5,6,13a,16,19,21,24,26,27	9
8. *Phlyctochytrium longicolum* Sparrow	13,25	2
9. *Polyphagus euglenae* Nowakowski	16	1
10. *Rhizophydium apiculatum* Karling	2,6,8,13,14,21,28,29	8
11. *Rhizophydium condylosum* Karling	1,2,5,7,13,15a,16,17,18,19,24,30	12
12. *Rhizophydium conicum* Karling	12	1
13. *Rhizophydium globosum* (Braun) Rabenhorst	1,4,11,16,19,21,30,31	8
14. *Rhizophydium laterale* (Braun) Rabenhorst	22	1
15. *Rhizophydium keratinophilum* Karling	1,2,3,4,5,6,7,8,10,11,12,13,13a,14,15,15a,16,17,19,20,21,22,23,24, 25,26,27,28,29,30,31	31
16. *Rhizophydium laterale* (Braun) Rabenhorst	4,7,9,10,19,21,31	7
17. *Rhizophydium macrosporum* Karling	12	1
18. *Rhizophydium nodulosum* Karling	2,5,6,7,9,11,13,13a,14,15,15a,17,18,20,22,24,25,28,29,30	20
19. *Rhizophydium piligenum* Ookubo et Kobayashi	11,12,14,20,27	5
20. *Rhizophydium pollinis-pini* (Braun) Zopf	10,14,31	3
21. *Rhizophydium rarotonganensis* Karling	7	*1*
22. *Rhizophydium verrucosum* Cejp	14,21	2
Blastocladiales 23. *Blastocladiopsis parva* (Whiffen) Sparrow	2,4,5,8,9,10,12,13,14,15,15a,16,17,18,22,23,25,26,27,28,29	21
24. *Catenaria anguillulae* Sorokin	3,6,7,8,9,11,14,15,18,21,22,23,25	13
25. *Catenaria sphaerocarpa* Karling	2,9,13,18,25	5
26. *Catenaria verrucosa* Karling	3,6,7,13,27	5
27. *Catenophlyctis variabilis* Karling	1,3,6,7,9,11,12,13a,15,16,17,18,20,21,22,23,29,30,31	19
Hyphochytriomycetes Hyphochytriales 28. *Hyphochytrium catenoides* Karling	1,4,6,7,13,14,18,22,27,28,29	11
Oomycetes Lagenidiales 29. *Olpidiopsis saprolegniae* (Braun) Cornu	11	1
30. *Lagenidium humanum* Karling	1,4,5,8,10,13a,16,25,26,30,31	11
Saprolegniales 31. **Achlya ambisexualis* Raper	21,30	2
32. **Achlya americana* Humphrey	4	1
33. **Achlya apiculata* de Bary	17	1
34. **Achlya bisexualis* Coker et Couch	16,26,31	3
35. **Achlya caroliniana* Coker	4,5,13a,16,19,24,26	7

