Aquatic fungi and straminipilous organisms on decomposing fragments of wetland plants

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Abstract. Straminipilous organisms and fungus species on dead fragments of 25 taxa of wetland plants from three water bodies were investigated. A total of 219 fungal taxa, including 85 straminipilous organisms and 134 fungus species were recorded. The largest number of straminipilous organisms and fungus species occurred on fragments of *Lathyrus palustre* and *Rorippa amphibia* (45 and 44 species respectively), the fewest on *Calla palustris* (20). The most common species were *Chytridium xylophilum* (on 23 plants), *Pythium rostratum* (on 15), *Pithomyces obscuriseptatus* (on all plants), *Trinacrium subtile* (on 17) and *Titaea* (*Tetracladium*) *maxilliformis* (on 16). The larger numbers of species were recorded in running water (Jaroszówka Spring, Supraśl River, 124 and 122 respectively), with fewest (106) in stagnant water at Dojlidy Pond. Thirty-one taxa were recorded for the first time from Poland.

Key words: aquatic fungi, hydrochemistry, Poland, straminipilous organisms, wetland plants

Introduction

The border between land and water reservoirs of different types is frequently overgrown with herbaceous plants which mostly die in autumn. This relatively large mass of organic matter is decomposed by various systematic groups of microorganisms. Until now, most studies on the decomposition of wetland plants have dealt with bacteria that participate in the mineralization of dead plant fragments (Gopal *et al.* 2000, 2001; Vymazal 2001; Kvet *et al.* 2002; Karjalainen *et al.* 2005). Our studies on aquatic plant species that form various ecological complexes (Czeczuga *et al.* 2003b, 2005, 2006; Czeczuga & Muszyńska 2005) have shown numerous lower aquatic fungi, both straminipilous and anamorphic species, are involved in the decomposition process.

In our studies on the hydromycota in different types of water reservoirs in northwestern Poland we have found many rare species, some of which may not be encountered for many years (Czeczuga *et al.* 2002, 2003a, b, 2004; Czeczuga 2004). Therefore, we decided to establish the species diversity of straminipilous and aquatic fungi which participate in the mineralization of some wetland plants in different freshwater ecosystems.

Materials and Methods

Twenty-five species of wetland plants collected from northeastern Poland in autumn 2000 were studied (Table 2).

A stem fragment and a few leaves were collected from 3 plants of each species. All three fragments were cut into small pieces, mixed and about 2 mg was added to each water sample (in 1 L vessels) from a particular water body. The water samples were collected from water reservoirs at three locations:

- Jaroszówka Spring, limnokrenic type, width 0.65 m, depth 0.12 m, discharge 2.4 L/s (northern of Białystok);

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Table 1. Chemical and physical properties of water in particular water bodies

Specyfication	Spring Jaroszówka	River Supraśl	Pond Dojlidy
Temperature (°C)	2.5	0.1	0.5
pH	7.92	7.52	7.84
O_2 (mg L^{-1})	10.8	11.4	9.6
BOD_5 (mg L^{-1})	1.8	7.2	5.4
COD (mg L^{-1})	2.50	7.00	7.03
CO_2 (mg L^{-1})	11.0	8.8	13.2
Alkalinity in $CaCO_3$ (mval L^{-1})	5.8	4.3	4.6
N-NH_3 (mg L^{-1})	0.12	0.23	0.61
N-NO_2 (mg L^{-1})	0.013	0.008	0.013
N-NO_3 (mg L^{-1})	2.25	0.37	0.36
P-PO_4 (mg L^{-1})	1.29	1.20	0.45
Sulphates (mg L^{-1})	53.07	54.97	43.61
Chlorides (mg L^{-1})	11.0	11.0	18.0
Total hardness (mg Ca L^{-1})	65.28	70.56	88.56
Total hardness (mg Mg L^{-1})	16.77	12.47	16.34
Fe (mg L^{-1})	0.40	0.50	0.70
Dry residue (mg L^{-1})	412	165	295
Dissolved solids (mg L^{-1})	410	141	280
Suspended solids (mg L^{-1})	2	14	15

- Supraśl River, length 106.6 km, on the right-bank tributary of the Narew River, flowing through the Knyszynska Forest;
- Dojlidy Pond, area 34.2 ha, max. depth 2.85 m its southern shores border with coniferous woods while its western part borders with the town of Białystok where this part of the pond is used as a beach.

For the determination of fungal species present in the water samples, the following procedure was used: 10-15 pieces of each plant species were transferred in two water samples (800 ml) from each site (six vessels for each plant species) and placed in the laboratory at ambient temperature between 5-7 °C. Some pieces (2-3) from each vessel were transferred to a glass slide with a pipette and observed under a light microscope. Fungal structures (zoospores, antheridia, oogonia, conidiophores and conidia) were recorded (Seymour & Fuller 1987). The pieces of the various plant species were microscopically examined every 3-4 days. The size of the fungal structures was measured using light-microscopy at ×600. The duration of the experiment was five weeks. The following keys aided identification of the fungi: Johnson (1956), Waterhouse (1968), Seymour (1970), Batko (1975), Karling (1977), Plaats-Niterink (1981), Dick (1990), Pystina (1998), Watanabe (2002) and for anamorphic fungi – Dudka (1974), Ingold (1975), Carmichael *et al.* (1980), Matsushima (1993). The systematics of straminipilous organisms was used according to Dick (2001).

Nineteen water parameters were determined at the sampling sites (Table 1) following the methods of Greenberg *et al.* (1995).

The chemical parameters of the water as well as the mycota were investigated by correlation analysis (Winer 1997).

Results

Chemical analysis of the water samples revealed that Jaroszówka Spring was most abundant in nutrients, and the ammonium nitrogen content was the lowest there. The highest ammonium nitrogen concentration was found in Dojlidy Pond, while the remaining nutrients in that water body occurred in trace amounts (Table 1).

Eighty-five straminipilous organisms and 134 fungus species were found to grow on the fragments of 25 wetland plant species, including 1 species of unidentified *Ascomycetes,* 3 *Ustilaginomycetes* and 84 conidial fungi (Table 3, Fig. 1). The largest number of species occurred on fragments of *Lathyrus palustre* and *Rorippa amphibia* (45 and 44 species respectively), the fewest on *Calla palustris* (20). The most common species were *Pithomyces obscuriseptatus* (on all plants), *Chytridium xylophilum* (on 23 plants), *Pythium rostratum* (on 15), *Titaea maxilliformis* (syn. *Tetracladium maxilliformis*) (on 16) and *Trinacrium subtile* (on 17).

