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The seasonal occurrence of aquatic Oomycetes in lakes and rivers of different water chemistry of Hesse, Germany

Key words: classification of water quality – Leptomitales – Saprolegniales - seasonal periodicity - trophic status

Abstract
We compared the seasonal occurrence of aquatic Oomycetes in 27 different lake water samples and water samples of 12 different rivers from Hesse from autumn 2003 to summer 2004. For isolating aquatic Oomycetes, the baiting method was used and some isolates could be cultivated additionally. A total of 27 species of aquatic Oomycetes belonging to the orders Saprolegniales, Leptomitales and Olpidiopsidales could be isolated from both water body types, lakes and rivers. One saprophytic isolate of *Hyphochytrium* (Hyphochytriomycetes), and additionally one species of Plasmodiophoromycetes, *Woronina polycystis*, was isolated as well. The species were examined and discussed with respect to their occurrence in the different lakes and/or rivers. 19 of 29 species (67 %) only occurred in lake or in river water samples. *Brevilegnia longicaulis* and *Calyptralegnia lipariensis* hitherto known only from soil, were first found in water. *Achlya oblongata* var. *gigantica*, *B. longicaulis*, *Pythiopsis irregularis* and *Saprolegnia furcata* are first reported for Germany. The simultaneous observation of limnochemical parameters of HLUG results in a trophic status of the lakes and in a classification of water quality of some rivers.

Zusammenfassung
Wir verglichen das jahreszeitliche Vorkommen aquatischer Oomycetes aus 27 verschiedenen Seewasserproben und aus Wasserproben von 12 verschiedenen Flüssen in Hessen von Herbst 2003 bis Sommer 2004. Um aquatische Oomycetes aus den Wasserproben zu isolieren, haben wir die Ködermethode angewandt. Einige der Isolate konnten wir außerdem kultivieren. Insgesamt konnten 27 Arten aquatischer Oomycetes der Ordnungen Saprolegniales, Leptomitales und Olpidiopsidales aus beiden Gewässertypen isoliert werden. Ein saprophytisches Isolat von *Hyphochytrium* (Hyphochytriomycetes) und außerdem eine Art der Plasmodiophoromycetes, *Woronina polycystis*, konnten ebenso isoliert werden. Die Arten wurden untersucht und im Hinblick auf ihr Vorkommen in verschiedenen Seen und/oder Flüssen diskutiert. 19 von 29 Arten (67 %) kamen entweder in Seewasser- oder in Flusswasserproben vor. Die Arten *Brevilegnia longicaulis* und *Calyptralegnia lipariensis*, welche bisher nur aus Bodenproben bekannt waren, wurden zum ersten Mal aus Wasser isoliert. *Achlya oblongata* var. *gigantica*, *B. longicaulis*, *Pythiopsis irregularis* und *Saprolegnia furcata* sind Neufunde für Deutschland. Die zeitgleiche Unter-

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suchung von limnochemischen Parametern durch das Hessische Landesamt für Umwelt und Geologie – HLUG ermöglicht eine Einschätzung der tropischen Situation der Seen und in eine Klassifizierung der Gewässergüte von einigen der untersuchten Fließgewässer.

Introduction

Species of aquatic Oomycetes occur in different water bodies all over the world and are saprophytes on organic substances. Some species also act as parasites e. g. on different species of fishes and then cause economical problems in hatcheries. RIETHMÜLLER & LANGER (2005b) focussed on the seasonal occurrence of species of Saprolegniales and Leptomitales in Lake Aue and the River Fulda in Kassel (Hesse) with special consideration of fishpathogenic species.

The isolation of aquatic Oomycetes by a baiting method is easy and cheep and the identification of species with newest available literature is practicable as well. Nevertheless, the research on aquatic Oomycetes, especially in correlation with statements on the trophic status of lakes or the classification of water quality of rivers is still underrepresented. RIETHMÜLLER (2000) examined 29 water samples from rivers and lakes in Baden-Württemberg on the occurrence of Oomycetes and the samples were characterised by several water parameters. She focussed on two lakes differing in their limnological character, and these lakes also showed differences in biodiversity and seasonal occurrence of species of Oomycetes. Only few authors examined the trophic status of the water body and correlated these results with the biodiversity of aquatic Oomycetes. RIETHMÜLLER & LANGER (2005a) also determined the trophic status of the Aue Lake and the classification of water quality of the River Fulda by limnochemical parameters obtained by simultaneous investigations of both water body types.