Continued of Table 3

Species of fungi	Animal (see Table 2)	Number of animals species
36. *Achlya colorata* Pringsheim	1,2,3,8,9,15,17,22,27,31	10
37. *Achlya crenulata* Ziegler	2	1
38. *Achlya debaryana* Humphrey	20	1
39. **Achlya diffusa* Harvey et Johnson	1,5,13,25,29	5
40. **Achlya dubia* Coker	10,13,25,26	4
41. **Achlya flagellata* Coker	24	1
42. *Achlya hypogyna* Coker et Pemberton	1,25	2
43. *Achlya inflata* Coker	1,16,25	3
44. **Achlya klebsiana* Pieters	2,3,6,7,8,9,13,14,16,18,21,25	12
45. *Achlya megasperma* Humphrey	1,2,4,8,10,12,13,18,21,30,31	11
46. *Achlya oligocantha* de Bary	12,26,27,29	4
47. **Achlya orion* Coker et Couch	2,4,5,8,12,25,26	7
48. **Achlya polyandra* Hildebrand	1,5,8,25,29	5
49. **Achlya prolifera* Nees	13,17,26	3
50. **Achlya racemosa* Hildebrand	8,10,14,16,21,26	6
51. *Achlya rodrigueziana* Wolf	4,5,10,13,14,16,21,29,30,31	10
52. *Achlya treleaseana* (Humphrey) Kauffman	7	1
53. *Aphanodictyon papillatum* Huneycutt	1	1
54. *Aphanomyces helicoides* Minden	17	1
55. *Aphanomyces irregularis* Scott	1,2,3,4,5,6,7,8,9,10,11,12,13,13a,14,15,15a,16,17,18,19,20,21,22,23, 24,25,26,27,28,29,30,31	33
56. *Aphanomyces keratinophilus* (Ookubo et Kobayasi) Seymour et Johnson	1,2,3,4,5,6,8,9,11,12,13,13a,14,16,19,21,24,25,26,27,28,29,30,31	24
57. **Aphanomyces laevis* de Bary	1,16,22,24	4
58. *Aphanomyces parasiticus* de Bary	15a,28	2
59. **Aphanomyces stellatus* de Bary	3,7,8,14,22,23,25,28	8
60. *Aplanes androgynus* (Archer) Humphrey	2,4,10,21,27	5
61. **Calyptralegnia achlyoides* (Coker et Couch) Coker	20,21,26	3
62. *Cladolegnia unispora* (Coker et Couch) Johannes	7	1
63. *Dictyuchus anomalus* Nagai	4,13	2
64. **Dictyuchus monosporus* Leitgeb	31	1
65. **Dictyuchus sterile* Coker	2,5,8,12,14,15,21,23,31	9
66. **Isoachlya anisospora* (de Bary) Coker	5,12,19	3
67. **Isoachlya monilifera* (de Bary) Kauffman	31	1
68. **Leptolegnia caudata* de Bary	2,4,6,7,10,12,17,20,21,26,29	11
69. *Leptolegniella keratinophila* Huneycutt	1,12,29	3
70. *Leptolegniella piligena* Ookubo et Kobayasi	12,25,26,27,28	5
71. *Protoachlya paradoxa* (Coker) Coker	19,31	2
72. **Pythiopsis cymosa* de Bary	14	1
73. *Saprolegnia anisospora* de Bary	15,23	2
74. *Saprolegnia asterophora* de Bary	20	1
75. **Saprolegnia australis* Elliot	12	1
76. **Saprolegnia diclina* Humphrey	4,5	2

Continued of Table 3

Species of fungi	Animal (see Table 2)	Number of animals species
77. **Saprolegnia ferax* (Gruith.) Thuret	3,4,6,7,8,9,11,12,15,17,18,22,23,30,31	15
78. *Saprolegnia glomerata* (Tiesenhausen) Lund	24	1
79. *Saprolegnia hypogyna* de Bary	4,10,16	3
80. *Saprolegnia irregularis* Jonson et Seymour	2,7,9,13a,17,19,21,31	8
81. *Saprolegnia megasperma* Coker	31	1
82. **Saprolegnia mixta* de Bary	1,8,29	3
83. **Saprolegnia monoica* Pringsheim	13a,16,24,26	4
84. *Saprolegnia papillosa* Humphrey	21,31	2
85. **Saprolegnia parasitica* Coker	2,5,8,10,12,14,28,30	8
86. **Saprolegnia subterranea* Dissman	15,23,31	3
87. *Saprolegnia turfosa* (Minden) Gaumann	23	1
88. *Saprolegnia uliginosa* Johannes	5	1
89. **Saprolegnia unispora* Coker et Couch	2,8,20	3
90. **Thraustotheca clavata* (de Bary) Humphrey	16,22	2
Leptomitales 91. *Leptomitus lacteus* (Roth) Agardh	10	1
Peronosporales 92. *Pythium acanthicum* Drechsler	22	1
93. *Pythium acanthophoron* Sideris	19	1
94. *Pythium afertile* Kanouse et Humphrey	3,7,9,31	4
95. *Pythium aquatile* Hohnk	20	1
96. *Pythium aristosporum* Vanterpool	8,13,26	3
97. *Pythium artotrogus* de Bary	4,5,14,21,24	5
98. *Pythium ascophallon* Sideris	4	1
99. *Pythium butleri* Subramaniam	13,24,29	3
100. *Pythium cactacearum* Preti	15	1
101. *Pythium capillosum* Paul	19,23,30	3
102. *Pythium carolinianum* Matthews	3,18	2
103. *Pythium cucurbitaceum* Takimoto	13	1
104. *Pythium debaryanum* Hesse	4,6,8,13a,19,24	6
105. *Pythium deliense* Meurs	7,8	2
106. *Pythium dichotomum* Dangered	16	1
107. *Pythium echinulatum* Matthews	3	1
108. *Pythium globosum* Schenk	16	1
109. *Pythium imperfectum* Hohnk	4,5,13,14	4
110. *Pythium inflatum* Matthews	15,23	2
111. *Pythium intermedium* de Bary	7,17,18,22,23,25	6
112. *Pythium maritinum* Hohnk	16,25	2
113. **Pythium middletonii* Sparrow	10	1
114. *Pythium myriotylum* Drechsler	5,11,12,20	4
115. *Pythium rostratum* Butler	1,11,12,16,17,21,29	7
116. *Pythium spinosum* Sawada	4,10,16,21,30,31	6
117. *Pythium splendens* Braun	9	1

