

AQUATIC FUNGI: BIODIVERSITY, CLASSIFICATION, AND ONLINE DATABASES

MARK SEASAT CALABON

DOCTER OF PHILOSOPHY
IN
BIOLOGICAL SCIENCE

SCHOOL OF SCIENCE
MAE FAH LUANG UNIVERSITY
2021
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"*Do not be anxious about anything, but in everything by prayer and supplication with thanksgiving let your requests be made known to God. And the peace of God, which surpasses all understanding, will guard your hearts and your minds in Christ Jesus*." — Philippians 4:6-7

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Mark Seasat Calabon

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ABSTRACT

Our knowledge on aquatic fungi has expanded exponentially for almost century and a half of research. The classification system has been updated by using molecular phylogenetics coupled with morphology, following the one fungus=one name ruling. In addition to barcoding of nuclear ribosomal regions (ITS, LSU, SSU), protein-coding genes were added for a better resolution of the phylogenetic tree and resolving the evolutionary relationships of closely related taxa. These resulted in a well-defined classification scheme for aquatic fungi that is unceasingly changing as the continuous exploration of various aquatic habitats in tropical and temperate countries lead to the discovery of novel aquatic fungal taxa and recollection of taxa wherein phylogenetic placement is unknown. Despite all this published information, our knowledge of aquatic fungi is still limited and mostly neglected by many researchers. The exploration of aquatic habitats in Thailand in the present work resulted in discoveries of novel fungi from Dothideomycetes (six species under Pleosporales) [*Halobyssothecium bambusicola* (Lentitheciaceae), Camposporium dulciaquae (Melanommataceae), *Brunneofusispora hyalina* (Occultibambusaceae), *Wicklowia phuketensis* (Wicklowiaceae)], Sordariomycetes (one genus *Neoxylomyces*, three species) [*Rattania aquatica* (Chaetosphaeriaceae), *Neoxylomyces multiseptatus*

(Phyllachorales genera *incertae sedis*), *Phaeoacremonium thailandense* (Togniniaceae), and Ascomycota genera *incertae sedis* (one species *Mycoenterolobium aquadictyosporium*). The sequence data for *Mycoenterolobium* was obtained and their closed affinity with Testudinaceae was elucidated. Since the morphology of *Mycoenterolobium* and taxa under Testudinaceae are vastly different, we placed the latter in Pleosporales *incertae sedis* until further taxon sampling is undertaken. The collection of plant substates from aquatic habitats in Thailand, the UK, and Sweden resulted in the isolation of novel Lentitheciaceae species wherein two genera, *Halobyssothecium* and *Lentithecium*, were assessed and revised. Three novel *Halobyssothecium* species were introduced (*H. bambusicola*, *H. phragmitis*, *H. versicolor*), and transfer of *L. cangshanense, L. carbonneanum, L. kunmingense, L. unicellulare,* and *L. voraginesporum* to *Halobyssothecium*. Collection of an asexual morph of *L. lineare* and phylogenetic analysis confirmed its taxonomic placement in *Keissleriella*.

In the present work, the taxonomic outline of salt marsh fungi is provided with 486 taxa listed in this ecosystem. Ascomycota dominates the taxa from salt marsh ecosystems accounting for 95.27% (463 taxa), followed by Basidiomycota (19 taxa), and Mucoromycota with four taxa. *Juncus roemerianus* has been extensively studied for its associates with 162 documented taxa, followed by *Phragmites australis* (137 taxa) and *Spartina alterniflora* (79 taxa). The highest number of salt marsh fungi have been recorded from Atlantic Ocean countries, wherein the USA had the highest number of species recorded (232 taxa), while China (165 taxa) and India (16 taxa) had the highest number of salt marsh fungi in the Pacific Ocean and the Indian Ocean, respectively.

The classification of basal and higher freshwater fungi has been updated, and numbers were provided based on the scattered taxonomic papers and biodiversity studies. Freshwater fungal taxa listed in this study total to 3,870 species with representatives from 13 phyla: Ascomycota (2,968 species, 1,018 genera), Chytridio-

mycota (333 species, 97 genera), Rozellomycota (221 species, 105 genera), Basidiomycota (218 species, 100 genera), Blastocladiomycota (47 species, ten genera), Monoblepharomycota (29 species, six genera), Mucoromycota (19 species, ten genera), Aphelidiomycota (15 species, three genera), Entomophthoromycota (six species, four genera), Mortierellomycota (five species, three genera), Olpidiomycota (four species, one genus), Zoopagomycota (three species, two genera), and Sanchytriomycota (two species, two genera).

The website https://freshwaterfungi.org/ is developed in the present work to amass scattered published information of freshwater fungi in one online platform and provide up-to-date information for all taxa. Furthermore, the author, together with other curators, also periodically updates the classification of marine fungi on the website https://marinefungi.org/. Though it is not included in the succeeding chapters, these open access websites contain essential information on the updated accounts of aquatic fungal classifications.

Keywords: Aquatic fungi websites, Freshwater fungi, Marine fungi, Phylogenetic analysis, Salt marsh fungi, Taxonomy

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ABBREVIATIONS AND SYMBOLS

cm	centimeter
com.	combination
diam.	diameter
e.g.	for example
et al.	and others
gen.	genus (singular) and genera (plural)
i.e.	that is
mm	millimeter
nov.	novum (Latin for new thing)
sp.	species
spp.	species (plural)
$\bar{x}$	average
°C	degree centigrade
=	heterotypic (taxonomic, facultative) a synonym
≡	homotypic (nomenclatural, obligate) a synonym
µm	micrometer
µl	microliter
%	percent

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Fungi are heterotrophic, eukaryotic microorganisms that are primary effective decomposers, and essential in nutrient cycling and, nutrient transport, and are indispensable for achieving sustainable development. Fungi are ubiquitous in nature, but when it comes to exploration and discovery, fungal studies are mostly concentrated on terrestrial taxa. Aquatic counterparts are considered underexplored, considering the ecological [1–2], taxonomical [3–7], and physiological studies [8–10].

The early works on aquatic fungal taxonomy were based on the morphological characterization of fungal taxa from freshwater habitats using rudimentary microscopes [11]. Technological innovations in microscopy leads to the characterization of several fungal taxa in freshwater and marine habitats [12–19]. From a morphology-based taxonomy, the incorporation of molecular data has revolutionized fungal classification [3, 5, 7, 20–23]. Phylogenetic analysis of extant species and the introduction of novel taxa has resulted in a modern classification system for the Kingdom Fungi [24–27]. Several new genera, families, orders, and even new subclasses of aquatic fungi have been introduced recently [3, 5, 7, 28–33]. With the continuous exploration of different aquatic habitats and substrates, new species, even the existing ones lacking DNA sequence data, are discovered that could continuously update the classification scheme at a certain taxonomic level, or fungal systematics as a whole.

It has been 140 years since the discovery of the first two freshwater hyphomycetes as described by Hartig [34] and Saccardo [35]. Unfortunately, from 1880 to the present, for almost two decades of morpho-phylogenetic taxonomy of freshwater fungi, there is no published information on the known number of freshwater taxa unlike those in marine habitats wherein Jones et al. [4] listed the

marine taxa and periodically update the numbers per taxonomic rank in www.marinefungi.org [36]. In the present study, the freshwater fungal numbers were tabulated based on the available published work. The number of fungi associated with salt marsh plants was also provided. The updated classification of aquatic fungi was uploaded on two webpages, https://marinefungi.org [36] and https://freshwaterfungi.org. Furthermore, to contribute to the increasing numbers of aquatic fungal taxa, fresh specimens of decomposing substrates were collected in different aquatic habitats. The complete illustrations, descriptions, and molecular sequence data of the aquatic fungal taxa were provided.

1.2 Definition of Aquatic Fungi

Aquatic fungi are broadly defined as fungi that rely on aquatic habitats for the whole or part of their life cycle. Park [37] categorized aquatic microorganisms as indwellers (indigenous organisms) and immigrants (Table 1.1). The former is fully adapted to the aquatic habitat and spend all their life-history in this environment, while the latter may normally have an extra-aquatic habitat to maintain their presence and activity in freshwater environments. Immigrants may range from those that are very active ecologically with periodic activity in aquatic habitats (periodic immigrants or migrants), to those that are not active at all and movement between aquatic and extra-aquatic habitats is haphazard rather than regular (versatile immigrants). Other than indwellers and immigrants, Shearer [38] includes amphibious fungi wherein species may occur at aquatic/terrestrial interfaces (e.g., edges of ponds, lakes, floodplains, backwaters of rivers or in ephemeral aquatic habitats such as temporary streams, seasonal ponds, and drainage ditches) or can maintain themselves equally well in the two habitats.

Table 1.1 Classification of Heterotrophic Microorganisms in Aquatic Habitats

Category			Presence in water	Activity*
Resident	Indwellers		Permanent	a, b, c
	Immigrants	Migrants	Periodic	b, c
		Versatile	Irregular	c, d

Note (a) constant; (b) periodic; (c) = sporadic; (d) no activity

Source Park [37]

Freshwater fungi can be defined as any species which, for the whole or part of their life cycle, rely on free freshwater, or which uses any resource of a predominantly aquatic or semi-aquatic nature as a substratum [39]. This means that all fungi found in studies on submerged organic material, freshwater, sediments, foam, and animals can be considered as freshwater fungi and are documented. There have been various definitions of freshwater fungi but most of these deal with ecological groups (Table 1.2). Kohlmeyer & Kohlmeyer [18] divided fungi in marine habitats into obligate and facultative marine fungi, but often referred to as “marine-derived fungi” which include both. Obligate marine fungi are those growing and sporulating exclusively in a marine and estuarine habitat. Facultative marine fungi are those from freshwater or terrestrial environment that are capable of growth and sporulation in the marine environment. Marine fungi that do not germinate in the natural marine habitat are not included in this definition. These broad ecological definition of what constitutes marine fungus is overly restrictive. The recent and presently accepted designation of marine fungus is by Pang [40] and can be defined as any fungus that is recovered repeatedly from marine habitats because: (1) it is able to grow and/or sporulate (on substrata) in marine environments; (2) it forms symbiotic relationships with other marine organisms; or (3) it is shown to adapt and evolve at the genetic level or be metabolically active in marine environments.

Table 1.2 Various Definitions of Freshwater Fungi

Term	Definition	Reference
Obligate freshwater ascomycetes / Indwellers	Fully adapted in water and often adapted for dispersal in water	[37]
Facultative freshwater ascomycetes / Immigrants	Originated from other habitats and must continually immigrate to maintain their population number in water; may show varying degrees of adaptation	[37]
"Amphibious" freshwater ascomycetes	Found in the interface between land and water (e.g., riparian zones, floodplains); may be adapted to fluctuating water levels	[38, 41]
Aeroaquatic hyphomycetes	Indwelling organisms characterized by the production of purely vegetative mycelium in substrates underwater and formation of conidia with special flotation devices, formed only when the substrates on which the fungus is growing are exposed to a moist environment	[42]
Freshwater ascomycetes	All ascomycetes that occur on submerged or partially submerged substrata in aquatic habitats	[38]
Freshwater fungi	Fungi that for the whole or part of their life cycle rely on freshwater, or which uses any resource of a predominantly aquatic or semi-aquatic nature as a substratum	[39]
Freshwater yeasts	Those isolated from freshwater or foam	[43]
Aquatic hyphomycetes	Hyphomycetes that able to sporulate under water and thrive on deciduous leaves decaying in streams and rivers.	[8]

1.3 History of Aquatic Fungi

1.3.1 Freshwater Fungi

Freshwater fungi, especially the freshwater hyphomycetes, have been observed as early as the 1880s. The tetraradiate, sigmoid and branched conidia were interesting characters that caught the attention of pioneer mycologists. *Heliscus lugdunensis* was the first described freshwater hyphomycete [35], while *Flagellospora penicillioides* was the first aquatic hyphomycete with a known sexual state [44]. An important contribution to aquatic hyphomycete research is that of de Wilderman [12, 45, 46] who described four new fungal species, three with tetraradiate and one with sigmoid conidia, from ponds, ditches, and marshy areas on different substrates (algae, willow leaves, aquatic macrophytes *Hippuris vulgaris*). The first prolific sporulation of freshwater hyphomycete *in vitro* was performed by Kegel [47] for *Varicosporium elodeae*, wherein the induction of sporulation occurs when overgrown agar blocks were placed in nutrient-poor water. Some authors who worked on freshwater were Grove [48], Fragoso [49], Huber-Pestalozzi [50, 51], Brutschy [52] and Lowe [53]. A major breakthrough occurred when Ingold [13] discovered a typical habitat for freshwater fungi, growing on submerged decaying leaves of broad-leaved trees in well-aerated waters and introduced the taxa *Alatospora acuminata*, *Anguillospora longissima* (≡ *Amniculicola longissima*), *Articulospora tetracladia* (≡ *Hymenoscyphus tetracladius*), *Clavariopsis aquatica*, *Flagellospora curvula*, *Heliscus aquaticus* (≡ *Nectria lugdunensis*), *Heliscus longibrachiatus* (≡*Clavatospora longibrachiata*), *Lemonniera aquatica, Lunulospora curvula, Margaritispora aquatica, Tetracladium marchalianum, Tetrachaetum elegans, Tetracladium setigerum, Tricladium angulatum, T. splendens,* and *Varicosporium elodeae*, almost 50 years after Wildeman observed their conidial morphology. At the time, Ingold was studying chytrids in a stream behind his house, and coincidentally found a large fungal spore collection trapped in scum behind a barrier of twigs [54]. After a long experimental period, he discovered their structure and detailed 16 species, of which ten were novel [13, 55]. Ainsworth [56] considered this discovery a “minor mycological industry” as the discovery of Ingold paved the way for an era where reports of fungal occurrence

multiplied. Presently, these hyphomycetes are popularly known as Ingoldian fungi, in honour of C.T. Ingold [57]. Ingoldian fungi were previously known as “aquatic hyphomycetes” [13, 46], freshwater hyphomycetes [58], and “amphibious hyphomycetes” [41]. In 1950s, Ingold [59–61] noted that aquatic ascomycetes were abundant in freshwater particularly on stalks of reed swamp plants with many ascospores with variously developed appendages (e.g., *Ceriospora caudae-suis*, *Loramyces macrospora*). A vast number of comprehensive studies were published after the initial work of Ingold [57, 58, 62–70]. Since Ingold’s early research, numerous studies, both on sexual and asexual taxa, have been published all over the world [71–82]. The most recent major publications on freshwater ascomycetes and hyphomycetes are from Luo et al. [5] and Dong et al. [7], while those on Ingoldian fungi on leaves are by Chan et al. [83], Selosse et al. [84], Sudheep and Sridhar [85], Ghate and Sridhar [86], Fiuza et al. [87, 88], and Tarda et al. [89].

1.3.2 Marine Fungi

The history of marine mycology was discussed by Wilson [90], Jones [91], Raghukumar [92], and Jones [93] and major contributions are listed in Table 1.3.

Table 1.3 Historical Outline of Major Events in Marine Mycology

Year	Major Events
1849	First report of marine fungus *Typhicola typharum* from the marshy plant *Typha* by J.B.H.J Desmazières
1848	Description of *Halotthia posidoniae* in the rhizomes of *Posidonia oceanica* [94]
1867–1916	Early works on documentation of marine fungi by Crouan and Crouan [95], Patouillard [96], Reed [97], Cotton [98], Sutherland [99–101]
1894	Fischer [102] and Fischer and Brebeck [103] first reported yeasts in marine environment
1936	Discovery of *Thraustochytrium proliferum* [104]

Table 1.3 (continued)

Year	Major Events
1944	Discovery of a fungal community with fascinating morphology in driftwood by Barghoorn and Linder [105]
1950s–1960s	Contributions on the marine lignicolous fungi by I.M. Wilson [14, 15, 106], S.P. Meyers [107–109], T.W. Johnson [110–112], G. Feldman [113], G. Doguet [114], W. Höhnk [115–119], J.W. Cribb [120, 121]; J. Kohlmeyer [122], K. Tubaki [123] and E.B.G. Jones [16, 124, 125]; H.S. Vishniac [126, 127] and S. Goldstein [128] on the taxonomy and physiology of thraustochytrids and labyrinthulids; marine yeasts [129–131]
1961	Johnson and Sparrow [132] published a book "*Fungi in Oceans and Estuaries*"
1966	First "International Marine Mycology Symposium" initiated by Willy Höhnk R.C. Cavaliere's contribution on ascomatal development and structure of marine ascomycetes [133] and G.C. Hughes' on intertidal fungi in Newfoundland [134] and geographical distribution of marine fungi [135]
1970s	Fungal studies in salt marsh grasses by R.D. Goos and R.V. Gessner [136–140]; E.B. Gareth Jones and Stephen T. Moss in electron microscopy of ascospores of marine fungi, a work which continued into the 1980s [141–145]; Koch's studies on marine fungi observed from wood buried or in contact with sand [146]
1976	E.B. Gareth Jones published a book "*Recent Advances in Aquatic Mycology*" [147]
1979	"*Marine Mycology: The Higher Fungi*" by Jan Kohlmeyer and Erika Kohlmeyer [18]

Table 1.3 (continued)

Year	Major Events
1986	"*Biology of Marine Fungi*" by S.T. Moss [148]
1980s–1990s	Marine fungal research by KD Hyde [149–154]
1990s–early 2000s	Taxonomy and phylogeny of marine fungal studies by K.D. Hyde, E.B.G. Jones and his group from Hong Kong University [155, 156], salt marsh fungal studies by J Kohlmeyer [157–168]
2000–2010	"*Marine Mycology—A Practical Approach*" edited by K.D. Hyde and S.B. Pointing [169]; "*Fungi in Marine Environments*" edited by K.D. Hyde [170]; "*Biology of Marine Fungi*" edited by C. Raghukumar [171]; and "*Marine Fungi and Fungal-like organisms*" edited by E.B.G. Jones and K.L. Pang [28] Continuous research on marine fungi by Kohlmeyer and Volkmann-Kohlmeyer [160] with incorporation of molecular methods by Suetrong et al. [3]
2010–2020	Classification of marine Ascomycota, Basidiomycota, Blastocladiomycota and Chytridiomycota [4] https://marinefungi.org was created and updated regularly about marine fungal classification [36] Updated classification of mangrove fungi [172]

1.4 Taxonomic Studies and Classification of Aquatic Fungi

Our knowledge on aquatic fungi has expanded exponentially for almost a century and a half of research. The classification system has been updated using molecular phylogenetics coupled with morphology, and by following the one fungus=one name ruling. These recent changes in fungal classification are products of continuous exploration by aquatic mycologists from different laboratories studying

the diversity and taxonomy of aquatic fungi. The last decade has greatly advanced our knowledge in the taxonomic and phylogenetic classification of freshwater fungi. The seminal paper of Luo et al. [5] on freshwater Sordariomycetes outlined 127 genera in 30 orders, documented and introduced novel taxa (two families, three genera, 47 species) with strong backbone tree using combined LSU, SSU, RPB2, and TEF1α sequence dataset. On the other hand, Dong et al. [7] provided a comprehensive outline of six orders (in 43 families, 145 genera), notes, illustrations, class-level phylogenetic tree using LSU, ITS, TEF, and RPB2 sequence dataset, and introduced novel taxa (nine new genera, 33 new species) based on freshwater specimens from Thailand and China. Hyde et al. [33] updated the backbone tree and provided the divergence time estimates for freshwater Diaporthomycetidae with five new orders (Barbatosphaeriales, Cancellidiales, Cancellidiales, Conlariales, Rhamphoriales), six new families (Aquapteridosporaceae, Bullimycetaceae, Cancellidiaceae, Ceratolentaceae, Phialemoniopsaceae Pseudostanjehughesiaceae), and three species. With the collection of novel *Cancellidium* species, Hyde et al. [33] conjectured that species of *Cancellidium* in different river systems may be distinct with more collections from different regions are needed, and species supported by molecular data. Bao et al. [173] introduced seven novel *Acrogenospora* species based on a collection from a small area in Yunnan Province, China. They proposed that there could be several additional new species within the genus and its diversity could be much higher than anticipated. Hyde et al. [33] suggested future focus areas of research on defining populations of freshwater taxa in unconnected river systems to establish if (1) each system has its distinct stream mycota, (2) freshwater mycota are generalists or (3) if a mixture of these occurs. Jones et al. [174] listed the classification and estimates of freshwater fungi with representatives from Ascomycota (33 orders, 622 species excluding ascomycetous yeasts), Basidiomycota (19 orders, 50 genera, 115 species), Blastocladiomycota, and Chytridiomycota (eight orders, 103 genera, 611 species). Various authors estimated the number of freshwater fungi: >600 [69], 2,535 [175], 1,422-1,524 [176], 20,000 [177], 3,069-4,145 [174].

Unlike freshwater fungi, Jones et al. [36] updated the classification of marine fungi which currently accounts for 1,257 species (539 genera, 74 orders, 168 families, 20 classes) under five phyla (Ascomycota, Basidiomycota, Blastocladiomycota,

Chytridiomycota, Mucoromycota). The number of higher fungi described in different periods is shown in Table 1.4. Marine derived fungi account for 1.29% (1,257 out of 97,330 described species) of the 6.5% (97,330 out of 1.5 million estimated number of species) described species from marine substrata (e.g., wood, mangroves, and sands) using cultivation-based methods [4, 178–186]. Ascomycota (97%) predominate as marine fungi with few Basidiomycota (~2%), and asexual morphs (<1%) [171]. Jones and Mitchell [187] estimated marine fungi to be 1,500, and Clement et al. [188] and Liberra and Lindequist [189] considered this as an underestimate of the biodiversity of this fungal group. Kis-Papo [184] suggested that there are 10,029 total species of marine fungi by extrapolating the overall estimate of the world fungi (1.5 million). This is lower compared to the estimate of Jones [190] which is 10,937 marine fungi (Table 1.5). Jones [190] suggested areas for finding the missing fungi and include (1) unidentified/misidentified species on a range of substrata, (2); marine derived (facultative) fungi isolated from soils, sand, and water; (3) planktonic fungi; (4) deep-sea fungi; (5) unculturable fungi; (6) cryptic species or species with similar morphology; and (7) characterization of host species specific parasites. The continuous explorations of marine habitats lead to discoveries of novel taxa. For instance, the investigation of Dayarathne et al. [6] on saprobic marine fungi in India, Thailand, Sweden and the UK resulted to the descriptions of novel taxa (two genera, 37 species). Other latest taxonomic and phylogenetic studies include, Dayarathne, Wanasinghe, et al. [191], Gonçalves et al. [192–194], Hagestad et al. [195], Jones et al. [32], Poli, Bovio, et al. [196], and Poli, Prigione, et al. [197], Devadatha et al. [198].

Table 1.4 Number of Higher Marine Fungi Described in Different Periods

Taxa	Kohlmeyer and Kohlmeyer [18]	Kohlmeyer and Volkmann-Kohlmeyer [179]	Hyde et al. [199]	Kis-Papo [184]	Jones et al. [200]	Jones et al. [4]
Ascomycota	149	255	360	453	424	805
Basidiomycota	4	6	10	11	12	21
Asexual morphs	56	60	74	3	94	43
Chytridiomycota and related phyla	–	–	–	–	–	26
Zygomycota	–	–	–	–	–	3
Blastocladiomycota	–	–	–	–	–	1
Marine yeasts	–	–	–	–	–	
Ascomycota						138
Basidiomycota						75
Total	**209**	**321**	**444**	**467**	**530**	**1,112**

Table 1.5 Estimated Number of Fungal Populations in Marine Environment

Group	Number
Obligate fungi	537
Facultative fungi	100
Marine yeasts	1,500
Misidentified fungi	500
Marine-derived and sediment fungi	1,500
Deep-sea fungi	300
Planktonic fungi	500
Endophytes of marine organisms	6,000
Total	**10,937 (7000–10,000 or higher)**

Source Jones [190]

1.5 Fungal Databases

Online databases are developed to compile data for general accounts of fungi (e.g., http://www.indexfungorum.org; http://www.speciesfungorum.org/; http://-www.mycobank.org [201]; http://www.facesoffungi.org [202]; http://www.fungalgenera.org [203]; https://www.outlineoffungi.org/ [204]], or even for certain habitats, substrates, hosts [e.g. http://marinefungi.org for marine fungi [36]; http://fungi.life.illinois.edu/ for freshwater ascomycetes and their anamorphs [205]; invertebrate fungi, https://invertebratefungi.org/; forest pathogens, https://www.-forestpathogens.org/], or taxonomic groups [e.g., Dothideomycetes: http://www.dothideomycetes.org [206]; Sordariomycetes: http://www.sordariomycetes.org [207]; Botryosphaeriales https://botryosphaeriales.org [208]; coelomycetes, http://www.-coelomycetes.org [209]; basidiomycetes: https://www.basidio.org [210]; discomycetes, https://discomycetes.org/; GMS mushrooms, https://gmsmushrooms.org/] or at certain geographical locations [Italian microfungi, https://italian-microfungi.org/ [211]; Greater Mekong Subregion, https://gmsmicrofungi.org/ [212]; Pakistan, https://www.fungiofpakistan.com [213]). Of all the websites mentioned, the webpage http://fungi.life.illinois.edu/ focuses only on freshwater fungi. With the advent of molecular techniques and the continuous exploration of different freshwater habitats and substrates, new species, even the existing ones lacking DNA sequence data, are discovered and there is a need to compile all the scattered published data on freshwater fungi using a user-friendly interface and is freely accessible to public users. Thus, the online database for freshwater fungi, www.freshwaterfungi.org, is developed.

1.6 Introduction to Molecular Phylogenetics

The phylogenetic relationships among species can be illustrated by modelling them using a phylogenetic tree. There are various comprehensive discussions of the methods for inferring phylogenies, see Felsenstein [214–216], Swofford et al. [217], Li [218], Yang [219], Yang and Rannala [220]. The two main approaches for

inferring phylogenies are phenetic and cladistic approaches whereas the former is based on similarity while the latter is on genealogy [1]. Phenetic or clustering approach (i.e., distance-based methods) operates by measuring distances between species and reconstructs the tree using a hierarchical clustering procedure. On the other hand, the cladistic approach considers possible pathways of evolution, inferring the features of the ancestor at each node and choosing an optimal tree according to some model of evolutionary change (i.e., maximum likelihood [ML], maximum parsimony [MP], and Bayesian methods). ML, MP, and Bayesian inference (BI) were performed to obtain the phylogenetic tree of both individual and combined gene datasets in the succeeding chapters. The ML method assigns quantitative probabilities to mutational events, rather than merely counting them, while MP infers phylogenetic trees by evaluating the possible mutations between sequences. Both ML and MP methods are superior to clustering techniques [221]. Generally, maximum likelihood appears to be an appealing way to estimate phylogenies wherein all possible mutational pathways that are compatible with the data are considered [222]. Edwards [223] also pointed out that likelihood functions are known to be a consistent and powerful basis for statistical inference. The Bayesian approach is closely related to maximum likelihood. The optimal hypothesis is the one that maximizes the posterior probability [224]. It differs from maximum likelihood in that parameters in the model are random variables with statistical distributions, whereas in maximum likelihood they are unknown fixed constants [220]. In the present study, all analyses were performed on the CIPRES web portal [225–229]. The details on the phylogenetic analyses are discussed in the succeeding chapters, see Chapters 3–6.

1.7 Research Objectives

1.7.1 To collect, isolate, and provide molecular data of lignicolous aquatic fungi from Thailand, UK, and Sweden

1.7.2 To resolve the phylogenetic placement of existing and novel taxa using multi-locus phylogenetic analysis

1.7.3 To amass available published information on aquatic fungi specifically freshwater fungi and salt marsh fungi

1.7.4 To update the classification and taxonomy of the group in an online data repository (https://freshwaterfungi.org)

1.8 Expected Outcome

1.8.1 The various lignicolous fungal taxa, existing or novel, from aquatic habitats will be documented with complete descriptions, illustrations, and molecular data. The morphology coupled with sequence data will clarify phylogenetic placements of observed fungal taxa

1.8.2 The compilation of fungal taxa observed from freshwater and salt marsh environments will determine the species composition and current numbers from these habitats. In addition, association of fungal taxa from the salt marsh plants will also be defined.

1.8.3 The number of extant freshwater fungi is rapidly increasing, and the published information on taxonomic data are scattered among different online journal archives. The webpage https://freshwaterfungi.org will serve as an online database for aquatic fungal classification that provides comprehensive and updated information including detailed descriptions, photographic plates and illustrations, notes, phylogenetic trees, estimated and extant list of species, and other related information.

1.9 Research Content

The dissertation is divided into eight chapters:

Chapter 1 is the general introduction to aquatic fungi, their definition, history, classification, taxonomic and phylogenetic studies, and available online fungal data repositories

Chapter 2 reviews the fungal biodiversity in salt marsh ecosystems, including their geographical distribution and plant host association

Chapter 3 introduces three new species of *Halobyssothecium* (*H. bambusicola, H. phragmitis, H. versicolor*), provides taxonomic revision of *Halobyssothecium* and *Lentithecium*, with the updated phylogenetic tree of Lentitheciaceae, and notes for taxa within Lentitheciaceae.

Chapter 4 introduces one novel genus *Neoxylomyces* and five novel species *Camposporium dulciaquae*, *Brunneofusispora hyalina*, *Rattania aquatica*, *Neoxylomyces multiseptatus*, and *Phaeoacremonium thailandense* from freshwater habitats in Thailand.

Chapter 5 introduces one novel freshwater fungus *Mycoenterolobium aquadictyosporium*, provides phylogeny based on LSU, SSU, ITS, TEF1-α, and RPB2 loci sequence data of *Mycoenterolobium* and their generic phylogenetic placement within *Pleosporomycetidae incertae sedis*.

Chapter 6 introduces one novel fungus *Wicklowia phuketensis* from freshwater habitat in Thailand.

Chapter 7 presents an up-to-date classification of freshwater fungi and the number of taxa recorded in freshwater habitats, including their isolation source and geographical distribution.

Chapter 8 provides the overall conclusion of the above-mentioned studies and suggestions for future work.

CHAPTER 2

FUNGAL BIODIVERSITY IN SALT MARSH ECOSYSTEMS[1]

Abstract

This review brings together the research efforts on salt marsh fungi, including their geographical distribution and host association. A total of 486 taxa associated with different hosts in salt marsh ecosystems are listed in this review. The taxa belong to three phyla wherein Ascomycota dominates the taxa from salt marsh ecosystems accounting for 95.27% (463 taxa). The Basidiomycota and Mucoromycota constitute 19 taxa and four taxa, respectively. Dothideomycetes has the highest number of taxa, which comprises 47.12% (229 taxa), followed by Sordariomycetes with 167 taxa (34.36%). Pleosporales is the largest order with 178 taxa recorded. Twenty-seven genera under 11 families of halophytes were reviewed for its fungal associates. *Juncus roemerianus* has been extensively studied for its associates with 162 documented taxa followed by *Phragmites australis* (137 taxa) and *Spartina alterniflora* (79 taxa). The highest number of salt marsh fungi have been recorded from Atlantic Ocean countries wherein the USA had the highest number of species recorded (232 taxa) followed by the UK (101 taxa), the Netherlands (74 taxa), and Argentina (51 taxa). China had the highest number of salt marsh fungi in the Pacific Ocean with 165 taxa reported, while in the Indian Ocean, India reported the highest taxa (16 taxa). Many salt marsh areas remain unexplored, especially those habitats in the Indian and Pacific Oceans areas that are hotspots of biodiversity and novel fungal taxa based on the exploration of various habitats.

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Keywords: Halophytes, Marine Fungi, Marine Mycology, Salt Marsh Fungi, Worldwide Distribution

2.1 Introduction

Salt marsh ecosystems are known for their high productivity, exceeding primary production estimates of species rich ecosystems (e.g., tropical rainforests, coral reefs) [230]. The flora in salt marsh ecosystems is mainly composed of grasses, herbs, and shrubs and these are terrestrial organisms variously adapted to, or tolerant of, a semi-marine environment. Halophytes are a diverse group of plants that have a worldwide distribution, and grow in different climatic regions, wherein soils have high salinity levels [231]. Halophytes are common in temperate and Mediterranean climates, and fewer both in the tropics and at high latitudes [232–235]. The vegetation in these ecosystems shows the vertical zonation of different communities as tidal submergence decreases with increasing elevation, and species tolerance to changing gradient conditions. Salt marsh vegetation generally increases the attenuation of both tidal currents and waves as they pass over the vegetated area and immobilize elements with their sediments. Furthermore, halophytes serve as a natural buffer, protecting other shoreline ecosystems from human impacts and disturbances. The area provides a habitat and nursery for marine organisms [236]. Worldwide, salt marshes cover an area of 5,495,089 hectare in 43 countries [237].

There are over 500 species of salt marsh plants worldwide [238]. The families Amaranthaceae (subfamilies Chenopodiaceae, Salicornieae), Poaceae, Juncaceae, and Cyperaceae are the major vegetation in salt marsh ecosystems, while the minor components are Plumbaginaceae and Frankeniaceae [232] and are represented in Figure 2.1 and Figure 2.2. Salinity, latitude, region of the world, the frequency and duration of tidal flooding, substrate, oxygen and nutrient availability, surface elevation, competition among species, disturbance by wrack deposition are interacting factors that influence the species of halophytes in the salt marshes [239, 240]. For example, *Spartina alterniflora* is a dominant grass from mid-tide to high-tide levels in

temperate Eastern North America, while Puccinellia dominates in boreal and arctic marshes [239, 240].

Major studies on halophytes focus on ecology and conservation [241–243]. One of these is the decomposition of vascular plant material wherein the detritus breakdown was reviewed in Pomeroy et al. [244], Howarth and Hobbie [245], and Long and Mason [246]. The active decomposition processes in salt marsh ecosystems reflects to the relatively high rates of primary production. Three phases of plant decomposition were noted by Valiela et al. [247]. The early phase involves the leaching of soluble compounds, resulting in a fast rate of weight loss lasting for less than a month. Organic matter breakdown by microorganisms and continuous leaching of decayed products occurs in the second phase that lasts for a year. The last phase lasts for another year when there is a slow decay of refractory materials such as humates and fulvates [248].

The continuous breakdown of detritus into smaller fragments increases the surface-to-volume ratio and this is exposed to further microbial degradation. Bacteria and fungi are key decomposers in the salt marsh ecosystem that are essential for the transformation and recycling of nutrients through the environment. The colonization of fungi on standing dead halophytes commences during the early stages of decomposition before leaf fall to the salt marsh sediment surface [136, 137]. The decomposition of the senescent tissues of halophytes by salt marsh fungi is brought about by the direct penetration of the host cell wall and the production of enzymes active in degrading lignocellulosic compounds, such as lignin, cellulose, and hemicellulose [249–253]. Bacterial communities are the major decomposers in the latter stage of decomposition [254, 255]. Studies in salt marsh ecosystems not only consider microbial activity and the recycling of nutrients, but also bacterial [256, 257] and fungal diversity [137, 258, 259].

The present review compiles the published data of fungi from halophytes, including their geographical distribution and host association. When compared to other fungal groups, salt marsh fungi are underexplored, and this review brings together the research efforts on these undiscovered habitats and plants. The pertinent literature from bibliographic databases (e.g., Scopus, Web of Science, Google

Scholar) and published resources on salt marsh fungi documenting halophytes were compiled. Published works, wherein the documented fungal taxa were observed directly from halophytic substrates, are included (Table 2.1). The different host parts, living and dead, that are either partly or wholly submerged are documented, as well as drift plant portions washed up in salt marsh areas. Salt marsh fungi isolated using cultivation-dependent techniques were not included since it is not known if these fungi were actively growing and reproducing on the halophytes. The taxa were listed based on the recent outline of fungi and fungus-like taxa by Wijayawardene et al. [204]. Since previous works only listed the taxa and the hosts [18, 260, 261], here we include the plant parts where the fungus was observed, the location (country: state/province) where the host was collected, the life mode of the fungus, and the pertinent literature citations are included (Table 2.1). The accepted name of the host was based on the webpage of the World Flora Online consortium (http://www.world-floraonline.org/; accessed on 10 May 2021), GrassBase (https://www.kew.org/data/-grasses-db/sppindex.htm; accessed on 10 May 2021) and CRC World Dictionary of Grasses by Quattrocchi [262]. The graphs presented in the next sections summarizes the information from Table 1 and was developed using data visualization tools (Excel Office 365, Tableau Desktop Professional Edition 19.2.2).