RIETHMÜLLER et al. (2006) studied in detail the seasonal occurrence of the sewage fungus *Leptomitus lacteus* (ROTH) C. AGARDH in the same stagnant and running water bodies in Hesse as in the present publication. In this study, we aim to obtain an insight into the seasonal occurrence of further different aquatic Oomycetes of these water bodies. Species of aquatic Oomycetes have the potential as indicator organisms in the microscopical-biological characterisation of water in future. Observing organismic biodiversity of aquatic Oomycetes will be an approach in advancing our knowledge of fundamental research on fungal diversity of freshwater ecosystems.

Materials and methods

We examined 27 lakes in cooperation with Hessisches Landesamt für Umwelt und Geologie HLUG (table 1.1) and observed three different types of lakes: High Dams Lakes (deep, constantly stratificated High Dam Lakes, polymictic Low Dams Lakes), lakes of ancient mining (stratificated ancient mining lakes, small ancient mining lakes) and quarry ponds (deep stratificated quarry ponds, flat unstratificated quarry ponds, lakes smaller than 5 ha). Some samples of the HLUG of the stagnant water bodies were collected and examined for the occurrence of the species in September 2003, April and June 2004. Other samples could only be collected and examined on aquatic Oomycetes in September 2003 or in April and June 2004. Additionally, High Dam Lake Ederstausee was examined at 3 sites in 2004 and at 4 different sites in 2003. A total of 58 lake water samples were collected together with HLUG and examined. We also examined 12 rivers in cooperation with HLUG at different sites (table 1.2). The samples of HLUG of the running water bodies were collected and examined for the occurrence of aquatic Oomycetes in October 2003, January, February, April, May and June 2004. Hence, a total of 102 river water samples was collected from HLUG and examined.

The HLUG annually surveys the water quality of the examined lakes and rivers in the region of North Hesse. For the limnochemical examinations standard-methods and the guidelines of the Länderarbeitsgemeinschaft Wasser – LAWA (1998, 2002) were used. The simultaneous observations of limnochemical parameters of HLUG were used to conduct a limnochemical

Table 1.1. Classification of lakes, number of samples and examined sites, trophic status and middle index in 2003 and 2004 according to Hessisches Landesamt für Umwelt und Geologie – HLUG (2003, 2004).

Classification of lakes	**Sample Nr.**	**Trophic status in 2003**	**Trophic status in 2004**	**Nr. of examined samples**
High Dam Lakes				
a) Deep, constantly stratificated				
High Dam Lakes (HDL)				
HDL Ederstausee, Edertal				10
Banfebucht	1_1	middle index: 3,3 actual state: eutrophic 2	middle index: 2,8 actual state: eutrophic 1	
Scheid	1_2			
Waldecker Bucht	1_3	middle index: 2,1 actual state: mesotrophic	middle index: 2,3 actual state: mesotrophic	
Outflow of the lake	1_4			
HDL Diemelstausee, Diemelsee-Heringhausen	2	middle index: 2,4 actual state: mesotrophic	middle index: 2,5 actual state: mesotrophic	3
b) Polymictic Low Dams Lakes (LDL)				
LDL Affolderner See, Edertal-Affoldern	3	middle index: 3,0 actual state: eutrophic 1	middle index: 3,2 actual state: eutrophic 2	3
LDL Twistestausee, Bad Arolsen-Wetterburg	4	middle index: 2,9 actual state: eutrophic 1	middle index: 2,6 actual state: eutrophic 1	3
LDL Antriftstausee, Antrifttal-Seibelsdorf	5	middle index: 3,1 actual state: eutrophic 2		1
LDL Haunestausee, Petersberg-Marbach	6	middle index: 4 actual state: polytrophic 1		1
LDL Ibrastausee, Kirchheim	7	middle index: 3,6 actual state: polytrophic 1		1
LDL Silbersee, Breitenbach a. Herzberg	8	middle index: 4 actual state: polytrophic 1		1
Lakes of ancient mining				
a) Stratificated ancient mining lakes (amL)				
amL Borkener See, Borken	9	middle index: 1,1 actual state: oligotrophic	middle index: 1,5 actual state: oligotrophic	3
amL Singliser See, Borken-Gombeth	10	< pH5, acidified	< pH5, acidified	3
amL Exbergsee, Großalmerode-Epterode	11	middle index: 1,8 actual state: mesotrophic		1
amL Goldbergsee, Malsfeld-ostheim	12	middle index: 2 actual state: mesotrophic		1
amL Zimmersroder See, Neuental-Zimmersrode	13	middle index: 1,7 actual state: mesotrophic		1
amL Hellkopfsee, hessisch Lichtenau	14	middle index: 1,6 actual state: mesotrophic		1
amL Silbersee Frielendorf, Frielendorf-Allendorf	15		middle index: 1,8 actual state: mesotrophic	2
b) Small ancient mining lakes (samL)				
samL Neuenhainer See, Neuental	16		middle index: 2,3 actual state: mesotrophic	2
samL Lake Stellbergsee, Guxhagen-Wollrode	17		middle index: 2,7 actual state: eutrophic	2
samL Guckaisee, Poppenhausen-Rodholz	18		middle index: 2,6 actual state: eutrophic 1	2