Continued of Table 3

Species of fungi	Animal (see Table 2)	Number of animals species
118. *Pythium tardicrescens* Vanterpool	15a	1
119. *Pythium tenue* Gobi	7,10,11,29	4
120. *Pythium thalassium* Atkins	4,5,26	3
121. *Pythium torulosum* Butler	7	1
122. **Pythium ultimum* Trow	5,8,31	3
Zygomycetes Zoopagales 123. *Zoophagus insidians* Sommerstorff	1,3,7,8,9,10,15a,17,18,20,23,24	12

* Known in literature as parasites or necrotrophs of fish

Table 4. Aquatic fungi found on hairs in water from different water bodies.

Water bodies	Fungi (see Table 3)	Only in one water	Number of fungus species
Cypisek Spring	1,2,3,7,10,11,13,15,16,17,18,20,21,23,24,25,26,27,28,30,32,39,40,44,45,46,55,56,57, 58,62,65,66,68,71,72,80,95,99,102,104,107,109,113,114,115,119,121,123	2,21,32,58, 62,72,95,113,121	49
Jaroszówka Spring	4,7,11,13,15,18,19,23,24,27,28,30,34,35,36,44,45,47,50,52,54,55,56,57,60,61,65,66, 67,68,69,70,74,76,77,78,79,83,85,89,91,97,100,104,108,109,115,116,123	52,54,74,91, 100,108	49
Supraśl River	3,4,7,8,10,11,15,16,18,22,23,25,26,27,28,29,31,34,35,36,39,40,44,45,46,47,48,55,56, 59,60,61,65,68,70,73,76,77,79,80,83,85,87,92,94,97,102,104,105,109,110,112,114, 116,118,122,123	8,87,92,105, 110,112,118	58
Akcent Pond	1,3,4,6,7,9,10,11,12,13,15,17,18,19,22,23,25,26,27,28,30,34,35,36,39,43,44,45,47,49, 50,51,55,56,59,65,66,67,68,71,75,77,82,84,88,96,97,99,104,106,109,115,116,117,119, 120,122,123	6,9,12,51,96, 106,117	58
Fosa Pond	1,3,4,7,10,11,13,15,16,17,18,19,23,24,25,26,27,29,30,35,37,38,44,45,46,47,48,49,50, 55,56,60,64,65,68,69,70,73,77,78,80,83,84,85,86,89,90,93,98,99,101,104,115,119, 122,123	37,38,64,86, 90,93,98,101,103	56
Komosa Lake	3,4,5,7,10,11,13,14,15,16,17,18,19,20,23,24,27,28,31,33,35,39,40,41,42,43,44,45,47, 48,50,53,55,56,57,59,63,65,66,69,71,73,77,79,80,81,82,85,97,99,102,103,104,107, 111,115,116,120,122	5,14,33,41,42, 53,63,81,111	59