Table 2. Occurrence of aquatic fungi and straminipilous organisms on fragments of the investigated wetland plants

	Species of wetland plants	Fungi and straminipilous organisms (see Table 3)	Number of species
1.	*Acorus calamus* L.	28, 35, 36, 38, 40, 44, 55, 65, 78, 81, 93, 96, 100, 115, 117, 140, 142, 143, 144, 145, 155, 156, 165, 170, 176, 184, 189, 191, 193, 204, 205, 211, 218	33
2.	*Alisma plantago-aquatica* L.	12, 28, 31, 35, 39, 51, 69, 71, 78, 81, 82, 83, 86, 93, 119, 133, 136, 144, 157, 160, 163, 164, 165, 170, 173, 176, 184, 213	28
3.	*Butomus umbellatus* L.	12, 35, 36, 44, 47, 67, 74, 80, 116, 134, 137, 138, 143, 144, 146, 151, 164, 170, 176, 184, 204, 205, 210, 211, 214, 217	26
4.	*Calla palustris* L.	12, 18, 28, 31, 38, 44, 51, 81, 92, 93, 136, 141, 144, 148, 164, 166, 170, 184, 193, 218	20
5.	*Caltha palustris* L.	12, 16, 26, 80, 81, 82, 93, 109, 113, 128, 144, 152, 153, 164, 170, 179, 183, 184, 193, 203, 205, 207, 211, 215	24
6.	*Carex elata* Bellrdi ex All.	21, 35, 44, 51, 53, 81, 93, 109, 137, 138, 142, 143, 144, 167, 168, 169, 173, 181, 184, 189, 194, 205, 215, 219	24
7.	*C. gracilis* Curtis	16, 30, 38, 51, 54, 59, 61, 93, 118, 138, 142, 144, 145, 173, 175, 176, 178, 180, 182, 184, 185, 189, 195, 200, 211	25
8.	*C. pseudocyperus* L.	12, 16, 28, 31, 35, 53, 54, 70, 93, 137, 138, 139, 144, 147, 161, 169, 170, 173, 175, 176, 180, 184, 205	23
9.	*C. vulpina* L.	13, 16, 28, 29, 35, 43, 54, 71, 80, 81, 93, 126, 138, 144, 170, 172, 175, 184, 188, 192, 202, 205, 207	23
10.	*Cyperus fuscus* L.	6, 16, 21, 44, 54, 59, 81, 93, 111, 131, 138, 144, 150, 164, 170, 171, 173, 180, 184, 188, 207, 211, 215, 217	24
11.	*Equisetum palustre* L.	7, 12, 14, 19, 20, 24, 25, 34, 39, 40, 44, 45, 49, 50, 53, 59, 71, 79, 81, 85, 93, 121, 126, 136, 144, 156, 157, 164, 165, 170, 173, 176, 182, 184, 185, 200, 203, 205, 207, 208, 211	41
12.	*Eleocharis acicularis* (L.) Roem. et Schult.	7, 50, 54, 56, 71, 79, 91, 93, 111, 125, 128, 138, 145, 150, 153, 173, 174, 176, 184, 193, 211, 216	22
13.	*E. palustris* (L.) Roem. et Schult.	7, 50, 54, 56, 71, 79, 91, 93, 100, 111, 125, 128, 130, 138, 141, 144, 145, 150, 153, 165, 173, 174, 176, 183, 184, 185, 193, 205, 211, 216	30
14.	*Juncus conglomeratus* L.	23, 37, 46, 50, 52, 53, 64, 72, 77, 79, 81, 87, 93, 100, 102, 110, 111, 144, 149, 158, 170, 173, 177, 179, 181, 183, 184, 187, 188, 191, 196, 207, 215	33
15.	*J. effuscus* L.	8, 28, 36, 53, 73, 75, 81, 91, 93, 103, 104, 126, 130, 138, 140, 144, 148, 170, 176, 180, 182, 183, 184, 200, 207, 211	26
16.	*Lathyrus palustre* L.	11, 12, 15, 18, 25, 27, 28, 33, 34, 36, 39, 46, 52, 54, 55, 56, 67, 74, 75, 84, 91, 93, 98, 100, 112, 122, 126, 140, 141, 142, 144, 145, 154, 159, 164, 170, 173, 184, 186, 187, 196, 197, 199, 205, 211	45
17.	*Mentha aquatica* L.	9, 21, 36, 37, 54, 56, 68, 71, 81, 91, 93, 111, 114, 120, 126, 127, 138, 144, 164, 165, 170, 173, 184, 205, 206, 207, 215	27
18.	*M. rotundifolia* (L.) Huds.	9, 21, 36, 37, 54, 56, 71, 81, 91, 93, 108, 111, 114, 120, 126, 136, 144, 152, 164, 170, 184, 203, 205, 207, 215	25
19.	*Menyanthes trifoliata* L.	4, 5, 34, 40, 48, 50, 53, 66, 71, 79, 93, 99, 102, 129, 131, 144, 162, 164, 165, 170, 173, 177, 184, 187, 198, 203, 211, 213, 218	29
20.	*Rorippa amphibia* L.	2, 9, 10, 12, 17, 21, 22, 25, 32, 33, 34, 36, 39, 40, 41, 42, 55, 60, 62, 71, 73, 76, 79, 87, 90, 93, 110, 112, 126, 128, 144, 148, 149, 164, 173, 177, 184, 185, 193, 201, 204, 205, 211, 212	44
21.	*Rumex aquaticus* L.	9, 16, 39, 50, 52, 55, 71, 81, 85, 95, 100, 123, 132, 138, 142, 144, 165, 177, 184, 190, 205, 211	22
22.	*Sagittaria sagittifolia* L.	1, 3, 22, 37, 39, 53, 62, 63, 64, 71, 78, 79, 92, 93, 100, 111, 126, 135, 138, 144, 148, 164, 171, 177, 184, 191, 197, 207, 209, 211, 218	31
23.	*Sparganium emersum* Rehmann	46, 57, 64, 65, 79, 88, 93, 94, 96, 97, 101, 105, 106, 107, 109, 111, 112, 113, 124, 126, 138, 140, 144, 145, 155, 156, 165, 170, 176, 177, 180, 181, 184, 205, 211, 218	36
24.	*S. erectum* L.	45, 50, 53, 67, 81, 93, 96, 105, 111, 112, 124, 126, 138, 142, 144, 145, 170, 173, 176, 177, 181, 184, 205, 211	24
25.	*S. minimum* Fr.	2, 45, 50, 53, 58, 67, 81, 89, 93, 96, 105, 111, 112, 124, 126, 142, 144, 170, 173, 176, 184, 205, 211	23