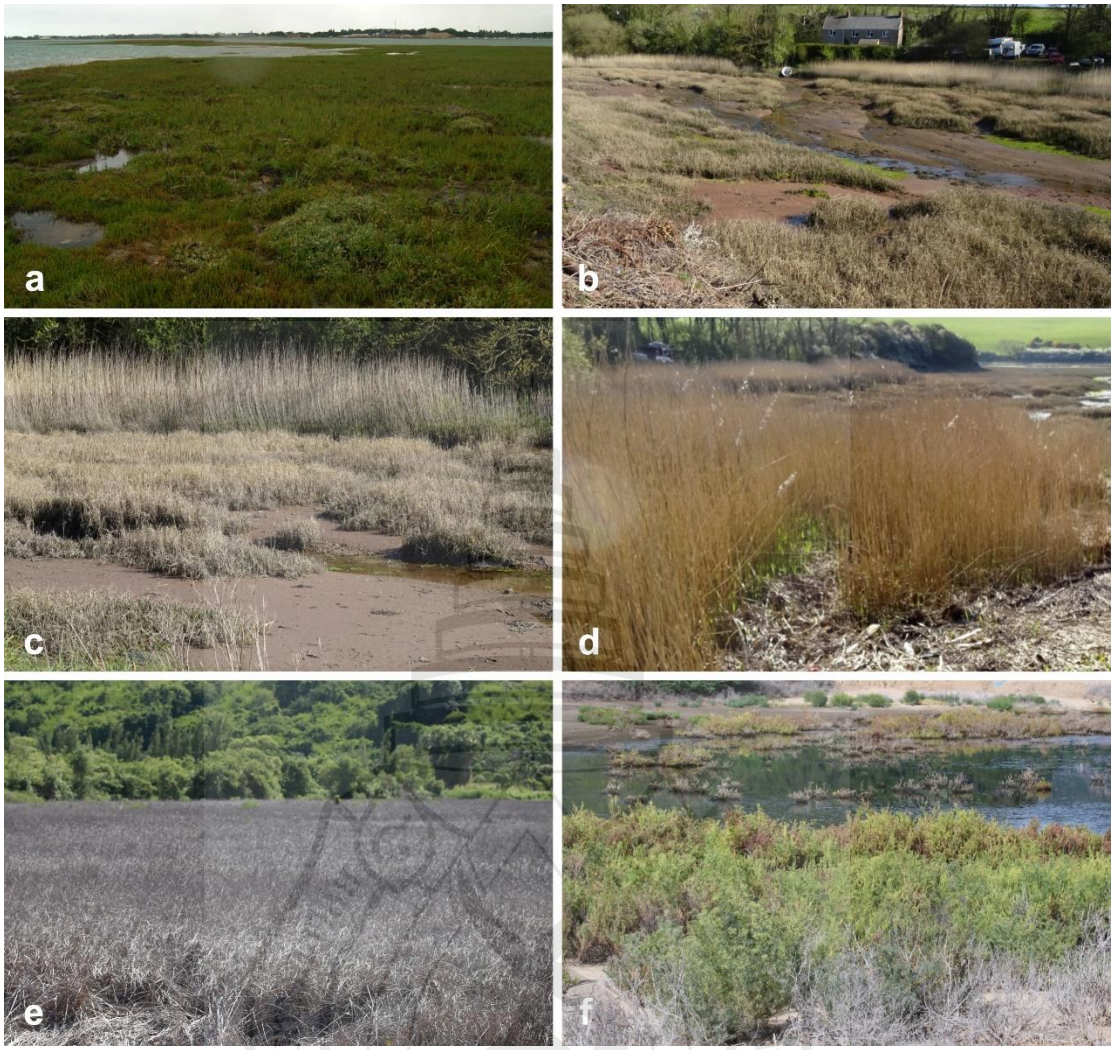


Figure 2.1 Salt Marsh Ecosystems in UK (a–d) and Thailand (e–f). (b–d) Tidal Grasses, *Spartina townsendii* (Poaceae) and *Phragmites* (Poaceae), Dominate the Salt Marsh in UK (50°49′55.4″ N 0°58′25.1″ W; 51°43′03.1″ N 5°10′24.8″ W); (e) *Spartina* (Poaceae) (12°22′4.0″ N 99°59′6.7″ E) (f) and *Suaeda* (Amaranthaceae) (12°10′19.6″ N 99°58′20.3″ E) in Tidal Marsh Areas in Southern Thailand.



Figure 2.2 Halophytes in Salt Marsh Ecosystems: (a) Flowering Inflorescence of *Spartina*, (b) *Phragmites*, (c) *Salicornia*, (d) *Typha*, (e,f) *Atriplex*, and (g,h) *Suaeda*.

2.2 Taxonomic Classification of Salt Marsh Fungi

2.2.1 Phyla

Calado and Barata [260] documented 332 taxa associated with *Juncus roemerianus, Phragmites australis,* and *Spartina* spp. In this review, we list 486 taxa that belong to three phyla (Ascomycota, Basidiomycota, Mucoromoycota) (Table 2.1, Figure 2.3) and selected species are illustrated in Figure 2.4. Ascomycota dominates the taxa from salt marsh ecosystems, accounting for 95.27% (463 taxa). Nineteen species in twelve genera (*Aecidium, Chaetospermum, Falmingomyces, Merismodes, Nia, Parvulago, Puccinia, Sporobolomyces, Stilbum, Tranzscheliella, Tremella, Uromyces*) belong to Basidiomycota (3.91%), while Mucoromycota account for 0.82% (four species) of the salt marsh fungi.

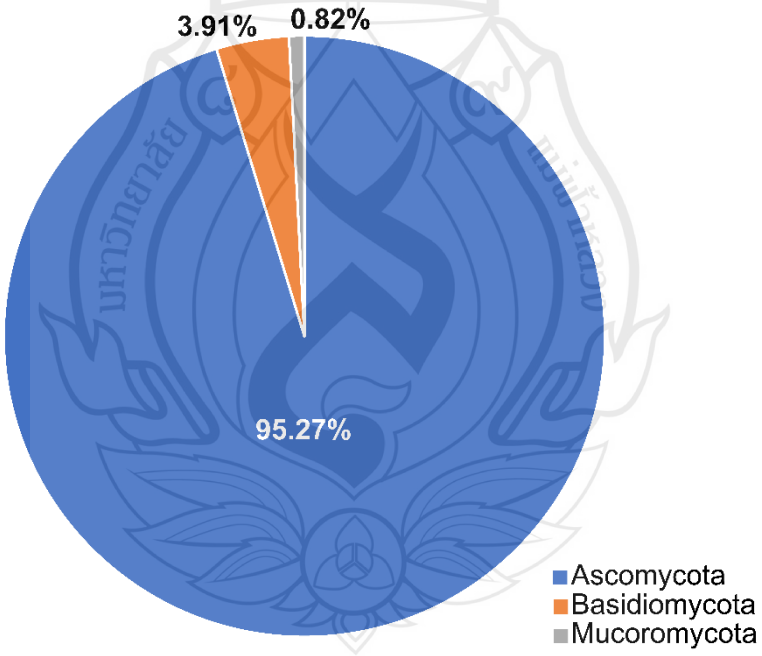


Figure 2.3 The Distribution of Salt Marsh Fungi Among Three Fungal Phyla

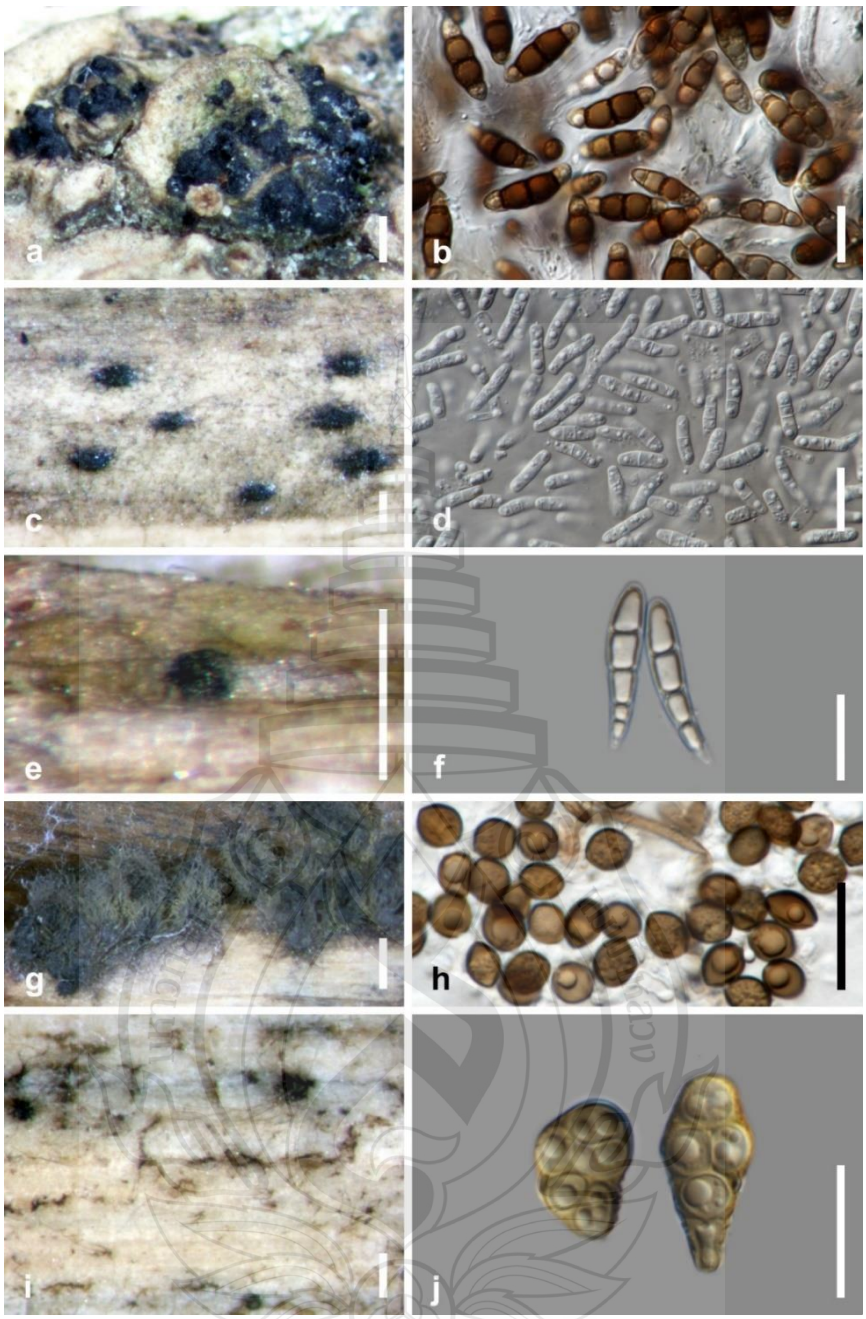


Figure 2.4 Salt Marsh Fungi. (a,b) *Halobyssothecium obiones* from *Atriplex portulacoides*; (c,d) *Halobyssothecium phragmites* from Culms of *Phragmites* sp.; (e,f) *Buergenerula spartinae* from Culms of *Spartina* sp.; (g,h) *Chaetomium* sp. from Stem of *Typha* sp.; (i,j) *Alternaria* sp. from Culms of *Spartina* sp. Scale bars: (a,g) = 500 µm; (b,d,f,h,j) = 20 µm; (c,i) = 200 µm; (e) = 100 µm

Table 2.1 Geographical Distribution of Salt Marsh Fungi Recorded from Various Halophytes

Taxon	Host Part	Life Mode	Hosts	Distribution	References
ASCOMYCOTA					
DOTHIDEOMYCETES					
Acrospermales					
Acrospermaceae					
Acrospermum graminum Lib.	–	–	*Elymus pungens*	UK	[263]
Asterinales					
Morenoinaceae					
Morenoina phragmitis J.P. Ellis	Living/decomposing leaf sheaths and stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Botryosphaeriales					
Botryosphaeriaceae					
Botryosphaeria festucae (Lib.) Arx and E. Müll.	Living/decomposing leaf sheaths and stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Macrophomina sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Tiarosporella halmyra Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[166]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
and Volkm.-Kohlm.					
Phyllostictaceae					
Guignardia spp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Phyllosticta sp.	–	Pathogenic	*Spartina cynosuroides*	USA: Maryland	[268]
Phyllosticta spartinae Brunaud	–	–	*Spartina maritima*	France	[269]
Phyllosticta suaedae Lobik	Leaves	–	*Suaeda maritima*	Russia	[270]
Capnodiales					
Cladosporiaceae					
Cladosporium algarum Cooke	–	–	*Spergularia marina*	–	[18]
and Massee	–	–	*Suaeda maritima*	–	[18]
Cladosporium allicinum (Fr.)	–	–	*Elymus pungens*	UK	[263]
Bensch, U. Braun and Crous					
Cladosporium cladosporioides	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos	[271]
(Fresen.) G.A. de Vries				Aires	
	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Leaves and roots	Saprobic	*Spartina* sp.	Canada: Bay of	[272]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Fundy	
Cladosporium herbarum (Pers.) Link	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Stem	Saprobic	*Spartina townsendii*	UK: England	[273]
	Leaves, stems, and roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Cladosporium macrocarpum Preuss	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Cladosporium sphaerospermum Penz.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf sheaths and blades	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 266, 274]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	–	Saprobic	*Spartina* sp.	Canada	[261]
Capnodiales genera *incertae sedis*					
Mucomycosphaerella eurypotami (Kohlm., Volkm.-Kohlm. and	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[167]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
O.E. Erikss.) Quaedvl. and Crous Mycosphaerellaceae					
Fulvia fulva (Cooke) Cif.	Leaves and stems	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Micronectriella agropyri Apinis and Chesters	–	–	*Elymus pungens*	UK	[263]
	–	–	*Puccinellia maritima*	UK	[263]
	–	–	*Spartina townsedii*	UK	[263]
Mycosphaerella lineolata (Roberge ex Desm.) J. Schröt.	Living/decomposing leaf sheaths and stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
	–	–	*Elymus pungens*	UK	[263]
Mycosphaerella salicorniae (Auersw.) Lindau	–	–	*Arthrocnemum subterminale*	–	[18]
	–	–	*Limonium* sp.	–	[18]
	–	–	*Sarcocornia perennis*	–	[18]
	–	–	*Salicornia fruticosa*	–	[18]
	–	–	*Salicornia procumbens*	–	[18]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Salicornia europaea*	–	[18]
	–	–	*Salicornia perennis*	–	[18]
	–	–	*Sarcocornia fruticosa*	–	[18]
	Drying stalks and inflorescence	Saprobic	*Salicornia* sp.	India	[275]
	Dried inflorescences	Saprobic	*Salicornia virginica*	Bermuda	[18, 276]
	–	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon	[277]
	–	–	*Suaeda vermiculata*	–	[18]
	Drying stalks and inflorescence	Saprobic	*Suaeda* sp.	India	[275]
Mycosphaerella spp.	–	–	*Elymus pungens*	UK	[263]
	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida, Mississippi	[267, 278]
	Decaying leaves, leaf blades	Saprobic	*Spartina alterniflora*	Argentina: Buenos Aires; USA: Alabama, California,	[18, 252, 261, 278–281]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Georgia, Mississippi	
	–	–	*Spartina* cf. *densiflora*	USA: California	[18, 252]
	–	–	*Spartina* cf. *pectinata*	–	[18]
	–	–	*Spartina* sp.	Argentina: Buenos Aires; Canada	[18, 261]
	Decaying leaf blades	Saprobic	*Spartina foliosa*	USA: California	[252]
	Leaf sheaths and blades, stem	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Centro	[277, 282]
Mycosphaerella staticicola (Pat.) Dias	–	–	*Armeria pungens*	–	[18]
Mycosphaerella suaedae-australis Hansf.	–	–	*Suaeda australis*	–	[18]
Rivilata ius Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Tips of senescent, very old, and brittle leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[283]
Septoria spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
	Upper leaves, inflorescence, seeds	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[138]
Septoria suaedae-australis Hansf.	Dead stems	Saprobic	*Suaeda australis*	South Australia	[284]
Sphaerulina albispiculata Tubaki	Sheath	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon	[277]
	Stem	Saprobic	*Spartina marítima*	Portugal: Alentejo	[285]
Sphaerulina orae-maris Linder	–	–	*Ammophila arenaria*	–	[18]
	Rhizome and root	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	Leaf sheaths and blades, stem	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282, 285]
Sphaerulina pedicellata T.W. Johnson	–	Saprobic	*Spartina townsendii*	–	[16]
	Attached culms, stems	Saprobic,	*Spartina alterniflora*	USA: Rhode Island	[137, 138]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
		parasitic			
Sphaerulina sp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Dothideales					
Saccotheciaceae					
Aureobasidium sp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Pseudoseptoria donacis (Pass.) B. Sutton	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Selenophoma sp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Dothideaceae					
Scirrhia annulata Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent culms and leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[165]
Dothideomycetes families *incertae sedis*					
Eriomycetaceae					
Heleiosa barbatula Kohlm.,	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[165]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Volkm.-Kohlm. and O.E. Erikss. Pseudorobillardaceae					
Pseudorobillarda phragmitis (Cunnell) M. Morelet	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories; UK	[266, 287]
Pseudorobillarda sp.	Dead stems	Saprobic	*Spartina alterniflora*	Canada	[261]
Dothideomycetes genera *incertae sedis*					
Bactrodesmium atrum M.B. Ellis	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
Lautitia danica (Berl.) S. Schatz	–	–	*Elymus pungens*	UK	[263]
	–	–	*Puccinellia maritima*	UK	[263]
Monodictys austrina Tubaki	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Monodictys castaneae (Wallr.) S. Hughes	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Neottiosporina australiensis B. Sutton and Alcorn	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
Neottiosporina sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Otthia sp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Trichometasphaeria setulosa. (Sacc. and Roum.) Apinis and Chesters ined.	–	–	*Elymus pungens*	UK	[263]
Trichometasphaeria sp. Microthyriales Microthyriaceae	–	–	*Elymus pungens*	UK	[263]
Microthyrium microscopicum Desm.	–	–	*Spartina patens*	–	[288]
Microthyrium gramineum Sacc., E. Bommer and M. Rousseau Muyocopronales Muyocopronaceae	–	–	*Elymus pungens*	UK	[263]
Ellisiodothis inquinans (Ellis and Everh.) Theiss. Mytilinidiales Mytilinidiaceae	–	Saprobic	*Spartina alterniflora*	Argentina: Buenos Aires	[261]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Septonema secedens Corda	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Phaeotrichales					
Phaeotrichaceae					
Trichodelitschia bisporula (P.	–	–	*Elymus pungens*	UK	[263]
Crouan and H. Crouan) E. Müll.	–	–	*Spartina townsendii*	UK	[263]
and Arx					
Pleosporales					
Amniculicolaceae					
Neomassariosphaeria typhicola	–	–	*Juncus roemerianus*	–	[18]
(P. Karst.) Y. Zhang ter, J. Fourn.	Decaying herbaceous stems	Saprobic	*Spartina densiflora*	Argentina: Buenos	[286]
and K.D. Hyde				Aires	
	–	Saprobic	*Spartina* spp.	Argentina: Buenos	[18, 259,
				Aires	261]
	–	Saprobic	Unidentified	USA: Mississippi	[281]
			saltmarsh plants		
Camarosporiaceae					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Camarosporium feurichii Henn.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Camarosporium palliatum Kohlm. and E. Kohlm.	–	–	*Sarcocornia perennis*	–	[18]
	–	–	*Salicornia* sp.	–	[18]
	–	–	*Salicornia virginica*	–	[18]
	–	Saprobic or perthophytic	Salt marsh plants	India: Maharashtra	[275]
	–	–	*Suaeda vermiculata*		[18]
Camarosporium roumeguerei Sacc.	–	–	*Atripex halimus*		[18]
	–	–	*Atripex* sp.		[18]
	–	–	*Distichlis spicata*		[18]
	Twigs	–	*Salicornia europaea*	France	[18, 289]
	–	–	*Sarcocornia fruticosa*		[18]
	–	–	*Salicornia* sp.		[18]
	–	Saprobic or	Salt marsh plants	India: Gujarat,	[275]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
		perthophytic		Maharashtra, Tamil Nadu, Andhara Pradesh, West Bengal	
Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve, Centro	[282]	Leaf sheaths and blades, stem
–	–	*Suaeda maritima*	–	[18]	–
Camarosporium salicorniae Hansf.	Twigs	–	*Sarcocornia quinqueflora*	South Australia	[284]
Camarosporium spp.	Living/decomposing leaf sheaths and stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Camarosporium suaedae-fruticosae S. Ahmad	Dead branches	Saprobic	*Suaeda vermiculata*	Pakistan	[290]
Coniothyriaceae					
Coniothyrium obiones Jaap	–	–	*Atriplex portulacoides*	–	[18]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	Saprobic	Salt marsh plants	India: Orissa	[275]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve	[282]
Coniothyrium spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Cyclothyriellaceae					
Massariosphaeria erucacea Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent culms and leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[165]
Massariosphaeria scirpina (G. Winter) Leuchtm.	–	Saprobic	*Spartina* sp.	USA: Florida, North Carolina	[132]
	–	Saprobic	Salt marsh plants	India: Orissa	[275]
Massariosphaeria sp.	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
Dictyosporiaceae					
Dictyosporium oblongum (Fuckel) S. Hughes	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
Dictyosporium pelagicum (Linder) G.C. Hughes ex E.B.G.	Decomposing culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 138]
	–	–	*Spartina* spp.	–	[259]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Jones	Leaf sheaths and blades, stem	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[277, 282, 285]
Jalapriya toruloides (Corda) M.J. D'souza, Hong Y. Su, Z.L. Luo and K.D. Hyde Didymellaceae	Stems	Saprobic	*Spartina* sp.	UK	[125]
Ascochyta cf. *arundinariae* Tassi	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Ascochyta leptospora (Trail) Hara	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Ascochyta salicorniae-patulae (Trotter) Melnik	–	Saprobic, parasitic	*Salicornia* spp.	Canada, Denmark, Germany, India, UK, USA	[275]
Ascochyta spp.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
	Sheath	Saprobic	*Spartina marítima*	Portugal: Alentejo	[277]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Ascochyta salicorniae-patulae (Trotter) Melnik	–	Saprobic, parasitic	*Salicornia* spp.	Canada, Denmark, Germany, India, UK, USA	[275]
Ascochyta spp.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
	Sheath	Saprobic	*Spartina marítima*	Portugal: Alentejo	[277]
Chaetasbolisia sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Didymella glacialis Rehm	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
Didymella glomerata (Corda) Qian Chen and L. Cai	Rhizome and basal area	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
Didymella spp.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
	–	Pathogenic	*Spartina cynosuroides*	USA: Louisiana	[268]
Epicoccum nigrum Link	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Inflorescence, upper leaves, seeds	Saprobic, parasitic	*Spartina alterniflora*	USA: Rhode Island, Connecticut, Virginia, Florida, North Carolina	[138, 139, 261, 291]
Epicoccum sp.	–	–	*Spartina alterniflora*	–	[18]
Microsphaeropsis spp.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 266, 274]
Phoma herbarum Westend.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Phoma leveillei Boerema and G.J. Bollen	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Phoma suaedae Jaap	Twigs, leaves, stems	Saprobic	*Suaeda maritima*, *Suaeda* sp.	Germany; India	[292]
	–	–	*Suaeda maritima*	–	[18]
Phoma spp.	–	–	*Crithmum maritimum*	–	[18]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Atriplex portulacoides*	–	[18]
	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Hong Kong: New Territories; Netherlands: Zeeland	[264–266, 274]
	–	–	*Salicornia europaea*	–	[18]
	–	–	*Spartina alterniflora*	USA: North Carolina, Rhode Island	[18, 137–139, 261, 291]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	–	Saprobic	*Spartina* sp.	Argentina: Buenos Aires; Canada; USA: Maine, South Carolina	[132, 261]
	–	–	*Spartina townsendii*	UK: England	[16, 18, 273]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	Leaf sheaths and blades, stem	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[277, 282, 285]
Paraboeremia putaminum (Speg.) Qian Chen and L. Cai	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Stagonosporopsis salicorniae (Magnus) Died.	–	–	*Salicornia europaea*	–	[18]
	–	–	*Salicornia patula*	–	[18]
Didymosphaeriaceae					
Didymosphaeria lignomaris Strongman and J.D. Mill.	Basal area of the sheath	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	–	*Spartina* spp.	–	[259]
Julella herbatilis Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[293]
Paraphaeosphaeria apicicola Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[167]
Paraphaeosphaeria pilleata	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[163]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Kohlm., Volkm.-Kohlm. and O.E. Erikss.					
Paraphaeosphaeria michotii (Westend.) O.E. Erikss.	–	–	*Elymus pungens*	UK	[263]
	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Pseudopithomyces atro-olivaceus (Cooke and Harkn.) G. Guevara, K.C. Cunha and Gené	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Pseudopithomyces chartarum (Berk. and M.A. Curtis) Jun F. Li, Ariyaw. and K.D. Hyde	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Pseudopithomyces maydicus (Sacc.) Jun F. Li, Ariyaw. and K.D. Hyde	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Spegazzinia tessarthra (Berk. and M.A. Curtis) Sacc.	Living leaves		*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Tremateia halophila Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower and middle parts of senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[157]
	–	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon	[277]
Lentitheciaceae					
Halobyssothecium estuariae B. Devadatha, Calabon, K.D. Hyde and E.B.G. Jones	Dead culm	Saprobic	*Phragmites australis*	UK: Pembrokeshire	[294]
Halobyssothecium obiones (P. Crouan and H. Crouan) Dayarathne, E.B.G. Jones and K.D. Hyde	Drift stems, attached and dead culms	Saprobic	*Spartina alterniflora*	India: Maharashtra, Tamil Nadu, Andhara Pradesh; USA: Maine, Rhode Island, Connecticut,	[18, 110, 132, 137, 138, 275, 291, 295, 296]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Massachusetts, New Jersey, Maryland, Virginia, North Carolina, South Carolina, Florida, Mississippi, Texas	
	–	–	*Spartina cynosuroides*	–	[18]
	Pod and rhizome	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	Culms	Saprobic	*Spartina* sp.	UK: England, Hampshire	[294, 297]
	Stem	Saprobic	*Spartina townsendii*	UK: Hampshire, Wales	[16, 273]
	–	Saprobic	*Spartina* spp.	USA: New Jersey, South Carolina; Mississippi,	[18, 259, 261, 281, 298]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Argentina: Buenos Aires	
	Stem, leaf sheaths, and blades	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282, 285]
	–	Saprobic	Unidentified saltmarsh plants	USA: Mississippi	[278, 281]
	–	–	*Elymus pungens*	–	[18]
	–	–	*Atriplex portulacoides*	–	[18]
	–	–	*Spartina townsendii*	–	[18]
Halobyssothecium phragmitis M.S. Calabon, E.B.G. Jones, S. Tibell and K.D. Hyde	Dead culm and stem	Saprobic	*Phragmites* sp.	Sweden: Gotland	[299]
Halobyssothecium versicolor M.S. Calabon, E.B.G. Jones and K.D. Hyde	Dead stem	Saprobic	*Atriplex portulacoides*	UK: Hampshire	[299]
Keissleriella culmifida (P. Karst.)	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
S.K. Bose					
Keissleriella linearis E. Müll. ex Dennis	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
	Dead culm	Saprobic	*Phragmites* sp.	Sweden: Gotland	[299]
Keissleriella phragmiticola Wanas., E.B.G. Jones and K.D. Hyde	Culms	Saprobic	*Phragmites australis*	UK: Wales	[294]
Keissleriella rara Kohlm., Volkm.- Kohlm. and O.E. Erikss.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[163]
Keissleriella spp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Lentithecium fluviatile (Aptroot and Van Ryck.) K.D. Hyde, J. Fourn. and Ying Zhang	Dead leaf sheaths	Saprobic	*Phragmites australis*	Belgium: East Flanders	[300]
	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
Setoseptoria arundinacea (Sowerby) Kaz. Tanaka and K.	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Hiray.	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
	–	Saprobic	*Spartina* sp.	USA: North Carolina, Florida	[132]
Setoseptoria phragmitis Quaedvl., Verkley and Crous	Culm	Saprobic	*Phragmites* sp.	Sweden: Södermanland	[301]
Towyspora aestuari Wanas., E.B.G. Jones and K.D. Hyde	–	–	*Phragmites australis*	UK: Wales	[302]
Leptosphaeriaceae					
Leptosphaeria albopunctata (Westend.) Sacc.	–	–	*Juncus maritimus*	–	[18]
	–	–	*Phragmites australis*	–	[18]
	Attached culms	-	*Spartina alterniflora*	USA: Rhode Island	[18, 110, 132, 138, 139, 261]
	–	–	*Spartina* spp.	Canada: Bay of Fundy; USA: New	[18, 261, 272, 303,