me fungus species growing on hair of animals (especially such as *Achlya pofyandra, Achlya prolifera, Aphanomyces laevis, Dictyuchus monosporus, Saprolegnia diclina, Saprolegnia ferax,* and *Saprolegnia parasitica)* was observed on fishes. Sometimes damage is great, e.g. on a fish farm in England the whole fish fry of *Anguilla anguilla* died of saprolegniosis [25]. *Achlya pofyandra* is known as a aparasite of the eggs [26] and grown-up individuals of salmonids [27], while *Achlya prolifera* frequently causes total loss of eggs in hateries [28]. *Aphanomyces laevis* attacks both eggs [29] and adult individuals of many economically valuable fish species [30]. *Dictyuchus monosporus* causes damage to acipenserids, salmonids and cyprinids in hatcheries [27, 29, 30]. However, the greatest damage in fish farming is due to *Saprolegnia diclina, Saprolegnia ferax* and *Saprolegnia parasitica* [31].

The zoosporic fungus species found on the hair of the animals examined have also been encountered in Polish waters on other keratin-containing substrates. However, such species as *Micromycopsis intermedia, Chytridium versalite, Dangeardia mammilata, Rhizophydium conicum,* and *Rhizophydium rarotonganensis* are new to Polish waters. *Micromycopsis intermedia* was found on the hair of *Procyon lotor* in spring Cypisek and pond Akcent. The water of spring Cypisek was found to have the highest content of CO_2 and nitrate nitrogen. Water of this spring had the lowest BOD_5 and oxidability (COD). However, the water of pond Akcent had the lowest content of oxygen and CO_2 but by the highest amounts of ammonium nitrogen, phosphates, sulphates and iron. Water of this pond had the highest alkalinity. In mycological literature it is described as a parasite of green algae [7]. *Chytridium versalite* colonized only the hair of dog *Canis familiaris* in lake Komosa. The water of lake Komosa had the lowest content of nitrite nitrogen, chlorides, and iron but the highest amount of oxygen. Water

of this lake had the lowest alkalinity. It was first described by Scherffel [32] as a parasite of algae and up to now has been reported as a parasite of diatoms [7]. *Dangeardia mammilata* was isolated from the hair of *Procyon lotor* only in pond Akcent. It was first described at the end of the 19th century as parasite of alga *Pandonna morum* [33]. It also parasites in the cells of alga of the genus *Eudorina* [7], *Rhizophydium conicum* was found to grow on the hair of *Cervus dama* in pond Akcent. It was first described by Karling [34] as a parasite of *Netrium* in Brazil. *Rhizophydium rarotonganensis* developed on the dog hair only in spring Cypisek. It was first isolated by Karling [35] as soil saprophyte in Oceania.

Worth noting is the occurrence of numerous fungi of the genus *Pythium* (the Peronosporales representatives) on the hair of the animals examined, known mainly as saprophytes or plant parasites [36, 37]. They include some species new to Polish waters, namely *Pythium acanthophoron, Pythium ascophallon, Pythium cactacearum, Pythium dichotomum, Pythium splendens,* and *Pythium tardicrescens. Pythium acanthophoron* was found to grow on the hair of hare *Lepus capensis* only in pond Fosa. The water of pond Fosa had the lowest content of phosphates but by the largest amounts of chlorides and magnesium. Water of this pond had the highest BOD_5 and oxidability. It was first isolated from diseased leaves of *Ananas sativus* on Hawaiian Archipelago [38]. *Pythium cactacearum,* first described in Italy near San Remo from cactus leaves [39] in our study was found only on the horse hair in spring Jaroszowka. *Pythium dichotomum,* isolated as a parasite of alga *Nitella tenuissima* [40] was observed in the present study only on the hair of tarpan *Equus gmelini. Pythium splendens* colonized the hair of *Capra hircus* only in pond Akcent. It was described by Braun [41] as a parasite of plant tissues of the genus *Pelargonium. Pythium tardicrescens,* first reported by Vanterpool [42] from Canada as a plant parasite on radicibus *Triticum aestivum,* in our experiment was found only on the hair of red horse in the river Suprasl. The water of river Suprasl was found to have a low content of nitrate nitrogen, sulphates, calcium and magnesium. Water of this river had the highest pH.