Table 3. Aquatic fungi and straminipilous organisms found on wetland plants

Taxa	Plant (see Table 2)	Number of plants
Straminipila		
Hyphochytriomycetes		
Hyphochytriales		
1. *Hypochytrium oceanum* Karling	22	1
2. *Reesia amoeboides* C. Fisch	20, 25	2
3. *R. lemnae* (C. Fisch) Karling	22	1
4. *Rhizidiomyces hansonii* Karling	19	1
5. *R. hirsutus* Karling	19	1
Myzocytiopsidales		
6. *Myzocytiopsis vermicola* (Zopf) M.W. Dick	10	1
7. *Syzygangia marchaliana* (De Wild.) M.W. Dick	11, 12, 13	3
***Peronosporomycetes* (*Oomycetes*)**		
Saprolegniales		
8. *Achlya ambisexualis* Raper	15	1
9. *A. americana* Humphrey	17, 18, 20, 21	4
10. *A. apiculata* de Bary	20	1
11. *A. bisexualis* Coker et Couch	16	1
12. *A. caroliniana* Coker	2, 3, 4, 5, 8, 11, 16, 20	8
13. *A. colorata* Pringsh.	9	1
14. *A. debaryana* Humphrey	11	1
15. *A. diffusa* J.V. Harv. ex T.W. Johnson	16	1
16. *A. klebsiana* Pieters	5, 7, 8, 9, 10, 21	6
17. *A. oblongata* de Bary	20	1
18. *A. oligacantha* de Bary	4, 16	2
19. *A. papillosa* Humphrey	11	1
20. *A. polyandra* Hildebr.	16	1
21. *A. prolifera* Nees	6, 10, 17, 18, 20	5
22. *A. racemosa* Hildebr.	20, 22	2
23. *A. radiosa* Maurizio	14	1
24. *A. rodrigueziana* F.T. Wolf	11	1
25. *Aphanomyces irregularis* W.W. Scott	11, 16, 20	3
26. *A. laevis* de Bary	5	1
27. *A. stellatus* de Bary	16	1
28. *Aplanes androgynus* (W. Archer) Humphrey	1, 2, 4, 8, 9, 15, 16	7
29. *Brevilegnia unisperma* (Coker et Braxton) Coker et Braxton	9	1
30. *Dictyuchus monosporus* Leitg.	7	1
31. *D. sterilis* Coker	2, 4, 8	3
32. *Isoachlya monilifera* (de Bary) Kauffman	20	1
33. *I. torulosa* (de Bary) Cejp	16, 20	2
34. *I. unispora* Coker et Couch	11, 16, 19, 20	4
35. *Leptolegnia caudata* de Bary	1, 2, 3, 6, 8, 9	6
36. *Pythiopsis cymosa* de Bary	1, 3, 15, 16, 17, 18, 20	7
37. *Saprolegnia anisospora* de Bary	14, 17, 18, 22	4
38. *S. diclina* Humphrey	1, 4, 7	3
39. *S. ferax* (Gruith.) Thur.	2, 11, 16, 20, 21, 22	6
40. *S. glomerata* (Tiesenh.) A. Lund	1, 11, 19, 20	4
41. *S. litoralis* Coker	20	1
42. *S. parasitica* Coker	20	1
43. *S. turfosa* (Minden) Gäum.	9	1
44. *Thraustotheca clavata* (de Bary) Humphrey	1, 3, 4, 6, 10, 11	6

Table 3. (comtinued)

Taxa	Plant (see Table 2)	Number of plants
Pythiales		
45. *Myzocytium proliferum* Schenk	11, 24, 25	3
46. *Phytophthora undulata* (H.E. Petersen) M.W. Dick		
47. *Pythiogeton autossytum* Drechsler	3	1
48. *P. transversum* Minden	19	1
49. *Pythium angustatum* Sparrow	11	1
50. *P. aquatile* Höhnk	11, 12, 13, 14, 19, 21, 24, 25	8
51. *P. aristosporum* Vanterp.	2, 4, 6, 7	4
52. *P. arrhenomanes* Drechsler	14, 16, 21	3
53. *P. butleri* Subraman.	6, 8, 11, 14, 15, 19, 22, 24, 25	9
54. *P. capillosum* B. Paul	7, 8, 9, 10, 12, 13, 16, 17, 18	9
55. *P. carolinianum* V.D. Matthews	1, 16, 20, 21	4
56. *P. catenulatum* V.D. Matthews	12, 13, 16, 17, 18	5
57. *P. debaryanum* R. Hesse	23	1
58. *P. diclinum* Tokun.	25	1
59. *P. dissimile* Vaartaja	7, 10, 11	3
60. *P. dissotocum* Drechsler	20	1
61. *P. flevoense* Plaäts-Nit.	7	1
62. *P. graminicola* Subraman.	20, 22	2
63. *P. helicandrum* Drechsler	22	1
64. *P. heterothallicum* W.A. Campb. et F.F. Hendrix	14, 22, 23	3
65. *P. hydnosporum* (Mont.) J. Schröt.	1, 23	2
66. *P. indigoferae* E.J. Butler	19	1
67. *P. inflatum* V.D. Matthews	3, 16, 24, 25	4
68. *P. intermedium* de Bary	17	1
69. *P. mastophorum* Drechsler	2	1
70. *P. megalacanthum* de Bary	8	1
71. *P. myriotylum* Drechsler	2, 9, 11, 12, 13, 17, 18, 19, 20, 21, 22	11
72. *P. oligandrum* Drechsler	14	1
73. *P. ostracodes* Drechsler	15, 20	2
74. *P. palingenes* Drechsler	3, 16	2
75. *P. papillatum* V.D. Matthews	15, 16	2
76. *P. periilum* Drechsler	20	1
77. *P. periplocum* Drechsler	14	1
78. *P. perniciosum* Serbinow	1, 2, 22	3
79. *P. polymastum* Drechsler	11, 12, 13, 14, 19, 20, 22, 23	8
80. *P. pulchrum* Minden	3, 5, 9	3
81. *P. rostratum* E.J. Butler	1, 2, 4, 5, 6, 9, 10, 11, 14, 15, 17, 18, 21, 24, 25	15
82. *P. tardicrescens* Vanterp.	2, 5	2
83. *P. torulosum* Coker et P. Patt.	2	1
84. *P. ultimum* Trow	16	1
85. *P. volutum* Vanterp. et Truscott	11, 21	2
Fungi		
Ascomycetes		
Hypocreales		
86. *Nectria spirostriata* Rossman	2	1

Table 3. (comtinued)