Classification of lakes	Sample Nr.	Trophic status in 2003	Trophic status in 2004	Nr. of examined samples
Quarry ponds				
a) Deep stratificated quarry ponds (qp)				
qp Großer Pfordter See, Schlitz	19		middle index: 3,0 eutrophic 1 to eutrophic 2	2
b) Flat unstratificated quarry ponds (fqp)				
fqp Werratalsee, Eschwege/Meinhard	20	middle index: 2,1 actual state: mesotrophic	middle index: 1,7 actual state: mesotrophic	3
fqp Auesee, Kassel	21		middle index: 2,8 actual state: eutrophic 1	2
fqp Fuldasee, Rotenburg-Braach	22		middle index: 3,8 actual state: polytrophic	2
fqp Werrasee, Jestädt	23	middle index: 3,4 actual state: eutrophic 2	middle index: 2,6 eutrophic 1 to mesotrophic	3
fqp Fuldasee, Bebra-Breitenbach	24	middle index: 3,3 actual state: eutrophic 2		1
c) Lakes <5 ha (sL)				
sL Bühl, Ahanatal-Weimar	25	middle index: 2,4actual state: mesotrophic		1
sL Fuldasee, Malsfeld-Beiseförth	26		middle index: 4,2 actual state: polytrophic 2	2
sL Inselteich Wildeck	27	middle index: 4,05 actual state: polytrophic 1/2		1
Total number of samples:				**58**

Table 1.2. Number of samples and examined sites of rivers, classification of water quality and German Saprobic Index in 2004 of some rivers based on AQEM according to Hessisches Landesamt für Umwelt und Geologie – HLUG (2005).

River sample Nr.		Evaluation date of Gsi	German Saprobic Index (old version)	Classification of water quality in 2004	Nr. of examined samples
1	Baunatal-Guntershausen			n.d.a.	6
2	**River Diemel**				
2_1	Diemelsee-Giebringshausen			n.d.a.	6
2_2	Diemelstadt-Wrexen	16.07.2004	2,00	II	6
2_3	Helmarshausen	16.07.2004	1,938	II	6
3	**River Eder**				
3_1	Estuary in Edermünde-Grifte	18.07.2004	2,088	II	6
3_2	Edertal-Mehlen	15.07.2004	2,154	II	6
3_3	Vöhl-Schmittlotheim	15.07.2004	1,935	II	6
	River Esse				
4	Trendelburg-Stammen			n.d.a.	6
5	**River Fulda**				
5_1	Gersfeld-Hettenhausen			n.d.a.	6
5_2	Rotenburg	23.07.2004	2,105	II	6
	River Haune				
6	Bad Hersfeld	24.07.2004	2,039	II	6

	River Losse				
7	Kassel-Bettenhausen			n.d.a.	6
	River Schwalm				
8	Estuary in Felsberg-Altenburg	17.07.2004	2,016	II	6
	River Twiste				
9	Volkmarsen-Külte			n.d.a.	6
	River Ulster				
10	Phillippsthal	24.07.2004	1,975	II	6
	River Wehre				
11	Eschwege-Oberhone	17.07.2004	2,089	II	6
	River Weser				
12	Bad Karlshafen	16.07.2004	2,175	II	6
Legend: n.d.a.: no data available					

characterisation of the examined water bodies, which are not presented here. We only focus on the results and indicate the trophic status of the lakes for 2003 and 2004 (HLUG 2003, 2004) and the classification of water quality of some rivers for 2004 (tables 1.1 and 1.2), based on the development and testing of an integrated assessment system for the ecological quality of streams and rivers throughout Europe using benthic macroinvertebrates AQEM.