Not only are these species new to Polish waters but also have never before been encountered on keratin-containing substrates [43].

General Conclusions

123 aquatic zoosporic fungus species were found to grow on the hair of 31 wild and domesticated animal species, including 33 known as fish parasites or necrotrophs.

Of these 123 species, some are typical keratinophilic fungi; there is also a large group of non-keratinophilic fungi, particularly of the genus *Pythium,* with 7 species new to Polish waters.

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References

1. CZECZUGA B., MUSZYNSKA E. Keratinophilic fungi in various types of water bodies. - Acta Mycol. **29,** 201, **1994.**
2. GREENBERG A.L., CLESCERI L.S., EATON A.D. Stan dard Methods for the Examination of Water and Waste water. - Washington, American Public Health Association, 1193 pp. 1992.
3. WILLOUGHBY L.G., PICKERING A.D. Viable Saprolegniaceae spores on the epidermis of the salmonid fish *Salmo trutta* and *Salvelinus alpinus.* - Trans. Br. Mycol. Soc. **68,** 91, **1977.**
4. FULLER M.S., JAWORSKI J. Zoosporic Fungi in Teaching and Research. - Athens, Southeastern Publishing Corpor ation, 310 pp. **1986.**
5. JOHNSON T.W. Jr. The genus *Achlya:* Morphology and Taxonomy. - Ann Arbor, The University of Michigan Press, 180 pp. **1956.**
6. SEYMOUR R.L. The genus *Saprolegnia.* - Nova Hedwigia **19,**1, **1970.**
7. BATKO A. Hydromycology - an ovierviev. Warszawa, PWN, 478 pp. **1975.** (In Polish).
8. KARLING J.S. Chytridiomycetarum Iconograpfia. An Illus trated and Brief Descriptive Guide to the Chytridiomecetous General with Supplement of the Hypochytriomycetes. - Vaduz, Lubrecht and Cramer, 414 pp. **1977.**
9. DICK M.W. Keys to *Pythium.* - Reading, College Estate Management Whiteknights, 64 pp. **1990.**
10. PYSTINA K.A. Genus *Pythium* Pringsh.- Sankt Petersburg, Nauka, 126 pp. **1998.** (In Russian).
11. CZECZUGA B., GODLEWSKA A., MROZEK E. Zoos poric fungi growing on dead dragonflies (Odonata). - Int. J. Odonatol. **2,** 187, **1999.**
12. CZECZUGA B., KOZLOWSKA M., GODLEWSKA A. Zoosporic fungus species growing on dead benthos crusta ceans. - Pol. J. Envir. Stud. **8,** 377, **1999.**
13. WILLOUGHBY L.G. Mycological aspects of a disease of young perch in Windermere. - J. Fish. Biol. 2, 113, **1970.**
14. CZECZUGA B., WORONOWICZ L. Aquatic fungi devel oping on the eggs of certain fresh-water fish species and their environment. - Acta Ichth. Piscat. **23,** 39, **1993.**
15. CZECZUGA B., MUSZYNSKA E., KRZEMINSKA A. Aquatic fungi growing on the spawn of certain amphibians. - Amphibia-Reptilia **19,** 239, **1998.**
16. CZECZUGA B., GODLEWSKA A. Aquatic fungi growing on substrates containing chitin. - Acta Mycol. **29,**189, **1994.**
17. CZECZUGA B., GODLEWSKA A. Chitinophilic zoosporic fungi in various types of water bodies. - Acta Mycol. **33,** 43, **1998.**
18. CZECZUGA B., MUSZYNSKA E. Aquatic fungi growing on coregonid fish eggs. - Acta Hydrobiol. **40,** 239, **1998.**
19. CZECZUGA B., MUSZYNSKA E. Aquatic fungi growing on the eggs of fishes representing 33 cyprinid taxa (Cyprinidae) in laboratory conditions. - Acta Ichth. Piscat. **29,** 53, **1999.**
20. MANGIAROTTI A.M., CARETTA G. Keratinophilic fungi isolated from a small pool. - Mycopathologia **85,** 9, **1984.**
21. GARG A.P., GANDOTRA S., MUKERJ K.G, PUGH G.J.K. Ecology of keratinophilic fungi. - Proc. Indian Acad. Sci. (Plant Sci.) **94,** 149, **1985.**
22. ABDEL-HAFEZ A.I.I., EL-SHAROUNY H.M.M. The oc currence of keratinophilic fungi in sewage sludge from Egypt. - J. Bas. Microbiol. **30,** 73, **1990.**