Taxa	Plant (see Table 2)	Number of plants
Chytridiomycetes		
Chytridiales		
87. *Blyttiomyces helikus* Sparrow et Barr	14	1
88. *B. laevis* Sparrow	23	1
89. *B. spinulosus* (A. Blytt) A.F. Bartsch	25	1
90. *Chytridium lagenula* A. Braun	20	1
91. *C. nodulosum* Sparrow	12, 13, 15, 16, 17, 18	6
92. *C. olla* A. Braun	4, 22	2
93. *C. xylophilum* Cornu	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25	23
94. *Chytriomyces hyalinus* Karling	23	1
95. *C. stellatus* Karling	21	1
96. *Cladochytrium aneurae* Thirum.	1, 23, 24, 25	4
97. *C. aureum* Karling	23	1
98. *C. hyalinum* Berdan	16	1
99. *C. menyanthis* (de Bary) de Bary	19	1
100. *C. polystomum* Zopf	1, 13, 14, 16, 21, 22	6
101. *C. replicatum* Karling	23	1
102. *C. setigerum* Karling	14, 19	2
103. *C. tenue* Nowak.	15	1
104. *Diplochytridium lagenaria* (Schenk) Karling	15	1
105. *Diplophlyctis laevis* Sparrow	23, 24, 25	3
106. *Endochytrium digitatum* Karling	23	1
107. *Entophlyctis bulligera* (Zopf) A. Fisch.	23	1
108. *Megachytrium westonii* Sparrow	18	1
109. *Nephrochytrium aurantium* Whiffen	5, 6, 23	3
110. *N. buttermerense* Willoughby	14, 20	2
111. *Nowakowskiella elegans* (Nowak.) J. Schröt.	10, 12, 13, 14, 17, 18, 22, 23, 24, 25	10
112. *N. macrospora* Karling	16, 20, 23, 24, 25	5
113. *N. profusa* Karling	5, 23	2
114. *Phlyctochytrium hirsutum* Karling	17, 18	2
115. *P. planicorne* G.F. Atk.	1	1
116. *Physoderma butomi* J. Schröt.	3	1
117. *P. calami* K. Krieg.	1	1
118. *P. gerhardti* J. Schröt.	7	1
119. *P. maculare* Wallr.	2	1
120. *P. menthae* J. Schröt.	17, 18	2
121. *Podochytrium clavatum* Pfitzer	11	1
122. *Polyphagus euglenae* (Bail) J. Schröt.	16	1
123. *Polyphlyctis unispina* (R.A. Paterson) Karling	21	1
124. *Rhizidium richmondense* Willoughby	23, 24, 25	3
125. *Rhizophlyctis petersenii* Sparrow	21, 13	2
126. *R. rosea* (de Bary et Woronin) A. Fisch.	9, 11, 15, 16, 17, 18, 20, 22, 23, 24, 25	11
127. *Rhizophydium elyense* Sparrow	17	1
128. *Synchytrium aureum* J. Schrőt.	5, 12, 13, 20	4
129. *S. taraxaci* de Bary et Woronin	19	1
130. *Truittella setifera* Karling	13, 15	2
Blastocladiales		
131. *Catenaria sphaerocarpa* Karling	10, 19	2
Monoblepharidales		
132. *Monoblepharis polymorpha* Cornu	21	1

Table 3. (comtinued)

Taxa	Plant (see Table 2)	Number of plants
Ustilaginomycetes		
Doassansiales		
133. *Doassansia alismatis* (Nees) Cornu	2	1
134. *D. punctiformis* (Niessl) J. Schröt.	3	1
135. *D. sagittariae* (Westend.) J.C. Fisch.	22	1
Anamorphic fungi		
136. *Acrodictys bambusicola* M.B. Ellis	2, 4, 11, 18	4
137. *A. elaeidicola* M.B. Ellis	3, 6, 8	3
138. *A. martinii* J.L. Crane et Dumont	3, 6, 7, 8, 9, 10, 12, 13, 15, 17, 21, 22, 23, 24	14
139. *Acremonium rhombicum* (Matsush.) Matsush.	8	1
140. *Alatospora acuminata* Ingold	1, 15, 16, 23	4
141. *Anguillospora filiformis* Greath.	4, 13, 16	3
142. *A. longissima* (Sacc. et P. Syd.) Ingold	1, 6, 7, 16, 21, 24, 25	7
143. *A. pseudolongissima* Ranzoni	1, 3, 6	3
144. *Angulospora aquatica* Sv. Nilsson	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25	24
145. *Arbusculina fragmentans* Marvanová	1, 7, 12, 13, 16, 23, 24	7
146. *Beverwykella pulmonaria* (Beverw.) Tubaki	3	1
147. *Bidenticula cannae* Deighton	8	1
148. *Calcarispora hiemalis* Marvanová et Marvan	4, 15, 20, 22	4
149. *Canalisporium caribense* (Hol.-Jech. et Mercado) Nawawi et Kuthub.	14, 20	2
150. *Chloridium obclavatum* Matsush.	10, 12, 13	3
151. *Clavariopsis aquatica* De Wild.	3	1
152. *Clavatospora longibrachiata* (Ingold) Sv. Nilsson	5, 18	2
153. *Colispora elongata* Marvanová	5, 12, 13	3
154. *Corynespora cubensis* Hol.-Jech.	16	1
155. *Corynesporella simpliphora* Matsush.	1, 23	2
156. *C. superioramifera* Matsush.	1, 11, 23	3
157. *Cylindrocarpon aquaticum* (Sv. Nilsson) Marvanová et Descals	2, 11	2
158. *C. aequatoriale* Matsush.	14	1
159. *Dactylella microaquatica* Tubaki	16	1
160. *Filosporella exilis* Gulis et Marvanová	2	1
161. *Fusariella candida* Matsush.	8	1
162. *Fusticeps bullatus* J. Webster et R.A. Davey	19	1
163. *Geniculospora intermedia* (R.H. Petersen) Sv. Nilsson	2	1
164. *Heliscus lugdunensis* Sacc. et Therry	2, 3, 4, 5, 10, 11, 16, 17, 18, 19, 20, 22	12
165. *H. submersus* H.J. Huds.	1, 2, 11, 13, 17, 19, 21, 23	8
166. *Helminthosporium bigenum* Matsush.	4	1
167. *H. longisinuatum* Matsush.	6	1
168. *Hypomyces rosellus* (Alb. et Schwein.) Tul. et C. Tul	6	1
169. *Kontospora halophila* A. Roldán, Honrubia et Marvanová	6, 8	2
170. *Lemonniera aquatica* De Wild.	1, 2, 3, 4, 5, 8, 9, 10, 11, 14, 15, 16, 17, 18, 19, 23, 24, 25	18
171. *L. terrestris* Tubaki	10, 22	2
172. *Leuliisinea amazonensis* Matsush.	9	1
173. *Lunulospora curvula* Ingold	2, 6, 7, 8, 10, 11, 12, 13, 14, 16, 17, 19, 20, 24, 25	15
174. *Melanocephala triseptata* (Shearer *et al*) S. Hughes	12, 13	2