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Jersey, South Carolina; Argentina: Buenos Aires	304]
	Stem	Saprobic	*Spartina townsendii*	UK: Wales	[16, 18]
Leptosphaeria australiensis (Cribb and J.W. Cribb) G.C. Hughes	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Pod	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	–	*Spartina* spp.	–	[259]
Leptosphaeria culmifraga (Fr.) Ces. and De Not.	–	–	*Elymus pungens*	UK	[263]
Leptosphaeria littoralis Sacc.	–	–	*Elymus pungens*	UK	[263]
Leptosphaeria marina Ellis and Everh.	–	–	*Juncus roemerianus*		[18]
		Saprobic	*Spartina alterniflora*	USA: Maine, Rhode Island, Connecticut, New Jersey,	[18, 110, 132, 139, 261]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Delaware, Virginia, North Carolina, South Carolina	
	–	Saprobic	*Spartina* spp.	Canada; USA: New Jersey	[16, 18, 259, 261, 303–305]
	–	–	*Spartina townsendii*	UK	[18, 263]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve	[258, 282]
Leptosphaeria orae-maris Linder	–	–	*Arundo donax*	–	[18]
	–	Saprobic	*Lysimachia maritima*	USA: Massachusetts	[18, 306]
	–	Saprobic	*Spartina alterniflora*	USA: Massachusetts, Rhode Island, North Carolina, Florida, Texas	[110, 132, 261, 306]
	Rhizome	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	–	*Spartina* spp.	–	[259]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	Saprobic	*Spartina townsendii*	UK	[16, 18, 307]
Leptosphaeria pelagica E.B.G.	–	–	*Elymus pungens*	UK	[18, 263]
Jones	–	–	*Puccinellia maritima*	UK	[263]
	Decaying herbaceous stems, dead culms, decaying leaves	Saprobic	*Spartina alterniflora*	USA: Connecticut, Mississippi, Rhode Island; India: Goa, Karanataka	[137, 139, 261, 275, 278, 308]
	–	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	–	–	*Spartina townsendii*	UK	[263]
	–	–	*Spartina* spp.	UK	[16, 259]
	Sheath	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon	[277]
	Stem	Saprobic	*Spartina marítima*	Portugal: Alentejo	[285]
Leptosphaeria peruvianae Speg.	Decaying stems	Saprobic	*Sarcocornia perennis*	Argentina: Buenos	[275]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Aires; in temperate marine waters	
Leptosphaeria spp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Mississippi	[278]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	–	–	*Spartina alterniflora*	USA: Rhode Island	[291]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Centro	[282]
Leptosphaeria suaedae Hansf.	Dead twigs	Saprobic	*Suaeda australis*	South Australia	[309]
Lindgomycetaceae					
Arundellina typhae Wanas., E.B.G. Jones and K.D. Hyde	Dead stem	Saprobic	*Typha* sp.	UK: England	[310]
Lophiostomataceae					
Lophiostoma semiliberum (Desm.) Ces. and De Not.	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
Lophiostoma sp.	–	–	*Elymus pungens*	UK	[263]
Sigarispora arundinis (Pers.) Thambug., Qing Tian, Kaz.	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Tanaka and K.D. Hyde					
Massarinaceae					
Helminthosporium sp.	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
*Massarina carolinensi*s Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[163]
Massarina igniaria (C. Booth) Aptroot	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Massarina phragmiticola Poon and K.D. Hyde	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Massarina ricifera Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower parts of senescent culms, decaying leaves	Saprobic	*Juncus roemerianus*	USA: Alabama, Mississippi, North Carolina	[161, 278, 281]
Massarina spp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Stagonospora abundata Kohlm.	Senescent leaves and bracts	Saprobic	*Juncus roemerianus*	USA: Florida,	[159]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
and Volkm.-Kohlm.				Georgia, North Carolina	
Stagonospora cylindrica Gunnell	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
Stagonospora elegans (Berk.) Sacc. and Traverso	Living/decomposing leaf sheaths, stems, culms	Saprobic	*Phragmites australis*	Australis; Netherlands: Zeeland	[264, 265, 309]
Stagonospora epicalamia (Cooke)–Sacc.	–	–	*Phragmites australis*	Australia	[309]
Stagonospora haliclysta Kohlm.	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve	[282]
Stagonospora spp.	Living and senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Hong Kong: New Territories; Netherlands: Zeeland	[264–266, 274]
	Senescent and dead leaves/inflorescence, living and dead seeds, decaying leaf blades	Saprobic, pathogenic	*Spartina alterniflora*	Canada; USA: Maine, Rhode Island, Georgia, Connecticut, New Jersey, Virginia, Florida, North	[18, 139, 261, 279, 291]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Carolina; Argentina: Buenos Aires	
	–	Pathogenic	*Spartina cynosuroides*	USA: Maryland	[268]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[18, 261]
	–	Saprobic	*Spartina* spp.	Canada	[18, 261]
	Leaf sheaths and blades, stem, limb	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282]
Stagonospora suaedae Syd. and P. Syd. Melanommataceae	Leaves	–	*Suaeda marítima*	Germany	[311]
Aposphaeria spp.	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Bicrouania maritima (P. Crouan and H. Crouan) Kohlm. and Volkm.-Kohlm. Morosphaeriaceae	Dead stems	Saprobic	*Atriplex portulacoides*	India	[18, 275]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Helicascus kanaloanus Kohlm.	–	–	*Spartina* spp.	–	[259]
Neocamarosporiaceae					
Neocamarosporium artemisiae Dayarathne and E.B.G. Jones	–	Saprobic	*Artemisia maritima*	Sweden: Bohuslän	[6]
Neocamarosporium maritimae Dayarathne and E.B.G. Jones	–	Saprobic	*Artemisia maritima*	Sweden: Bohuslän	[6]
Neocamarosporium obiones (Jaap) Wanas. and K.D. Hyde	–	–	*Atriplex portulacoides*	–	[18]
Neocamarosporium phragmitis D.N. Wanasinghe, E.B.G. Jones and K.D. Hyde	Decaying culms	Saprobic	*Phragmites australis*	UK	[312]
Neocamarosporium salicorniicola Dayar., E.B.G. Jones and K.D. Hyde	Dead stems	Saprobic	*Salicornia* sp.	Thailand	[313]
Periconiaceae					
Periconia cookei E.W. Mason and M.B. Ellis	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Periconia digitata (Cooke) Sacc.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Periconia digitata (Cooke) Sacc.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Periconia echinochloae (Bat.) M.B. Ellis	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Periconia minutissima Corda	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Periconia sp.	–	Saprobic	Unidentifed saltmarsh plants	USA: Mississippi	[281]
Phaeosphaeriaceae					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Amarenomyces ammophilae (Lasch) O.E. Erikss.	–	–	*Ammophila arenaria*	–	[18]
	–	–	× *Ammocalamagrostis baltica*	–	[18]
	–	–	*Uniola paniculata*	–	[18]
Amphisphaeria culmicola Sacc.	Stem		*Spartina townsendii*	UK: England	[273]
Camarosporioides phragmitis W.J. Li and K.D. Hyde	Dead stem	Saprobic	*Phragmites australis*	Germany	[310]
Hendersonia culmiseda Sacc.	Living/decomposing leaf blades	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[274]
	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
	–	–	*Spartina townsendii*	UK	[314]
Hendersonia spp.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland; USA: Florida	[264, 267, 274]
Loratospora aestuarii Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[315]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Loratospora aestuarii Kohlm. and Volkm.-Kohlm.	–	Saprobic	Unidentified saltmarsh plants	USA: Mississippi	[281]
Ophiobolus littoralis (P. Crouan and H. Crouan) Sacc.	–	–	*Elymus pungens*	UK	[263]
Phaeoseptoria sp.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Phaeosphaeria anchiala Kohlm., Volkm.-Kohlm. and C.K.M. Tsui	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida, Georgia, Maryland, North Carolina, Virginia	[316]
Phaeosphaeria caricinella (P. Karst.) O.E. Erikss.	–	–	*Spartina* sp.	USA: Florida, North Carolina	[132]
Phaeosphaeria culmorum (Auersw.) Leuchtm.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Phaeosphaeria eustoma (Fuckel) L. Holm	Living/decomposing leaf blades and sheaths, stems, culms	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274, 309]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Phaeosphaeria fuckelii (Niessl) L. Holm	–	–	*Elymus pungens*	UK	[263]
Phaeosphaeria gessneri Shoemaker and C.E. Babc.	–	–	*Spartina* spp.	–	[259]
Phaeosphaeria halima (T.W. Johnson) Shoemaker and C.E. Babc.	Dead culms; Decaying leaves, leaf blades	Saprobic	*Spartina alterniflora*	India: Kerala; USA: California, Georgia, Mississippi, Vancouver, North Carolina	[18, 110, 132, 252, 275, 278–281]
	Decaying leaf blades	Saprobic	*Spartina densiflora*	USA: California	[252]
			Spartina spp.		[259]
	Decaying leaves	Saprobic	*Spartina foliosa*	USA: California	[252]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve, Centro	[258]
Phaeosphaeria herpotrichoides (De Not.) L. Holm	–	–	*Spartina patens*	USA: North Carolina, Florida	[132]
Phaeosphaeria juncina (Auersw.)	–	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
L. Holm					
Phaeosphaeria luctuosa (Niessl ex Sacc.) Y. Otani and Mikawa	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
	–	–	*Elymus pungens*	UK	[263]
Phaeosphaeria macrosporidium (E.B.G. Jones) Shoemaker and C.E. Babc.	Decaying stems	Saprobic	*Spartina sp*	UK: Wales, England	[16]
	Stem	Saprobic	*Spartina marítima*	Portugal: Lisbon	[277, 285]
Phaeosphaeria microscopica (P. Karst.) O.E. Erikss.	–	–	*Elymus pungens*	UK	[263]
Phaeosphaeria neomaritima (R.V. Gessner and Kohlm.) Shoemaker and C.E. Babc.	–	–	*Juncus maritimus*	–	[18]
	–	–	*Juncus roemerianus*	–	[18]
	–	Saprobic	*Juncus sp.*	Canada; India: Maharashtra, Karnataka; USA: Virginia, North	[110, 132, 261, 275]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Carolina	
	–	–	*Spartina alterniflora*	–	[18]
	–	Saprobic	*Spartina* spp.	Canada; USA: North Carolina, Virginia	[110, 132, 259]
	–	–	*Spartina townsendii*	UK	[18, 307]
	Stem	Saprobic	*Spartina marítima*	Portugal: Alentejo	[285]
Phaeosphaeria nigrans (Roberge ex Desm.) L. Holm	–	–	*Elymus pungens*	UK	[263]
Phaeosphaeria olivacea Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina, Mississippi	[281, 293]
Phaeosphaeria pontiformis (Fuckel) Leuchtm.	–	–	*Elymus pungens*	UK	[263]
	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
Phaeosphaeria roemeriani Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Mississippi, North Carolina	[278, 281, 283]
Phaeosphaeria spartinae (Ellis	–	Saprobic	*Spartina* spp.	India: Kerala	[259, 275]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
and Everh.) Shoemaker and C.E. Babc.	Decaying herbaceous stems and pod	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	Saprobic	*Spartina marítima*	Portugal: Lisbon	[277]
Phaeosphaeria spartinicola	–	Saprobic	*Juncus sp.*	India	[275]
Leuchtm.	Dead leaves, decaying leaf blades	Saprobic	*Spartina alterniflora*	Mexico; USA: Alabama, California, Georgia, Mississippi; Canada: Nova Scotia, New Brunswick	[252, 261, 278–281]
	Pod, leaf blades	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires; USA: California	[252, 286]
	–	–	*Spartina* spp.	–	[259]
	Leaf blades	Saprobic	*Spartina foliosa*	USA: California	[252]
	Leaf sheaths and blades, stem, limb	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282, 285]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Phaeosphaeria spp.	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
	–	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[291]
Sclerostagonospora sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Septoriella phragmitis Oudem.	Living/decomposing leaf sheaths and stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Septoriella spp.	Decaying stems and leaf sheaths and blades, stems	Saprobic	*Phragmites australis*	Hong Kong: New Territories; Netherlands: Zeeland	[264–266, 274]
Septoriella thalassica (Speg.) Nag–Raj	–	–	*Distichlis spicata*	–	[18]
			Distichlis spicata		[18]
Septoriella unigalerita Kohlm. and Volkm.-Kohlm.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[159]
Septoriella vagans (Niessl) Y. Marín and Crous	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Puccinellia maritima*	UK	[263]
	–	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[291]
Pleomassariaceae					
Splanchnonema sp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Pleosporaceae					
Alternaria alternata (Fr.) Keissl.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 266, 274]
	–	Saprobic	*Spartina alterniflora*	USA: North Carolina	[291]
	Leaves, stems, and roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Alternaria infectoria E.G.	–	–	*Elymus pungens*	UK	[263]
Simmons	Living/decomposing leaf	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	Sheaths				
Alternaria longissima Deighton and MacGarvie	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Alternaria maritima G.K. Sutherl.	Stem	Saprobic, pathogenic	*Spartina townsendii*	UK: England	[273]
Alternaria spp.	–	–	*Atriplex portulacoides*	–	[18]
	–	–	*Juncus roemerianus*	–	[18]
	–	–	*Salsola kali*	–	[18]
	Inflorescence and upper leaves	Saprobic, parasitic	*Spartina alterniflora*	USA: Rhode Island	[18, 138]
	Culms	Saprobic	*Spartina* sp.	Thailand	This study
	–	–	*Spartina townsendii*	–	[18]
Bipolaris cynodontis (Marignoni) Shoemaker	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Curvularia hawaiiensis (Bugnic. ex M.B. Ellis) Manamgoda, L. Cai and K.D. Hyde	Living and senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Curvularia protuberata R.R. Nelson and Hodges	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Curvularia spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	–	Saprobic	*Spartina altrerniflora*	USA: North Carolina	[291]
Curvularia tuberculata B.L. Jain	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Decorospora gaudefroyi (Pat.) Inderb., Kohlm. and Volkm.-Kohlm.	Stems	Saprobic	*Atriplex* sp.	UK: Portsmouth	[317]
	–	–	*Atriplex portulacoides*	–	[18]
	–	–	*Sarcocornia perennis*	–	[18]
	–	–	*Sarcoconia fructicosa*	–	[18]
	–	–	*Salicornia europaea*	–	[18]
	–	–	*Salicornia* sp.	–	[18]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve	[282]
	–	–	*Suaeda maritima*	–	[18]
Drechslera sp.	Living, senescent, and	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	decaying leaves				
Exserohilum rostratum (Drechsler) K.J. Leonard and Suggs	–	–	*Distichlis spicata*	–	[18]
	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Senescent and dead leaves	Saprobic	*Spartina alterniflora*	USA: Rhode Island, North Carolina, Florida	[18, 139, 261]
	–	–	*Spartina* spp.	–	[259]
Paradendryphiella arenariae (Nicot) Woudenb. and Crous	Decomposing culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 138]
	–	–	*Spartina* spp.	–	[259]
Paradendryphiella salina (G.K. Sutherl.) Woudenb. and Crous	–	–	*Atriplex portulacoides*	–	[18]
	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	–	–	*Puccinellia maritima*	–	[18]
	–	–	*Salicornia europaea*	–	[18]
	Decomposing culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 138]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Spartina* spp.	–	[259]
	–	–	*Spartina townsendii*	–	[18]
	Leaves and stems	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
	–	–	*Suaeda maritima*	–	[18]
Pleospora abscondita Sacc. and Roum.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Pleospora pelagica T.W. Johnson	Decomposing culms; decaying leaf blades	Saprobic	*Spartina alterniflora*	India: Maharashtra, Kerala; USA: Georgia, Rhode Island, North Carolina, Florida	[18, 110, 132, 139, 261, 275, 279, 291]
	Decaying leaf blades	Saprobic	*Spartina densiflora*	USA: California	[252]
		Saprobic	*Spartina* spp.	USA: South Carolina	[259, 261]
			Typha sp.		[18]
Pleospora pelvetiae G.K. Sutherl.	–	Saprobic	Unidentifed saltmarsh plants	USA: Mississippi	[281]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Pleospora spp.	–	–	*Salicornia virginica*	–	[18]
	Dead leaves/culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[138]
Pleospora spartinae (J. Webster and M.T. Lucas) Apinis and Chesters	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
	Stem	Saprobic	*Spartina* spp.	Canada: Bay of Fundy	[259, 272]
	–	–	*Spartina townsendii*	UK	[18, 263, 318]
Pleospora straminis Sacc. and Speg.	–	–	*Elymus pungens*	UK	[263]
Pleospora vagans Niessl var. *vagans*	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
	Dead culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[139]
Pyrenophora tritici-repentis (Died.) Drechsler	–	–	*Elymus pungens*	UK	[263]
Stemphylium botryosum Wallr.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos	[271]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Stemphylium botryosum Wallr.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Stemphylium lycopersici (Enjoji) W. Yamam.	Living leaves	–	*Juncus roemerianus*	USA: Florida	[267]
Stemphylium maritimum T.W. Johnson	–	Saprobic	*Spartina* sp.	UK	[16]
Stemphylium spp.	–	–	*Salsola kali*	–	[18]
	Leaves	Saprobic	*Spartina* spp.	Canada: Bay of Fundy	[18, 272]
Stemphylium vesicarium (Wallr.) E.G. Simmons	–	–	*Elymus pungens*	UK	[263]
	Living, senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	–	Saprobic	*Lysimachia maritima*	USA: Massachusetts	[306]
	–	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[138]
	Glumes, rachis	–	*Spartina townsendii*	UK: England	[263, 273]
			Spartina sp.	UK	[16]
Stemphylium triglochinicola B.	–	–	*Triglochin maritima*	Sweden:	[18, 301]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Sutton and Piroz.				Västergötland	
	Dead leaves and inflorescences	Saprobic	*Triglochin sp.*	India: Kerala; UK	[275, 319]
Typhicola typharum (Desm.) Crous	Senescent and dead leaves	Saprobic, pathogenic	*Spartina alterniflora*	Canada; USA: Maine, Rhode Island, Connecticut, New Jersey, Virginia, North Carolina, Florida	[18, 138, 139, 261, 291]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	–		*Spartina tonwsendii*	UK	[263]
	–	Saprobic	*Spartina* spp.	Argentina: Buenos Aires; Canada; USA: Maine	[18, 261]
	Stems	Saprobic	*Spartina townsendii*	UK: England	[16, 18, 273]
Pleosporales genera *incertae sedis*					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Phialophorophoma litoralis Linder	Stem and sheath	Saprobic	*Spartina marítima*	Portugal: Alentejo, Lisbon	[277, 285]
Phialophorophoma spp.	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Pyrenochaeta sp.	Living leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Scolecobasidium humicola G.L. Barron and L.V. Busch	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Roussoellaceae					
Cytoplea sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Sporormiaceae					
Preussia funiculata (Preuss) Fuckel	–	–	*Spartina townsendii*	UK	[263]
Preussia terricola Cain	–	–	*Elymus pungens*	UK	[263]
Sporormia longipes Massee and E.S. Salmon	–	–	*Elymus pungens*	UK	[263]
Sporormia sp.	Senescent and decaying	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	leaves				
Sporormiella intermedia (Auersw.) S.I. Ahmed and Cain ex Kobayasi	–	–	*Elymus pungens*	UK	[263]
Sporormiella lageniformis (Fuckel) S.I. Ahmed and Cain	–	–	*Spartina townsendii*	UK	[263]
Sporormiella minima (Auersw.) S.I. Ahmed and Cain	–	–	*Elymus pungens*	UK	[263]
	–	–	*Spartina townsendii*	UK	[263]
Teichosporaceae					
Teichospora striata (Kohlm. and Volkm.-Kohlm.) Jaklitsch and Voglmayr	Senescent leaves and inflorescences	Saprobic	*Juncus roemerianus*	USA: North Carolina, Virginia	[159]
Teichospora suaedae Speg.	Dead branches	Saprobic	*Suaeda divaricata*	Argentina: Mendoza	[320]
Testudinaceae					
Verruculina enalia (Kohlm.) Kohlm. and Volkm.-Kohlm.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Tetraplosphaeriaceae					
Tetraploa aristata Berk. and Broome	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Torulaceae					
Torula herbarum (Pers.) Link	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Trematosphaeriaceae					
Halomassarina thalassiae (Kohlm. and Volkm.-Kohlm.) Suetrong, Sakay., E.B.G. Jones, Kohlm., Volkm.-Kohlm. and C.L. Schoch	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
EUROTIOMYCETES					
Chaetothyriales					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Herpotrichiellaceae					
Rhinocladiella spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Veronaea sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Eurotiales					
Aspergillaceae					
Aspergillus fumigatus Fresen.	–	–	*Elymus pungens*	UK	[263]
Aspergillus nidulans (Eidam) G.	–	–	*Elymus pungens*	UK	[263]
Winter	–	–	*Spartina townsendii*	UK	[263]
Aspergillus niger Tiegh.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Aspergillus spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	–	–	*Spartina townsendii*	UK: England	[273]
Monascus purpureus Went	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Penicillium aurantiogriseum Dierckx	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Penicillium brevicompactum Dierckx	Roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Penicillium chrysogenum Thom	Roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Penicillium lividum Westling	Leaves and stems	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Penicillium spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	–	–	*Spartina townsendii*	UK: England	[273]
Thermoascaceae					
Thermoascus crustaceus (Apinis and Chesters) Stolk	–	–	*Elymus pungens*	UK	[263]
Paecilomyces spp.	Senescent and decaying	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	leaves				
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	–	Saprobic	Salt marsh plants	India: Goa	[275]
Trichocomaceae					
Thermomyces dupontii (Griffon and Maubl.) Houbraken and Samson	–	–	*Elymus pungens*	UK	[263]
Onygenales					
Onygenaceae					
Amauroascus albicans (Apinis) Arx	–	–	*Elymus pungens*	UK	[263]
Amauroascus albicans (Apinis) Arx	–	–	*Spartina townsendii*	UK	[263]
LECANOROMYCETES					
Ostropales					
Stictidaceae					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Glomerobolus gelineus Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[164]
Stictis sp.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
LEOTIOMYCETES					
Helotiales					
Amorphothecaceae					
Amorphotheca resinae Parbery	Roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Calloriaceae					
Cistella fugiens (W. Phillips) Matheis	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
Helotiaceae					
Cyathicula culmicola (Desm.) De Not.	–	–	*Elymus pungens*	UK	[263]
Helotium sp.	–	–	*Elymus pungens*	UK	[263]
Lachnaceae					
Brunnipila palearum (Desm.)	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Baral					
	–	–	*Spartina townsendii*	UK	[263]
Lachnum controversum (Cooke) Rehm	–	–	*Elymus pungens*	UK	[263]
Lachnum spartinae S.A. Cantrell	Decaying leaf sheaths	Saprobic	*Spartina alterniflora*	USA: Georgia	[279, 321]
	–	–	*Spartina* spp.	–	[259]
Mollisiaceae					
Belonopsis atriella (Cooke) Lindau	–	–	*Spartina cynosuroides*	USA: Louisiana	[288, 304, 322]
Mollisia hydrophila (P. Karst.) Sacc.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Mollisia palustris (P. Karst.) P. Karst.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Trichobelonium kneiffii (Wallr.) J. Schröt.	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Ploettnerulaceae					
Cadophora melinii Nannf.	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of	[272]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Fundy	
Sclerotiniaceae					
Botrytis cinerea Pers.	Stem		*Spartina townsendii*	UK: England	[273]
	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Monilia sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Solenopeziaceae					
Halenospora varia (Anastasiou)	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
E.B.G. Jones	Basal area of the sheath	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	–	*Spartina* spp.	–	[259]
Helotiales genera *incertae sedis*					
Cejpia hystrix (De Not.) Baral	–	–	*Elymus pungens*	UK	[263]
Dactylaria sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Crocicreas gramineum (Fr.) Fr.	–	–	*Elymus pungens*	UK	[263]
Leotiales					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Leotiales genera *incertae sedis*					
Flagellospora sp.	Living leaves	–	*Juncus roemerianus*	USA: Florida	[267]
Rhytismatales					
Rhytismataceae					
Lophodermium arundinaceum	–	–	*Elymus pungens*	UK	[263]
(Schrad.) Chevall.	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Thelebolales					
Thelebolaceae					
Thelebolus crustaceus (Fuckel)	–	–	*Elymus pungens*	UK	[263]
Kimbr.	–	–	*Puccinellia maritima*	UK	[263]
	–	–	*Spartina townsendii*	UK	[263]
ORBILIOMYCETES					
Orbiliales					
Orbiliaceae					
Arthrobotrys conoides Drechsler	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Arthrobotrys sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Orbilia junci Kohlm., Baral and Volkm.-Kohlm.	Tips of senescent leaves	–	*Juncus roemerianus*	USA: North Carolina	[323]
PEZIZOMYCETES					
Pezizales					
Pezizaceae					
Belonium heteromorphum (Ellis and Everh.) Seaver	–	–	*Spartina cynosuroides*	USA: Louisiana	[288, 324]
SACCHAROMYCETES					
Saccharomycetales					
Debaryomycetaceae					
Debaryomyces hansenii (Zopf) Lodder and Kreger-van Rij	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Louisiana	[279]
Scheffersomyces spartinae (Ahearn, Yarrow and Meyers) Kurtzman and M. Suzuki	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Louisiana	[279]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Saccharomycetaceae					
Kluyveromyces lactis (Stell.-Dekk.) Van der Walt	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Louisiana	[279]
SORDARIOMYCETES					
Amphisphaeriales					
Amphisphaeriaceae					
Massariella sp.	–	–	*Spartina townsendii*	UK	[263]
Ommatomyces coronatus Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower parts of senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[161]
Pestalotia sp.	Living, senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Apiosporaceae					
Arthrinium arundinis (Corda) Dyko and B. Sutton	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
	Dead culms	Saprobic	*Phragmites* sp.	South Australia	[284]
Arthrinium phaeospermum (Corda) M.B. Ellis	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[138]
	Inflorescence and upper leaves	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[261]
Arthrinium spp.	Living leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Nigrospora oryzae (Berk. and Broome) Petch	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Beltraniaceae					
Beltrania querna Harkn.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Hyponectriaceae					
Phragmitensis ellipsoidea M.K.M. Wong, Goh and K.D. Hyde	Intertidal to aerial culms	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[325]
Phragmitensis marina M.K.M.	Decaying stems and leaf	Saprobic	*Phragmites australis*	Hong Kong: New	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Wong, Poon and K.D. Hyde	sheaths			Territories	
Physalospora citogerminans Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower and upper parts of senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[162]
Sporocadaceae					
Discostroma sp.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Pestalotiopsis juncestris Kohlm. and Volkm.-Kohlm.	Senescent involucral leaves and culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[326]
Pestalotiopsis planimi (Vize) Steyaert	–	–	*Spartina alterniflora*	USA: Rhode Island	[138]
Pestalotiopsis sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Coronophorales					
Ceratostomataceae					
Melanospora sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Microthecium fimicola (E.C.	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Hansen) Y. Marín, Stchigel, Guarro and Cano					
Microthecium levitum Udagawa and Cain	Dead leaves/culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[138]
Coronophorales genera *incertae sedis*					
Papulaspora halima Anastasiou	Living and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Papulosa amerospora Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[327]
Diaporthales					
Diaporthaceae					
Phomopsis spp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	–	–	*Spartina* sp.	–	[132]
Gnomoniaceae					
Gnomonia salina E.B.G. Jones	–	Saprobic	*Spartina alterniflora*	USA: Connecticut	[261]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
(*probably a nomen dubium and possibly a Halosarpheia species)*			*Spartina* spp.		[18, 259]
	–	–	*Spartina townsendii*	UK	[16, 18]
Diaporthales *incertae sedis*					
Botryodiplodia sp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Glomerellales					
Glomerellaceae					
Colletotrichum sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Plectosphaerellaceae					
Stachylidium bicolor Link	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Hypocreales					
Bionectriaceae					
Acremonium spp.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Living, senescent, and	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	decaying leaves				
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Clonostachys rosea (Link) Schroers, Samuels, Seifert and W. Gams	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Fusariella obstipa (Pollack) S. Hughes	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Gliomastix spp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Hydropisphaera arenula (Berk. and Broome) Rossman and Samuels	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Hydropisphaera erubescens (Roberge ex Desm.) Rossman	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
	–	–	*Spartina* spp.	–	[259]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
and Samuels					
Clavicipitaceae					
Atkinsonella hypoxylon (Peck) Diehl	–	–	*Spartina cynosuroides*	–	[288]
Claviceps purpurea (Fr.) Tul.	–	Saprobic	*Phragmites australis*	UK: England (Southampton Hampshire, Sussex, Oxon)	[328, 329]
	Replaced seeds in the inflorescence, ovaries of the flowers	Saprobic, parasitic	*Spartina alterniflora*	USA: Rhode Island; Argentina	[138, 139, 261, 288, 330, 331]
	–	Pathogenic	*Spartina anglica*	UK	[332]
	–	Saprobic, parasitic	*Spartina cynosuroides*	USA: New York, Florida, Mississippi	[268, 288, 330, 333]
			Spartina patens	USA: Maryland, Mississippi	[268, 288, 333, 334]
	–	–	*Spartina townsendii*	UK: England	[329, 335]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Spartina* sp.	Argentina	[331]
Claviceps sp.	–	–	*Spartina foliosa*	USA: California	[336]
Metarhizium anisopliae (Metschn.) Sorokīn	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Hypocreaceae					
Cladobotryum sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Gliocladium sp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Trichoderma citrinum (Pers.) Jaklitsch, W. Gams and Voglmayr	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Trichoderma sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Trichoderma viride Pers.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Nectriaceae					
Calonectria sp.	–	–	*Elymus pungens*	UK	[263]
Fusarium fujikuroi Nirenberg	–	Saprobic	*Suaeda australis*	South Australia	[284]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Fusarium graminearum Schwabe	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Fusarium heterosporum Nees and T. Nees	–	–	*Spartina maritima*	–	[337]
Fusarium incarnatum (Desm.) Sacc.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Fusarium oxysporum Schltdl.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Leaves and roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Fusarium poae (Peck) Wollenw.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Fusarium solani (Mart.) Sacc.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Fusarium spp.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	Living, senescent, and	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	decaying leaves				
	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Hong Kong: New Territories; Netherlands: Zeeland	[264–266]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve	[282]
Gibberella sp.	–	Saprobic	*Spartina alterniflora*	Argentina: Buenos Aires	[261]
Nectria sp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Tubercularia pulverulenta Speg.	–	–	*Sarcocornia perennis*	–	[18]
	–	–	*Salicornia europaea*	–	[18]
	–	Saprobic	Unidentifed saltmarsh plants	USA: Mississippi	[281]
	–	–	*Sarcocornia fruticosa*	–	[18]
Tubercularia sp.	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
Volutella ciliata (Alb. and Schwein.) Fr.	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Sarocladiaceae					
Sarocladium implicatum (J.C. Gilman and E.V. Abbott) A. Giraldo, Gené and Guarro	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Sarocladium sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Stachybotryaceae					
Albifimbria verrucaria (Alb. and Schwein.) L. Lombard and Crous	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Paramyrothecium roridum (Tode) L. Lombard and Crous	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Stachybotrys chartarum (Ehrenb.) S. Hughes	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Stachybotrys cylindrosporus C.N. Jensen	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Stachybotrys echinatus (Rivolta) G. Sm.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Stachybotrys kampalensis Hansf.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Stachybotrys nephrosporus Hansf.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Stachybotrys spp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
Striaticonidium cinctum (Corda) L. Lombard and Crous	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Xepicula jollymannii (N.C. Preston) L. Lombard and Crous	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Hypocreales genera *incertae sedis*					
Cephalosporium spp.	Dead leaves/culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[138]
Lulworthiales					
Lulworthiaceae					
Cumulospora marina I. Schmidt	Dead culm	Saprobic	*Phragmites australis*	Iraq, Egypt, Germany,	[338]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Thailand	
	–	–	*Spartina* spp.	–	[259]
Halazoon fuscus (I. Schmidt) Abdel-Wahab, K.L. Pang, Nagah., Abdel-Aziz and E.B.G. Jones	Decaying rhizomes	Saprobic	*Phragmites australis*	France, Germany, Japan	[18, 339]
	Rhizomes and culms	Saprobic	*Phragmites* sp.	Sweden	[301]
Halazoon melhae Abdel-Aziz, Abdel-Wahab and Nagahama	Decaying stem	Saprobic	*Phragmites australis*	Egypt: Port Said	[339]
Lulworthia floridana Meyers	–	Saprobic	*Spartina alterniflora*	USA: North Carolina, Rhode Island	[137, 340]
*Lulworthia medus*a (Ellis and Everh.) Cribb and J.W. Cribb	–	–	*Elymus pungens*	UK	[263]
	–	Saprobic	*Spartina cynosuroides*	USA: New Jersey	[303, 341]
	–		*Spartina* spp.	USA: New Jersey	[259, 303]
	Stems	Saprobic	*Spartina townsendii*	UK: England (Wales); USA: Virginia, North Carolina, South	[111, 125, 132, 263, 273,

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Carolina, Florida, Texas	303, 341, 342]
Lulworthia spp.	–	–	*Elymus pungens*	–	[18]
	–	–	*Juncus roemerianus*	–	[18, 261]
	Dead culms	Saprobic	*Spartina alterniflora*	Argentina: Buenos Aires; USA: Rhode Island, North Carolina	[18, 138, 139, 261, 291]
	–	–	*Spartina cynosuroides*	–	[18]
	–	Saprobic	*Spartina* sp.	Argentina: Buenos Aires; Canada; USA: Maine, North Carolina	[261]
	–	–	*Spartina townsendii*	–	[18]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282, 285]
Moleospora maritima Abdel-Wahab, Abdel-Aziz and Nagah. Magnaporthales Ceratosphaeriaceae	Decayed stems	Saprobic	*Phragmites australis*	Egypt: Port Said	[339]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Ceratosphaeria sp. Magnaporthaceae	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Buergenerula spartinae Kohlm. and R.V. Gessner	Lower stem and leaf sheath during the growth phase of the plant/living and dead; decaying leaf blades	Saprobic, parasitic	*Spartina alterniflora*	USA: Alabama, Rhode Island, Maine, New Hampshire, Connecticut, Mississippi, New Jersey, Virginia, North Carolina, Florida, Georgia	[18, 137, 306, 138, 139, 261, 278, 279, 281, 291, 296]
	Leaves	Saprobic	*Spartina* spp.	Canada: Bay of Fundy; USA: South Carolina; UK	[16, 18, 259, 261, 272], this study
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282]
Gaeumannomyces sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Kohlmeyeriopsis medullaris (Kohlm., Volkm.-Kohlm. and O.E. Erikss.) Klaubauf, M.-H. Lebrun and Crous	Lower parts of senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[158, 161]
Utrechtiana roumeguerei (Cavara) Videira and Crous	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Pseudohalonectriaceae					
Pseudohalonectria falcata Shearer	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Pseudohalonectria halophila Kohlm. and Volkm.-Kohlm.	Fragments of leaves and culms in the wrack	Saprobic	*Juncus roemerianus*	USA: North Carolina	[316]
Meliolales					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Meliolaceae					
Meliola arundinis Pat.	–	–	*Phragmites australis*	Australia: Queensland	[284]
Microascales					
Halosphaeriaceae					
Aniptodera chesapeakensis Shearer and M.A. Mill.	Dead leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[18]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	–	–	*Spartina alterniflora*	–	[18]
	–	–	*Spartina* spp.	–	[259]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Alentejo, Algarve, Centro	[282, 285]
Aniptodera juncicola Volkm.-Kohlm. and Kohlm.	Dead standing culms of	Saprobic	*Juncus roemerianus*	India: Kerala, West Bengal, Tamil Nadu; USA: North Carolina	[275, 343]
Aniptodera phragmiticola O. K. Poon et K. D. Hyde	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Ceriosporopsis halima Linde	–	–	*Arundo donax*	–	[18]
	Submerged seeds	Saprobic	*Spartina alterniflora*	USA	[140]
	–	–	*Spartina* spp.	–	[259]
	–	–	*Spartina townsendii*	UK	[18, 263]
	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Cirrenalia macrocephala	–	–	*Ammophila arenaria*	–	[18]
(Kohlm.) Meyers and R.T. Moore	Decaying culms	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decomposing culms, submerged seeds	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 138, 140]
	–	–	*Spartina* spp.	–	[259]
	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Cirrenalia pseudomacrocephala Kohlm.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Corollospora maritima Werderm.	Submerged seeds, decomposing culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 137, 138, 140]
	–	–	*Spartina* spp.	–	[259]
	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	Saprobic	Unidentified saltmarsh plants	USA: Mississippi	[281]
Corollospora ramulosa (Meyers and Kohlm.) E.B.G. Jones and Abdel-Wahab	–	Saprobic	Unidentifed saltmarsh plants	USA: Mississippi	[281]
	–	Saprobic	*Zostera marina*	USA: North Carolina	[291]
Haligena elaterophora Kohlm.	–	–	*Spartina alterniflora*	–	[18]
	–	–	*Spartina tonwsendii*	UK	[263]
	–	–	*Spartina* spp.	–	[259]
Halosarpheia culmiperda Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower parts of senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[161]
Halosarpheia sp.	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Halosarpheia viscosa I. Schmidt ex Shearer and J.L. Crane	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
	–	Saprobic	*Spartina maritima*	Portugal: Lisbon	[277]
Halosphaeria appendiculata Linder	–	–	*Arundo donax*	–	[18]
Halosphaeria sp.	Submerged seeds	Saprobic	*Spartina alterniflora*	USA	[140]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Lautisporopsis circumvestita (Kohlm.) E.B.G. Jones, Yusoff and S.T. Moss	–	–	*Arundo donax*	–	[18]
Lignincola laevis Höhnk	–	–	*Elymus pungens*	–	[18]
	–	Saprobic	*Spartina* spp.	USA: North Carolina	[259, 344]
	–	–	*Spartina townsendii*	–	[18]
	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Magnisphaera spartinae (E.B.G. Jones) J. Campb., J.L. Anderson and Shearer	–	–	*Elymus farctus*	–	[18]
	–	–	*Elymus pungens*	–	[18]
	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
	–	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 137, 138]
	–		*Spartia* spp.		[259]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	Stem	Saprobic	*Spartina townsendii*	UK: Wales	[18, 124]
	–		*Typha* sp.		[18]
Nais inornata Kohlm.	Decomposing culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 137,

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
					138]
	–		*Spartina* spp.		[259]
Natantispora unipolaris K.L. Pang, S.Y. Guo and E.B.G. Jones	Dead stem	Saprobic	*Phragmites australis*	Taiwan: Nankunshen	[345]
Natantispora retorquens (Shearer and J.L. Crane) J. Campb., J.L. Anderson and Shearer	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Alentejo, Lisbon, Algarve, Centro	[258, 277, 282, 285]
Oceanitis unicaudata (E.B.G. Jones and Camp.-Als.) J. Dupont and E.B.G. Jones	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Panorbis viscosus (I. Schmidt) J. Campb., J.L. Anderson and Shearer	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Alentejo, Algarve	[282, 285]
Remispora hamata (Höhnk) Kohlm.	–	–	*Elymus pungens*	UK	[18, 263]
	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265,

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	blades and sheaths, stems				274]
	–	Saprobic	*Phragmites* sp.	Sweden	[301]
	Dead leaves	Saprobic	*Spartina alterniflora*	USA: Rhode Island, Maine, Florida	[18, 137–139, 261]
	–	Saprobic	*Spartina patens*	USA: Rhode Island	[261]
	–	Saprobic	*Spartina* sp.	USA: North Carolina; Argentina: Buenos Aires	[261, 344]
	–	–	*Spartina townsendii*	–	[18]
	–	–	*Typha* sp.	–	[18]
Remispora trullifera Kohlm.	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Centro	[282]
Tirispora unicaudata E.B.G. Jones and Vrijmoed	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Microascaceae					
Scopulariopsis spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Myrmecridiales					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Myrmecridiaceae					
Myrmecridium schulzeri (Sacc.) Arzanlou, W. Gams and Crous	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Ophiostomatales					
Ophiostomataceae					
Sporothrix sp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Phomatosporales					
Phomatosporaceae					
Phomatospora bellaminuta Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower parts of senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[162]
Phomatospora berkeleyi Sacc.	Living/decomposing leaf blades and sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265, 274]
Phomatospora dinemasporium J. Webster	Decaying stems and leaf sheaths, stems	Saprobic	*Phragmites australis*	Hong Kong: New Territories; Netherlands: Zeeland	[265, 266]
	Dead leaves	Saprobic	*Phragmites* sp.	South Australia	[284]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Spartina townsendii*	UK	[263]
Phomatospora phragmiticola Poon and K.D. Hyde	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Phomatospora spp.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Phyllachorales					
Phyllachoraceae					
Phyllachora graminis (Pers.) Fuckel	–	–	*Elymus pungens*	UK	[263]
	–	Saprobic, pathogenic	*Spartina alterniflora*	USA: Massachusetts	[268]
	–	–	*Spartina cynosuroides*	–	[288]
Phyllachora cynodontis Niessl.	–	Saprobic, pathogenic	*Spartina alterniflora*	USA	[288]
	–	Saprobic,	*Spartina foliosa*	USA: California	[268, 322,