23. VIDAL P., SANCHEZ-PUELLES J.M., MILAN D., GUARRO J. *Chrysosporium fluviale,* a new keratinophilic species from river sediments. - Mycol. Res. **104,** 244, **2000.**
24. CZECZUGA B., GODLEWSKA A. Aquatic fungi growing on feathers of bird species in various water bodies. - Limnologica **31,** in press, **2001.**
25. COPLAND J.W., WILLOUGHBY L.G. The pathology of *Saprolegnia* infections of *Anguilla anguilla* L. elvers. - J. Fish. Diseases 5, 421, **1982.**
26. OSIPIAN L.L., HAKOBIAN L.A., VARDAMIAN G.S. On the species composition on Oomycetes of the lake Sevan, developing on the fish caviar. - Biol. J. Armen. **41,** 170, **1988.** (In Russian).
27. FLORINSKAYA A.A. Data on the species composition and ecology of moulds - agents of fish saprolegniosis in Leningrad district. - Izv. Gos. NIORCh **69,** 103, **1969.** (In Russian).
28. ATI S.C., KHULBE R.D. A new host records for the fungal genus *Achtya. - Can.* Sci. (India) **50,** 313, **1981.**
29. LARTSEVA L.V. *Saprolegnia* on the spawn of sturgeons and salmons. - Hydrobiol. J. **20,** 103, **1986.** (In Russian).
30. DUDKA I.A., ISAYEVA N.M., DAVYDOW O.N. Saprolegniaceae inducing fish mycosis. - Mikol. Phytopathol. **23,** 488, **1989.** (In Russian).
31. NEISH G.A., HUGHES G.C. Diseases of fishes. Book. 6: Fungal diseases of fisches. - Reigate, T.F.H. Publication, 155 pp. **1980.**
32. SCHERFFEL A. Einiges iiber neue oder ungeniigend bekannte Chytridineen (Der "Beitrage zur Kenntnis der Chytridinnen". Teil II). - Arch. Protistenk. **54,** 167, **1926.**
33. SCHRODER B. *Dangeardia,* ein neues Chytridianeen Genus *anfPandorina morum* Bory. - Ber. deut. Bot. Gesell. **16,** 314,**1898.**
34. KARLING J.S. Brazilian chytrids. IX. Species of *Rhizidium.* - Amer. **J.** Bot. **33,** 328, **1946.**
35. KARLING J.S. Zoosporic fungi of Oceania. III. Monocentric chytrids. - Arch. Mikrobiol. **61,** 112, **1968.**
36. PLAATS-NITERINK A.J. VAN der Monograph of the genus *Pythium.* - Stud. Mycol. **21,** 1, **1981.**
37. YU Y.-N., MA G.-Z. The genus *Pythium* in China. - Mycosystema **2,** 1, **1989.**
38. SIDERIS C.P. Taxonomic studies in the family Pythiaceae. - Mycologia **24,** 14, **1932.**
39. PRETI G. Un' infezione de *"Pythium"* su piante di *"Phyllocactus phyllanthoides"* - Riv. Patol. Veget. **26,** 331, **1936.** (In Italian).
40. DANGEARD P. Recherckes sur les organismes inferieurs. - Ann. Sci. Natur. Bot., Ser. **7,** 241, **1886.**
41. BRAUN H. Comparative studies of *Pythium debaryanum* and two relative species from *Geranium.* - J. Agric. Res. **30,** 1043, **1925.**
42. VANTERPOOL T.C. Some species of *Pythium* parasitic on wheat in Canada and England. - Ann. Appl. Biol. **25,** 528, **1938.**
43. CZECZUGA B. Species of *Pythium* isolated from eggs of fresh-water fish. - Acta Mycol. **31,** 117, **1996.**