Table 3. (comtinued)

Taxa	Plant (see Table 2)	Number of plants
175. *Microstella pluvioriens* K. Ando et Tubaki	7, 8, 9	3
176. *Mirandina corticola* G. Arnaud	1, 2, 3, 7, 8, 11, 12, 13, 15, 23, 24, 25	12
177. *Monacrosporium iridis* (Ts. Watan.) A. Rubner et W. Gams	14, 19, 20, 21, 22, 23, 24	7
178. *Monodisma fragilis* Alcorn	7	1
179. *Mycocentrospora aquatica* (S.H. Iqbal) S.H. Iqbal	5, 14	2
180. *Paraarthrocladium amazonense* Matsush.	7, 8, 10, 15, 23	5
181. *Paradactylella peruviana* Matsush.	6, 14, 23, 24	4
182. *Phaeodactylium acutisporum* Matsush.	7, 11, 15	3
183. *Phialogeniculata multiseptata* Matsush.	5, 13, 14, 15	4
184. *Pithomyces obscuriseptatus* Matsush.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25	25
185. *Polycladium equiseti* Ingold	7, 11, 13, 20	4
186. *Polystratorictus fasciculatus* Matsush.	16	1
187. *P. fusarioideus* Matsush.	14, 16, 19	3
188. *Pseudaegerita corticalis* (Peck) J.L. Crane et Schokn.	1, 9, 10, 14	4
189. *Pseudohansfordia dimorpha* Matsush.	6, 7	2
190. *Pseudospiropes longipilus* (Corda) Hol.-Jech.	21	1
191. *P. lotorum* Morgan-Jones	1, 14, 21	3
192. *Pyricularia peruamazonica* Matsush.	9	1
193. *P. submersa* Ingold	1, 4, 5, 12, 13, 20	6
194. *Scolecobasidium fusarioides* Matsush.	6	1
195. *Scolecosporiella amazonensis* Matsush.	7	1
196. *Sesquicillium amazonense* Matsush.	14, 16	2
197. *Sigmoidea prolifera* (R.H. Petersen) Crane	16, 22	2
198. *Sporidesmium acutifusiforme* Matsush.	19	1
199. *S. moniliforme* Matsush.	16	1
200. *S. peruamazonicum* Matsush.	7, 11, 15	3
201. *Stenella novae-zelandiae* Matsush.	20	1
202. *Tetrachaetum elegans* Ingold	9	1
203. *Tetracladium marchalianum* De Wild.	5, 11, 18, 19	4
204. *T. setigerum* (Grove) Ingold	1, 3, 20	3
205. *Titaea maxilliformis* Rostr.	1, 3, 5, 6, 8, 9, 11, 13, 16, 17, 18, 20, 21, 23, 24, 25	16
206. *Triadelphia heterospora* Shearer et J.L. Crane	17	1
207. *Tricellula aquatica* J. Webster	5, 9, 10, 11, 14, 15, 17, 18, 22	9
208. *Tricladiospora stricta* Nawawi et Kothub.	11	1
209. *Tricladium anomalum* Ingold	22	1
210. *T. gracile* Ingold	3	1
211. *Trinacrium subtile* Riess	1, 3, 5, 7, 10, 11, 12, 13, 15, 16, 19, 20, 21, 22, 23, 24, 25	17
212. *Tripospermum camelopardus* Ingold, Dann et McDoug	20	1
213. *Triscelophorus monosporus* Ingold	2, 19	2
214. *Trisulcosporium acerinum* H.J. Huds. et B. Sutton	3	1
215. *Varicosporium delicatum* S.H. Iqbal	5, 6, 10, 14, 17, 18	6
216. *V. elodeae* W. Kegel	12, 13	2
217. *Veronaea botryosa* Cif. et Montemart.	3, 10	2
218. *Volucrispora graminea* Ingold, P.J. McDougall et Dann	1, 4, 19, 22, 23	5
219. *Xylomyces aquaticus* (Dudka) K.D. Hyde et Goh	6	1

One hundred and twenty four straminipilous organisms and fungal species were encountered in the water of Jaroszówka Spring and 122 in the Supraśl River (both running water bodies), 106 in Dojlidy Pond (a stagnant water body). This also included straminipilous organisms and fungal species growing only in one water body (47 species in Jaroszówka Spring; 45 in Supraśl River, and 38 in Dojlidy Pond). In these three reservoirs, calcium in a greater (spring, pond) or lesser (river) amount appeared to delimit the number of straminipilous organisms and fungi growing on dead fragments of wetland plants (Table 4). Some straminipilous organisms and fungi grew only on fragments of single plants (Table 5). Quantitative and qualitative examinations of water chemistry, wetland plant species, straminipilous organisms and aquatic fungi were carried out during the experiment. The correlation analysis showed a dependence of the straminipilous organisms and fungal species number on the concentration of sulphates in Jaroszówka Spring and Supraśl River (-0.8052 and -0.8105 respectively) as well as a dependence of species number on the concentration of chlorides (-0.7632, level of significance 0.04) in Dojlidy Pond.

Discussion

The wetland plant species that we investigated are common and widespread in European wetlands (Broll *et al.* 2002), which include peat bogs, banks of rivers, ponds and lakes of various types (Cronk & Fennesy 2001). As revealed by recent studies, wetland plants contribute greatly to the functioning of aquatic reservoirs, and are particularly important in the transformation of nutrients and aeration of plant root systems (Raspopov *et al*. 1998; Otte *et al*. 2000; Sorrell *et al*. 2000; Vymazal 2001). The above ground parts of these plants may constitute a large biomass, which supplies ponds, rivers and lakes with dead phytogenic organic matter when the plants die in autumn. Numerous microorganisms are involved in the mineralization of this great mass of organic matter; however, only the role of bacteria has been discussed in the literature (Vymazal 2001). In view of the considerable number of straminipilous organisms and fungal species found on dead fragments of wetland plants, we can assume that their involvement in the mineralization of the biomass in the water is significant. Straminipilous organisms and aquatic fungi which are mostly plant saprotrophs contain a number of enzymes which take part in the decomposition of phytogenic organic matter (Zemek *et al*. 1985; Howard & Gow 2001). In particular, pectinases have an important role in decomposition (Chamier & Dixon 1982) as they are known to break down pectins that occur in the intercellular spaces, causing disintegration of plant fragments. Another group of enzymes, cellulases, decompose cellulose walls of plant cells (Chamier 1985; Chandrashekar & Kaveriappa 1988; Abdullah & Taj-Aldeen 1989). In aquatic fungi there are also specific enzymes involved in the decomposition of specific chemical compounds (Singh *et al*. 2001).