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
		pathogenic			346]
Phyllachora paludicola Kohlm. and Volkm.-Kohlm.	Dead leaves (lower half of standing culms)	Saprobic	*Spartina alterniflora*	USA: Florida, Georgia, North Carolina, Maryland, Delaware	[347]
Phyllachora sylvatica Sacc. and Speg.	–	Saprobic	*Spartina patens*	USA: South Carolina	[346]
Savoryellales					
Savoryellaceae					
Savoryella paucispora (Cribb and J.W. Cribb) J. Koch	–	–	*Elymus pungens*	–	[18]
	–	–	*Juncus roemerianus*	–	[18]
	–	–	*Spartina alterniflora*	–	[18]
	–	–	*Spartina* sp.	–	[18]
	–	–	*Spartina townsendii*	–	[18]
Sordariales					
Chaetomiaceae					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Achaetomium sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Chaetomium elatum Kunze	–	–	*Elymus pungens*	UK	[263]
	–	–	*Puccinellia maritima*	UK	[263]
	–	–	*Spartina townsendii*	UK	[263]
	–	–	*Elymus pungens*	UK	[263]
Chaetomium globosum Kunze	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
	–	–	*Elymus pungens*	UK	[263]
	–	–	*Puccinellia maritima*	UK	[263]
	–	–	*Spartina townsendii*	UK	[263]
Chaetomium spirale Zopf	–	–	*Elymus pungens*	UK	[263]
Chaetomium thermophilum La	–	–	*Elymus pungens*	UK	[263]
Touche	–	–	*Puccinellia maritima*	UK	[263]
	–	–	*Spartina townsendii*	UK	[263]
Chaetomium sp.	Stem	Saprobic	*Typha* sp.	UK	This study
Corynascus sepedonium (C.W.	–	–	*Elymus pungens*	UK	[263]
Emmons) Arx	–	–	*Puccinellia maritima*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	–	*Spartina townsendii*	UK	[263]
Dichotomopilus funicola (Cooke)	–	–	*Elymus pungens*	UK	[263]
X.Wei Wang and Samson	–	–	*Spartina alterniflora*	USA: Rhode Island	[138]
	–	–	*Spartina townsendii*	UK	[263]
Dichotomopilus indicus (Corda)	–	–	*Elymus pungens*	UK	[263]
X.Wei Wang and Samson					
Humicola sp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Thermothielavioides terrestris	–	–	*Elymus pungens*	UK	[263]
(Apinis) X. Wei Wang and Houbraken					
	–	–	*Puccinellia maritima*	UK	[263]
Trichocladium constrictum I. Schmidt	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Trichocladium crispatum	–	–	*Elymus pungens*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
(Fuckel) X. Wei Wang and Houbraken Lasiosphaeriaceae	–	–	*Spartina townsendii*	UK	[263]
Schizothecium hispidulum (Speg.) N. Lundq.	Living/decomposing leaf sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264]
Zopfiella latipes (N. Lundq.) Malloch and Cain Sordariaceae	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Neurospora calospora (Mouton) Dania García, Stchigel and Guarro	–	–	*Elymus pungens*	UK	[263]
Sordaria fimicola (Roberge ex Desm.) Ces. and De Not.	–	–	*Elymus pungens*	UK	[263]
	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
	–	–	*Puccinellia maritima*	UK	[263]
	–	–	*Spartina townsendii*	UK	[263]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Sordariomycetes families *incertae sedis*					
Koorchaloma galateae Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[326]
Koorchaloma spartinicola V.V. Sarma, S.Y. Newell and K.D. Hyde	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
Koorchaloma sp.	Decaying leaf blades	Saprobic	*Spartina alterniflora*	USA: Georgia	[279]
Lautospora simillima Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Lower parts of senescent, soft culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[157]
Sordariomycetes genera *incertae sedis*					
Aquamarina speciosa Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent culms		*Juncus roemerianus*	USA: Georgia, North Carolina, Virginia	[163]
Aropsiclus junci (Kohlm. and Volkm.-Kohlm.) Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[348]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Zalerion maritima (Linder) Anastasiou	Basal area of the sheath	Saprobic	*Spartina densiflora*	Argentina: Buenos Aires	[286]
	–	–	*Spartina* spp.	–	[259]
Ellisembia sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Torpedosporales					
Juncigenaceae					
Juncigena adarca Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[293]
Moheitospora adarca (Kohlm., Volkm.-Kohlm. and O.E. Erikss.) Abdel-Wahab, Abdel-Aziz and Nagah	Stems	Saprobic	*Juncus roemerianus*	USA	[339]
Moheitospora fruticosae Abdel-Wahab, Abdel-Aziz and Nagah.	Decayed stems	Saprobic	*Suaeda vermiculata*	Egypt: Alexandria	[339]
Torpedospora radiata Meyers	–	Saprobic	Unidentified saltmarsh plants	USA: Mississippi	[281]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Tracyllalales					
Tracyllaceae					
Tracylla spartinae (Peck) Tassi	–	Saprobic, pathogenic	*Spartina patens*	USA: Mississippi	[268, 288]
Xylariales					
Diatrypaceae					
Cryptovalsa suaedicola Spooner	Dead twigs	Saprobic	*Suaeda vermiculata*	UK: Great Britain	[349]
Halocryptovalsa salicorniae Dayar. and K.D. Hyde	Dead stem	Saprobic	*Salicornia* sp.	Thailand: Prachuap Khiri Khan	[191]
Xylariaceae					
Anthostomella atroalba Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[283]
Anthostomella lugubris (Roberge ex Desm.) Sacc.	–	–	*Elymus pungens*	UK	[263]
Anthostomella phaeosticta (Berk.) Sacc.	–	–	*Elymus pungens*	UK	[263]
Anthostomella poecila Kohlm.,	Lower and upper parts of	Saprobic	*Juncus roemerianus*	USA: Alabama,	[162, 278,

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Volkm.-Kohlm. and O.E. Erikss.	senescent culms, decaying leaves			Mississippi, North Carolina	281]
Anthostomella punctulata (Roberge ex Desm.) Sacc.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Anthostomella semitecta Kohlm., Volkm.-Kohlm. and O.E. Erikss.	Senescent culms	–	*Juncus roemerianus*	USA: North Carolina	[162]
Anthostomella spissitecta Kohlm. and Volkm.-Kohlm.	Leaf sheaths of senescent culms	Saprobic	*Spartina alterniflora*, *S. densiflora.*	USA: Connecticut, Florida, North Carolina, Rhode Island; Argentina: Buenos Aires	[259]
	–	–	*Spartina* sp.	–	[259]
	Leaf sheaths and blades, stem	Saprobic	*Spartina maritima*	Portugal: Algarve	[282]
Anthostomella spp.	–	–	*Elymus pungens*	UK	[263]
	–	Saprobic	*Spartina alterniflora*	USA: Connecticut, Florida, North Carolina, Rhode	[138, 261]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Island; Argentina	
	–	–	*Spartina townsendii*	UK	[263]
Anthostomella torosa Kohlm. and Volkm.-Kohlm.	Senescent culms (restricted to short culms)	Saprobic	*Juncus roemerianus*	USA: North Carolina	[259]
Geniculosporium sp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Rosellinia sp.	Dead leaves/culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[138]
Virgaria nigra (Link) Nees	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Zygosporiaceae					
Zygosporium gibbum (Sacc., M. Rousseau and E. Bommer) S. Hughes	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Zygosporium masonii S. Hughes	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Zygosporium sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Xylariales genera *incertae sedis*					
Circinotrichum maculiforme Nees	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Xylariomycetidae family *incertae sedis*					
Cainiaceae					
Atrotorquata lineata Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[315]
		Saprobic	Unidentified saltmarsh plant	USA: Mississippi	[281]
Ascomycota genera *incertae sedis*					
Asteromyces cruciatus C. Moreau and Moreau ex Hennebert	–	–	*Agropyron* sp.	–	[18]
	–	–	*Ammophila arenaria*	–	[18]
	–	–	*Spartina* spp.	–	[18, 259]
	–	Saprobic	*Zostera* sp.	USA: California	[291]
Cremasteria cymatilis Meyers and R.T. Moore Nomen dubium	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Cytoplacosphaeria phragmiticola Poon and K.D. Hyde	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Cremasteria cymatilis Meyers and R.T. Moore, *nomen dubium*	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Cytoplacosphaeria rimosa (Oudem.) Petr.	Living/decomposing leaf sheaths, stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
Cytosporina sp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Didymosamarospora euryhalina T.W. Johnson and H.S. Gold	Culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[350]
Haplobasidion lelebae Sawada ex M.B. Ellis	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Hymenopsis chlorothrix Kohlm. and Volkm.-Kohlm.	Senescent culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[351]
Hyphopolynema juncatile Kohlm. and Volkm.-Kohlm.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[168]
Kolletes undulatus Kohlm. and Volkm.-Kohlm.	Senescent leaves and culms	Saprobic	*Juncus roemerianus*	USA: North Carolina	[316]
Minimidochium parvum Cabello, Aramb. and Cazau	Leaves	Saprobic	*Distichlis spicata*	Argentina: Buenos Aires	[271]
Monodictys pelagica	–	–	*Juncus* sp.	–	[18]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
(T. Johnson) E.B.G. Jones	Decomposing culms	Saprobic	*Spartina alterniflora*	USA: Rhode Island	[18, 137–139]
	–	–	*Spartina* spp.	–	[259]
Neottiospora sp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Octopodotus stupendus Kohlm. and Volkm.-Kohlm.	Dead leaves (lower half of standing culms)	Saprobic	*Spartina alterniflora*	USA: North Carolina	[347]
Pycnodallia dupla Kohlm. and Volkm.-Kohlm.	Senescent inforescences (involucral leaves and branchlets)	Saprobic	*Juncus roemerianus*	USA: North Carolina	[351]
Sphaeronaema sp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Stauronema sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
Tetranacriella papillata Kohlm. and Volkm.-Kohlm.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: North Carolina	[326]
Tetranacrium sp.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Zythia spp.	Living, senescent, and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Psammina sp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
BASIDIOMYCOTA					
AGARICOMYCETES					
Agaricales					
Niaceae					
Merismodes bresadolae (Grelet) Singer	Living/decomposing stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[265]
Nia globispora Barata and Basilio	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
Nia vibrissa R.T. Moore and Meyers	Old stem	Saprobic	*Spartina alterniflora*	USA: North Carolina	[18, 352]
	–	Saprobic	*Spartina* spp.	USA: North Carolina	[259, 353]
	Stem	Saprobic	*Spartina maritima*	Portugal: Alentejo	[285]
AGARICOSTILBOMYCETES					
Agaricostilbales					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Chionosphaeraceae					
Stilbum sp.	Decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
BARTHELETIOMYCETES					
Sebacinales					
Sebacinaceae					
Chaetospermum camelliae Agnihothr.	Decaying stems and leaf sheaths	Saprobic	*Phragmites australis*	Hong Kong: New Territories	[266]
MICROBOTRYOMYCETES					
Sporidiobolales					
Sporidiobolaceae					
Sporobolomyces roseus Kluyver and C.B. Niel	Leaves	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Sporobolomyces spp.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
PUCCINIOMYCETES					
Pucciniales					
Pucciniaceae					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Puccinia distichlidis Ellis and Everh.	–	–	*Distichlis spicata*	USA	[354]
Puccinia magnusiana Körn.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Puccinia phragmitis (Schumach.) Tul.	Living/decomposing leaf blades and sheaths	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 274]
Puccinia sparganioidis Ellis and Barthol.	–	Saprobic, parasitic	*Spartina alterniflora*	USA: Maine, New Hampshire, Massachusetts, Rhode Island, Delaware, Virginia, North Carolina, Florida, Mississippi	[139, 261, 268, 288, 355]
	–	–	*Spartina cynosuroides*	USA: New Jersey, Delaware, Maryland, South Carolina, Florida, Louisiana	[268, 288, 356]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
	–	Saprobic, pathogenic	*Spartina patens*	USA: Connecticut, Maryland, New Jersey, New York	[268, 288, 356]
Uromyces acuminatus Arthur	–	Saprobic, pathogenic	*Spartina alterniflora*	USA: Maine, New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Delaware, Maryland, Florida	[268, 288, 355]
	–	Saprobic, pathogenic	*Spartina cynosuroides*	USA: Florida	[268, 288, 356]
	–	Saprobic	*Spartina patens*	USA: Connecticut, Delaware, Florida, Maine, Maryland, Massachusetts, New Hampshire, New	[268, 288]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
				Jersey	
Uromyces argutus F. Kern	–	Saprobic, pathogenic	*Spartina alterniflora*	France; USA: Florida	[268, 288, 355]
Uromyces salicorniae (DC.) de Bary	–	–	*Salicornia* sp.	South Australia	[309]
Pucciniales genera *incertae sedis*					
Aecidium suaedae Thüm.	Leaves	–	*Suaeda verae*	Egypt	[357]
TREMELLOMYCETES					
Tremellales					
Tremellaceae					
Tremella spicifera Van Ryck., Van de Put and P. Roberts	Living/decomposing leaf sheaths and stems	Saprobic	*Phragmites australis*	Netherlands: Zeeland	[264, 265]
USTILAGINOMYCETES					
Ustilaginales					
Ustilaginaceae					
Tranzscheliella distichlidis (McAlpine) Vánky	–	Pathogenic	*Distichlis spicata*	Australia: Victoria	[358]

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Ustilaginales genera *incertae sedis*					
Parvulago marina (Durieu) R. Bauer, M. Lutz, Piątek, Vánky and Oberw.	–	–	*Eleocharis parvula*	Finland, France, Germany, UK, Norway, Sweden	[359]
Urocystidales					
Urocystidaceae					
Flamingomyces ruppiae (Feldmann) R. Bauer, M. Lutz, Piątek, Vánky and Oberw.	–	Parasitic	*Ruppia maritima*	France	[359]
MUCOROMYCOTA					
MUCOROMYCETES					
Mucorales					
Choanephoraceae					
Blakeslea trispora Thaxt.	Senescent and decaying leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
Mucoraceae					

Table 2.1 (continued)

Taxon	Host Part	Life Mode	Hosts	Distribution	References
Mucor sp.	Senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]
	Roots	Saprobic	*Spartina* sp.	Canada: Bay of Fundy	[272]
Rhizopodaceae					
Rhizopus stolonifer (Ehrenb.) Vuill.	Stems	Saprobic	*Spartina townsendii*	UK: England	[273]
Syncephalastraceae					
Syncephalastrum racemosum Cohn ex J. Schröt.	Living and senescent leaves	Saprobic	*Juncus roemerianus*	USA: Florida	[267]

2.2.2 Class

Salt marsh fungi are distributed into 17 classes (Table 2.1, Figure 2.5). Dothideomycetes has the highest number of taxa, which comprises 47.12% (229 taxa), followed by Sordariomycetes with 167 taxa (34.36%). Twenty-one species (in 20 genera) can be referred to as Ascomycota genera *incertae sedis*. The Ascomycetes with the least number of species include Leotiomycetes (21 species, 4.32%), Eurotiomycetes (16 species, 3.29%), Orbiliomycetes (three species, 0.62%), Saccharomycetes (three species, 0.62%), Lecanoromycetes (two species, 0.41%), and Pezizomycetes (one species, 0.21%).

Seven classes represent the Basidiomycota (Figure 2.5). Puccinomycetes has the highest number of taxa documented (eight species, three genera) followed by Agaricomycetes (three species, two genera), Ustilaginomycetes (three species, three genera), and Microbotryomycetes (two taxa, one genus). Agaricostilbomycetes, Bartheletiomycetes, and Tremellomycetes have one representative taxon each.

The Mucoromoycota accounts for the taxa *Blakeslea trispora*, *Mucor* sp., *Rhizopus stolonifera*, and *Syncephalastrum racemosum* [267, 272, 273].

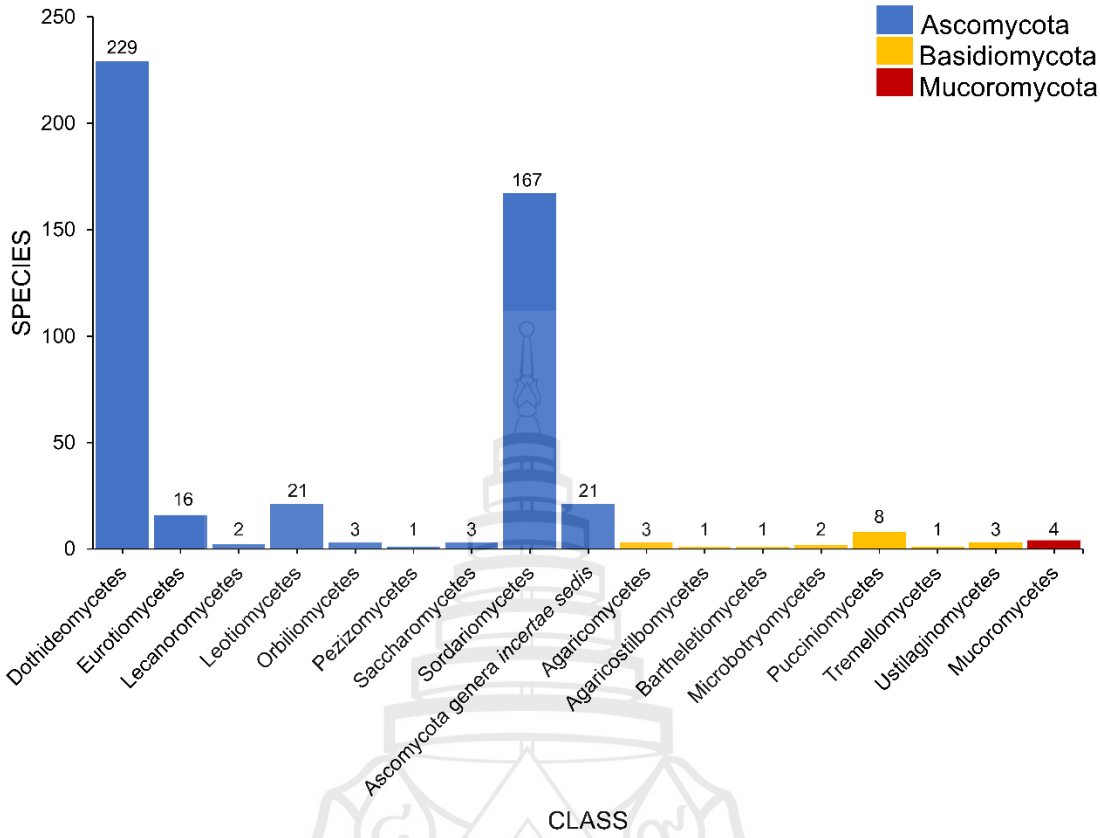


Figure 2.5 The Distribution of Salt Marsh Fungi in Different Fungal Classes

2.2.3 Orders

Salt marsh fungi recorded from different halophytes were distributed among 48 orders (Table 2.1, Figure 2.6). The Pleosporales is the largest order, with 178 taxa recorded followed by Hypocreales (41), Microascales (26), Capnodiales (22), Helotiales (18), Xylariales (17), Sordariales (16), Amphisphaeriales (15), and Eurotiales (13). The remaining 41 orders have less than ten species (Table 2.1, Figure 2.5). Forty-two taxa belong to *incertae sedis* (Ascomycota genera *incertae sedis*: 21; Dothideomycetes families *incertae sedis*: 11; Sordariomycetes families *incertae sedis*: nine; Xylariomycetidae family *incertae sedis*: one).

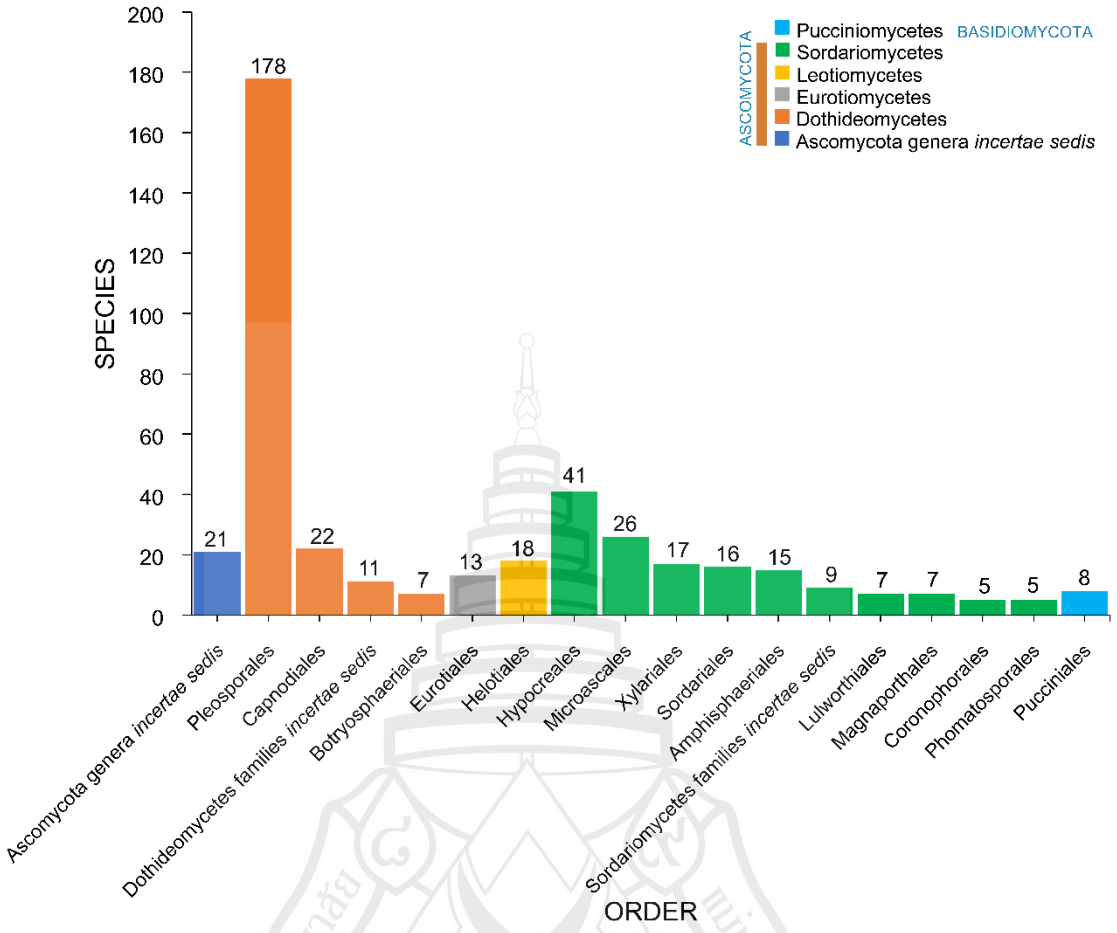


Figure 2.6 The distribution of salt marsh fungi in major fungal orders

2.2.4 Families

A total of 108 families and 12 *incertae sedis* were recorded to be associated with salt marsh fungi (Table 2.1, Figure 2.7). Phaeosphaeriaceae and Pleosporaceae account for the largest families with 34 and 31 taxa recorded, respectively. Thirteen families have ten or more than taxa and include Nectriaceae (25), Halosphaeriaceae (25), Didymellaceae (17), Mycosphaerellaceae (14), Lentitheciaceae (13), Massarinaceae (13), Chaetomiaceae (12), Xylariaceae (11), Didymosphaeriaceae (ten), Leptosphaeriaceae (ten), and Aspergillaceae (ten). The remaining 95 families have less than ten species recorded. Forty-four taxa are placed as *incertae sedis*, wherein 21 of these belong to Ascomycota genera *incertae sedis*.

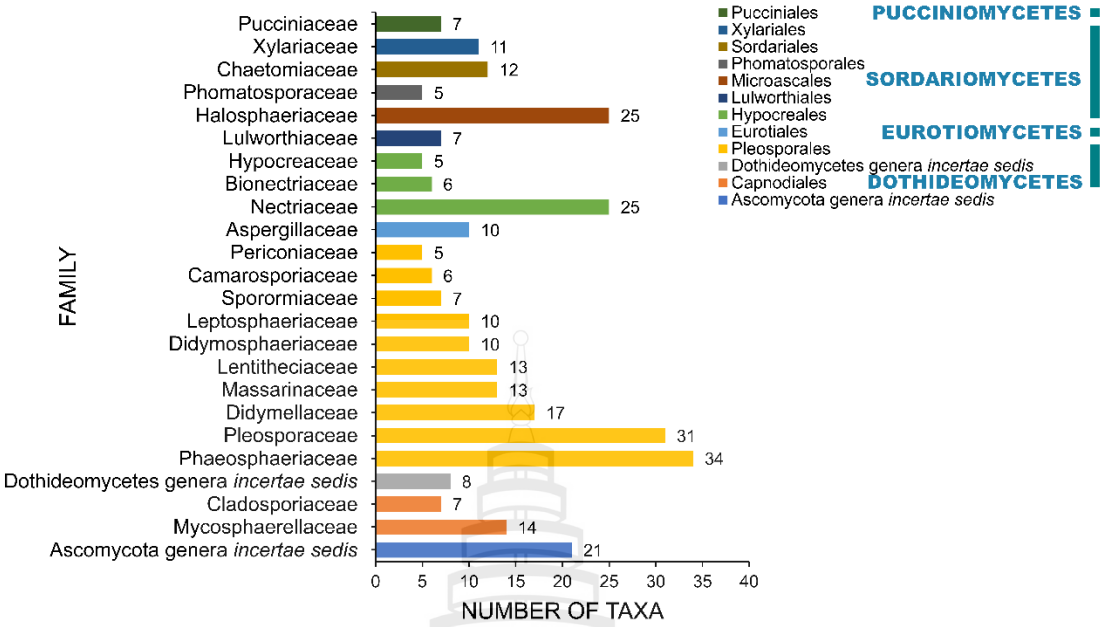


Figure 2.7 The Distribution of Salt Marsh Fungi Among Major Fungal Families

2.3 Diversity of Fungi in Halophytes

Twenty-seven genera under 11 families (Amaranthaceae, Apiaceae, Caryophyllaceae, Compositae, Juncaceae, Juncaginaceae, Plumbaginaceae, Poaceae, Primulaceae, Ruppiaceae, Typhaceae, Zosteraceae) of halophytes were reviewed for its fungal associates (Table 2.1, Figure 2.8). Halophytic species are represented in Figures 2.1 and 2.2.

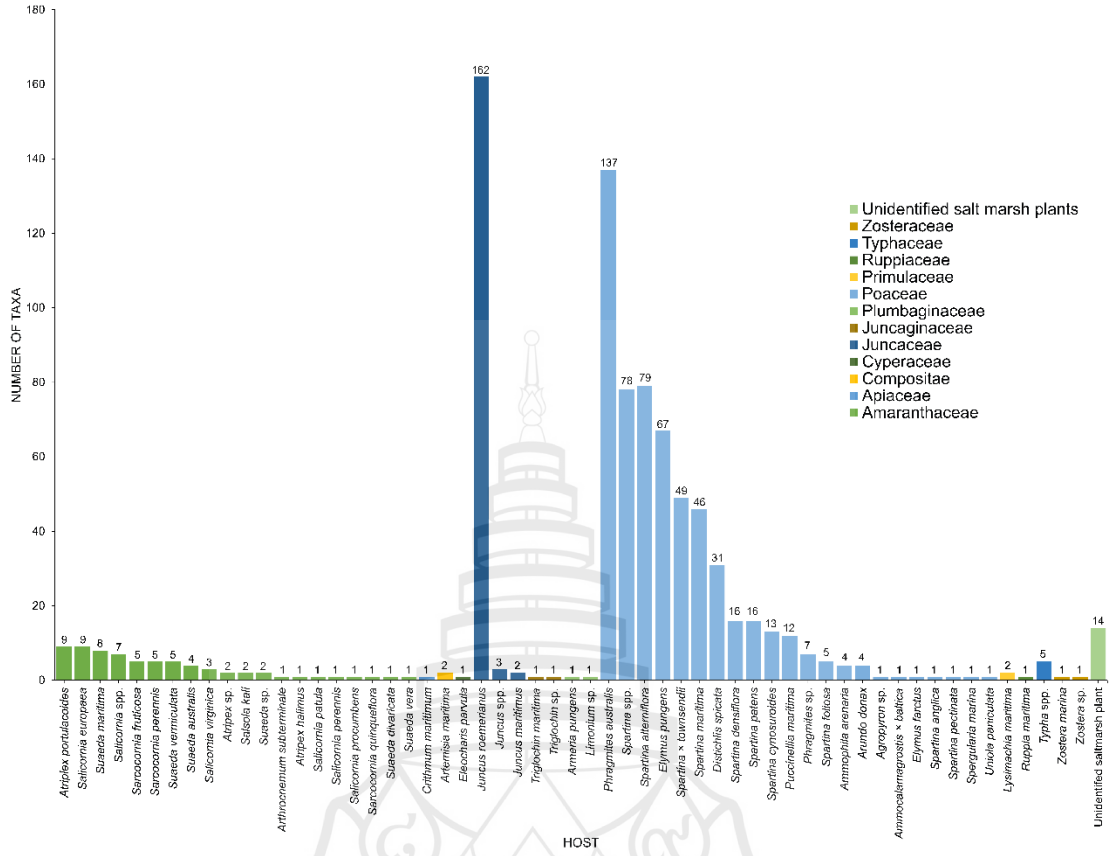


Figure 2.8 The Number of Taxa Observed from Different Hosts in Salt Marsh Ecosystems

2.3.1 Amaranthaceae

Six genera (*Arthrocnemum, Atriplex, Salicornia, Salsola, Sarcocornia, Suaeda*) represent the Amaranthaceae. *Suaeda* and *Salicornia* are the most studied hosts in Amaranthaceae. Ascomycota account for 96.30% of the 52 taxa recorded in Amaranthaceae (Figure 2.9, Table 2.1). Two Pucciniomycetes species, *Aecidium suaedae* [357] and *Uromyces salicorniae* [309], represent Basidiomycota. The taxa in Amaranthaceae represent three classes wherein Dothideomycetes accounts for 85.19% (46 taxa), followed by Sordariomycetes with six taxa reported.

Fungi associated with *Suaeda* total 18 taxa. Dothideomycetes was represented by 14 taxa (77.78%), while three taxa were Sordariomycetes (*Cryptovalsa suaedicola* [349], *Fusarium fujikuroi* [284], *Moheitospora fruticosae* [339]) and one taxon of Pucciniomycetes (*Aecidium suaedae* [357]).

A total of 14 taxa were documented in *Salicornia*. Eleven of these belong to Dothideomycetes (Pleosporales: ten; Capnodiales: one), followed by Sordariomycetes (two taxa: *Halocryptovalsa salicorniae* [191], *Tubercularia pulverulenta* [18]), and Pucciniomycetes (one taxon: *Uromyces salicorniae* [309]).

Fungi from *Atriplex* total 11 taxa (ten genera) and all of these belong to Pleosporales (Dothideomycetes). *Sarcocornia* harbors seven taxa (six Dothideomycetes, one Sordariomycetes). Only two taxa (*Alternaria* spp., *Stemphylium* spp.) and a single taxon (*Mycosphaerella salicorniae*) were reported from *Salsola* and *Arthrocnemum*, respectively [18].

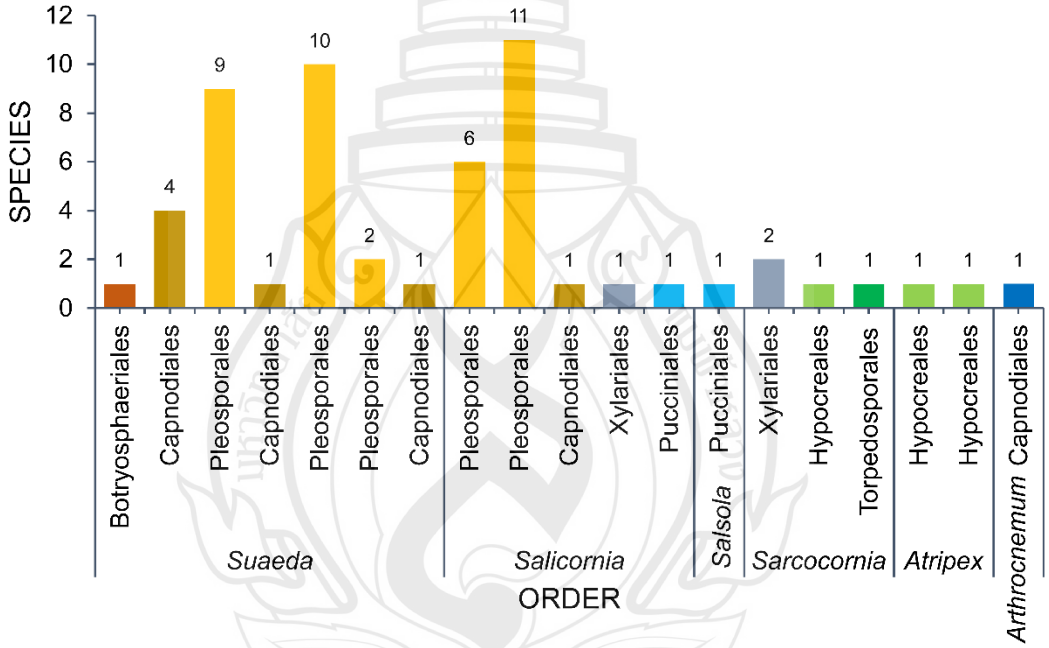


Figure 2.9 The Number of Taxa Observed from Amaranthaceae

2.3.2 Poaceae

The association of fungi with grasses have been documented and most of the host plants are members of Poaceae. Ten genera of salt marsh grasses under Poaceae are included in this review wherein *Spartina* is the most studied of halophytic hosts for direct observation of marine fungi. In addition to *Spartina*, salt marsh grasses such as *Phragmites* and *Distichlis* were well studied also for their fungal associates.

Salt marsh fungi are not well-documented from grasses such as *Spartina anglica, S. pectinata*, *Spergularia marina*, *Uniola paniculata, Elymus farctus*, × *Ammocalamagrostis baltica*, and *Agropyron* sp. with one taxon recorded for each host [18]. Furthermore, there are few studies on the fungal composition of *Arundo donax* (four taxa) [18] and *Ammophila arenaria* (four taxa). Marram grass (*Ammophila arenaria*) is more common in sand dunes and supports quite a diverse fungal community [360, 361], while arbuscular mycorrhizal fungi (AMF) play a key role in the establishment, growth, and survival of plants [362].

2.3.2.1 *Distichlis spicata*

Ascomycota dominates the taxa associated with *Distichlis spicata* (93.55%) wherein 16 and 13 species are members of Dothideomycetes and Sordariomycetes, respectively. Pleosporalean taxa constitute the majority of fungi associated with *D. spicata* (14 species), followed by Hypocreales with nine species recorded. *Puccinia distichlidis* and *Tranzscheliella distichlidis* represent the Basidiomycota. A total of 26 genera were recorded as associates of *D. spicata* and were mostly observed on senescent and decaying leaves.

2.3.2.2 *Elymus pungens*

Sixty-seven taxa were recorded in *Elymus pungens* and belong to Ascomycota. Most of the taxa belong to Dothideomycetes (32 taxa), followed by Sordariomycetes (21 taxa), Leotiomycetes, and Eurotiomycetes (six taxa) (Table 2.1, Figure 2.10).

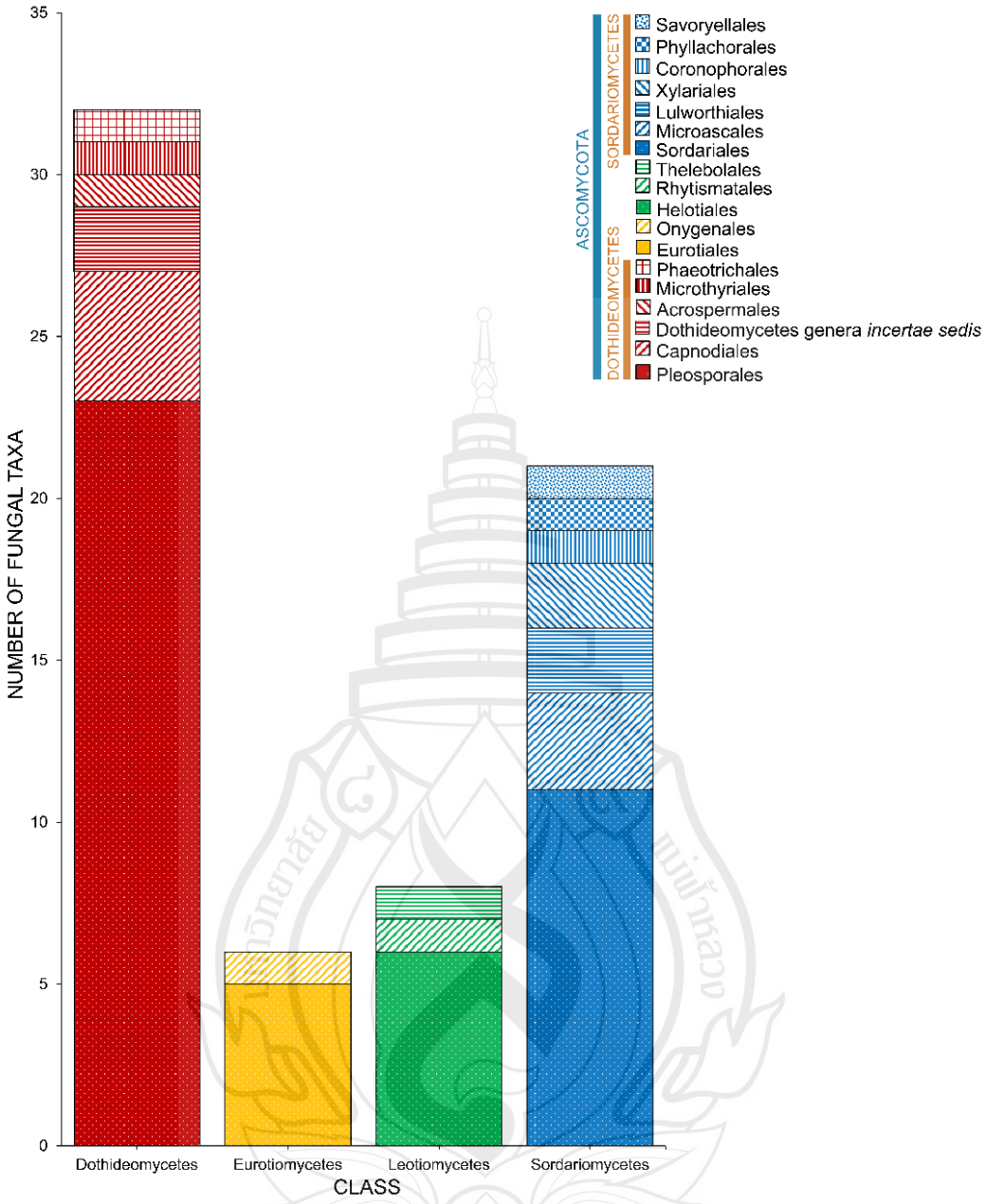


Figure 2.10 The Distribution of Fungal Taxa Associated with *Elymus pungens*

2.3.2.3 *Puccinellia maritima*

A total of 12 taxa (six Sordariomycetes; the following five Dothideomycetes: *Micronectriella agropyri, Lautitia danica, Leptosphaeria pelagica, Septoriella vagans, Paradendryphiella salina*; one Leotiomycetes: *Thelebolus crustaceus*) were recorded in *Puccinellia maritima* [263]. All the taxa from Sordariomycetes belong to

Sordariales (*Chaetomium elatum, C. globosum, C. thermophilum, Corynascus sepedonium, Thermothielavioides terrestris, Sordaria fimicola*) [263].