All water samples were collected from surface water in polyethylene bottles (0.5 L each) for the isolation of aquatic Oomycetes. For the detection of aquatic Oomycetes from the collected samples, the baiting technique was used. Aliquots of 50 mL of the collected water samples were introduced into each of ten Petri dishes containing some seeds of *Sesamum indicum* L. which had previously been boiled for 8 minutes. The Petri dishes were incubated in natural light and at room temperature for 4 weeks. During this time, the zoospores colonised the sesame seeds and the seeds were examined every day under a light microscope and the species were identified. The recovered isolates were treated as one isolate while occurring once or several times on seeds in one or in different Petri dishes of the same sample. Additionally, they were cultivated on glucose-peptone agar medium according to Willoughby (1997), modified by adding 0.5 g L^{-1} sodium benzylpenicilline or 0.5 g L^{-1} streptomycine sulfate at approx. 50 oC. The strains were identified with ZOPF (1892), COKER (1923), JOHNSON (1956), SPARROW (1960), SEYMOUR (1970), KARLING (1977), DICK (2001), and JOHNSON et al. (2002); the nomenclature followed SPARROW (1960), DICK (2001), and JOHNSON et al. (2002).

Results

All species and isolates, which could be isolated from rivers and lakes are compiled in table 2. Many isolates attributable to the genera *Achlya* NEES, *Dictyuchus* LEITGEB, *Pythiopsis* DE BARY, *Saprolegnia* NEES (Saprolegniales), *Apodachlya* PRINGSHEIM (Leptomitales), and *Pythium* PRINGSHEIM (Pythiales), which could only be identified on generic level, do not count as species and are treated as isolates, just as well as *Achlya oblongata* var. *gigantica* FORBES.

Achlya oblongata var. *gigantica*, *B. longicaulis* JOHNSON and *Pythiopsis irregularis* SEYMOUR, and *S. furcata* MAURIZIO are first reported for Germany. 27 species of aquatic Oomycetes could be isolated from one or both examined water body types. Additionally, one saprophytic species of *Hyphochytrium* ZOPF (Hyphochytriomycetes) could also be isolated by the baiting technique from one lake sample; and one species of Plasmodiophoromycetes, *Woronina polycystis* CORNU, an endoparasite in hyphae of different isolates of Oomycetes, could be isolated as well from lakes and rivers. 19 of 29 species (67 %) only occurred in lake or in river water samples, 7 species [*A. apiculata* DE BARY, *A. colorata* PRINGSHEIM,

	Nr. of lakes	Nr. of rivers
Oomycetes:		
Saprolegniales		
Achlya americana	4	2
A. apiculata	**1**	
A. colorata	**1**	
A. debaryana	3	2
A. oblongata		**5**
A. oblongata* var. *gigantica*		**1**
A. oligacantha	2	1
A. racemosa	5	3
A. radiosa		**3**
Achlya spp.*	14	11
Brevilegnia longicaulis		**1**
Calyptralegnia achlyoides		**4**
C. ripariensis		**1**
Dictyuchus monosporus		**7**
Dictyuchus spp.*	4	9
Pythiopsis irregularis	1	1
Pythiopsis* spp.		**2**
Saprolegnia diclina	1	5
S. ferax	18	12
S. furcata	**1**	
S. glomerata	1	8
S. itoana		**3**
S. litoralis	**1**	
S. torulosa		**2**
S. uliginosa	**1**	
S. unispora		**1**
Saprolegnia spp.*	20	12
Scoliolegnia asterophora		**1**
Leptomitales		
Apodachlya brachynema		**1**
Apod. pyrifera		**2**
Apodachlya* spp.		**3**
Leptomitus lacteus	2	11
Olpidiopsidales		
***Olpidiopsis saprolegniae* in *Saprolegnia* spp.**	**2**	
Pythiales		
Pythium spp.*	12	12
Plasmodiophoromycetes:		
Woronina polycystis	3	17
W. polycystis* in *Achlya* spp.		**6**
W. polycystis in *Saprolegnia* spp.*	3	11
Hyphochytriomycetes:		
***Hyphochytrium* sp.**	**1**	

Legend:
bold: species found only in one type of water body
*: treated as isolate

left site, Table 2: Aquatic Oomycetes, Plasmodiophoromycetes and Hyphochytriomycetes from samples of 27 lakes and 12 rivers in Hesse and number of water bodies, in which the species and isolates occurred.

S. furcata, *S. litoralis* COKER, *S. uliginosa* JOHANNES, *Olpidiopsis saprolegniae* (A. BRAUN) CORNU in *Saprolegnia* spp. and *Hyphochytrium* sp.] are unique to lake water samples; and 12 species [*A. oblongata* DE BARY, *A. radiosa* MAURIZIO, *B. longicaulis*, *Calyptralegnia achlyoides* (COKER & COUCH) COKER, *C. ripariensis* HÖHNK, *Dictyuchus monosporus* LEITG., *S. itoana* (NAGAI) SEYMOUR, *S. torulosa* DE BARY, *S. unispora* (COKER & COUCH) SEYMOUR, *Scoliolegnia asterophora* (DE BARY) M. W. DICK, *Apodachlya brachynema* (HILDEBR.) PRINGSH., and *Apod. pyrifera* ZOPF] are restricted to river water samples.