Thirty-one straminipilous organisms and fungal species found on dead fragments of 25 wetland plant species are new to Polish hydromycology. Two *Pythium* species, previously reported from soil are also new to Poland. *Pythium flevoense* was described from a soil in Netherlands (Plaats-Niterink 1972). In our study it was found to grow on the fragments of *Carex gracilis* in the Suprasl River. On the fragments of *Juncus conglomeratus, Sagittaria sagittifolia* and *Sparganium emersum* collected from the Jaroszówka Spring we observed *Pythium heterothallicum.* It was orginally described by Hendrix & Campbell (1968) from soil in North America. This species has also been found in Europe (Pystina 1998).

Chytridium lagenula described by Braun (1855) is also new to Poland. This fungus occurs as a parasite of algae, especially green algae (Karling 1977). We observed it on fragments of *Rorippa amphibia* in Jaroszówka Spring. *Synchytrium aureum* and *S. taraxaci* were also described in the 19th century (de Bary & Woronin 1863; Schroeter 1870) as parasites of flowering plants (Rytz 1917). We observed *Synchytrium aureum* on fragments of *Caltha palustris,* on two species of *Eleocharis* and on *Rorippa amphibia* in Jaroszówka Spring and in the Supraśl River. Batko (1975) reported its occurrence on *Caltha* and *Hydrocotyle. Synchytrium taraxaci* was also found in Jaroszówka Spring on *Menyanthes trifoliata* fragments. In the Supraśl River on fragments of *Sparganium minimum* we found *Blyttiomyces spinulosus,* known as a parasite of the algal genera *Spirogyra* and *Moueotia* (Bartsch 1939; Batko 1975).

Also new to Poland are the two species *Cladochytrium polystomum* and *C. replicatum.* The former was found to grow on a few plants in Dojlidy Pond and the Supraśl River, while the latter was found only on fragments of *Sparganium emersum* in Dojlidy Pond. *Cladochytrium polystomum* (Zopf 1884) and *C. replicatum* (Karling 1937) are known as saprotrophic on submerged decayed vegetation, from soil and water. *Diplochytrium lagenaria,* known as parasite of numerous green algal species (Karling 1936) was found in Jaroszówka Spring on *Juncus effuscus.* In the same spring we also observed the growth of *Entophlyctis bulligera,* another species new to Poland. It has been reported in the literature as a saprotroph on the dead thalli of green algae (Batko 1975).

Two new species *Nephrochytrium aurantium* and *N. buttermerense,* are plant saprotrophic organisms. The former was reported from plant remains in America (Whiffen 1941), the latter from lake bed clay (Willoughby 1962). In our study its growth was observed on a few plant species (Table 3). *Phlyctochytrium planicorne* was encountered on fragments of *Acorus calamus* in Jaroszówka Spring. This fungus was originally described as a parasite of algae (Atkinson 1909), later it was observed on dead fragments of *Acorus calamus* (Batko 1975).

All species of the genus *Physoderma* are also new to Poland. This genus contains over 80 widespread species (Karling 1977), which are parasitic on aquatic and land plants. In our study, species of the genus *Physoderma* were found on eight fragments of the investigated plants. Their biology has been

Table 4. Aquatic fungi and straminipilous organisms found on wetland plants in different water bodies

Water from	Fungi and straminipilous organisms (see Table 3)	Only in one water bodies	Total number of species
Spring Jaroszówka	3, 5, 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 21, 22, 24, 25, 28, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 41, 42, 43, 44, 50, 51, 52, 53, 54, 55, 56, 64, 65, 67, 68, 69, 70, 71, 73, 79, 80, 81, 82, 85, 88, 89, 90, 93, 95, 97, 98, 103, 104, 107, 109, 111, 112, 113, 114, 115, 118, 122, 123, 126, 127, 128, 129, 131, 136, 137, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 152, 153, 154, 155, 156, 157, 158, 160, 161, 162, 163, 164, 165, 166, 167, 169, 170, 173, 176, 179, 180, 182, 183, 185, 193, 197, 203, 204, 207, 211, 212, 213, 215, 218	3, 5, 6, 8, 14, 20, 24, 25, 33, 37, 41, 42, 51, 64, 65, 69, 70, 88, 90, 95, 97, 98, 104, 114, 115, 118, 122, 123, 127, 131, 139, 146, 147, 152, 153, 154, 156, 157, 158, 160, 161, 162, 163, 166, 167, 182, 185	124 (47)*
River Supraśl	1, 2, 4, 7, 9, 10, 12, 15, 16, 17, 18, 21, 22, 28, 31, 34, 35, 36, 39, 40, 43, 44, 46, 47, 48, 49, 50, 52, 53, 55, 56, 57, 58, 59, 60, 61, 62, 63, 66, 67, 68, 71, 74, 75, 76, 77, 78, 79, 80, 81, 82, 84, 89, 92, 93, 94, 99, 100, 102, 106, 107, 108, 109, 111, 112, 113, 119, 120, 121, 124, 125, 126, 128, 129, 132, 137, 138, 140, 141, 142, 143, 144, 145, 149, 150, 151, 155, 164, 165, 170, 171, 172, 173, 176, 180, 181, 183, 184, 189, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 210, 211, 213, 214, 215, 216, 218	1, 2, 4, 17, 47, 48, 49, 57, 59, 61, 66, 74, 76, 77, 78, 84, 92, 94, 99, 102, 106, 108, 119, 120, 125, 132, 138, 151, 181, 184, 189, 194, 195, 196, 198, 199, 200, 201, 202, 206, 208, 210, 212, 214, 216	122 (45)
Pond Dojlidy	10, 11, 12, 13, 19, 21, 23, 26, 27, 28, 29, 30, 31, 32, 34, 35, 36, 38, 39, 40, 44, 45, 46, 50, 53, 54, 55, 56, 58, 62, 63, 67, 68, 71, 72, 73, 75, 79, 81, 82, 83, 85, 86, 87, 91, 93, 96, 100, 101, 103, 105, 110, 111, 112, 116, 117, 121, 124, 126, 128, 129, 130, 133, 134, 135, 136, 140, 141, 142, 143, 148, 149, 150, 159, 164, 165, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 180, 183, 186, 187, 188, 190, 191, 192, 193, 197, 203, 204, 205, 207, 209, 211, 213, 217, 219	11, 13, 19, 23, 26, 27, 29, 45, 72, 83, 86, 87, 91, 96, 101, 105, 110, 116, 117, 130, 133, 134, 135, 159, 168, 174, 175, 177, 178, 186, 187, 188, 190, 191, 192, 209, 217, 219	106 (38)

* Only in this water body

described in details by Schroeter (1882), Büsgen (1887), Clinton (1902), Tisdale (1919), Karling (1950) and Sparrow (1946, 1959, 1964a, b, 1974). *Polyphlyctis unispina,* first described as a saprotroph from the Douglas Lake Region, U.S.A. (Paterson 1956), and was observed on fragments of *Rumex aquaticus* in Jaroszówka Spring.