2.3.2.4 *Spartina*

A total of 149 taxa (141 Ascomycota, six Basidiomycota, two Mucoromycota) were recorded in *Spartina.* The majority of the taxa belong to Dothideomycetes (70 taxa), followed by Sordariomycetes (59 taxa). Pleosporaceae and Halosphaeriaceae dominate the fungi documented in *Spartina* with 19 and 17 taxa recorded, respectively. *Spartina alterniflora*, *S. maritima*, and *Spartina* × *townsendii* harbor 79, 46, and 49 taxa, respectively (Figure 2.11, Table 2.1). A total of 78 taxa were recorded in the unidentified *Spartina* species. The identification of the *Spartina* species can be challenging, wherein species are morphologically similar.

Halobyssothecium obiones was recorded from six species of *Spartina* (*S. alterniflora* [18, 110, 132, 137, 138, 275, 291, 295, 296], *S. cynosuroides* [18], *S. densiflora* [286], *S. maritima* [258, 277, 282, 285], *S. patens* [261], *S. townsendii* [16, 273], and the unidentified *Spartina* sp. [18, 259, 261, 281, 298], while six *Spartina* spp. harbors unidentified *Mycosphaerella* species. Six species (*Leptosphaeria pelagica, Lulworthia* spp., *Phaeosphaeria halima, Phaeosphaeria spartinicola, Phoma* spp., *Stagonospora* spp.) were recorded in five different hosts. The unidentified *Spartina* species harbors 28 unique species. Amongst the taxa found in *Spartina*, 32 species can only be found in *S. alterniflora*, while *S. maritima* harbors 21 unique species, the most intensively surveyed species.

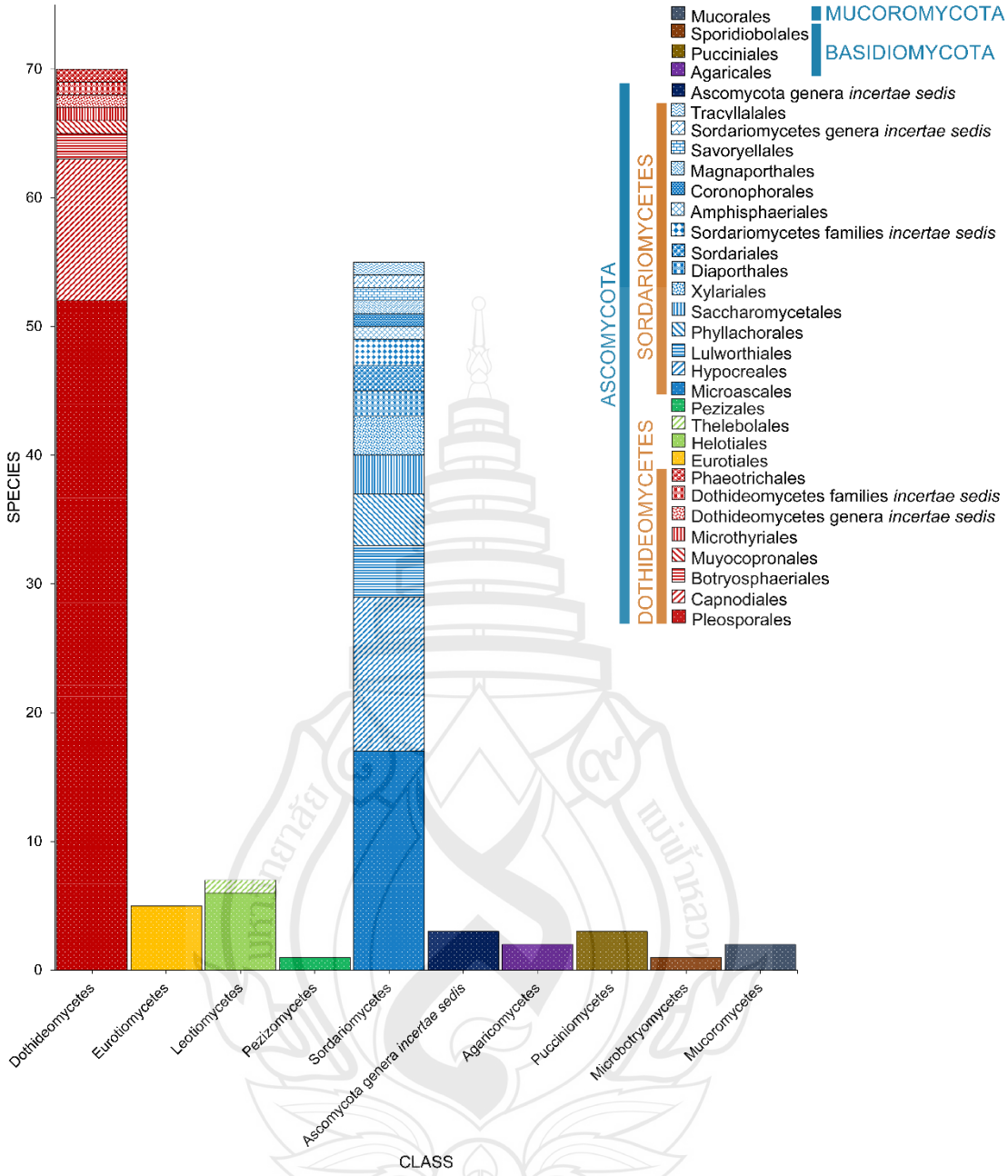


Figure 2.11 The Distribution of Fungal Taxa Associated with *Spartina*

2.3.2.5 *Phragmites*

A total of 138 taxa have been documented in *Phragmites* (Figure 2.12, Table 2.1). Most of the taxa belong to Ascomycota (131 taxa), while six taxa represent the Basidiomycota. Dothideomycetes dominates half of the taxa in *Phragmites* (71 taxa, 51.45%) followed by Sordariomycetes (44 taxa, 31.88%),

Leotiomycetes (six taxa, 4.35%), Ascomycota genera *incertae sedis* (five taxa, 3.62%), Eurotiomycetes (three taxa, 2.17%), Orbiliomycetes (two taxa, 1.45%), and Pucciniomycetes (one taxon each were recorded to Agaricomycetes [265], Bartheletiomycetes [266], Lecanoromycetes [264], Microbotryomycetes [264, 274], and Tremellomycetes [264, 265]. Pleosporalean taxa accounts for the highest number of fungi associated with *Phragmites* (42.75%, 59 taxa).

Phragmites australis harbors diverse fungi that totals to 137 taxa (101 genera) [264–266, 274, 294, 325]. Seven species (*Arthrinium arundinis* [284], *Halazoon fuscus* [301], *Halobyssothecium phragmitis* [299], *Keissleriella linearis* [299], *Phomatospora dinemasporium* [284], *Remispora hamata* [301], *Setoseptoria phragmitis* [301]) were recorded in unidentified *Phragmites* species.

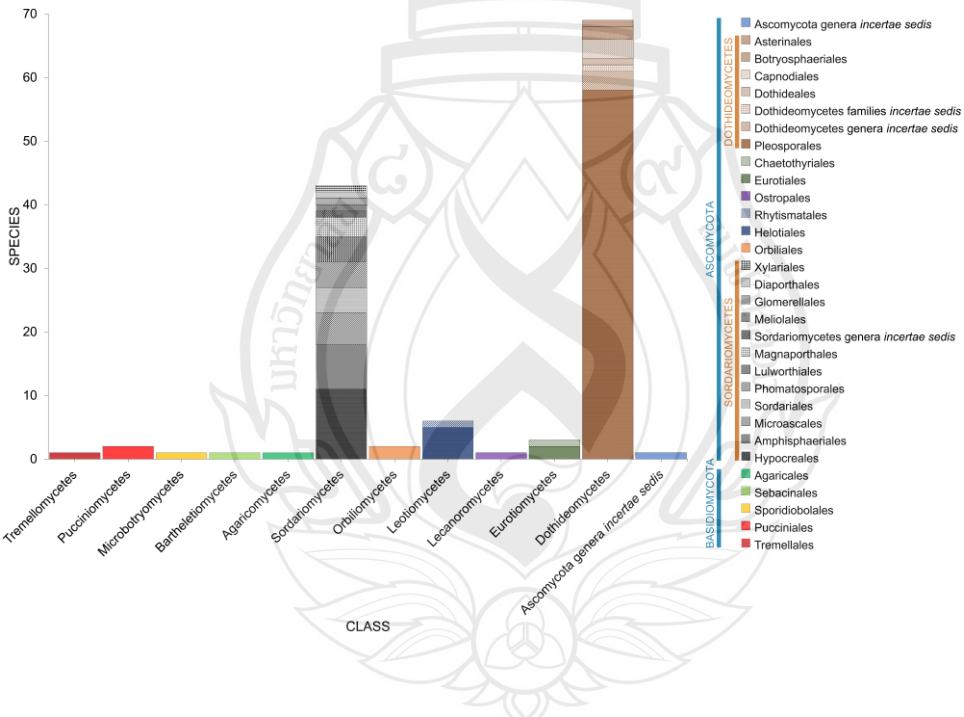


Figure 2.12 The Distribution of Fungal Taxa Associated with *Phragmites*

2.3.3 Juncaceae

Juncus roemerianus, *J. maritimus*, and an unidentified *Juncus* species represent Juncaceae. Salt marsh fungi are diverse in *Juncus* and dominated by Ascomycota, which constitutes 97.58% of the 165 reported taxa (Figure 2.13, Table 2.1). *Stilbum* sp. represented the Basidiomycota, while three taxa (*Blakeslea trispora*,

Mucor sp., *Syncephalastrum racemosum*) of Mucoromycota were recorded. Dothideomycetes and Sordariomycetes account for the highest number of *Juncus*-associated fungi with 72 (43.64%) and 64 (38.79%) taxa documented.

Juncus roemerianus has been extensively studied for its associates with 162 documented taxa [157, 158, 259, 267, 283, 293, 315, 316, 326, 327, 351, 159, 161–166, 168]. Few species were reported to *Juncus maritimus* that harbor only two taxa (*Leptosphaeria albopunctata, Phaeosphaeria neomaritima*) [18]. *Phaeosphaeria neomaritima* [110, 132, 261, 275], *P. spartinicola* [275], and *Monodictys pelagica* [18] were observed in an unidentified species of *Juncus*.

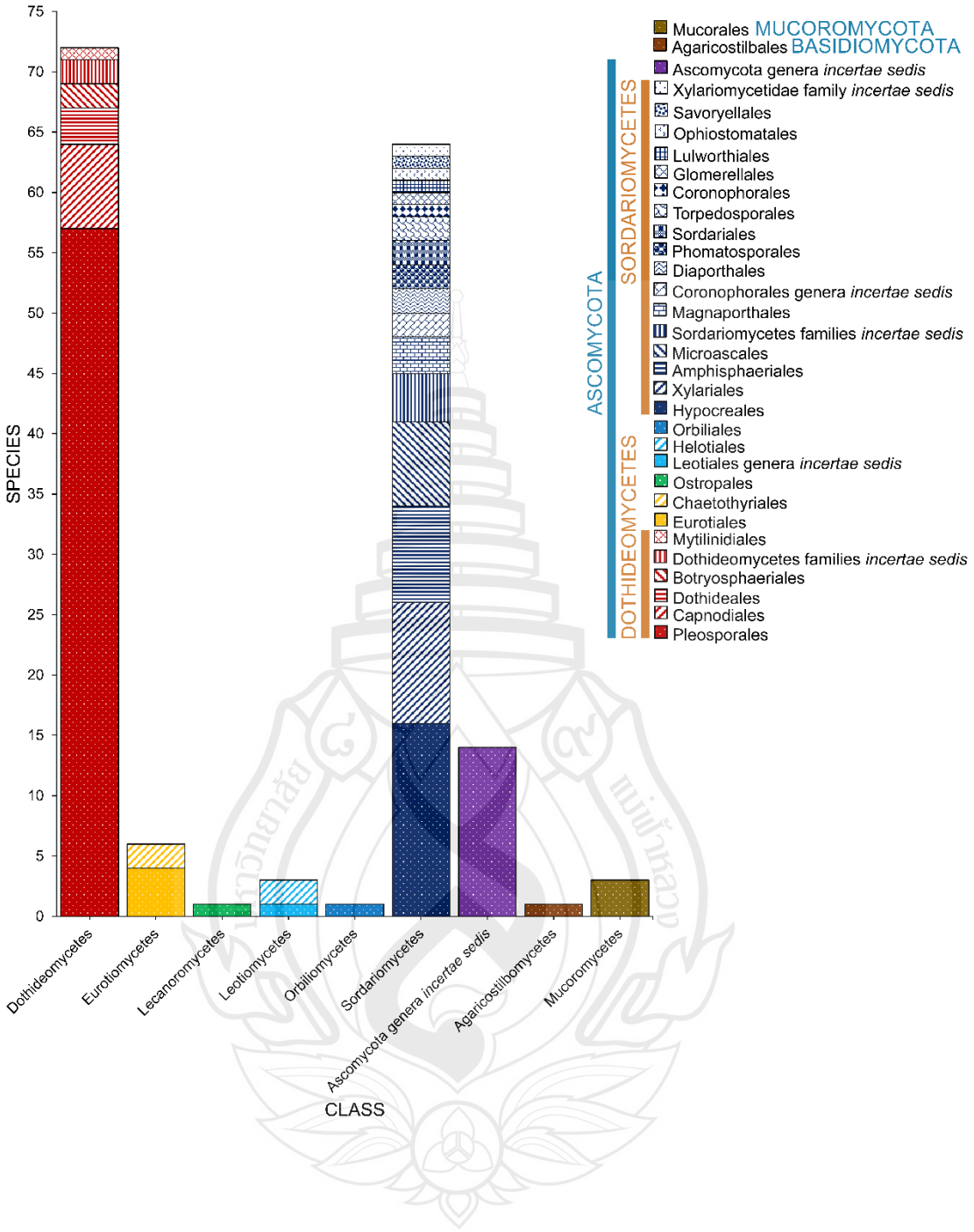


Figure 2.13 The Distribution of Fungal Taxa Associated with *Juncus*

2.3.4 Other Families

Few reports on salt marsh fungi are from the following hosts: Apiaceae: *Crithmum maritimum* (one taxon: *Phoma* sp.), Typhaceae: *Typha* spp. (five taxa: *Arundellina typhae*, *Chaetomium* sp., *Magnisphaera spartinae*, *Pleospora pelagica*,

Remispora hamata); Compositae: *Artemisia maritima* (two taxon: *Neocamarosporium artemisiae, N. maritimae*); Caryophyllaceae: *Spergularia marina* (one taxon: *Cladosporium algarum*); Plumbaginaceae: *Limonium* sp. (one taxon: *Mycosphaerella salicorniae*); *Armeria pungens* (one taxon: *Mycosphaerella staticicola*); Juncaginaceae: *Triglochin* sp. and *T. maritima* (one taxon: *Stemphylium triglochinicola*); Primulaceae: *Lysimachia maritima* (two taxa: *Leptosphaeria orae-maris, Stemphylium vesicarium*); Ruppiaceae: *Ruppia maritima* (one taxon: *Flamingomyces ruppiae*); and Zosteraceae: *Zostera marina* (one taxon: *Corollospora ramulosa*) and *Zostera* sp. (*Asteromyces cruciatus*). Alva et al. (2002) report *Penicillium chrysogenum* as an endophyte from *Zostera japonica*.

Fourteen taxa were documented from unidentified salt marsh plants. All of the taxa belong to Ascomycota (seven Dothideomycetes, five Sordariomycetes, one Eurotiomycetes). Pleosporalean taxa from six families account for half of the taxa (the following seven species: *Camarosporium palliatum, C. roumeguerei, Coniothyrium obiones, Halobyssothecium obiones, Periconia* sp., *Loratospora aestuarii, Pleospora pelvetiae*).

2.4 Geographical Distribution of Salt Marsh Fungi

The salt marsh fungi reported are from countries of three major oceans, as documented in Figure 2.14. The Atlantic Ocean consists of 12 countries, wherein the USA had the highest number of species recorded (232 taxa) followed by the UK (101 taxa), the Netherlands (74 taxa), and Argentina (51 taxa). China had the highest number of salt marsh fungi in the Pacific Ocean with 165 taxa reported, while in the Indian Ocean, India reported the highest taxa (16 taxa). Most of the biodiversity studies documenting salt marsh fungi in the Atlantic Ocean are mostly from the USA and the UK and this reflects the high number of taxa [138, 259, 261, 263, 273]. China ranked second with the most number of salt marsh fungal taxa, mainly due to the biodiversity study in *Phragmites australis* conducted by Poon and Hyde [266].

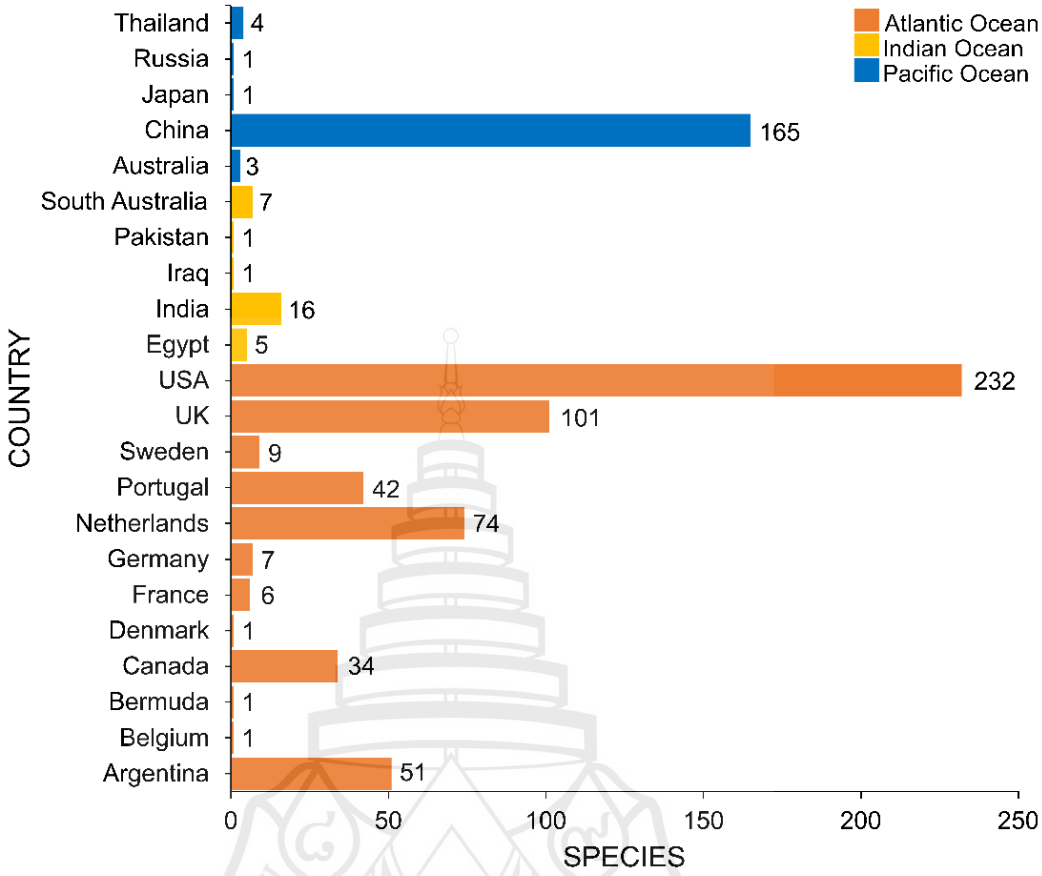


Figure 2.14 The Number of Salt Marsh Fungi Reported in the Pacific, Atlantic, and Indian Oceans

The geographical distribution of salt marsh fungi and the different halophytes are presented in Figure 2.15. The fungi associated with salt marsh grass *Phragmites australis* have been studied in different countries (Australia, Belgium, Egypt, France, Germany, China, Iraq, Japan, the Netherlands, South Australia, Thailand*). Spartina alterniflora* was recorded in countries along the Atlantic (Argentina, Canada, France, USA) and the Indian Ocean (India), but lacks data from countries in the Pacific Ocean.

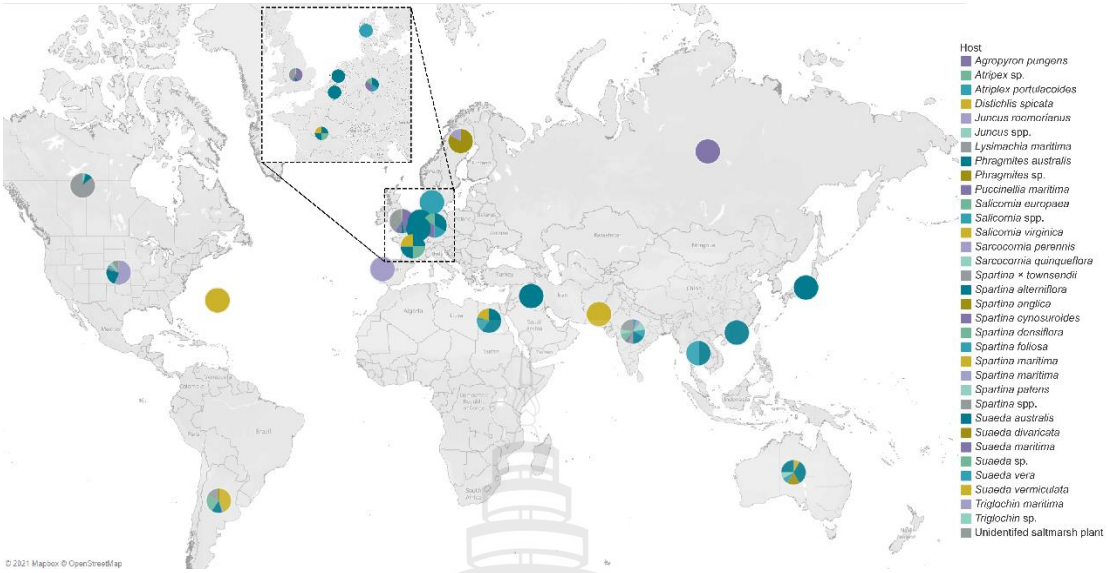


Figure 2.15 Map of Countries Showing the Global Distribution of Fungal Diversity Studies in Halophytes. The Different Color of Each Pie Chart Represents the Hosts, and the Angle Measured the Number of their Fungal Associates.

2.4.1 United States of America

Most of the studies of halophytes-associated fungi were concentrated on the United States of America (USA) (Figure 2.16). Table 2.1 lists the salt marsh fungi in 20 states. Florida has been the frequently studied, wherein seven hosts (*Juncus roemerianus*: 108 taxa; *Spartina* × *townsendii*: one; *Spartina alterniflora*: 16; *Spartina cynosuroides*: three; *Spartina densiflora*: one; *Spartina patens*: two; *Spartina* spp.: three) were observed for salt marsh fungi. Six hosts were studied in North Carolina, wherein *Juncus roemerianus* harbored the highest number of fungi (48 taxa). In Rhode Island, *Spartina alterniflora* accounts for the highest number of fungi, with 41 taxa recorded.

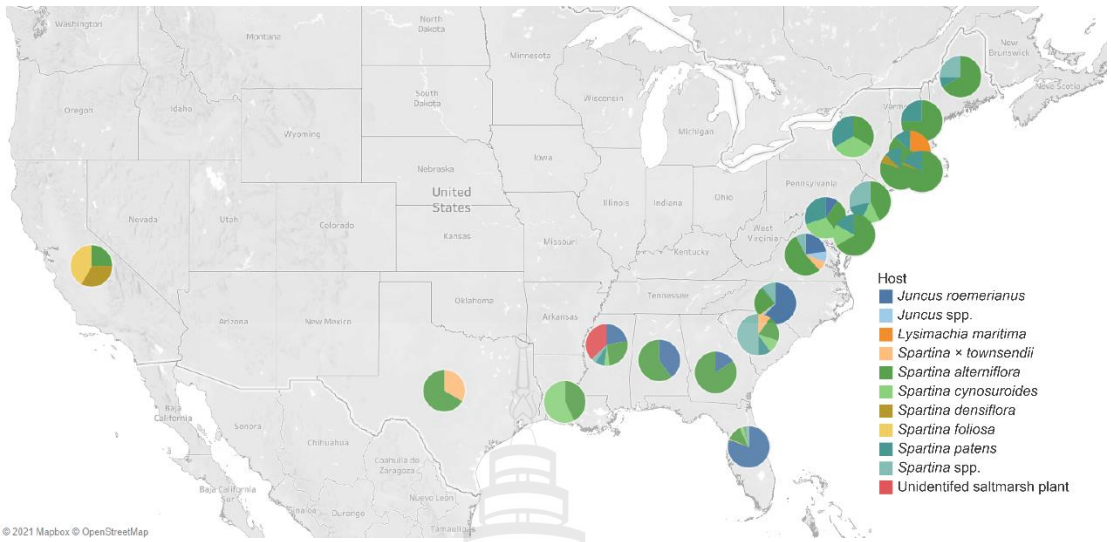


Figure 2.16 Map of the United States of America (USA) Showing the Distribution of Fungal Diversity Studies of Halophytes in Different States. The Different Color of Each Pie Chart Represents the Hosts, and the Angle Measured the Number of their Fungal Associates

2.5 Conclusions and Future Perspectives

Most studies of fungi on salt marsh plants are from *Spartina*, *Juncus*, and *Phragmites*, probably due to the huge biomass generated by these taxa. The mycota of less bulky halophytes (e.g., *Limonium*, *Triglochin*, *Uniola*) and litter from the surrounding sea grass beds washed off to marsh areas (e.g., *Zostera japonica*, *Z. marina*, *Z. noltii*) are also less represented, or these hosts are yet to be explored. The checklist presented in the current study updates the list of Calado and Barata [260] and the inclusion of fungi associated with rarely studied halophytes record 486 taxa worldwide. Ascomycota dominate the taxa (463 taxa) and are comprised mostly of Dothideomycetes with their ability to eject their ascospores forcibly and widely, spore type, the formation of ascomata or ascostromata under a clypeus or just immersed in thin leaves, and an ability to decompose lignocellulose substrates [280, 364]. Meyers et al. [365] showed that salt marsh yeasts and the ascomycete, *Buergenerula spartinae*, produce degradative enzymes and utilize simple carbon and nitrogen

compounds. The yeast, *Pichia spartinae*, produces β-glucosidase and other degradative enzymes. Gessner [291] demonstrated that a number of salt marsh fungi isolated from *Spartina alterniflora*, *Zostera* sp., and *Z. marina* produced enzymes capable of degrading cellulose, cellobiose, lipids, pectin, starch, tannic acid, and xylan, thus, play a key role in the degradation of storage and structural compounds. Salt marsh fungi might possess high biotransformation and metabolic abilities, which could be related to their ecology.

Basidiomycota (19 taxa) and Mucoromycota (four taxa) are poorly represented in salt marsh ecosystems as they are in other marine habitats [36]. There are no records of Chytridiomycota listed in the present work and only a few authors detected this group, and other basal fungal lineages, in salt marsh ecosystems using molecular analysis [366–369]. These groups are worth exploring to determine the overall fungal communities in the salt marsh ecosystems. Many chytrids and other basal fungi are more challenging to cultivate and require different isolation methods (e.g., baiting techniques in liquid culture) than the saprobes, methods that have rarely been applied in the study of saltmarsh plants. When appropriate techniques are used, chytrids and other zoosporic organisms have been reported. For example, the fungal-like organism *Phytophthora inundata* has been recovered from the halophilic plants *Aster tripolium* and *Salicornia europaea*, while *P. gemini* and *P. chesapeakensis* occur on *Zostera marina*, and *Salisapilia nakagirii* on the decaying litter of *Spartina alterniflora* (www.marinefungi.org; accessed on 10 May 2021) [36]. Marine chytrids have been isolated from substrates such as seaweeds and mangrove leaves [36].

The taxa listed are mostly saprobes and these can be attributed to the inclusion of salt marsh fungi observed directly from the different host parts, which are mostly submerged decaying substrates. When compared to saprobic fungi in halophytes, few studies have been carried out on the diversity of endophytes and pathogens and their interaction in the salt marsh ecosystems. Surveys on endophytic fungi from halophytes using cultivation-dependent methods coupled with molecular approaches, showed that endophytes were dominated by Ascomycota and a few belonged to Basidiomycota and Zygomycota [370–377]. Pathogenic fungi from salt marsh ecosystems are poorly documented but play a significant role in the dynamics of the ecosystem [378–380]. For example, Govers et al. [381] reported that the fungal-like

organisms *Phytophthora gemini* and *P. inundata* caused widespread infection of the common seagrass species, *Zostera marina* (eelgrass), across the northern Atlantic and Mediterranean that threatened the conservation and restoration of vegetated marine coastal systems. Likewise, *Claviceps purpurea* affects the viability of *Spartina townsendii* in south coast UK salt marshes. Fisher et al. [382] noted that *Cl. purpea* in the Alabama and Mississippi coastlines rendered the seeds of one of the primary salt marsh grasses sterile. Raybould et al. [383] recorded epidemics of *C. purpurea* on *Spartina anglica* in Poole Harbor (UK) and that ergot growth was detrimental to seed production. These underexplored fungal groups are worthy to be explored for their ecological and biotechnological importance.

This shows how salt marsh fungal studies were concentrated in countries in the Atlantic Ocean specifically the USA (232 taxa) and the UK (101 taxa). Many salt marsh areas remain unexplored, especially those in the Indian and Pacific Oceans, and these areas are hotspots of biodiversity and novel fungal taxa based on the exploration of various habitats [5–7, 36, 172, 299, 384–386]. Recently, novel species were isolated in halophytes [6, 191, 299] and further taxa remain to be discovered, isolated, and sequenced, while vast areas worldwide have yet to be surveyed. For example, salt marsh plants are immensely numerous, diverse, and common along the south-east coast of Australia, yet little is known of their fungal associates [387].

The salt marsh vegetation and its fungal associates are adapted to salt stress and inundation and are subjected to extreme environmental conditions such as being periodically wet to different lengths of time leading to drying out at low tides and exposure to high temperatures and drying out at midday. Many are well adapted to prevailing conditions by their fleshy leaves (*Suaeda australis*), others can tolerate high flooding.

Few data are currently available on the specificity of fungi on their salt marsh hosts. Figure 2.17 shows the number of fungal taxa recorded from the three commonly studied hosts, *Juncus*, *Phragmites*, and *Spartina*, wherein there is little overlap in the species composition. One of the common species on *Spartina* plants is undoubtedly *Halobyssothecium obiones*, while *Leptosphaeria pelagica* is common. A common ascomycete on *Atriplex portulacoides* and *Suaeda maritima* is *Decorospora gaudefroyi*. Host plants that have been little surveyed for fungi are *Limonium vulgare*

(sea lavender) and *Atriplex portulacoides* (sea purslane), yet they do support a number of taxa, e.g., *Neocamarosporium obiones* and *Amarenomyces ammophilae*. The fungal community reported on *Juncus roemerianus* in the salt marsh at North Carolina is significantly different from those on *Spartina* and *Phragmites*. It remains to be seen if this is due to the host plant or its geographical location.

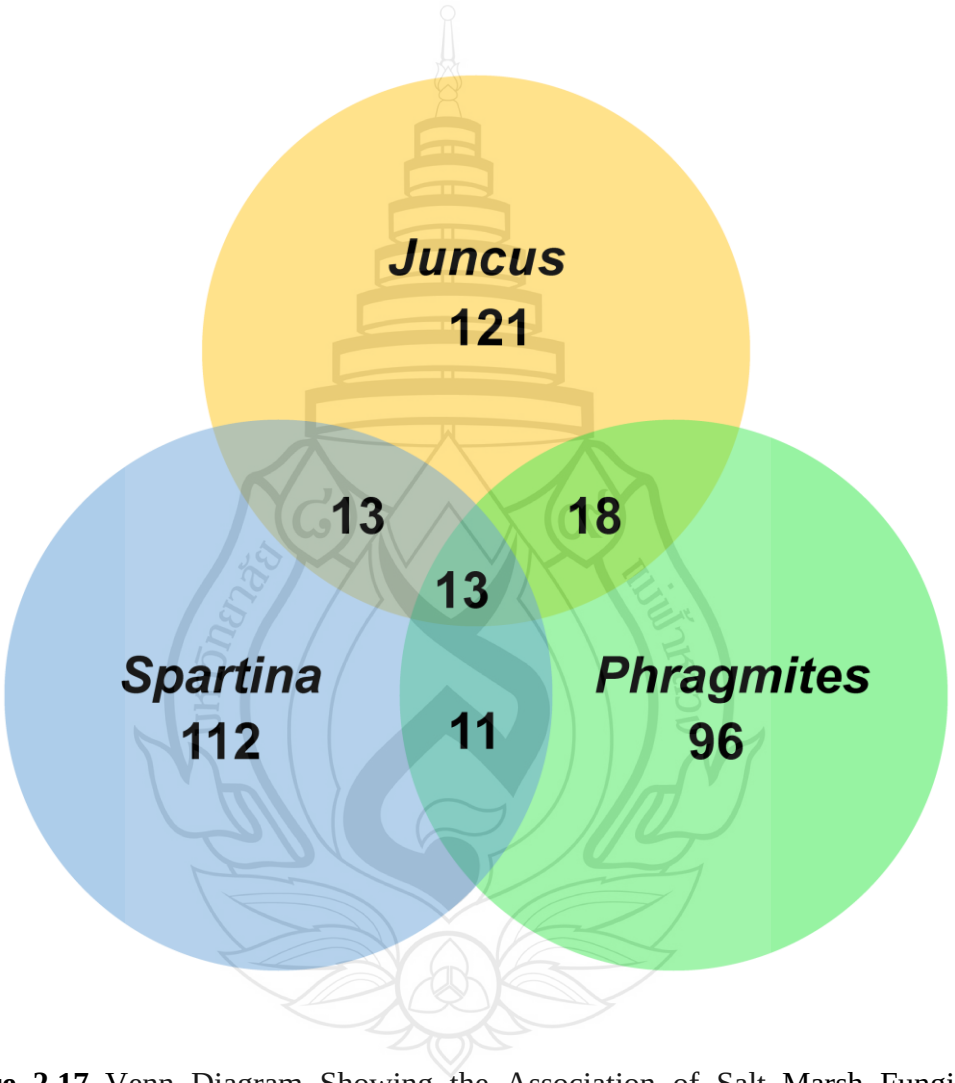


Figure 2.17 Venn Diagram Showing the Association of Salt Marsh Fungi from Commonly Studied Halophytes

2.6 Acknowledgments

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CHAPTER 3

PHYLOGENETIC ASSESSMENT AND TAXONOMIC REVISION OF *Halobyssothecium* AND *Lentithecium* (LENTITHECIACEAE, PLEOSPORALES)[2]

Abstract

Our studies on lignicolous aquatic fungi in Thailand, Sweden, and the UK resulted in the collection of three new *Halobyssothecium* species *H. bambusicola*, *H. phragmitis*, *H. versicolor*) assigned to Lentitheciaceae (Pleosporales, Dothideomycetes). Multi-loci phylogenetic analyses of the combined large subunit, small subunit, internal transcribed spacers of ribosomal DNA, and the translation elongation factor 1-alpha sequence data enabled a revision of the taxa assigned to *Lentithecium* and the transfer of *L. cangshanense*, *L. carbonneanum*, *L. kunmingense*, *L. unicellulare*, and *L. voraginesporum* to *Halobyssothecium*. Collection of an asexual morph of *L. lineare* and phylogenetic analysis confirmed its taxonomic placement in *Keissleriella*. Detailed descriptions and illustrations of *H. bambusicola*, *H. phragmitis*, and *H. versicolor* are provided.