Based on the sampling dates in tables 1.1 and 1.2, the seasonal occurrence of the isolated species and isolates can be compared additionally. March to May are assigned to spring, June to August to summer, September and October to autumn and November to February to winter. Note that the lakes were only examined in spring, summer and autumn. According to table 3, species or isolates occurring the **whole year** in only one or in both examined water body types are *Achlya* spp., *Dictyuchus* spp., *S. diclina* HUMPHREY, *S. ferax* (GRUITH.) THURET, *Saprolegnia* spp., *L. lacteus*, *Pythium* spp. and *W. polycystis* in *Saprolegnia* spp. Nearly during the whole year, in **spring**, **summer** and **winter**, *A. racemosa* HILDEBR. and *C. achlyoides* could be isolated from rivers.

Species occurring only in **spring** and therefore considered as "**spring species**" in one or both examined water body types are *A. colorata*, *Pythiopsis irregularis*, *S. furcata*, *S. glomerata* (THIESENH.) A. LUND, *S. itoana,* and *S. litoralis*. Species or isolates occurring only in **summer** and therefore considered as „**summer species**" unique to river samples are *C. ripariensis*, *Apod. brachynema*, *Apod. pyrifera* and *Apodachlya* spp. Species occurring only in **autumn** and therefore considered as „**autumn species**" in lakes or in rivers are *A. apiculata*, *B. longicaulis*, *S. uliginosa*, *O. saprolegniae* in

Table 3: Compilation of seasonal occurrence of isolated aquatic Oomycetes, Plasmodiophoromycetes and Hyphochytriomycetes isolated from 27 lakes and 12 rivers in Hesse and comparison of seasonal occurrence of Saprolegniales and Leptomitales with literature.

					Riethmüller & Langer (2005b)				**Riethmüller (2000)**			
Species list:	**sp**	**su**	**au**	**w****	**sp**	**su**	**au**	**w**	**sp**	**su**	**au**	**w**
Oomycetes:												
Saprolegniales												
Achlya americana		R/L	R/L		x				x	x	x	x
A. apiculata			L									
A. colorata	L											
A. debaryana		R/L	R/L							x		
A. oblongata			R	R	x	x	x	x				
A. oblongata var. *gigantica**				R								
A. oligacantha	L		R							x		
A. racemosa	R/L	R		R	x			x	x	x		x
A. radiosa	R			R					x	x		x
Achlya spp.*	R/L	R/L	R/L	R	x	x	x	x	x	x	x	x
Brevilegnia longicaulis			R									
Calyptralegnia achlyoides	R	R		R								x
C.ripariensis		R										
Dictyuchus monosporus		R	R			x			x		x	
Dictyuchus spp.*	L	R/L	R/L	R	x	x	x		x	x	x	x
Pythiopsis irregularis	R/L											
Pythiopsis spp.*				R		x						
Saprolegnia diclina	R	R	L	R		x		x	x	x	x	x
S. ferax	R/L	R/L	R/L	R	x	x	x	x	x	x	x	x
S. furcata	L											
S. glomerata	R/L								x	x		
S. itoana	R							x				
S. litoralis	L								x	x	x	x
S. torulosa	R			R					x	x		x
S. uliginosa			L							x		
S. unispora				R	x							
Saprolegnia spp.*	R/L	R/L	R/L	R	x	x	x	x	x	x	x	x
Scoliolegnia asterophora				R					x	x	x	x
Leptomitales												
Apodachlya brachynema		R				x						
Apod. pyrifera		R										
Apodachlya spp.*		R										
Leptomitus lacteus	R/L	R	R	R	x			x				
Olpidiopsidales												
Olpidiopsis saprolegniae in *Saprolegnia* spp.			L									
Pythiales												
Pythium spp.*	R/L	R	R/L	R								
Plasmodiophoromycetes:												
Woronina polycystis in *Achlya* spp.			R									
Woronina polycystis in *Saprolegnia* spp.	R	R	R/L	R								
Hyphochytriomycetes:												
Hyphochytrium sp.			L									

Legend: w: winter; sp: spring; su: summer; au: autumn; R: river; L: lake;
*: treated as isolate; **: only rivers in winter examined