On fragments of *Equisetum palustre* and *Mentha aquatica* in the Supraśl River we observed *Rhizophlyctis mastigotrichus,* first described by Nowakowski (1876) as a parasite of cyanobacteria of the genus *Calothrix.* Also from the Supraśl River, on fragments of *Sagittaria sagittifolia,* we found *Hypochytrium oceanum* known as a saprotroph of plant remnants from wet soil in New Zealand (Karling 1967). In the same water reservoir we encountered *Rhizidiomyces hansonii* on fragments of *Menyanthes trifoliata.* This fungus grows on plant remnants and chitin fragments of insects (Batko 1975) and was first reported from Brazil (Karling 1944).

New to Poland is one species of the genus *Doassansia* (*Ustilaginomycetes*), *D. punctiformis,* observed in water of Dojlidy Pond on fragments of *Butomus umbellatus.*

Of the eight new Polish records of anamorphic fungi, two (*Chloridium obclavatum* and *Sesquicillum amazonense*) were originally described by Matsushima (1993) from the Amazon Basin, the remaining six from waters at various latitudes, including the Amazon and its tributaries (Matsushima 1993). *Chloridum obclavatum* was isolated from palm leaves in Rio Yalapa. We found it on fragments of *Cyperus fuscus* in the Supraśl River and on *Eleocharis palustris* in Jaroszówka Spring. *Sesquicillium amazonense* was first isolated from petioles of a plant locally called "Oje" from Rio Negro. During our study, it was found on fragments of *Lathyrus palustre* in Dojlidy Pond. Another new species *Fusticeps bullatus,* was found to grow on fragments of *Menyanthes trifoliata* in the water collected for the experiment from the Supraśl River. It was described by Webster & Davey (1980) in Malaysia as an aero-aquatic fungus belonging to anamorphic fungi, and later was observed on leaves fallen onto the lake in Chyabeno National Park in Ecuador (Matsushima 1993). *Melanocephala triseptata* was encountered in our study on fragments of *Eleocharis palustris* in the Supraśl River. It was originally described from a water reservoir in Illinois (Shearer *et al.* 1976) as *Edophragmiella triseptata* and later reported on fallen palm leaves in Tampobata Reserve in Peru. *Nectria spirostriata* was described by Rossman (1983) on fallen leaves and then encountered on twigs fallen into the river Rio Itaya, the Amazon tributary in Loreto, Peru. We found this fungus on fragments of *Butomus umbellatus* in Jaroszówka Spring. *Pseudospiropes longipilus,* a telemorph of *Melanonima subdispersum* (Ellis 1976) was observed on fragments of *Rumex aquaticus* in the Supraśl River. It was also found on fallen palm leaves in Tambopata Reserve in Peru (Matsushima 1993). *Tricladiospora stricta,* the last on the list of new anomorphic fungi was found in Jaroszówka Spring. It was first described from submerged decaying leaves of trees in a stream in Pasuh Forest Reserve, Negri Sembilan in Malaysia (Nawawi & Kuthubutheen 1988).