Keywords: 3 New Taxa, Dothideomycetes, Freshwater Fungi, Marine Fungi, Multi Locus Phylogeny

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3.1 Introduction

Pleosporales, typified by *Pleospora herbarum* (Pers.) Rabenh. (Pleosporaceae), was formally established by Luttrell and Barr (in Barr [388] and characterized by perithecioid ascomata, usually with a papillate apex, ostiolate, cellular pseudoparaphyses, and bitunicate asci. Phylogenetic studies of Pleosporales have been provided by Schoch et al. [389], Zhang et al. [390, 391], Hyde, Jones, et al. [24], Liu et al. [20], and Hongsanan et al. [22]. Lumbsch and Huhndorf [392] included 28 families and 175 genera in Pleosporales, with 12 genera listed under Pleosporales, genera *incertae sedis*. Hyde, Jones, et al. [24] accepted 88 families in Pleosporales. Wijayawardene et al. [204] and Hongsanan et al. [22] included 91 families in Pleosporales. Ecologically, the order includes saprotrophs, parasites, pathogens, epiphytes, and endophytes [22].

Zhang, Wang, et al. [393] established Lentitheciaceae with *Lentithecium fluviatile* (Aptroot & Van Ryck.) K.D. Hyde, J. Fourn. & Ying Zhang as the genus and species type, and included *L. arundinaceum* (Sowerby) K.D. Hyde, J. Fourn. & Ying Zhang, *L. aquaticum* Ying Zhang, J. Fourn. & K.D. Hyde, *Stagonospora macropycnidia* Cunnell, *Wettsteinina lacustris* (Fuckel) Shoemaker & C.E. Babc., *Keissleriella cladophila* (Niessl) Corbaz, and *Katumotoa bambusicola* Kaz. Tanaka & Y. Harada. Suetrong et al. [3] also referred *Massarina phragmiticola* Poon & K.D. Hyde to the new family. Lentitheciaceous taxa are saprobic on herbaceous and woody plants having narrow peridia, fusiform to broadly cylindrical pseudoparaphyses, hyaline ascospores with 1–3-transverse septa and containing refractive globules, surrounded by a mucilaginous sheath or extended appendage-like sheaths and asexual morphs producing stagonospora-like or dendrophoma-like asexual morphs [24, 391, 394]. Fourteen genera from different habitats are included in Lentitheciaceae based on molecular data: *Darksidea*[395], *Halobyssothecium* [297], *Katumotoa* [396], *Keissleriella* [397], *Lentithecium* [393], *Murilentithecium* [394], *Neoophiosphaerella* [398], *Phragmocamarosporium* [399], *Pleurophoma* [400, 401], *Poaceascoma* [402], *Pseudomurilentithecium* [403], *Setoseptoria* [404], Tingoldiago [405], and *Towyspora* [302].

Lentithecium was proposed to accommodate *Massarina arundinacea* (Sowerby) Leuchtm., *M. fluviatilis* Aptroot & Van Ryck., and *Keissleriella linearis* E. Müll. ex Dennis [393]. The genus currently contains ten species that were described from aquatic habitats, seven from freshwater, and three from marine environments. *Lentithecium* species have been described from submerged wood [310, 398, 406–408] and submerged parts of plant host species (*Juncus, Phragmites, Fraxinus, Alnus,* and *Platanus*) [3, 163, 300, 393]. *Lentithecium* is characterized by its immersed to semi-immersed, globose to subglobose ascomata, a thin peridium, cellular pseudoparaphyses, short pedicellate asci and fusoid or filiform, subglobose, hyaline, brown, uni- to multi-septate ascospores, usually surrounded by a sheath [24, 310, 393].

Halobyssothecium was introduced by Dayarathne et al. [297] to accommodate several taxa variously described under *Pleospora obiones* P. Crouan & H. Crouan by Crouan and Crouan [95] and *Leptosphaeria discors* Sacc. & Ellis by Saccardo [409]. This "taxon" had been assigned to various genera: *Metasphaeria* [410], *Heptameria* [411], and *Passeriniella* [263, 412, 413]. Various studies have shown that *Pleospora obiones*/*Leptosphaeria discors* are synonyms, but clearly do not belong in any of these genera [413]. Jones [16], Cavaliere [414], and Webber [296] reported *Leptosphaeria discors* collections with larger ascospores than those by Crouan and Crouan [95] indicating that there might be a second morphologically similar species. *Halobyssothecium obiones* (P. Crouan & H. Crouan) Dayarathne, E.B.G. Jones & K.D. Hyde has a worldwide distribution in temperate regions and occurs as a saprobe of *Agropyron junceiforme*, *Halimione portulacoides, Spartina* species, on intertidal wood, bamboo, and exposed test panels of *Betula pubescens* and *Fagus sylvatica* [18, 36]. Devadatha et al. [294] introduced *Halobyssothecium estuariae* B. Devadatha, Calabon, K.D. Hyde & E.B.G. Jones collected on a dead culm of *Phragmites communis* from Slebech Estuary, Pembrokeshire, UK, which resembles the generic type *H. obiones* in possessing subglobose or ellipsoidal, carbonaceous ascomata, conical papilla and ascospores with brown central cells and hyaline end cells [297]. However, *H. estuariae* is distinct from *H. obiones* in having a longer and narrower papilla (65–85 × 55–85 vs. 25–35 × 130–145 μm) and smaller ascospores (20–44 × 4–9 vs. 28–47 × 10–18 μm). *Halobyssothecium obiones* and *H. estuariae* differ by 5.1% (22/431 bp) in ITS and 3.12% (28/895 bp) in TEF1-α sequence data.

Keissleriella, typified by *K. aesculi* (Höhn.) Höhn., is characterized by an ostiolar neck covered by short dark setae [22, 398]. *Keissleriella* is the most speciose genus in Lentitheciaceae with 46 epithets listed in Species Fungorum (http://www.-speciesfungorum.org/Names/Names.asp; accessed on December 2020) and 38 morphological species, 25 of which have molecular data. Sequence data for the type species of *Keissleriella* is unavailable, but phylogenetic studies confirmed its placement within Lentitheciaceae [22, 398, 415].

In the present study, a phylogenetic tree of taxa in Lentitheciaceae was constructed based on sequence data of four loci (LSU, SSU, ITS, TEF1-α) to reevaluate the taxonomic status of *Halobyssothecium* and *Lentithecium*. The latest treatments and updated accounts of Lentitheciaceae in Dayarathne et al. [297], Hongsanan et al. [22], and Wijayawardene et al. [204] are followed in this paper. The insights from the multi-loci analyses and morphological observations reveal three new species of *Halobyssothecium* and confirm the taxonomic placement of *Lentithecium lineare* (E. Müll. ex Dennis) K.D. Hyde, J. Fourn. & Ying Zhang in *Keissleriella*, and *L. cangshanense* Z.L. Luo, X.J. Su & K.D. Hyde, *L. carbonneanum* J. Fourn., Raja & Oberlies, *L. kunmingense* Dong, H. Zhang & K.D. Hyde, *L. unicellulare* Abdel-Aziz and *L. voraginesporum* Abdel-Wahab, Bahkali & E.B.G. Jones in *Halobyssothecium*. The transfers are made, and descriptions, photographic plates, and multi-loci phylogenetic analyses are provided.

3.2 Materials and Methods

3.2.1 Sample Collection, Morphological Observation, and Fungal Isolation

Samples of submerged decayed wood were collected from a freshwater stream in Chiang Mai, Thailand. Dead and decaying *Halimione portulacoides* was collected from Hayling Island bridge, Hampshire, UK. Drift culms and stems of *Phragmites* sp. were obtained from Sudersand and Kappelshamnsviken in Gotland, Sweden. The samples were observed using a stereomicroscope for the presence of fruiting bodies. Micromorphological features were photographed using a Motic SMZ 168 Series dissection microscope for fungal structures on the woody substrate while microscopic

characters were documented using a Nikon Eclipse 80i microscope. Single spore isolation was used to obtain pure cultures and colonial characteristics described. Herbarium-type specimens are deposited in Mae Fah Luang University (MFLU). Ex-type and ex-paratype living cultures are deposited at Mae Fah Luang University Culture Collection (MFLUCC). The new species and combinations were registered in Faces of Fungi (http://www.facesoffungi.org/; Jayasiri et al. [202]) and Index Fungorum database (http://www.indexfungorum.org/names/IndexFungorumRegisterName.asp).

3.2.2 DNA Extraction, PCR Amplification, and Sequencing

Fungal mycelia from pure cultures grown in malt extract agar (MEA) for 30 days were scraped using a sterilized scalpel and kept in a sterilized 1.5 mL microcentrifuge tube. Genomic DNA was extracted using the Biospin Fungus Genomic DNA Extraction Kit (BioFlux®, China) following the manufacturer's protocol. Polymerase chain reaction (PCR) was used to amplify four markers: the large subunit (LSU), small subunit (SSU), internal transcribed spacers (ITS) of rDNA, and the translation elongation factor 1-alpha gene (TEF1-α). The LSU was amplified using the primers LR0R and LR5 [416]. The SSU was amplified using the primers NS1 and NS4 [417]. For ITS, primers ITS5 and ITS4 were used [417]. TEF1-α was amplified using primers EF1-983F and EF1-2218R [418]. Polymerase chain reaction was performed in a volume of 25 µl, which contained 12.5 µl of 2× Power Taq PCR Master Mix (Bioteke Co., China), 1 µl of each primer (10 pM), 1 µl genomic DNA, and 9.5 µl double-distilled water (ddH2O). The PCR thermal cycle program for LSU, SSU, ITS, and TEF1-α amplification were as follows: initial denaturing step of 94 °C for 3 min, followed by 40 cycles of denaturation at 94 °C for 45 seconds, annealing at 56 °C for 50 seconds, elongation at 72 °C for 1 min, and final extension at 72 °C for 10 min. Agarose gel electrophoresis was done to confirm the presence of amplicons at the expected molecular weight. PCR products were purified and sequenced with the primers mentioned above at a commercial sequencing provider (Beijing Qingke Biotechnology Co., Ltd). A BLASTn search of the newly generated sequences was carried out to exclude contamination and to search for related taxa in GenBank database (www.ncbi.nlm.nih.gov/blast/).

3.2.3 Phylogenetic Analyses

The taxa table was assembled based on the closest matches from the BLASTn search results and from recently published data in Dayarathne et al. [297] and Devadatha et al. [294]. Sequences generated from the four markers were analyzed along with other sequences retrieved from GenBank (Table 3.1). Four datasets, one for each marker, were aligned with MAFFT v. 7 using the web server (http://mafft.cbrc.jp/-alignment/server; Katoh et al. (2019) with the following settings: L-INS-i tree-based iterative refinement methods, 20PAM/k = 2 scoring matrix for nucleotide sequences and 1.53 gap opening penalty. Alignment was further refined manually, where necessary, using BioEdit v.7.0.9.0 [420]. Aligned sequences were automatically trimmed using TrimAl v. 1.3 on the web server (http://phylemon.bioinfo.cipf.es/-utilities.html). The online tool "ALTER" [421] was used to convert the alignment file to phylip and nexus formats. Phylogenetic analyses of both individual and combined gene data were performed using maximum likelihood (ML), maximum parsimony (MP), and Bayesian inference (BI).

Maximum parsimony (MP) analysis was performed using the heuristic search option with 1000 random taxa addition and tree bisection and reconnection (TBR) as the branch-swapping algorithm in PAUP* 4.0b4 [422]. All characters were unordered and of equal weight and gaps were treated as missing data. Maxtrees were unlimited, branches of zero length were collapsed and all multiple, equally parsimonious trees were saved. Clade stability was assessed using a bootstrap (BS) analysis with 1000 replicates, each with ten replicates of random stepwise addition of taxa [423]. Descriptive tree statistics for parsimony (tree length [TL], consistency index [CI], retention index [RI], relative consistency index [RC], and homoplasy index [HI]) were calculated for trees generated under different optimality criteria.

Maximum likelihood analysis was performed using RAxML-HPC2 on XSEDE on the CIPRES web portal [225–227] (http://www.phylo.org/portal2/; Miller et al. [228]). The GTR+GAMMA model of nucleotide evolution was used. RAxML rapid bootstrapping of 1,000 replicates was performed. The best-fit evolutionary models for individual and combined datasets were estimated under the Akaike Information Criterion (AIC) using jModeltest 2.1.10 on the CIPRES web portal and each resulted to the GTR+I+G model [424, 425]. Bayesian inference analyses were performed using

MrBayes v. 3.2.6 on XSEDE at the CIPRES webportal [229], using the parameter setting of two parallel runs, four chains, the run for 4,000,000 generations at which point the standard deviation of split frequencies was below 0.01. Trees were sampled every 1,000 generations and all other parameters were left as default. Bayesian analysis resulted in 4,000 trees after the run wherein the first 1,000 trees, 25% of the total, were in the burn-in phase and were discarded. The remaining 3,000 trees were used to calculate the posterior probability (PP). Newly generated sequences have been deposited in GenBank (Table 3.1).

3.2.4 Genealogical Concordance Phylogenetic Species Recognition Analysis

New species and their most closely related species were analyzed using the Genealogical concordance phylogenetic species recognition (GCPSR) model. A pairwise homoplasy index (PHI) [426] test was performed in SplitsTree4 [427, 428] as described by Quaedvlieg et al. [429]. This was done to determine the recombination level within phylogenetically closely related species using a four-locus concatenated dataset for new species of *Halobyssothecium*. The test detects incompatibility between pairs of sites regarding whether there is genealogical history that can be inferred parsimoniously that does not involve any recurrent or convergent mutations. Pairwise homoplasy index below a 0.05 threshold ($\Phi w < 0.05$) indicates that there is significant recombination present in the dataset. The relationships between closely related species were visualized by constructing a split graph, using both the LogDet transformation and splits decomposition options.

Table 3.1 Taxa Used in this Study for the Analysis of Combined LSU, SSU, ITS rDNA, and TEF1-α Sequence Data and their GenBank Accession Numbers. The Newly Generated Sequences are Indicated with Asterisk (*)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Bambusicola bambusae	MFLUCC 11–0614	JX442035	JX442039	NR_121546	KP761722
Bambusicola irregulispora	MFLUCC 11–0437	JX442036	JX442040	NR_121547	KP761723
Bambusicola massarinia	MFLUCC 11–0389	JX442037	JX442041	JX442033	KP761725
Bambusicola splendida	MFLUCC 11–0439	JX442038	JX442042	NR12154 9	KP761726
Bimuria novae-zelandiae	CBS 107.79	AY016356	AY016338	NR_159620	DQ471087
Byssothecium circinans	CBS 675.92	GU205217	GU205235	–	GU349061
Corynespora cassiicola	CBS 100822	GU301808	GU296144	–	GU349052
Corynespora smithii	CABI5649b	GU323201	–	–	GU349018
Darksidea alpha	CBS 135650	KP184019	KP184049	NR_137619	KP184166
Darksidea beta	CBS 135637	KP184023	KP184074	NR_137957	KP184189
Darksidea delta	CBS 135638	KP184024	KP184069	NR_137075	KP184184
Darksidea epsilon	CBS 135658	KP184029	KP184070	NR_137959	KP184186

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	**SSU**	**ITS**	***TEF1-α***
Darksidea gamma	CBS 135634	KP184031	KP184073	NR_137587	KP184188
Darksidea zeta	CBS 135640	KP184013	KP184071	NR_137958	KP184191
Falciformispora lignatilis	BCC 21117	GU371826	GU371834	KF432942	GU371819
Falciformispora lignatilis	BCC 21118	GU371827	GU371835	KF432943	GU371820
*Halobyssothecium bambusicola**	MFLUCC 20–0226	MT068489	MT068494	MN83341	MT477868
Halobyssothecium cangshanense	DLUCC 0143	KU991149	KU991150	–	–
Halobyssothecium carbonneanum	CBS 144076	MH069699	–	MH062991	–
Halobyssothecium estuariae	MFLUCC 19–0386	MN598871	MN598868	MN598890	MN597050
Halobyssothecium estuariae	MFLUCC 19–0387	MN598872	MN598869	MN598891	MN597051
Halobyssothecium kunmingense	KUMCC 19–0101	MN913732	MT864313	MT627715	MT954408
Halobyssothecium obiones	20AV2566	–	–	KX263862	–
Halobyssothecium obiones	27AV2385	–	–	KX263864	–
Halobyssothecium obiones	MFLUCC 15–0381	MH376744	MH376745	MH377060	MH376746
*Halobyssothecium phragmitis**	MFLUCC 20–0223	MT068486	MT068491	MT232435	MT477865

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	**SSU**	**ITS**	***TEF1-α***
*Halobyssothecium phragmitis**	MFLUCC 20–0225	MT06848 8	MT06849 3	MT2324 37	MT4778 67
Halobyssothecium unicellulare	MD129	KX50537 5	KX50537 3	–	–
Halobyssothecium unicellulare	MD6004	KX50537 6	KX50537 4	–	–
*Halobyssothecium versicolor**	MFLUCC 20–0222	MT06848 5	MW3460 47	MT2324 34	MT4778 64
Halobyssothecium voraginesporum	CBS H-22560	NG_0661 71	NG_0630 65	–	–
Helicascus nypae	BCC 36752	GU47978 9	GU47975 5	–	GU4798 55
Kalmusia scabrispora	KT2202	AB52459 4	AB52445 3	LC01457 6	AB5391 07
Karstenula rhodostoma	CBS 690.94	GU30182 1	GU29615 4	–	GU3490 67
Katumotoa bambusicola	KT 1517a	AB52459 5	AB52445 4	LC01456 0	AB5391 08
Keissleriella bambusicola	KUMCC 18–0122	MK9958 80	MK9958 78	MK9958 81	MN2131 56
Keissleriella breviasca	KT 581	AB80758 7	AB79729 7	AB81145 4	AB8085 66
Keissleriella breviasca	KT 649	AB80758 8	AB79729 8	AB81145 5	AB8085 67
Keissleriella camporesiana	MFLUCC 15–0029	MN4017 41	MN4017 43	MN4017 45	MN3979 07
Keissleriella camporesii	MFLUCC 15–0117	MN2528 86	MN2529 07	MN2528 79	–

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	**SSU**	**ITS**	***TEF1-α***
Keissleriella caraganae	KUMCC 18–0164	MK3594 39	MK3594 44	MK3594 34	MK3590 73
Keissleriella cirsii	MFLUCC 16–0454	KY49778 0	KY49778 2	KY49778 3	KY4977 86
Keissleriella cladophila	CBS 104.55	GU30182 2	GU29615 5	MH8573 91	GU3490 43
Keissleriella culmifida	KT2308	AB80759 1	AB79730 1	LC01456 1	AB8085 70
Keissleriella culmifida	KT2642	AB80759 2	AB79730 2	LC01456 2	AB8085 71
Keissleriella dactylidicola	MFLUCC 13–0866	KT31550 6	KT31550 5	–	KT3155 07
Keissleriella dactylidis	MFLUCC 13–0751	KP19766 8	KP19766 6	KP19766 7	KP19766 9
Keissleriella genistae	CBS 113798	GU20522 2	GU20524 2	–	–
Keissleriella gloeospora	KT829	AB80758 9	AB79729 9	LC01456 3	AB8085 68
Keissleriella linearis	IFRD2008	FJ795435	FJ795478	–	–
Keissleriella linearis	MFLUCC 19–0410	MN5988 73	MN5988 70	MN5988 92	MN6079 78
*Keissleriella linearis**	MFLUCC 20–0224	MT06848 7	MT06849 2	MT2324 36	MT4778 66
Keissleriella phragmiticola	CPC 33249	MT22390 3	–	MT2238 08	MT2237 15
Keissleriella phragmiticola	MFLUCC 17–0779	MG8290 14	–	MG8289 04	–

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Keissleriella poagena	CBS 136767	KJ869170	–	KJ869112	–
Keissleriella quadriseptata	KT2292	AB807593	AB797303	AB811456	AB808572
Keissleriella rara	CBS 118429	GU479791	GU479757	–	–
Keissleriella rosacearum	MFLUCC 15–0045	MG829015	MG829123	–	–
Keissleriella rosae	MFLUCC 15–0180	MG829016	MG922549	–	–
Keissleriella rosarum	MFLUCC 15–0089	MG829017	MG829124	MG828905	–
Keissleriella sp.	KT895	AB807590	AB797300	–	AB808569
Keissleriella sparticola	MFLUCC 14–0196	KP639571	–	–	–
Keissleriella tamaricicola	MFLUCC 14–0168	KU900300	–	KU900328	–
Keissleriella taminensis	KT571	AB807595	AB797305	LC014564	AB808574
Keissleriella taminensis	KT594	AB807596	AB797306	–	–
Keissleriella taminensis	KT678	AB807597	AB797307	LC014565	AB808575
Keissleriella trichophoricola	CBS 136770	KJ869171	–	KJ869113	–
Keissleriella yonaguniensis	HHUF 30138	NG_059402	NG_064856	NR_155212	AB808573

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Latorua caligans	CBS 576.65	MH870362	–	MH858723	–
Latorua grootfonteinensis	CBS 369.72	NG_058181	–	–	–
Lentithecium aquaticum	CBS 123099	GU301823	GU296156	NR_160229	GU349068
Lentithecium clioninum	KT1149A	AB807540	AB797250	LC014566	AB808515
Lentithecium clioninum	KT1220	AB807541	AB797251	LC014567	AB808516
Lentithecium fluviatile	CBS 122367	FJ795451	FJ795493	–	GU349074
Lentithecium fluviatile	CBS 123090	FJ795450	FJ795492	–	–
Lentithecium pseudoclioninum	KT1111	AB807544	AB797254	AB809632	AB808520
Longipedicellata aptrootii	MFLUCC 10–0297	KU238894	KU238895	KU238893	KU238892
Longipedicellata aptrootii	MFLUCC 18–0988	MN913744	–	MT627733	–
Macrodiplodiopsis desmazieri	CBS 140062	NG_058182	–	NR_132924	–
Massarina cisti	CBS 266.62	FJ795447	FJ795490	LC014568	AB808514
Massarina eburnea	CBS 139697	AB521735	AB521718	LC014569	AB808517
Massarina eburnea	CBS 473.64	GU301840	GU296170	AF383959	GU349040

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Montagnula opulenta	AFTOL-ID 1734	DQ67808 6	AF16437 0	AF38396 6	–
Morosphaeria ramunculicola	JK5304B	GU47979 4	GU47976 0	–	–
Multiseptospora thailandica	MFLUCC 11–0183	NG_0595 54	KP75395 5	NR_1480 80	KU7056 57
Murilentithecium clematidis	MFLUCC 14–0561	KM4087 58	KM4087 60	KM4087 56	KM4544 44
Murilentithecium clematidis	MFLUCC 14–0562	KM4087 59	KM4087 61	KM4087 57	KM4544 45
Murilentithecium lonicerae	MFLUCC 18–0675	MK2143 73	MK2143 76	MK2143 70	MK2143 79
Murilentithecium rosae	MFLUCC 15–0044	MG8290 30	MG8291 37	MG8289 20	–
Neoophiosphaerella sasicola	KT1706	AB52459 9	AB52445 8	LC01457 7	AB5391 11
Palmiascoma gregariascomum	MFLUCC 11–0175	KP74449 5	KP75395 8	KP74445 2	–
Parabambusicola thysanolaenae	KUMCC 18–0147	NG_0664 35	NG_0676 81	NR_1640 44	MK0982 09
Parabambusicola thysanolaenae	KUMCC 18–0148	MK0981 98	MK0982 02	MK0981 93	MK0982 11
Paraconiothyrium brasiliense	CBS 100299	JX49612 4	AY64252 3	JX49601 1	–
Paraphaeosphaeria michotii	MFLUCC 13–0349	KJ93928 2	KJ93928 5	KJ93927 9	–
Paraphaeosphaeria minitans	CBS 122788	EU75417 3	EU75407 4	–	GU3490 83

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Phaeodothis winteri	CBS 182.58	GU301857	GU296183	–	DQ677917
Phragmocamarosporium hederae	MFLUCC 13–0552	KP842915	KP842918	–	–
Phragmocamarosporium platani	MFLUCC 14–1191	KP842916	KP842919	–	–
Phragmocamarosporium rosae	MFLUCC 17–0797	MG829051	MG829156	–	MG829225
Pleohelicoon fagi	MFLUCC 15–0182	NG_066320	NG_065791	NR_163353	–
Pleomonodictys descalsii	CBS 142298	KY853522	–	KY853461	–
Pleurophoma ossicola	CBS139905	KR476769	–	KR476736	–
Pleurophoma ossicola	CPC24985	KR476770	–	KR476737	–
Pleurophoma pleurospora	CBS130329	JF740327	–	–	–
Poaceascoma aquaticum	MFLUCC 14–0048	KT324690	KT324691	–	–
Poaceascoma halophila	MFLUCC 15–0949	MF615399	MF615400	–	–
Poaceascoma helicoides	MFLUCC 11–0136	KP998462	KP998463	KP998459	KP998461
Poaceascoma taiwanense	MFLUCC 18–0083	MG831567	MG831568	MG831569	
Pseudomurilentithecium camporesii	MFLUCC 14–1118	MN638846	MN638850	MN638861	MN648730

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Pseudoxylomyces elegans	KT 2887	AB807598	AB797308	–	AB808576
Setoseptoria arundelensis	MFLUCC 17–0759	MG829073	MG829173	MG828962	–
Setoseptoria arundinacea	CBS 123131	GU456320	GU456298	–	GU456281
Setoseptoria arundinacea	CBS 619.86	GU301824	GU296157	–	–
Setoseptoria englandensis	MFLUCC 17–0778	MG829074	MG829174	MG828963	–
Setoseptoria lulworthcovensis	MFLU 18–0110	MG829075	MG829175	–	–
Setoseptoria magniarundinacea	KT1174	AB807576	AB797286	LC014596	AB808552
Setoseptoria phragmitis	CBS 114802	KF251752	–	KF251249	KF253199
Setoseptoria phragmitis	CBS 114966	KF251753	–	KF251250	KF253200
Setoseptoria scirpi	MFLUCC 14–0811	KY770982	KY770980	MF939637	KY770981
Splanchnonema platani	CBS 221.37	MH867404	–	MH855894	DQ677908
Splanchnonema platani	CBS 222.37	KR909316	KR909318	KR909311	KR909319
Stagonospora macropycnidia	CBS 114202	GU301873	GU296198	–	GU349026
Tingoldiago clavata	MFLUCC 19–0495	MN857180	MN857188	MN857184	–

Table 3.1 (continued)

Species	Strain/voucher number	GenBank accession number			
		LSU	SSU	ITS	*TEF1-α*
Tingoldiago clavata	MFLUCC 19–0496	MN8571 78	MN8571 86	MN8571 82	–
Tingoldiago clavata	MFLUCC 19–0498	MN8571 79	MN8571 87	MN8571 83	–
Tingoldiago graminicola	KH155	AB52174 5	AB52172 8	LC01459 9	AB8085 62
Tingoldiago graminicola	KH68	AB52174 3	AB52172 6	LC01459 8	AB8085 61
Tingoldiago graminicola	KT891	AB52174 4	AB52172 7	LC01460 0	AB8085 63
Tingoldiago hydei	MFLUCC 19–0499	MN8571 77	–	MN8571 81	–
Towyspora aestuari	MFLUCC 15–1274	KU24885 2	KU24885 3	NR_1480 95	–
Trematosphaeria pertusa	CBS 122368	FJ201990	FJ201991	KF01566 8	KF01570 1
Trematosphaeria pertusa	CBS 122371	GU30187 6	GU34899 9	KF01566 9	KF01570 2

3.3 Results

3.3.1 Phylogenetic Analyses

The combined LSU, SSU, ITS and TEF1-α dataset comprised of 133 taxa from Lentitheciaceae, with *Corynespora cassiicola* (Berk. & M.A. Curtis) C.T. Wei (CBS 100822) and *C. smithii* (Berk. & Broome) M.B. Ellis (CABI5649b) as outgroup taxa (Table 3.1). The analyzed dataset, after trimming, comprised a total 3,578 characters including gaps (LSU = 1,274 bp, SSU = 916 bp, ITS = 473 bp, TEF1-α = 915 bp) with

1,632 distinct alignment patterns and 28.64% proportion of gaps and completely undetermined characters, 2,235 constant, 414 parsimony uninformative and 940 parsimony informative characters. The MP analysis resulted a single most parsimonious tree (TL = 5,457, CI = 0.364, RI = 0.674, RC = 0.245, HI = 0.636). The ML analysis for the combined dataset provided the best scoring tree (Fig. 1) with a final ML optimization likelihood value of -32434.024914 (ln). Parameters for the GTR+I+G model of the combined LSU, SSU, ITS and TEF1-α dataset are as follows: estimated base frequencies; A = 0.241074, C = 0.248510, G = 0.273533, T = 0.236882; substitution rates AC = 1.038579, AG = 2.219296, AT = 1.397250, CG = 1.151737, CT = 6.450277, GT = 1.000000; gamma distribution shape parameter α = 0.228421. The Bayesian analysis indicated the average standard deviation of split frequencies at the end of total MCMC generations is 0.007035. Phylogenetic analyses of the combined data matrix resulted in well-resolved clades (Figure 3.1). The tree topologies resulted from maximum likelihood (ML), maximum parsimony (MP), and Bayesian posterior probabilities (BYPP) analyses were congruent.

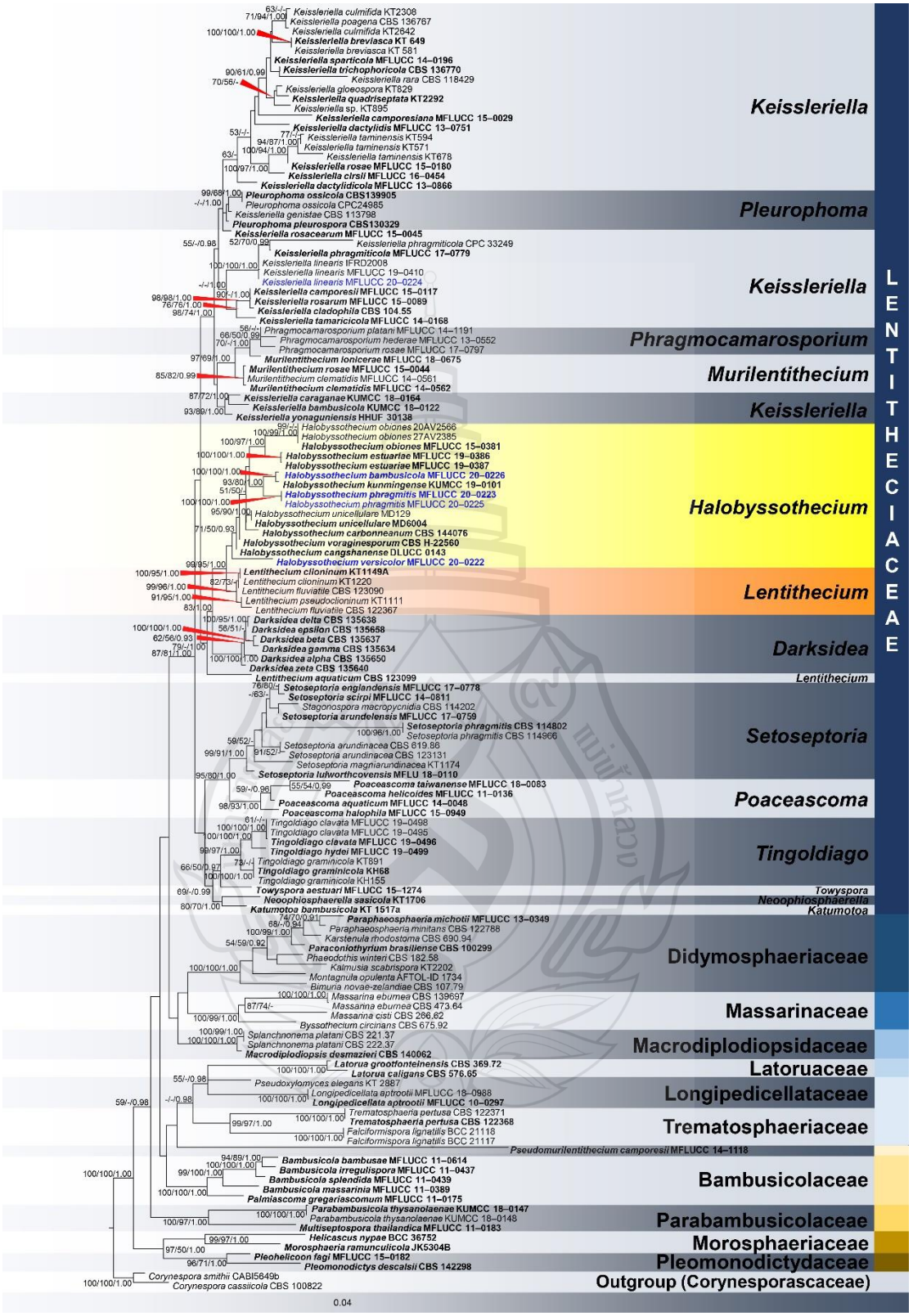

Keissleriella culmifida KT2308
Keissleriella poagena CBS 136767
Keissleriella culmifida KT2642
Keissleriella breviasca KT 649
Keissleriella breviasca KT 581
Keissleriella sparticola MFLUCC 14–0196
Keissleriella trichophoricola CBS 136770
Keissleriella rara CBS 118429
Keissleriella gloeospora KT829
Keissleriella quadriseptata KT2292
Keissleriella sp. KT895
Keissleriella camporesiana MFLUCC 15–0029
Keissleriella dactylidis MFLUCC 13–0751
Keissleriella taminensis KT594
Keissleriella taminensis KT571
Keissleriella taminensis KT678
Keissleriella rosae MFLUCC 15–0180
Keissleriella clrsii MFLUCC 16–0454
Keissleriella dactylidicola MFLUCC 13–0866
Keissleriella
Pleurophoma ossicola CBS139905
Pleurophoma ossicola CPC24985
Keissleriella genistae CBS 113798
Pleurophoma pleurospora CBS130329
Keissleriella rosacearum MFLUCC 15–0045
Pleurophoma
Keissleriella phragmiticola CPC 33249
Keissleriella phragmiticola MFLUCC 17–0779
Keissleriella linearis IFRD2008
Keissleriella linearis MFLUCC 19–0410
Keissleriella linearis MFLUCC 20–0224
Keissleriella camporesii MFLUCC 15–0117
Keissleriella rosarum MFLUCC 15–0089
Keissleriella cladophila CBS 104.55
Keissleriella tamaricicola MFLUCC 14–0168
Keissleriella
Phragmocamarosporium platani MFLUCC 14–1191
Phragmocamarosporium hederae MFLUCC 13–0552
Phragmocamarosporium rosae MFLUCC 17–0797
Phragmocamarosporium
Murilentithecium lonicerae MFLUCC 18–0675
Murilentithecium rosae MFLUCC 15–0044
Murilentithecium clematidis MFLUCC 14–0561
Murilentithecium clematidis MFLUCC 14–0562
Murilentithecium
Keissleriella caraganae KUMCC 18–0164
Keissleriella bambusicola KUMCC 15–0122
Keissleriella yonaguniensis HHUF 30138
Keissleriella
Halobyssothecium obiones 20AV2566
Halobyssothecium obiones 27AV2385
Halobyssothecium obiones MFLUCC 15–0381
Halobyssothecium estuariae MFLUCC 19–0386
Halobyssothecium estuariae MFLUCC 19–0387
Halobyssothecium bambusicola MFLUCC 20–0226
Halobyssothecium kunmingense KUMCC 19–0101
Halobyssothecium phragmitis MFLUCC 20–0223
Halobyssothecium phragmitis MFLUCC 20–0225
Halobyssothecium unicellulare MD129
Halobyssothecium unicellulare MD6004
Halobyssothecium carbonnearum CBS 144076
Halobyssothecium voraginesporum CBS H-22560
Halobyssothecium cangshanense DLUCC 0143
Halobyssothecium versicolor MFLUCC 20–0222
Halobyssothecium
Lentithecium clioninum KT1149A
Lentithecium clioninum KT1220
Lentithecium fluviatile CBS 123090
Lentithecium pseudoclioninum KT1111
Lentithecium fluviatile CBS 122367
Lentithecium
Darksidea delta CBS 135638
Darksidea epsilon CBS 135658
Darksidea beta CBS 135637
Darksidea gamma CBS 135634
Darksidea alpha CBS 135650
Darksidea zeta CBS 135640
Darksidea
Lentithecium aquaticum CBS 123099
Lentithecium
Setoseptoria englandensis MFLUCC 17–0778
Setoseptoria scirpi MFLUCC 14–0811
Stagonospora macropycnidia CBS 114202
Setoseptoria arundelensis MFLUCC 17–0759
Setoseptoria phragmitis CBS 114802
Setoseptoria phragmitis CBS 114966
Setoseptoria arundinacea CBS 619.86
Setoseptoria arundinacea CBS 123131
Setoseptoria magnia rundinacea KT1174
Setoseptoria luhworthcovensis MFLU 18–0110
Setoseptoria
Poaceascoma taiwanense MFLUCC 18–0083
Poaceascoma helicoides MFLUCC 11–0136
Poaceascoma aquaticum MFLUCC 14–0048
Poaceascoma halophila MFLUCC 15–0949
Poaceascoma
Tingoldiago clavata MFLUCC 19–0498
Tingoldiago clavata MFLUCC 19–0495
Tingoldiago clavata MFLUCC 19–0496
Tingoldiago hydei MFLUCC 19–0499
Tingoldiago graminicola KT891
Tingoldiago graminicola KH68
Tingoldiago graminicola KH155
Tingoldiago
Towyspora aestuari MFLUCC 15–1274
Towyspora
Neoophiosphaerella lasiicola KT1706
Neoophiosphaerella
Katumotoa bambusicola KT 1517a
Katumotoa
Paraphaeosphaeria michotii MFLUCC 13–0349
Paraphaeosphaeria minitans CBS 122788
Karstenula rhodostoma CBS 690.94
Paraconiothyrium brasiliense CBS 100299
Phaeodothis winteri CBS 182.58
Didymosphaeriaceae
Kalmusia scabrispora KT2202
Montagnula opulenta AFTOL-ID 1734
Bimuria novae-zelandiae CBS 107.79
Massarina eburnea CBS 139697
Massarina eburnea CBS 473.64
Massarina cisti CBS 266.62
Byssothecium circinans CBS 675.92
Massarinaceae
Splanchnonema platani CBS 221.37
Splanchnonema platani CBS 222.37
Macrodiplodiopsis desmazieri CBS 140062
Macrodiplodiopsidaceae
Latorua grootfonteinensis CBS 369.72
Latorua caligans CBS 576.65
Latoruaceae
Pseudoxylomyces elegans KT 2887
Longipedicellata aptrootii MFLUCC 18–0988
Longipedicellata aptrootii MFLUCC 10–0297
Longipedicellataceae
Trematosphaeria pertusa CBS 122371
Trematosphaeria pertusa CBS 122368
Falciformispora lignatilis BCC 21118
Falciformispora lignatilis BCC 21117
Trematosphaeriaceae
Pseudomurilentithecium camporesii MFLUCC 14–1118
Bambusicola bambusae MFLUCC 11–0614
Bambusicola irregulispora MFLUCC 11–0437
Bambusicola splendida MFLUCC 11–0439
Bambusicola massarinia MFLUCC 11–0389
Palmiascoma gregariascomum MFLUCC 11–0175
Bambusicolaceae
Parabambusicola thysanolaenae KUMCC 18–0147
Parabambusicola thysanolaenae KUMCC 18–0148
Multiseptospora thailandica MFLUCC 11–0183
Parabambusicolaceae
Helicascus nypae BCC 36752
Morosphaeria ramunculicola JK5304B
Morosphaeriaceae
Pleohelicoon fagi MFLUCC 15–0182
Pleomonodictys descalsii CBS 142298
Pleomonodictydaceae
Corynespora smithii CABI5649b
Corynespora cassiicola CBS 100822
Outgroup (Corynesporascaceae)
0.04
LENTITHECIACEAE