Saprolegnia spp., *W. polycystis* in *Achlya* spp. and *Hyphochytrium* sp. Species or isolates occurring only in **winter** and therefore considered as „**winter species“** in the only examined river samples are *A. oblongata* var. *gigantica*, *Pythiopsis* spp., *S. unispora*, and *Scol. asterophora. A. radiosa* and *S. torulosa* occur in **winter** and in **spring** in river samples; *A. americana* HUMPHREY, *A. debaryana* HUMPHREY and *D. monosporus* occur in **summer** and in **autumn** in both examined water body types. Finally, *A. oblongata* occurs in **autumn** and in **winter** in river samples. Interestingly, *A. oligacantha* DE BARY occurs in **spring** in lakes and in **autumn** in river samples. Table 4.1 shows the species and isolates, obtained from the respective lake samples and table 4.2 shows the species and isolates, obtained from the respective river samples. According to table 4.1, the ancient mining Lake Singliser See, Borken-Gombeth

Table 4.1: Species and isolates, obtained from the respective lake samples.

Species/isolates of lake samples:	1_1	1_2	1_3	1_4	2	3	4	5	6	7	8	9	10	11	12
Achlya americana					x										
A. apiculata													x		
A. colorata													x		
A. debaryana							x			x					
A. oligacantha															
A. racemosa			x												
Achlya spp.*					x		x	x					x	x	x
Dictyuchus spp.*							x		x						
Pythiopsis irregularis															
Saprolegnia diclina													x		
S. ferax			x	x	x	x	x	x	x	x	x	x	x		
S. furcata													x		
S. glomerata															
S. litoralis													x		
S. uliginosa													x		
Saprolegnia spp.*			x	x	x	x	x	x	x	x	x	x			x
Leptomitus lacteus															
Olpidiopsis saprolegniae in *Saprolegnia* spp.					x		x								
Pythium spp.*		x			x		x			x			x		x
Woronina polycystis in *Saprolegnia* spp.							x			x					
Hyphochytrium sp.							x								
Species/isolates of lake samples:	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Achlya americana			x	x											x
A. apiculata															
A. colorata															
A. debaryana				x											
A. oligacantha						x	x								
A. racemosa			x	x	x	x									
Achlya spp.*		x	x		x		x		x			x	x		x
Dictyuchus spp.*			x						x						
Pythiopsis irregularis								x							
Saprolegnia diclina															
S. ferax		x	x	x	x	x	x		x	x		x		x	
S. furcata															
S. glomerata					x										
S. litoralis															
S. uliginosa															

Saprolegnia spp.*	x	x		x	x	x		x	x	x	x	x	x		x
Leptomitus lacteus			x			x									
Olpidiopsis saprolegniae in *Saprolegnia* spp.															
Pythium spp.*				x	x	x		x	x		x			x	
Woronina polycystis in *Saprolegnia* spp.												x			
Hyphochytrium sp.															
Legend: *: treated as isolate															

Table 4.2: Species and isolates, obtained from the respective river samples.

Species/isolates of river samples:	1	2	3	4	5	6	7	8	9	10	11	12
Achlya americana		x		x								
A. debaryana		x				x						
A. oblongata	x	x		x		x				x		
A. oblongata var. *gigantica**	x											
A. oligacantha												x
A. racemosa	x	x						x				
A. radiosa		x			x			x				
Achlya spp.*	x	x		x	x	x	x	x	x	x	x	x
Brevilegnia longicaulis			x									
Calyptralegnia achlyoides	x			x	x		x					
C. ripariensis	x											
Dictyuchus monosporus		x	x		x	x	x	x				x
Dictyuchus spp.	x	x	x	x	x	x	x	x	x			
Pythiopsis irregularis		x										
Pythiopsis spp.		x	x									
Saprolegnia diclina		x	x		x		x					x
S. ferax	x	x	x	x	x	x	x	x	x	x	x	x
S. glomerata		x	x		x	x		x	x	x	x	
S. itoana		x	x							x		
S. torulosa			x			x						
S. unispora			x									
Saprolegnia spp.*	x	x	x	x	x	x	x	x	x	x	x	x
Scoliolegnia asterophora		x										
Leptomitus lacteus	x	x	x	x	x	x	x	x	x	x	x	
Apodachlya brachynema								x				
Apod. pyrifera		x							x			
Apodachlya spp.*			x		x		x					
Pythium spp.*	x	x	x	x	x	x	x	x	x	x	x	x
W. polycystis in *Achlya* spp.		x		x	x	x	x		x			
W. polycystis in *Saprolegnia* spp.	x	x	x	x	x	x	x	x	x		x	x
Legend: *: treated as isolate												

(lake Nr. 10) with a pH-value < 5 has the highest species diversity of all examined lakes.