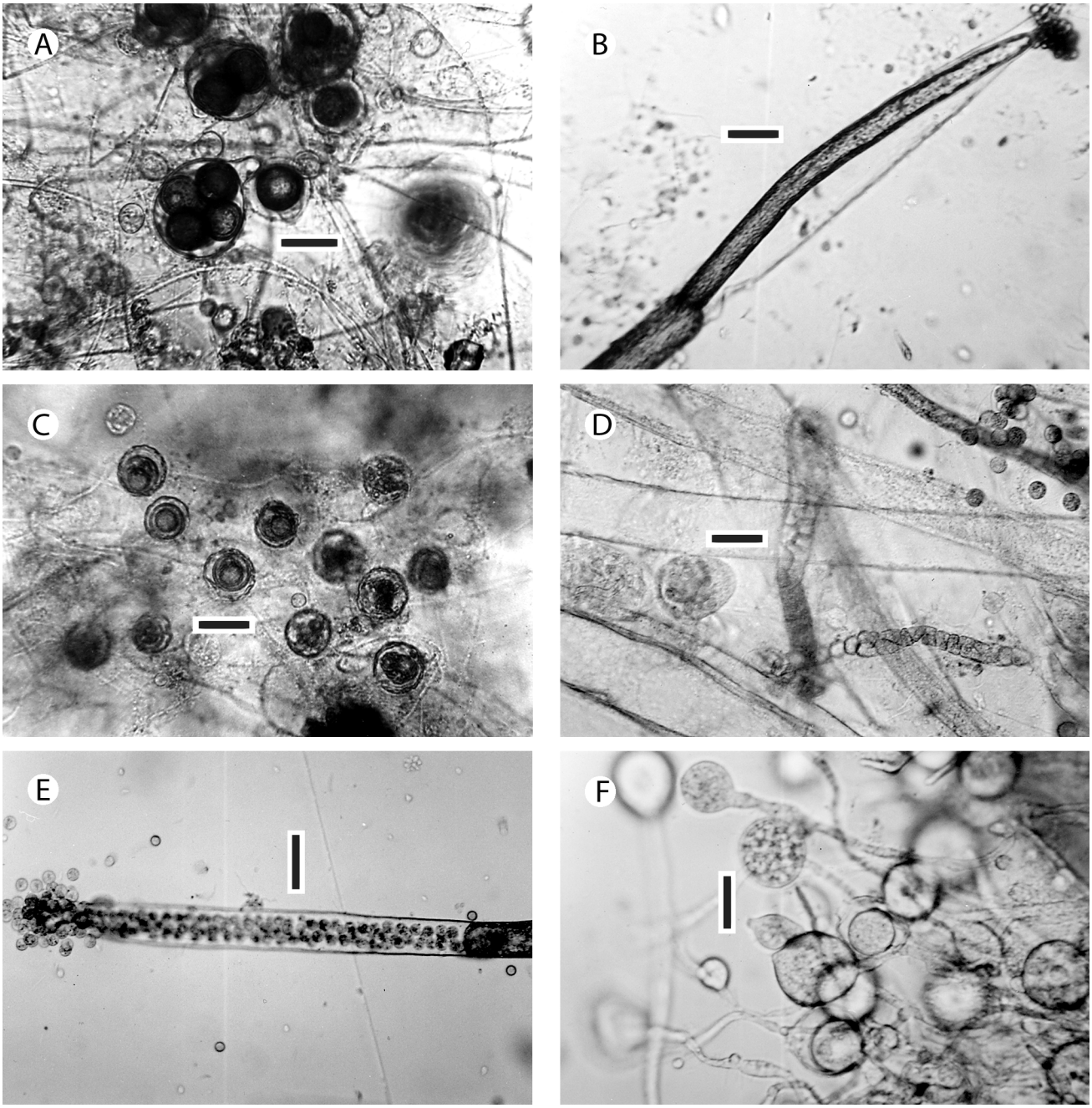

Fig. 1. Some straminipilous organisms growing on the fragments of wetland plants: **a** – *Achlya americana* – oogonium; **b** – *Achlya apiculata* – sporangia; **c** – *Aphanomyces irregularis* – oogonium; **d** – *Dictyuchus sterilis* – sporangia; **e** – *Pythium ostracodes* – sporangium; **f** – *Saprolegnia ferax* – sporangia. Scale bar = 25 µm

Apart from the species which are new to Polish waters, some rare species were found. *Truitella setifera* is a rare chytrid species, while the group of rare anamorphic fungi include *Acremonium rhombicum, Bidenticula cannae* and *Triadelphia heterospora. Truitella setifera* was observed on fragments of *Eleocharis palustris* and *Juncus effuscus* only in Dojlidy Pond. We have already found this fungus in the Płaska River (Czeczuga 1996). It was first described in Maryland, U.S.A. (Karling 1949). *Acremonium rhombicum* and *Bidenticula cannae* were found on fragments of *Carex pseudocyperus* in Jaroszówka Spring. The former was described from Solomon Islands (Matsushima 1971), while the latter was reported by Deighton (1972) from decaying twigs. *Triadelphia heterospora* was encountered on fragments of *Mentha aquatica* in the Supraśl River. This is the second site occurrence of this fungus in northeastern Poland. We have already found it during studying anamorphic fungi in the Biebrza National Park (Czeczuga *et al.* 2003a). It was first isolated from the water of the River Patuxent in the U.S.A. (Shearer & Crane 1971).

Table 5. Aquatic fungi and straminipilous organisms growing only on fragments of single wetland plants

	Species of plants	Fungi and straminipilous organisms (see Table 3)	Number of species
1.	*Acorus calamus* L.	115, 117	2
2.	*Alisma plantago-aquatica* L.	69, 83, 86, 119, 133, 160, 163	7
3.	*Butomus umbellatus* L.	47, 116, 134, 146, 151, 210, 214	7
4.	*Calla palustris* L.	166	1
5.	*Caltha palustris* L.	26	1
6.	*Carex elata* Bellardi ex All.	167, 168, 194	3
7.	*C. gracilis* Curtis	30, 61, 118, 178, 195	5
8.	*C. pseudocyperus* L.	70, 139, 147, 161	4
9.	*C. vulpina* L.	13, 29, 43, 172, 192, 202	6
10.	*Cyperus fuscus* L.	6	1
11.	*Equisetum palustre* L.	5, 24, 49, 121, 208	5
12.	*Eleocharis acicularis* (L.) R. et Sch.	-	-
13.	*E. palustris* (L.) R. et Sch.	-	-
14.	*Juncus conglomeratus* L.	23, 72, 77, 158	4
15.	*J. effuscus* L.	8, 103, 104	3
16.	*Lathyrus palustre* L.	11, 14, 20, 27, 84, 98, 122, 154, 159, 199, 208	11
17.	*Mentha aquatica* L.	68, 127, 206	3
18.	*M. rotundifolia* (L.) Huds.	108	1
19.	*Menyanthes trifoliata* L.	4, 48, 66, 90, 162, 198	6
20.	*Rorippa amphibia* L.	10, 17, 32, 41, 42, 60, 76, 87, 201, 212	10
21.	*Rumex aquaticus* L.	95, 123, 132, 190	4
22.	*Sagittaria sagittifolia* L.	1, 2, 63, 135, 209	5
23.	*Sporganium emersum* Rehmann	57, 91, 94, 97, 101, 106, 107	7
24.	*S. erectum* L.	-	-
25.	*S. minimum* Fr.	92	1

Most of the species found during the present study were observed on the investigated fragments of many plant species, but some were observed only on one plant (Table 5). The largest number of these single species occurred on fragments of *Lathyrus palustre* (11 species) and *Rorippa amphibia* (10). No species of this group was found on the two species of the genus *Eleocharis* and *Sparganium erectum.* This would suggest that the quality of vegetable substrate, probably its chemical composition, affects the growth of some aquatic fungal species.

In the present study, the largest number of fungi occurred on fragments of plant species in the Jaroszówka Spring and the Supraśl River (124 and 122 respectively); the fewest in Dojlidy Pond (106) where the water had the highest level of CO_2, ammonium nitrogen, chlorides, calcium and iron. Correlation analysis showed that the number of straminipilous organisms and fungi species depended on chemical factors such as sulphates (in running water bodies) and chlorides (in stagnant water bodies). Chlorides reduce the amount of mycota in some water reservoirs (Czeczuga *et al.* 2002, 2003b). In running waters, mycota is more abundant than in stagnant reservoirs (Batko 1975).

It should be emphasized that some of the straminipilous organisms found on a few species of wetland plants are known to cause significant losses in fish farms (Schaperclaus 1991), by parasiting eggs (Czeczuga & Muszyńska 1999), hatch (Mueller 1994) and many adult fish species. Of such straminipilous organisms we found *Achlya americana, A. caroliniana, A. klebsiana, A. prolifera* and *Saprolegnia ferax.* They were found to grow on plant species in the water of all the three reservoirs. *Saprolegnia parasitica,* a particularly dangerous fish parasite (Noga 1996) was encountered on fragments of *Rorippa amphibia* in Jaroszówka Spring. All these species have caused losses in fish stock at various latitudes (Schaperclaus 1991).

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