Figure 3.1 Phylogenetic Tree Generated from Maximum Likelihood (ML) Analysis Based on LSU, SSU, ITS And TEF1-A Sequence Data for the Species from Lentitheciaceae and Closely Related Families in Pleosporales. Bootstrap Support Values for Maximum Likelihood (ML) and Maximum Parsimony (MP) Higher Than 50% and Bayesian Posterior Probabilities (BYPP) Greater Than 0.90 are Indicated Above the Nodes in this Order. The New Isolates are Represented in Blue. The Ex-Type Strains are Indicated in Bold. The Tree is Rooted to *Corynespora cassiicola* (CBS 100822) and *C. smithii* (CABI5649b) (Corynesporascaceae). Bar = 0.04 Estimated Number of Nucleotide Substitutions Per Site Per Branch

In the phylogenetic analysis (Figure 3.1), *Halobyssothecium* formed a well-supported monophyletic clade, separate from *Lentithecium* (99% ML, 95% MP, 1.00 BYPP). Three novel *Halobyssothecium* species, *H. bambusicola, H. phragmitis* and *H. versicolor* grouped with the other *Halobyssothecium* species in Lentitheciaceae. Moreover, five species of *Lentithecium* (*L. cangshanense, L. carbonneanum, L. kunmingense, L. unicellulare, L. voraginesporum*) clustered with *Halobyssothecium*. Therefore, these five *Lentithecium* species are transferred to *Halobyssothecium* in this study. *Halobyssothecium bambusicola* MFLUCC 20–0226 and *H. kunmingense* KUMCC 19–0101 were strongly supported as sister species (100% ML, 100% MP, 1.00 BYPP) and clustered with *H. phragmitis* (MFLUCC 20–0223, MFLUCC 20–0225) with high support (93% ML, 80% MP, 1.00 BYPP). *Halobyssothecium versicolor* MFLUCC 20–0222 forms a distinct lineage and basal to other *Halobyssothecium* species. *Lentithecium clioninum* (Kaz. Tanaka, Sat. Hatak. & Y. Harada) Kaz. Tanaka & K. Hiray. and *L. pseudoclioninum* Kaz. Tanaka & K. Hiray. clustered together with *L. fluviatile*, the type species of *Lentithecium* (99% ML, 96% MP, 1.00 BYPP). Furthermore, *L. lineare* MFLUCC 20–0224 clustered with the other two strains of *L. lineare* (IFRD2008, MFLUCC 19–0410) (100% ML, 100% MP, 1.00 BYPP).

The relationships between the three new species of *Halobyssothecium* were visualized by constructing a split graph and PHI-test revealed significant genetic recombination levels between two strains of *H. phragmitis* suggesting that they are

conspecific. The presence of recombination among fungal isolates is the hallmark that these belong to the same biological species. No significant recombination events were observed between *H. bambusicola, H. kunmingense,* and *H. phragmitis* indicating that these are different species (Figure 3.2). PHI-test returns the probability of observing the data under the null hypothesis of no recombination.

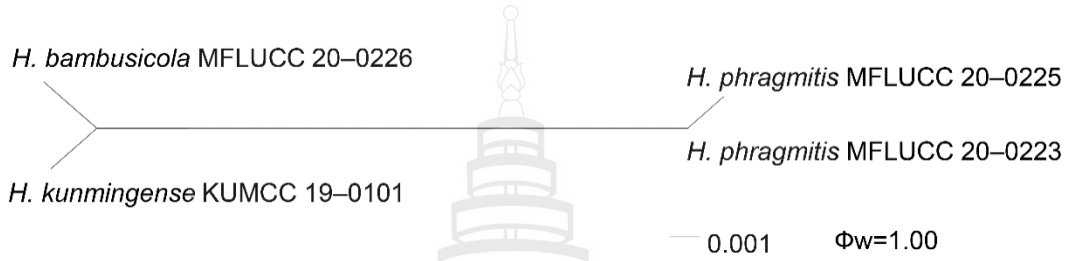


Figure 3.2 Results of The Pairwise Homoplasy Index (PHI) Test of Three Novel *Halobyssothecium* Species Using Both Logdet Transformation and Splits Decomposition. PHI Test Results (Φw) < 0.05 Indicating Significant Recombination Within the Dataset

3.3.2 Taxonomy

3.3.2.1 *Halobyssothecium* Dayar., E.B.G. Jones & K.D. Hyde.

Saprobic on salt marsh halophytes and submerged decaying wood in aquatic habitats. Sexual morph: *Ascomata* immersed, semi-immersed or erumpent, scattered to clustered, globose to subglobose or ellipsoidal, carbonaceous, dark brown to black, gregarious, ostiolate. *Peridium* comprising of only pseudoparenchyma or two layers: outer layer of brown, inner layer of elongated, hyaline cells. *Pseudoparaphyses* cellular, septate, branched. *Asci* 8-spored, bitunicate, fissitunicate, cylindric-clavate to subcylindrical, short pedicellate, thick-walled, with or without an ocular chamber. *Ascospores* overlapping uni- to bi-seriate, clavate, ellipsoid, subcylindrical ovoid or fusoid with rounded ends, versicolored, initially hyaline when young to pale brown, golden brown or brown when mature, end cells hyaline, central cells brown, 1–3-septate, constricted at the septa, guttulate, slightly curved, lacking gelatinous sheath or appendages, slimy material without well-defined sheath. Asexual morph: Coelomycetous. *Conidiomata* pycnidial, immersed, erumpent at maturity, solitary or

aggregated, unilocular, globose to subglobose, ellipsoidal, dark brown to black, ostiolate. *Ostiole* single, circular to subcylindrical, papillate, dark brown to black, centrally located. *Conidiomatal wall* composed of thick-walled, dark brown cells of *textura angularis*. *Conidiophores* reduced to conidiogenous cells. *Conidiogenous cells* enteroblastic, phialidic, determinate, smooth-walled, hyaline, aseptate, globose to subglobose, ellipsoidal, cylindrical to subcylindrical. *Conidia* spherical to globose, subglobose, ovate to obovate, ellipsoidal, clavate to subclavate, lageniform, hyaline, aseptate, straight to slightly curved, guttulate, smooth, and thick-walled. *Chlamydospores* apical, rarely intercalary, single or in chains, branching, filamentous, filiform to narrowly fusiform straight or curved, catenate, rarely solitary, branched, septate, with thickened septa, brown to dark brown at the septa, smooth-walled.

Type species: *Halobyssothecium obiones* (P. Crouan & H. Crouan) Dayar., E.B.G. Jones & K.D. Hyde, Mycological Progress 17 (10): 1165 (2018)

Notes: Two species were included in *Halobyssothecium*, *H. obiones* and *H. estuariae* [294, 297], collected from various host substrates in temperate regions. In the present study, three collections of morphologically distinct isolates were encountered, two were asexual morphs (*H. bambusicola* and *H. phragmitis*) and one sexual morph (*H. versicolor*), which advances the current understanding of how complex the genus is. The complexity was noted by Devadatha et al. [294] based on previous collections by various authors. For instance, two morphologically similar taxa of *H. obiones* were collected but differed in ascospore measurements (24–38 × 8–14 μm vs. 38–56 × 16–22 μm) [16, 296, 414], but no sequence data was available at that time to distinguish them. *Halobyssothecium versicolor* agrees with the generic description of the genus and its placement in the phylogenetic tree redefines what comprises *Halobyssothecium*. Currently, the *Lentithecium* clade includes *L. fluviatile, L. clioninum and L. pseudoclioninum*, while *L. cangshanense, L. carbonneanum, L. kunmingense, L. unicellulare*, and *L. voraginesporum* grouped within the *Halobyssothecium* clade and are transferred herein.

1. *Halobyssothecium bambusicola* M.S. Calabon, Boonmee, E.B.G. Jones & K.D. Hyde, sp. nov. (Figure 3.3)

Index Fungorum number: IF558089; Facesoffungi number: FoF 09430

Etymology: the specific epithet “bambusicola” refers to the host, of which the fungus was collected

Holotype: MFLU 20–0549

Saprobic on decaying bamboo culms submerged in freshwater habitat. Sexual morph: Undetermined. Asexual morph: *Conidiomata* 350–470 μm high, 230–260 μm wide ($\bar{x}$ = 415.4 × 238.6, n = 10), pycnidial, immersed, erumpent at maturity, solitary or aggregated, globose, unilocular, dark brown to black, ostiolate. *Ostiole* 150–160 × 170–180 μm, single, circular to subcylindrical, centrally located. *Conidiomatal wall* 14–28 μm, composed of thick-walled, dark brown cells of *textura angularis*. *Conidiophores* reduced to conidiogenous cells. *Conidiogenous cells* 6–45 × 2–5 μm ($\bar{x}$ = 19.7 × 3.3, n = 30), enteroblastic, phialidic, hyaline, aseptate, cylindrical to subcylindrical. *Conidia* 6–12 × 5–10 μm ($\bar{x}$ = 8.7 × 6.8, n = 50), spherical to globose, obovate, ellipsoidal, subclavate, hyaline, aseptate, guttulate, smooth, and thick-walled.

Culture characteristics: On MEA, colony circular with filamentous margin, reaching 25–30 mm diam. in 25 days at 25 °C, brown to grayish brown from above, yellowish brown to dark brown from below, surface rough, dry, raised, with dense mycelia, edge filiform.

Material examined: THAILAND, Chiang Mai Province, on submerged bamboo culm in a stream, 11 February 2019, M.S. Calabon (MFLU 20–0549, holotype), ex-type living culture MFLUCC 20–0226

Notes: Several species of freshwater fungi growing on submerged bamboo have been recorded, e.g. *Acrodictys liputii* L. Cai, K.Q. Zhang, McKenzie, W.H. Ho & K.D. Hyde, *Annulatascus liputii* L. Cai & K.D. Hyde, *Ascoyunnania aquatica* L. Cai & K.D. Hyde, *Cataractispora receptaculorum* W.H. Ho, K.D. Hyde & Hodgkiss, *Dictyosporella thailandensis* W. Dong, H. Zhang & K.D. Hyde, *Fluminicola saprophytica* W. Dong, H. Zhang & K.D. Hyde, *Dictyochaeta curvispora* L. Cai, McKenzie & K.D. Hyde, *D. plovercovensis* Goh & K.D. Hyde, *Diluviicola aquatica* W. Dong, H. Zhang & K.D. Hyde, *Linocarpon bambusicola* L. Cai & K.D. Hyde, *Ophioceras guttulatum* C.K.M. Tsui, H.Y.M. Leung, K.D. Hyde & Hodgkiss, *Microthecium sepedonioides* (Preuss) Y. Marín, Stchigel, Guarro & Cano, *Payosphaeria minuta* H.Y.M. Leung, *Pseudoproboscispora thailandensis* W. Dong, H. Zhang & K.D. Hyde, and *Saccardoella minuta* L. Cai & K.D. Hyde [430–437].

Halobyssothecium bambusicola closely resembles *H. kunmingense*, and *H. unicellulare*. *Halobyssothecium kunmingense* has wider conidiomata (210–250 × 320–350 μm vs. 350–470 × 230–260 μm), a thicker peridium (60–80 μm vs 14–28 μm), smaller conidiogenous cells (5–19 × 2–5 μm vs. 6–45 × 2–5 μm) and larger globose to obovoidal conidia (8–14 × 5–8 μm vs 6–12 × 5–10) with large guttules, compared to *H. bambusicola* [7]. The guidelines on species delimitation for new species by Jeewon and Hyde [438] was followed and pairwise comparison of ribosomal ITS sequences showed 15 nucleotide base pair differences among the 800 nucleotides analyzed between *H. bambusicola* and *H. kunmingense*. Moreover, a SplitsTree analysis supports the introduction of H. bambusicola (Figure 3.2).

Halobyssothecium bambusicola has larger conidiomata (350–470 μm high × 230–260 μm wide vs. 115–235 μm high × 140–235 μm wide) and larger globose to obovoidal conidia (6–12 × 5–8 μm vs. 6–9 × 4–5 μm) with large guttules as compared to *H. unicellulare* [310]. *Halobyssothecium bambusicola* differs from *H. phragmitis* in conidial shape (globose to obovate conidia vs. ovoid to fusoid-ellipsoidal). *Halobyssothecium bambusicola* and *H. phragmitis* differ by 6.84% (36/526 bp) and 2.63% (25/952 bp) in ITS and TEF1-α, respectively. The multigene phylogenetic analysis placed *H. bambusicola* within *Halobyssothecium* in a well-supported subclade with *H. kunmingense* (100% ML, 100% MP, 1.00 BYPP) and the coelomycetous marine *H. phragmitis* (93% ML, 80% MP, 1.00 BYPP).

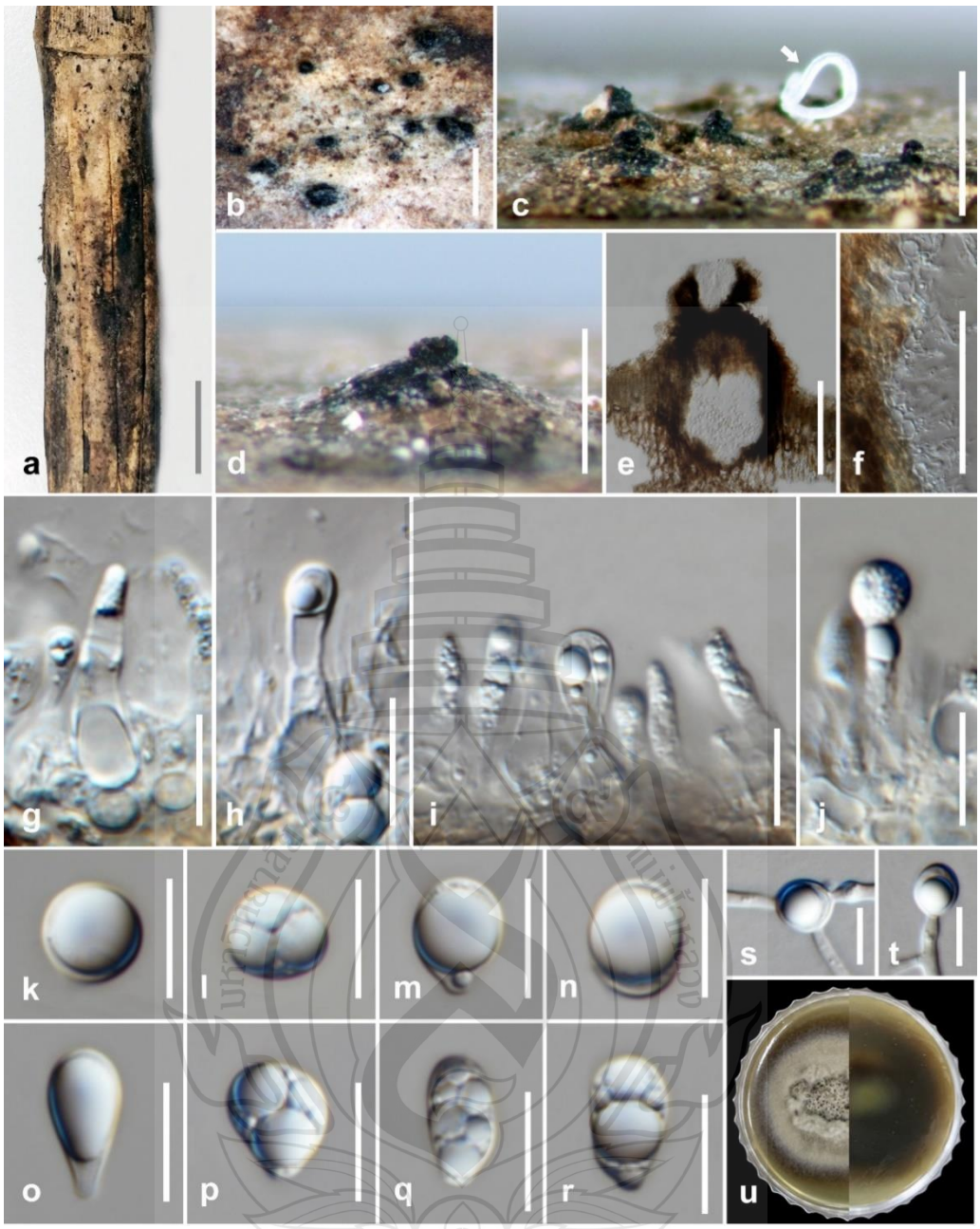


Figure 3.3 *Halobyssothecium bambusicola* (MFLU 20–0549, Holotype). a Host. b–d Appearance of Conidiomata on Host Surface Releasing Conidia in a Cirrus (Arrow). e Vertical Section of Conidioma. f Conidiomatal Wall. g–j Developing Conidia Attach to Conidiogenous Cell. k–r Conidia. s–t Germinated Conidia. u Colony on MEA (Obverse, Reverse). Scale Bars: a = 200 mm; b = 1 mm; c–e = 500 μm; f = 50 μm; g–t = 10 μm

2. *Halobyssothecium phragmitis* M.S. Calabon, E.B.G. Jones, S. Tibell & K.D. Hyde, sp. nov. (Figure 3.4)

Index Fungorum number: IF558090; Facesoffungi number: FoF 09431

Etymology: In reference to the host genus Phragmites, from which the species was isolated.

Holotype: MFLU 20–0550

Saprobic on dead *Phragmites* culm and stem. Sexual morph: Undetermined. Asexual morph: *Conidiomata* 205–340 μm high, 215–280 μm wide, solitary, scattered, immersed to slightly immersed, pycnidial, subglobose to ellipsoidal, unilocular, black, with indistinct ostioles. *Ostioles* 82–96 μm, central, circular, papillate, dark brown to black. *Conidiomatal wall* 13.3–31 μm, thick-walled, 7–9 layers, comprising of dark brown cells, of *textura angularis*, inner layer comprising hyaline gelatinous layer, thickening at the upper and basal zone. *Conidiophores* reduced to conidiogenous cells. *Conidiogenous cells* 8–18 × 1–5 μm ($\overline{x}$ = 11.6 × 3.2 μm, n = 20), enteroblastic, phialidic, cylindrical to lageniform, determinate, hyaline, formed from inner layers of conidiomata. *Conidia* 9–19 × 2–6 μm ($\overline{x}$ = 13.7–4.1 μm, n = 50), cylindrical, fusoid-ellipsoidal, straight or slightly curved, hyaline, aseptate to 1–2-septate, unicellular, mostly with one large central guttule per cell, smooth-walled.

Culture characteristics: Conidia germinated on MEA within 24 h. Colonies on MEA, reaching 10–12 mm diam. in 14 days at 25 °C. Mycelium superficial, white, flattened, hairy, dense, circular, flattened, margin entire; reverse pale brown.

Material examined: SWEDEN, Gotland, Kappelshamnsviken, on dead *Phragmites* culm (Poaceae), 7 March 2019, E.B.G. Jones, GJ653 (MFLU 20–0550, holotype), ex-type living cultures MFLUCC 20–0223; ibid, Sudersand, on dead *Phragmites* (Poaceae) stem, 7 March 2019, E.B.G. Jones, GJ659 (MFLU 20–0552, paratype), ex-paratype living culture MFLUCC 20–0225.

Notes: *Halobyssothecium phragmitis* resembles *Stagonospora macro-pycnidia* but the former species has smaller conidiomata (205–340 μm high × 215–280 μm wide vs. 410–1020 μm high × 120–380 μm wide), and smaller conidia (9–19 × 2–6 μm vs. 22–42 × 2.5–5 μm) [439]. *Setoseptoria phragmitis* Quaedvl., Verkley & Crous is distinct from *H. phragmitis* with smaller conidiomata (up to 200 μm vs. 205–340 μm)

and longer subcylindrical conidia (19–38 × 3.5–4 μm vs. 9–19 × 2–6 μm) [404]. *Phragmocamarosporium platani* Wijayaw., Yong Wang bis & K.D. Hyde differs from *H. phragmitis* with smaller conidiomata (100–320 μm high, 150–300 μm diam. vs. 205–340 μm high, 215–280 μm wide) and larger brown conspicuous phragmospores (12–13 × 5–7.5 μm vs. 9–19 × 2–6 μm) [399]. *Pleurophoma ossicola* Crous, Krawczynski & H.-G. Wagner differs from *H. phragmitis* with smaller conidia (3–5 × 1.5–2 μm vs. 9–19 × 2–6 μm) [401]. *Murilentithecium clematidis* Wanas., Camporesi, E.B.G. Jones & K.D. Hyde is distinct from *H. phragmitis* with larger conidiomata (0.5–1.5 mm diam vs. 205–340 μm) [394]. *Keissleriella quadriseptata* Kaz. Tanaka & K. Hiray. differs from *H. phragmitis* with larger cylindrical conidia (25–32 × 6–8.5 μm vs. 9–19 × 2–6 μm) [398]. Based on multi-loci phylogenetic analyses, the above-mentioned species are phylogenetically distinct to *H. phragmitis*.

Halobyssothecium phragmitis is phylogenetically close to *H. bambusicola* and *H. kunmingense* (93% ML, 80% MP, 1.00 BYPP). It differs from the latter with ovoidal to fusoid-ellipsoidal conidia. *Halobyssothecium kunmingense* has 14 base pair differences (800 bp, 1.75%) with *H. bambusicola* in ITS region.

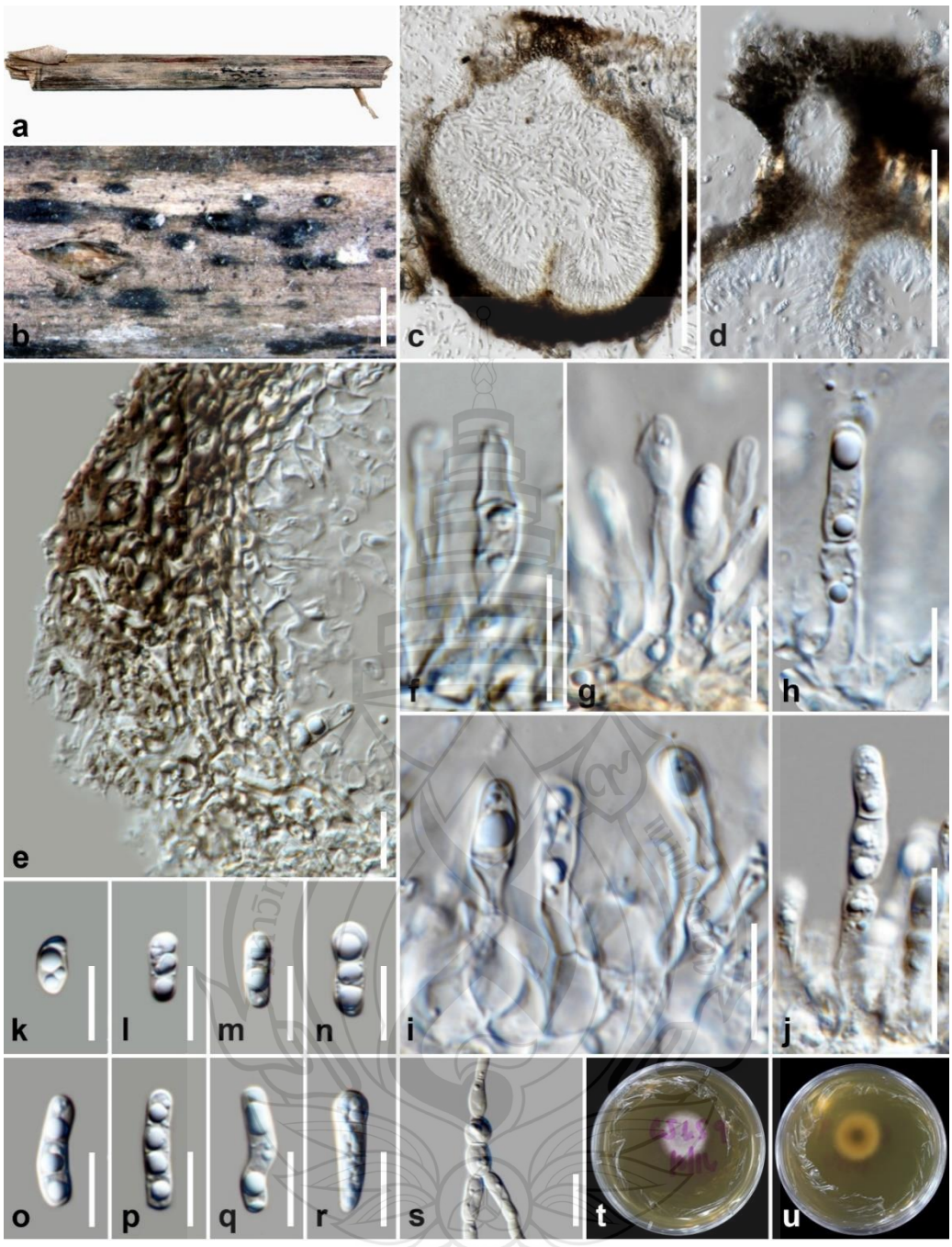


Figure 3.4 *Halobyssothecium phragmitis* (MFLU 20–0550, Holotype). a Host. b Appearance of Conidiomata on Host Surface. c Vertical Section of Conidioma. d Ostiole. e Conidiomatal Wall. f–j Developing Conidia Attach to Conidiogenous Cells. k–r Conidia. s Germinated Conidium. t–u Colony on MEA: from t Obverse, u Reverse. Scale bars: b, c = 200 μm, d = 100 μm, e–s = 10 μm

3. *Halobyssothecium versicolor* M.S. Calabon, E.B.G. Jones & K.D. Hyde, sp. nov. (Figure 2.5)

Index Fungorum number: IF558091; Facesoffungi number: FoF 09432

Etymology: Referring to the versicolored ascospore

Holotype: MFLU 19–0676

Saprobic on *Halimione portulacoides* in intertidal habitat. Sexual morph: *Ascomata* 265–510 μm high, 365–530 μm wide ($\bar{x}$ = 408 × 459, n = 10), superficial to semi-immersed, clustered, sometimes solitary, scattered, subglobose or ellipsoidal, dark brown to black, carbonaceous, conspicuous at the surface, uni- to bi-loculate, ostiolate, with periphyses. *Ostiolar neck* 105–190 μm long, 95–175 μm wide ($\bar{x}$ = 150 × 135, n = 10) central, papillate, rounded, short, crest-like, dark brown, composed of several layers of pseudoparenchymatous cells. *Peridium* 37–94 μm thick, comprising two layers: outer layer of brown pseudoparenchyma; inner layer of elongated, hyaline cells. *Pseudoparaphyses* 2–3 μm wide, septate, hyaline, filiform, branched and anastomosing above the asci. *Asci* 137–173 × 17–12 μm ($\bar{x}$ = 153.4 × 14.7 μm, n = 20), 8-spored, clavate to subcylindrical, short pedicellate with an ocular chamber. *Ascospores* 18–41 × 6–12 μm ($\bar{x}$ = 27.4 × 8.6, n = 20), overlapping, uniseriate to biseriately arranged, versicolored, central cells are pale brown to dark brown, end cells hyaline, 1-septate at an early stage, 3-septate when mature, and constricted at the septa, slightly curved, lacking gelatinous sheaths or appendages. Asexual morph: Undetermined.

Culture characteristics: Ascospores germinated on MEA within 24 h. Colonies on MEA, reaching 10–15 mm diam. in 15 days at 25 °C. Mycelium superficial, initially pale yellow, becoming yellowish brown with age, hairy, effuse with wavy edge, dense, circular, raised, undulate, reverse dark yellowish brown.

Material examined: UK, Hampshire, Hayling Island bridge, on dead *Halimione portulacoides* (Amaranthaceae), 28 February 2019, E.B.G Jones, GJ597 (MFLU 19–0676, holotype), ex-type living cultures MFLUCC 20–0222.

Notes: *Halobyssothecium versicolor* resembles *H. obiones* and *H. estuariae* in having versicolored ascospores with brown central cells and hyaline end cells. *Halobyssothecium versicolor* differs from *H. obiones* with larger ascomata (265–510 μm high, 365–530 μm diam. vs. 360–400 μm high, 340–380 μm diam.) and smaller

ascospores (18–41 × 6–12 μm vs. 28–47 × 10–18 μm) [297]. The asexual morph was not observed in the culture, but *Halobyssothecium* species have xylomyces-like chlamydospores [294] and phoma-like conidia [18, 282].

Phylogenetic analysis shows that *Halobyssothecium versicolor* clustered within Lentitheciaceae and basal to other *Halobyssothecium* species. *Halobyssothecium versicolor* is phylogenetically close to *H. bambusicola, H. kunmingense,* and *H. phragmitis*. A comparison of ITS and TEF1-α sequence data of *H. versicolor* differs by 40 (8.97%, 446 bp) and 56 (6.26%, 895 bp) base pairs with *H. obiones*, type species of the genus.