Discussion

A. *oblongata* var. *gigantica*, described from the British Isles by Forbes (1935) and *B. longicaulis* obtained from Ozeania by JOHNSON (1950) are, according to the cited references in JOHNSON et al. (2002), both first recorded for Germany. *Pythiopsis irregularis* described as a new species in JOHNSON et al. (2002) from tropical regions, is also first recorded for Germany. *S. furcata* is indicated in Johnson et al. (2002) as occurring in Germany, which is based on the references MINDEN (1912), HÖHNK (1935) and RICHTER (1936-1937). Verifying these references, the authors examined not *S. furcata* but *S. spiralis* CORNU, which is not synonymous with *S. furcata*. According to SEYMOUR (1970) it is very likely that *S. furcata* was originally described under the name *S. spiralis*, however he rejects this report on the grounds that the description was based on a culture of infected material. Hence, the specifications in JOHNSON et al. (2002) concerning the occurrence of *S. furcata* in Germany concern *S. spiralis* and not *S. furcata*, and *S. furcata* can be considered as also first reported for Germany.

According to table 2, a discussion on the specific occurrence of species in rivers and lakes is shown in a comparison of the respective species only occurring in lakes (12 of 29) or only in rivers (7 of 29) and their occurrence according to literature is shown in table 5.

The results of the seasonal occurrence of the isolated species by RIETHMÜLLER & LANGER (2005b) and of RIETHMÜLLER (2000) are also shown in table 3. In accordance to the presented results, isolates of *Achlya* spp., *Saprolegnia*

spp., and of *S. ferax* also occur during the whole year in RIETHMÜLLER & LANGER (2005b). As a further comparison with RIETHMÜLLER & LANGER (2005b) shows, does *Apod. brachynema* occur in summer in both studies. *Dictyuchus* spp. were not collected in winter by RIETHMÜLLER & LANGER (2005b). In RIETHMÜLLER (2000) isolates of *Dictyuchus* occurred during the whole year as in the results presented here. *S. diclina* occurred in these studies in accordance with the results of RIETHMÜLLER (2000) during the whole year, whereas RIETHMÜLLER & LANGER (2005b) observed the species only in winter and summer. The results fit also well with the results of the both cited references for *A. debaryana*, which has a shorter period of growth and sporulating time (only in summer) in RIETHMÜLLER (2000), for *A. radiosa*, *S. glomerata* and *S. torulosa*, who have a longer period of growth and sporulating time (additionally in summer) in RIETHMÜLLER (2000). *A. racemosa* has a shorter period of growth and sporulating time (not in summer) in RIETHMÜLLER & LANGER (2005b). In RIETHMÜLLER (2000) *S. torulosa* also grows from winter to summer. For the species *A. americana*, *A. oblongata*, *A. oligacantha*, *C. achlyoides*, *D. monosporus*, *Pythiopsis* spp., *S. itoana*, *S. litoralis*, *S. uliginosa*, *S. unispora*, *Scoliolegnia asterophora* and *L. lacteus* the results do not fit well with the two cited studies, what means that a seasonal specificity in growth and sporulating can not be derived. Our

Species	Isolated of	References	RW	SW	Details	Country
Achlya apiculata	L	RICHTER (1936-1937)	x		ditch	Germany
		MISHRA & DWIVEDI (1988)		x	lake	India
		CZECZUGA et al. (1988)		x	pond	Poland
		CZECZUGA (1991)		x	lake	Poland
A. colorata	L	RICHTER (1936-1937)	x		ditch	Germany
				x	pond	
A. oblongata	R	DE BARY (1888)	x		ditch	Germany
				x	pond	
A. radiosa	R	RIETHMÜLLER (2000)		x	lake	Germany
			x		river	
Brevilegnia longicaulis	R	KALLIL et al. (1995)			soil	Egypt
		JOHNSON (1950)			soil	New Caled.
		JOHNSON (1977)			soil	Norway
Calyptralegnia achlyoides	R	RIETHMÜLLER (2000)		x	lake	Germany
		CZECZUGA (1995)	x		river	Poland
C. ripariensis	R	HÖHNK (1953)			soil of ditches	Germany
Dictyuchus monosporus	R	HÖHNK (1935)	x		dich	Germany
				x	pond	
Saprolegnia furcata	L	SEYMOUR (1970)			soil	
					swamps	
					Sphagnum-bogs	
		JOHNSON (1974)			mossy, bog like areas	Iceland
S. itoana	R	RIETHMÜLLER & LANGER (2005a)		x	lake	Germany
			x		river	
S. litoralis	L	SEYMOUR (1970)			soil	
					freshwater	
					swamps	
					marshes	
					bogs	
		RIETHMÜLLER (2000)		x	lake	Germany
		EL-HISSY & KALLIL (1989)	x		river	Egypt
S. torulosa	R	RIETHMÜLLER (2000)		x	lake	Germany
S. uliginosa	L	RIETHMÜLLER (2000)		x	lake	Germany
		JOHANNES (1950)		x	bomb crater in a bog	Germany

Species	Isolated of	References	RW	SW	Details	Country
		HOWARD et al. (1970)			water	Iceland
					soil	
		SEYMOUR (1970)			freshwater	
					soil of bogs	
S. unispora	R	RIETHMÜLLER & LANGER (2005a)		x	lake	Germany
		HÖHNK (1935)	x		brook	Germany
Scoliolegnia asterophora	R	RIETHMÜLLER (2000)		x	lake	Germany
			x		river	
Olpidiopsis saprolegniae in *Saprolegnia* spp.	L	BOCK (1956)		x	lake	Germany
		CZECZUGA (1995)	x		river	Poland
Apodachlya brachynema	R	RIETHMÜLLER & LANGER (2005a)		x	lake	Germany
		CZECZUGA et al. (1990)	x		river	Poland
Apod. pyrifera	R	RICHTER (1936-1937)		x	pond	Germany
			x		brook	
Hyphochytrium sp.	L	HÖHNK (1956)	x		brook	Germany
					soil	

Legend: R: examined rivers; L: examined lakes; RW: According to literature in running water bodies; grey: specificity uncertain; SW: According to literature in stagnant water bodies

Table 5: Isolated species/isolates only occurring in rivers or in lakes in Hesse and comparison with literature, with respect to the country and the source of isolation.

data also demonstrate that samples must be taken during all seasons of the year to get a representative survey of species occurring in a water body.

No species only occurring in the examined lakes is, according to the cited references, specific in its occurrence in lakes and the same results can be concluded for species obtained only from river water samples. Nevertheless, the specificity to a certain water body type of the species grey underlined in table 5 remains unclear. According the literature, *B. longicaulis* and *C. ripariensis* only occur in soils. Additionally, the information on the ecological occurrence of *S. furcata* and *S. uliginosa* is very unspecific and further investigations are necessary to clarify their occurrence in different ecosystems.

Combining the results of the tables 1.1 and 1.2 with the results of the tables 4.1 and 4.2, the occurrence of aquatic Oomycetes by considering the typification of the examined lakes with their trophic status as well as the classification of water quality and the German Saprobic Index of the examined rivers is given in detail. Hence, an actual view of the tolerance of the isolated species against limnological conditions is given. A similar comparison with available literature is nearly impossible. Only few authors examined the trophic status of the water body and correlated these results with the biodiversity of aquatic Oomycetes. CZECZUGA (1996) investigated lakes mostly of the eutrophic type, and isolated e. g. *A. oligacantha* and *Hyphochytrium catenoides* KARLING from these water bodies. According to the tables 1.1 and 4.1, *Hyphochytrium* sp. and *A. oligacantha* could also be isolated of eutrophic water samples in our studies as well. RANCOVIC (2004) examined the biodiversity of aquatic Oomycetes in the oligosaprobic Lake Sjenica Reservoir in Serbia and he isolated e. g. *S. ferax*. In our examination, we focus on the trophic status, while examining lakes and obtained *S. ferax* from the oligotrophic ancient mining Lake Borkener See, Borken (lake Nr. 9). Interestingly, the ancient mining Lake Singliser See, Borken-Gombeth (lake Nr. 10) with a pH value < 5 has the highest species diversity of all examined lakes. RIETHMÜLLER (2000) also isolated very interesting species e. g. *Blyttiomyces helicus* SPARROW and Barr (Chytridiales) from samples with low pH value.

In future, it would be very interesting to study the biodiversity of aquatic fungi in habitats with particular conditions like acidificated lakes.

Additionally, in further examinations, the obtained results of the species occurring in three different types of lakes, High Dams Lakes, lakes of ancient mining, and quarry ponds could be compared with further results and the respective trophic status should be considered as well. A long-termed comparison with species occurring in water bodies e. g. in deep, constantly stratificated High Dam Lakes under consideration of their trophic status might provide a database for aquatic fungi in correlation with current limnological ecological statements of water bodies.

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