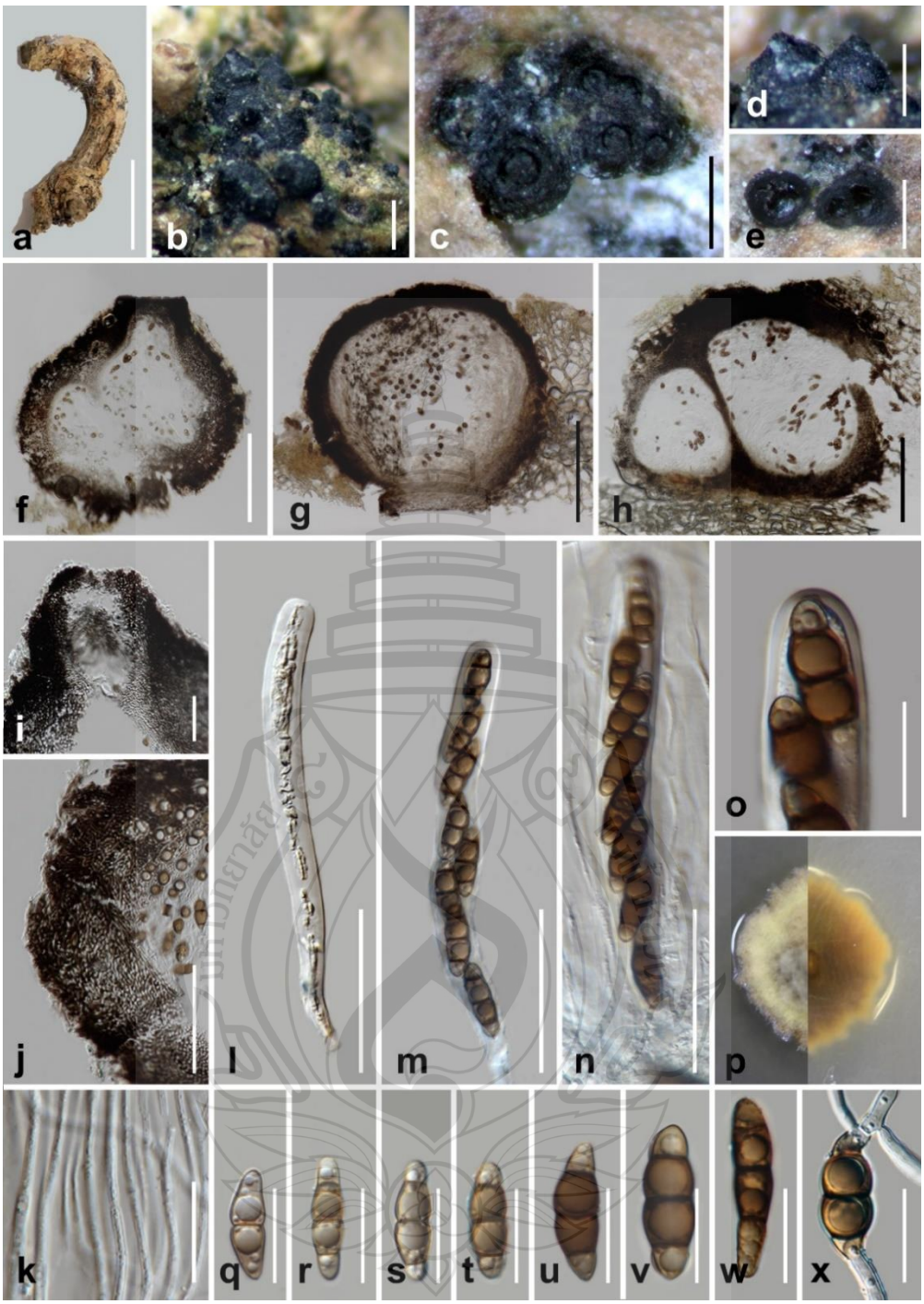


Figure 3.5 *Halobyssothecium versicolor* (MFLU 19–0676, Holotype). a Host. b–e Appearance of Ascomata on the Host. f–h Sections of Ascomata. i Ostiole. j Section of Peridium. k Pseudoparaphyses. l–n Asci. o Apex of Ascus. p Colony on MEA. q–w Ascospores. x Germinated Conidium. Scale Bar: a = 20 mm, b–e = 500 μm, f–h = 200 μm, i–n = 50 μm, o, q–x = 20 μm

4. *Keissleriella linearis* E. Müll. ex Dennis, Kew Bulletin 19 (1): 120 (1964)

Facesoffungi number: FoF 09433

Saprobic on decaying culm of *Phragmites* sp. Sexual morph: [for descriptions and illustrations, see Dennis (1964)]. Asexual morph: *Conidiomata* 42.6–53 μm high, 15.5–22.2 μm wide ($\bar{x}$ = 51 × 18.8 μm, n = 10), black, solitary, scattered, immersed, pycnidial, subglobose to ellipsoidal, unilocular. *Conidiomatal wall* 2.2–7.4 μm, thick-walled, 7–9 layers, comprising of dark brown cells, of *textura angularis* to *textura globosa*, inner layer comprising hyaline gelatinous layer, thickening at the upper zone. *Conidiophores* reduced to conidiogenous cells. *Conidiogenous cells* 4.1–7.7 × 1.6–3.8 μm, ($\bar{x}$ = 5.8 × 3.1 μm, n = 20), enteroblastic, phialidic, cylindrical to lageniform, determinate, hyaline. *Conidia* 4.0–6.5 × 1.0–2.5 μm ($\bar{x}$ = 5.4 × 1.8 μm, n = 50), ovoid, obovoidal, cylindrical, fusoid-ellipsoidal, straight, or slightly curved, unicellular, hyaline, guttulate, smooth-walled. Beta conidia not observed. For illustrations of morphological characters, refer to Tibell et al. (2020).

Culture characteristics: Ascospores germinated on MEA within 24 h. Colonies on MEA, reaching 22–24 × 26–28 mm diam. in 25 days at 25 °C. Mycelium superficial, white to grayish white with age, hairy, effuse with wavy edge, dense, circular, raised, undulate to filiform with age; reverse dark yellowish brown.

Material examined: SWEDEN, Gotland, Kappelshamnsviken, on dead *Phragmites* culm (Poaceae), 7 March 2019, E.B.G. Jones, GJ654 (MFLU 20–0551), living culture MFLUCC 20–0224.

Notes: *Keisslerialla linearis* (MFLUCC 20–0224) groups with two strains of *K. linearis* (IFRD2008, MFLUCC 19–0410) with strong bootstrap support (100% ML, 100% MP, 1.00 BYPP; Figure 3.1). The new strain is an asexual morph of *K. linearis* observed from *Phragmites* sp. in Sweden [301]. In the phylogenetic analysis, *K. linearis* clustered with other *Keissleriella* species. A comparison of the LSU and SSU sequence data of *K. linearis* (IFRD2008) and the new strain (MFLUCC 20–0224) revealed no nucleotide differences.

3.3.3 New Combinations

3.3.3.1 *Halobyssothecium cangshanense* (Z.L. Luo, X.J. Su & K.D. Hyde) M.S. Calabon, K.D. Hyde & E.B.G. Jones, comb. nov.

Index Fungorum number: IF558092; Facesoffungi number: FoF 09434

Basionym: *Lentithecium cangshanense* Z.L. Luo, X.J. Su & K.D. Hyde, Phytotaxa 267 (1): 65 (2016)

Sexual morph: Descriptions and illustrations refer to Su et al. [407]. Asexual morph: Undetermined

Distribution: CHINA, Yunnan Province, saprobic on decaying wood submerged in a stream.

Notes: Holotype HKAS 84021. LSU and SSU sequence data are available.

3.3.3.2 *Halobyssothecium carbonneanum* (J. Fourn., Raja & Oberlies) M.S. Calabon, K.D. Hyde & E.B.G. Jones, comb. nov.

Index Fungorum number: IF558093; Facesoffungi number: FoF 09435

Basionym: *Lentithecium carbonneanum* J. Fourn., Raja & Oberlies, Persoonia 40: 295 (2018)

Sexual morph: Descriptions and illustrations refer to Crous et al. [408]. Asexual morph: Undetermined

Distribution: FRANCE, Haute-Garonne, Carbonne, SW of route du Lançon, artificial lake in a gravel pit, on submerged decorticated branch of *Populus*

Notes: Holotype ILLS 81639. ITS, LSU and RPB2 sequence data are available.

3.3.3.3 *Halobyssothecium kunmingense* (W. Dong, H. Zhang & K.D. Hyde) M.S. Calabon, Boonmee, K.D. Hyde & E.B.G. Jones, comb. nov.

Index Fungorum number: IF556948; Facesoffungi number: FoF 09436

Basionym: *Lentithecium kunmingense* W. Dong, H. Zhang & K.D. Hyde

Sexual morph: Undetermined. Asexual morph: Descriptions and illustrations refer to Dong et al. [7].

Distribution: CHINA, Yunnan Province, Kunming University of Science and Technology, on submerged wood in a stream [7].

Notes: HKAS 102150. LSU, SSU, ITS, TEF1-α sequence data are available.

3.3.3.4 *Halobyssothecium unicellulare* (Abdel-Aziz) M.S. Calabon, K.D. Hyde & E.B.G. Jones, comb. nov.

Index Fungorum number: IF558094; Facesoffungi number: FoF 09437

Basionym: *Lentithecium unicellulare* Abdel-Aziz, Fungal Diversity 80: 53 (2016)

Sexual morph: Undetermined. Asexual morph: Descriptions and illustrations refer to Hyde et al. [310].

Distribution: EGYPT, Sohag City, on decayed wood submerged in the River Nile [310]

Notes: Holotype CBS H-22674. LSU and SSU sequence data are available.

3.3.3.5 *Halobyssothecium voraginesporum* (Abdel-Wahab, Bahkali & E.B.G. Jones) M.S. Calabon, K.D. Hyde & E.B.G. Jones, comb. nov.

Index Fungorum number: IF558095; Facesoffungi number: FoF 09438

Basionym: *Lentithecium voraginesporum* Abdel-Wahab, Bahkali & E.B.G. Jones, Fungal Diversity 80: 53 (2016)

Sexual morph: Descriptions and illustrations refer to Hyde et al. [310].

Asexual morph: Undetermined

Distribution: SAUDI ARABIA, Arabian Gulf, Tarut mangroves, on submerged, decayed *Phragmites australis* (Poaceae), stem inside the mangrove stand [310]

Notes: Holotype CBS H-22560. LSU and SSU sequence data are available.

3.3.4 Notes for Lentitheciaceae

3.3.4.1 *Lentithecium aquaticum* Ying Zhang, J. Fourn. & K.D. Hyde, Fungal Diversity 38: 234 (2009)

Phylogenetic analysis shows that *Lentithecium aquaticum* does not cluster within the *Lentithecium* clade but forms a weakly supported subclade basal to *Darksidea* species. Further collections are required to establish the taxonomic position of *L. aquaticum.*

3.3.4.2 *Pseudomurilentithecium camporesii* Mapook & K.D. Hyde, Fungal Diversity 100: 69 (2020)

In the phylogenetic analysis (Figure 3.1), *Psedomurilentithecium camporeesii* does not cluster within Lentitheciaceae but forms a weakly supported clade basal to Latoruaceae, Longipedicellataceae, and Trematosphaeriaceae. Broader taxon sampling, including other families in Pleosporales, is necessary to confirm its placement.

3.3.4.3 *Keissleriella caudata* (E. Müll.) Corbaz, Phytopathologische Zeitschrift 28 (4): 411 (1957)

Preliminary phylogenetic analysis shows that *Keissleriella caudata* does not group with other *Keissleriella* species, but clusters instead with *Corynespora* species. Only ITS sequence data of *K. caudata* is available in GenBank with an accession number MH857034. BLAST analysis did not show any *Keissleriella* species in the first 100 closely related sequence data. A fresh collection of specimens and additional DNA sequence data are required to confirm its placement within Pleosporales.

3.4 Discussion

Since *Lentithecium* was established for *L. fluviatile* (≡ *Massarina fluviatilis*), ten additional species have been introduced from lotic and lentic freshwater [310, 393, 398, 407, 408], as well as marine habitats [3, 310, 393] and from different hosts. *Lentithecium arundinaceum* (≡ *Massarina arundinacea*), whose phylogenetic position was unclear for a long time and has been assigned to various genera (i.e., *Ampullina, Heptameria, Leptosphaeria, Lophiostoma, Massarina, Metasphaeria, Peripherostoma, Phaeosphaeria, Pleospora, Rhopographus, Sphaeria, Sphaeropsis*), was transferred by Tanaka et al. [398] to *Setoseptoria*. *Setoseptoria arundinacea* clustered with other *Setoseptoria* species in the phylogenetic analysis (Figure 3.1).

Multi-locus phylogenetic analysis shows that the three *Lentithecium* species, L. *aquaticum, L. lineare* and *L. rarum (*Kohlm., Volkm.-Kohlm. & O.E. Erikss.) Suetrong, Sakay., E.B.G. Jones, Kohlm. & Volkm.-Kohlm. do not group with other *Lentithecium* species, which was also reported by Tanaka et al. [398], Devadatha et al. [294], Dong et al. [7], and Wijayawardene et al. [204]. *Lentithecium aquaticum*, a species introduced by Zhang, Wang, et al. [393] based on LSU, SSU and RPB2 sequence data, forms a weakly supported clade basal to *Darksidea* and *Lentithecium*, which confirms the

observations of Tanaka et al. [398] (Figure 3.1). Dayarathne et al. [297] and Devadatha et al. [294] showed that *Lentithecium aquaticum* clustered within *Setoseptoria* and the asexual morph *Stagonospora macropycnidia*, while Crous et al. [408] confirmed that it does not group in *Lentithecium*.

Keissleriella rara was transferred to *Lentithecium* by Suetrong et al. [3] together with *K. cladophila* and *Massarina phragmiticola*. The present phylogenetic analysis shows that *Lentithecium rarum* clustered in *Keissleriella* as sister taxon to *K. trichophoricola* Crous & Quaedvl. (Figure 3.1). The same placement was observed also by Singtripop et al. [441]. *Keissleriella linearis* was transferred by Zhang, Wang, et al. [393] to *Lentithecium* based on LSU and SSU sequence data. *Keissleriella linearis*, in common with other *Keissleriella* species, has short brown setae around the apex of the ascomatal ostiole, but Zhang, Wang, et al. [393] opined that the presence of setae has little phylogenetic significance. In their phylogenetic analysis, other species and strains of *Keissleriella* were not included. Singtripop et al. [441] reexamined the type specimen of *L. lineare* and transferred it to *Keissleriella* based on morphology and LSU sequence data, and this is in agreement with recent studies by Tanaka et al. [398], Hyde et al. [310], and the present study. However, Dayarathne et al. [297] and Devadatha et al. [294] placed *L. lineare* in the *Lentithecium* clade. The recent discovery of the asexual morph of *L. lineare* by Tibell et al. [301] and the phylogenetic analysis based on the four-locus sequence dataset in the present study supports its taxonomic placement in *Keissleriella*.

The continuous discovery of novel fungal species has significantly contributed to the revision of fungal taxa [384, 385, 398, 403, 442–445]. Phylogenetic analysis of the newly discovered *Halobyssothecium* species, including all the members of Lentitheciaceae, with molecular data supports the transfer of *Lentithecium cangshanense, L. carbonneanum, L. kunmingense, L. unicellulare,* and *L. voraginesporum* to *Halobyssothecium*. In the present placement, members of *Halobyssothecium* have brown and versicolored ascospores without sheath and hyaline conidia, while *Lentithecium* species possess hyaline ascospores with mucilaginous sheaths.

Key to *Halobyssothecium* species

1 Asexual morph 2

1* Sexual morph.....5

2 Conidia, globose to obovate.....3

2* Conidia, ellipsoidal to cylindrical..... *H. phragmitis*

3 Conidiomata > 350 μm long..... *H. bambusicola*

3* Conidiomata < 350 μm long.....4

4 Conidiomata 210–250 × 320–350 μm .....*H. kunmingense*

4* Conidiomata 115–235 × 140–235 μm ..... *H. unicellulare*

5 Ascospores, brown.....6

5* Ascospores, versicolored 8

6 Asci > 100 μm long .....*H. carbonneanum*

6* Asci < 100 μm long 7

7 Asci 38–50 × 8–10 μm.....*H. voraginesporum*

7* Asci 65–78 × 11–13 μm..... *H. cangshanense*

8 Asci > 200 μm high 9

8* Asci < 200 μm high ..... *H. versicolor*

9 Asci 180–214 × 12–16 μm .....*H. obiones*

9* Asci 120–235 × 10–25 μm.....*H. estuariae*

3.5 Data availability

All data generated or analyzed in this study are included in this article. All alignments and trees from this study are available from TreeBASE (accession number 27520) and all sequences generated here are available from GenBank with accession numbers: MT232434–MT232437, MN833419 (ITS); MT068485–MT068489 (LSU); MT068491–MT068494, MW346047 (SSU); MT477864–MT477868 (TEF1-α).

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CHAPTER 4

FIVE NOVEL FRESHWATER ASCOMYCETES INDICATE HIGH UNDISCOVERED DIVERSITY IN LOTIC HABITATS IN THAILAND[3]

Abstract

An investigation of freshwater fungi in Thailand resulted in the collection of one new monotypic genus, *Neoxylomyces*, and a novel species each in *Camposporium*, *Brunneofusispora*, *Rattania*, *Neoxylomyces*, and *Phaeoacremonium*. *Camposporium dulciaquae* resembles *C. septatum* in conidial morphology and number of septa but differs in conidial sizes. *Brunneofusispora hyalina* is similar to *B. sinensis* in conidiogenesis and conidial shape but differs in the sizes of conidiomata and conidiogenous cells. *Rattania aquatica* is the second species in *Rattania*, while *Phaeoacremonium thailandense* is the third species recorded from freshwater habitats. A new genus, *Neoxylomyces*, typified by *N. multiseptatus*, is similar to *Xylomyces giganteus*, but differs in the number of septa, chlamydospore measurements, and absence of a mucilaginous coating around the chlamydospores. These novel taxa form an independent lineage distinct from other species based on multi-loci phylogenetic analyses. Descriptions, illustrations, and notes are provided for each taxon. These new freshwater ascomycetes add to the increasing number of fungi known from Thailand and it is now evident that there are numerous novel taxa awaiting to be described as new freshwater habitats are explored. An update of newly discovered taxa in the widely studied freshwater habitats of Thailand over the last five years is also provided.

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Keywords: 6 New Taxa, Dothideomycetes, *Neoxylomyces*, Sordariomycetes, Aquatic Fungi, Freshwater Fungi, Multi-Loci Phylogenetic Analyses, Tropical Mycology

4.1 Introduction

Freshwater fungi are a diverse and heterogenous taxonomic group occurring on a wide variety of substrates and with a global distribution [79, 174, 446, 447]. Jones et al. [174] estimated the number of freshwater fungi to be between 3069–4145, which is lower as compared to marine fungi with an estimated 12,500 species [36, 190]. There are 1898 species under 767 genera of marine fungi listed in www.marinefungi.org [36], but there are no recent published reports of freshwater fungal numbers [174, 448]. An online platform on freshwater fungi, www.freshwater-fungi.org. is presently being compiled. This comprehensive database presently includes 451 species of freshwater Sordariomycetes, while the outline of freshwater Dothideomycetes is in preparation [449]. Many habitats and substrates are still not well-explored and freshwater fungi are likely to be more numerous than those thriving in marine environments.

Freshwater fungi have been relatively well-studied in Asia over the past decade, particularly in China and Thailand. Several new taxa have been introduced and existing taxa lacking molecular data have been recollected and sequenced resolving their taxonomic placements [5, 449–453]. Several monographs and taxonomic revisions of freshwater fungi have also been published [5, 7, 22, 23]. In Thailand, Zhang et al. [82] listed 173 species belonging to 112 genera recorded from freshwater habitats in 2010. Hu et al. [454] reported 782 species of freshwater fungi in China. Since then, many additional novel taxa have been described in these countries, bringing the number even higher see [5, 24, 173, 299, 450, 451, 455–460]. In this paper, six novel taxa of freshwater ascomycetes in Thailand are introduced by combining multi-loci phylogeny and morphology approaches. It appears that there are numerous new taxa awaiting to be discovered and described as new freshwater

habitats are explored, or a particular genus is studied with molecular data, wherein its diversity is much higher than previously anticipated [5, 7, 173, 403].

We are carrying out surveys of freshwater fungi on submerged wood in streams along a north–south gradient in the Asia region [461] and here we introduce one new genus, *Neoxylomyces* (Phyllachorales genera *incertae sedis*, Phyllachorales), and one new species in each of *Camposporium* (Melanommataceae, Pleosporales), *Brunneofusispora* (Occultibambusaceae, Pleosporales), *Rattania* (Chaetosphaeriaceae, Chaetosphaeriales), and *Phaeoacremonium* (Togniniaceae, Togniniales).

4.2 Materials and Methods

4.2.1 Sample Collection, Morphological Observation, and Fungal Isolation

Samples of submerged decayed wood were collected from a freshwater stream in Chiang Mai Province (19°07.200′ N, 98°44.044′ E) and river in Tak Province in Thailand (17°28′20.7834″ N, 98°1′16.3236″ E) and treated as detailed in Senanayake et al. [462]. The samples were incubated for five days and periodically observed using stereomicroscope to check the presence of fruiting bodies. Micromorphological features were photographed using a Motic SMZ 168 Series dissection microscope for fungal structures on the woody substrate while microscopic characters were documented using Nikon Eclipse 80i microscope-camera system. Tarosoft (R) Image FrameWork was used to measure the micromorphological characters and photographic plates' preparation was done using Adobe Photoshop CC 2020. The mean size/length of at least 10 ascomata/conidiomata, 20 conidiophores, 20 asci, and 30 conidia/ascospores were measured and recorded. Single-spore isolation was used to obtain pure cultures and colonial characteristics in malt extract agar (MEA) were described. Herbarium type specimens were deposited in Mae Fah Luang University (MFLU). Ex-type living cultures were deposited at Mae Fah Luang University Culture Collection (MFLUCC). The new species were registered in Faces of Fungi (http://http://www.facesoffungi.org/ (accessed on 13 January 2021) [202] and MycoBank databases (https://www.mycobank.org/ (accessed on 13 January 2021) [201].

4.2.2 DNA Extraction, PCR Amplification, and Sequencing

DNA extraction, polymerase chain reaction (PCR) amplification, agarose gel electrophoresis, PCR product purification, and sequencing were carried out as detailed in Dissanayake et al. [463] with the following modifications. Fungal mycelia from pure cultures grown in malt extract agar (MEA) (Difco™) for 30 days were scraped using a sterilized scalpel and kept in a 1.5 mL microcentrifuge tube. Genomic DNA was extracted using a Biospin Fungus Genomic DNA Extraction Kit (BioFlux®, Hangzhou, China) following the manufacturer's protocol. Polymerase chain reaction (PCR) was used to amplify six markers: the nuclear ribosomal large subunit 28S rRNA gene (LSU), the nuclear ribosomal small subunit 18S rRNA gene (SSU), nuclear ribosomal internal transcribed spacers (ITS), and fragments of the translation elongation factor 1-alpha (TEF1-α), β-tubulin (TUB2) and Actin (ACT) genes. LSU was amplified using the primers LROR and LR5 [416], while SSU was amplified using the primers NS1 and NS4 [417]. For ITS, primers ITS5 and ITS4 were used [417]. TEF1-α was amplified using primers EF1–983F and EF1–2218R [464]. Partial regions of the TUB2 and ACT gene were amplified using the primer pairs T1 [465] and Bt2b [466], ACT-512F and ACT-783R [467], respectively. Polymerase chain reaction was performed in a volume of 25 μL, which contained 12.5 μL of 2× Power Taq PCR Master Mix (Bioteke Co., Jiangsu, China), 1 μL of each primer (10 μM), 1 μL genomic DNA, and 9.5 μL deionized water. The PCR thermal cycle programs for LSU, SSU, ITS and TEF1-α amplification were as follows: initial denaturing step of 94 °C for 3 min, followed by 40 cycles of denaturation at 94 °C for 45 s, annealing at 51 °C (TUB2) or 60 °C (ACT) or 55 °C (ITS, LSU, SSU, TEF1-α) for 50 sec, elongation at 72 °C for 1 min, and final extension at 72 °C for 10 min. Agarose gel electrophoresis was done to confirm the presence of amplicons at the expected molecular weight. PCR products were purified and sequenced with the primers mentioned above at a commercial sequencing provider (Beijing Qingke Biotechnology Co., Ltd., Beijing, China). A BLAST search of the newly generated sequences was carried out to exclude contamination and to search for related taxa in GenBank database (www.ncbi.nlm.nih.gov/blast/ (accessed on 13 January 2021).

4.2.3 Phylogenetic Analyses

Multi-loci phylogenetic analysis followed Dissanayake et al. [463]. The taxa table was assembled based on the closest matches from the BLASTn search results and from recently published data. Sequences generated from each marker were analyzed along with other sequences retrieved from GenBank. The individual loci matrix was aligned with MAFFT v.7 using the web server (http://mafft.cbrc.jp-/alignment/server (accessed on 13 January 2021; Katoh et al. [419]) with the following settings: L-INS-i tree-based iterative refinement methods, 20PAM/k = 2 scoring matrix for nucleotide sequences and 1.53 gap opening penalty. Alignment was further refined manually, where necessary, using BioEdit v.7.0.9.0 [420]. Aligned sequences were automatically trimmed using TrimAl v. 1.3 on the web server (http://phylemon.bioinfo.cipf.es/utilities.html (accessed on 13 January 2021)) with the gappyout method. The online tool "ALTER" was used to convert the alignment file to phylip and nexus formats [421]. Phylogenetic analyses of both individual and combined gene data were performed using maximum likelihood (ML) and Bayesian inference (BI).

Maximum likelihood analysis was performed using RAxML-HPC2 on XSEDE on the CIPRES web portal [225–227] (http://www.phylo.org/portal2/ (accessed on 13 January 2021); [228]. The GTR + GAMMA model of nucleotide evolution was used. RAxML rapid bootstrapping of 1000 replicates was performed. The best-fit evolutionary models for individual and combined dataset were estimated under the Akaike Information Criterion (AIC) using jModeltest 2.1.10 on the CIPRES web portal and each resulted to GTR + I+G model [424]. Bayesian inference analyses was performed using MrBayes v. 3.2.6 on XSEDE at the CIPRES webportal [229]. The parameter setting of the Bayesian analysis is detailed on the phylogenetic trees of each species. Trees were sampled every 100 generations and all other parameters were left as default. Newly generated sequences were deposited in GenBank, and alignments and trees were deposited in TreeBASE (www.treebase.org (accessed on 13 January 2021).

4.3 Results

4.3.1 Taxonomy

4.3.1.1 Dothideomycetes O.E. Erikss. & Winka, Myconet 1(1): 5 (1997). Dothideomycetes are characterized by bitunicate asci with fissitunicate dehiscence, and ascolocular ascomatal development [22, 24]. The class comprises 38 orders and 211 families and is considered to be the largest and most ecologically diverse class of ascomycetes [204]. Two new taxa are introduced in this article.

1. Pleosporales Luttr. ex M.E. Barr, Prodr. Cl. Loculoasc. (Amherst): 67 (1987). Wijayawardene et al. [204] listed 91 families and 566 genera under Pleosporales, with 48 genera in Pleosporales *incertae sedis*. It is the largest order of Dothideomycetes with members characterized mostly by flask-shaped pseudothecia [24]. In this paper, two new pleosporalean fungi are documented.

1) Melanommataceae G. Winter, Rabenhorst's Kryptogamen-Flora, Pilze—Ascomyceten, Edn 2 1(2): 220 (1885). Melanommataceae was introduced by Winter [468] and *Melanomma* was regarded as the type genus based on its diagnostic character of trabeculate pseudoparaphyses. The latest treatment of the family by Hongsanan et al. [22] and Wijayawardene et al. [204] with 33 accepted genera in Melanommataceae are followed here.

A. *Camposporium* Harkn., Bull. South. Calif. Acad. Sci. 1: 37 (1884) *Camposporium* was introduced by Harkness [469], with the single species *C. antennatum*. *Camposporium* is characterized by dematiaceous conidiophores, terminal, integrated, denticulate conidiogenous cells, and cylindrical and elongate, multiseptate conidia with one or more cylindrical appendages at the apex [470–473]. Twenty species are accepted in this genus (Species Fungorum 2020, http://www.-speciesfungorum.org/Names/Names.asp (accessed on 13 January 2021)) and we introduced one novel *Camposporium* species in this paper.

a. *Camposporium dulciaquae* M.S. Calabon & K.D. Hyde, sp. nov. (Figure 4.1)

MycoBank number: MB838551; Facesoffungi number: FoF 09156

Etymology: of freshwater

Holotype: MFLU 21–0015

Saprobic on submerged decaying wood in freshwater. Sexual morph: Undetermined. Asexual morph: Hyphomycetous. *Colonies* on natural substrate, effuse, golden brown, velvety. *Mycelium* mostly immersed, composed of white, septate, branched and guttulate hyphae. *Conidiophores* 16–95 × 5–9 μm ($\bar{x}$ = 54.4 × 6.7 μm, n = 20) macronematous, mononematous, often procumbent on substrate, light brown to brown, unbranched, irregularly cylindrical, flexuous, septate, thick-walled. *Conidiogenous cells* 9–41 × 3–5 μm ($\bar{x}$ = 22.2 × 4.4 μm, n = 20) monoblastic, terminal, integrated, subcylindrical, pale brown. *Conidia* 100–130 μm ($\bar{x}$ = 115 μm, n = 30) long, 8.5–13 μm ($\bar{x}$ = 10.7 μm, n = 30) wide at middle, 4–9 μm ($\bar{x}$ = 6.1 μm, n = 30) wide at base, solitary, dry, cylindrical, elongate, median brown, paler at base, finely verrucose, 8–11-septate, not constricted or slightly constricted at septa, apex rounded, basal cell truncate, apical cell gives rise to (2–)3 simple appendages; appendage hyaline, aseptate, smooth, tapering from base to apex. *Chlamydospores* 8–18 × 5–13 μm ($\bar{x}$ = 12.4–9.1 μm, n = 30) diameter, numerous, mostly in chains, intercalary or solitary, globose to subglobose, hyaline.

Culture characteristics: Conidia germinating on malt extract agar (MEA) within 24 h. Germ tubes produced from the basal and apical cell of conidia. Colonies growing on MEA, reaching 20 mm in 2 weeks at 25 °C. Mycelia superficial, circular, with entire edge, flat, rugose, from above mossy gray in the center and pale yellow at the edge, from below brown at the center then becoming yellow orange at the edge. Chlamydospores produced in culture and induced with plant tissues within 60 days. Formation of crystals in the culture was observed.

Material examined: THAILAND, Chiang Mai Province, Mushroom Research Center, on decaying wood submerged in a freshwater stream, 29 January 2019, S. Boonmee, SB14-7 (MFLU 21–0015, holotype), ex-type living culture, MFLUCC 21–0009.

GenBank accession numbers: LSU = MT860430, SSU = MW485612, ITS = MT864352, TEF1-α = MW537104

Notes: *Camposporium dulciaquae* closely resembles *Camposporium septatum* based on conidial morphology with 2–3 appendages and

number of septa, but the former has larger conidia (100–130 μm long, 8.5–13 μm wide at middle, 4–9 μm wide at base versus 98–125 μm long, 7–11.5 μm wide at middle, 3.5–6 μm wide at base). BLAST results of ITS and TEF1-α sequence data were C. cambrense CBS 132,486 (95% similarity) and *C. septatum* MFLUCC 19–0483 MFLUCC 16–0274 (97% similarity), respectively. Phylogenetic analyses of the combined LSU, SSU, ITS, and TEF1-α sequence dataset showed that *C. dulciaquae* clustered with *C. septatum* (MFLUCC 19–0483), *Fusiconidium aquaticum* (MFLUCC 16–0991 and *F. mackenziei* (HKAS 95019; MFLUCC 14-0434) (Figure 4.2) [403]. In addition, an unknown species of *Camposporium* (MHR 1565) isolated from a dead wood in Nan Province, Thailand grouped as a sister taxon to *C. dulciaquae* with high bootstrap support (95% ML, 1.00 BYPP) [474]. The former did not have morphological data, but since comparison of its LSU sequence with the latter revealed 2 base pair differences (0.25%, 794 bp), we considered this as another strain of *Camposporium dulciaquae*. A comparison of ITS and TEF1-α sequence data of *C. dulciaquae* differed by 19 (3.81%, 499 bp) and 33 (3.48%, 947 bp) base pairs with *C. septatum*, respectively. *Camposporium dulciaquae* had 33 (914 bp, 3.61%) and 32 (838 bp, 3.82%) base pair differences with *F. aquaticum* and *F. mackenziei* in TEF1-α region, respectively. *Camposporium dulciaquae* differed from *Fusiconidium* in conidiogenesis (monoblastic versus enteroblastic), conidial shape (cylindrical versus fusiform to ellipsoidal), and presence of apical appendage. Furthermore, *C. dulciaquae* fit to the description of the genus, so in this paper, we introduced a new species under *Camposporium.* A key to freshwater *Camposporium* is provided.

1 Appendage absent ..... *C. ontariense*
1 Appendage present 2
2 Appendage branched ..... *C. japonicum*
2 Appendage simple 3
3 Conidial septation ≤10 4
3 Conidial septation >10 5
4 Conidia 20–75 × 3–5 μm ..... *C. hyalinum*
4 Conidia 28–45 × 3.5–4.5 μm ..... *C. quercicola*
5 Conidial length ≤50 μm ..... *C. marylandicum*
5 Conidial length >50 μm 6

6 Appendage aseptate.....7
6 Appendage septate.....10
7 Conidial length up to <100 μm.....*C. antennatum*
7 Conidial length up to >100 μm.....8
8 Conidial width ≥13.....9
8 Conidial width <13.....*C. septatum*
9 Conidia 100–130 × 8.5–13 μm.....*C. dulciaquae*
9 Conidia 86–115 × 13.5–19 μm.....*C. fusisporum*
10 Conidial septation ≤13.....11
10 Conidial septation >13.....12
11 Conidia 107–119 × 9.5–11.5 μm.....*C. appendiculatum*
11 Conidia 97–111 × 9–11 μm.....*C. multiseptatum*
12 Conidia 62–115 × 8–10 μm.....*C. cambrense*
12 Conidia 78–140 × 7.5–12 μm.....*C. pellucidum*

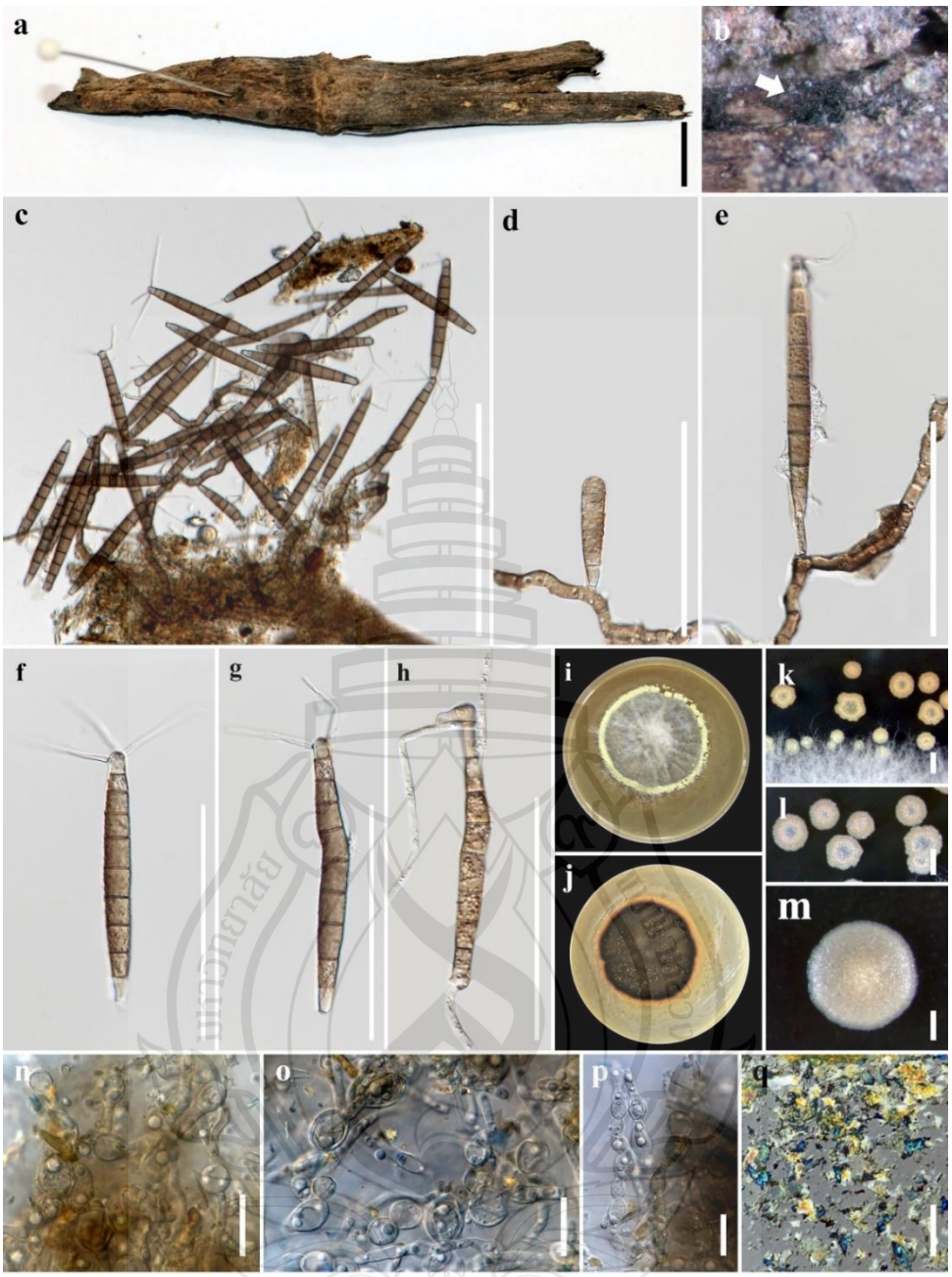


Figure 4.1 *Camposporium dulciaquae* (MFLU 21–0015, Holotype). (a) Substrate; (b) Colonies on Wood; (c–e) Conidiophores with Conidia; (f,g) Conidia; (h) Germinated Conidium; (i,j) Culture on Malt Extract Agar (MEA) from Surface and Reverse; (k–m) Crystals in Culture; (n–p) Chlamydospores; (q) Crystal Structure Observed in Microscope. Scale bars: (a,m) 10 mm; (c) 200 µm; (d–h) 100 µm; (k,l) 50 µm; (n–q) 20 µm

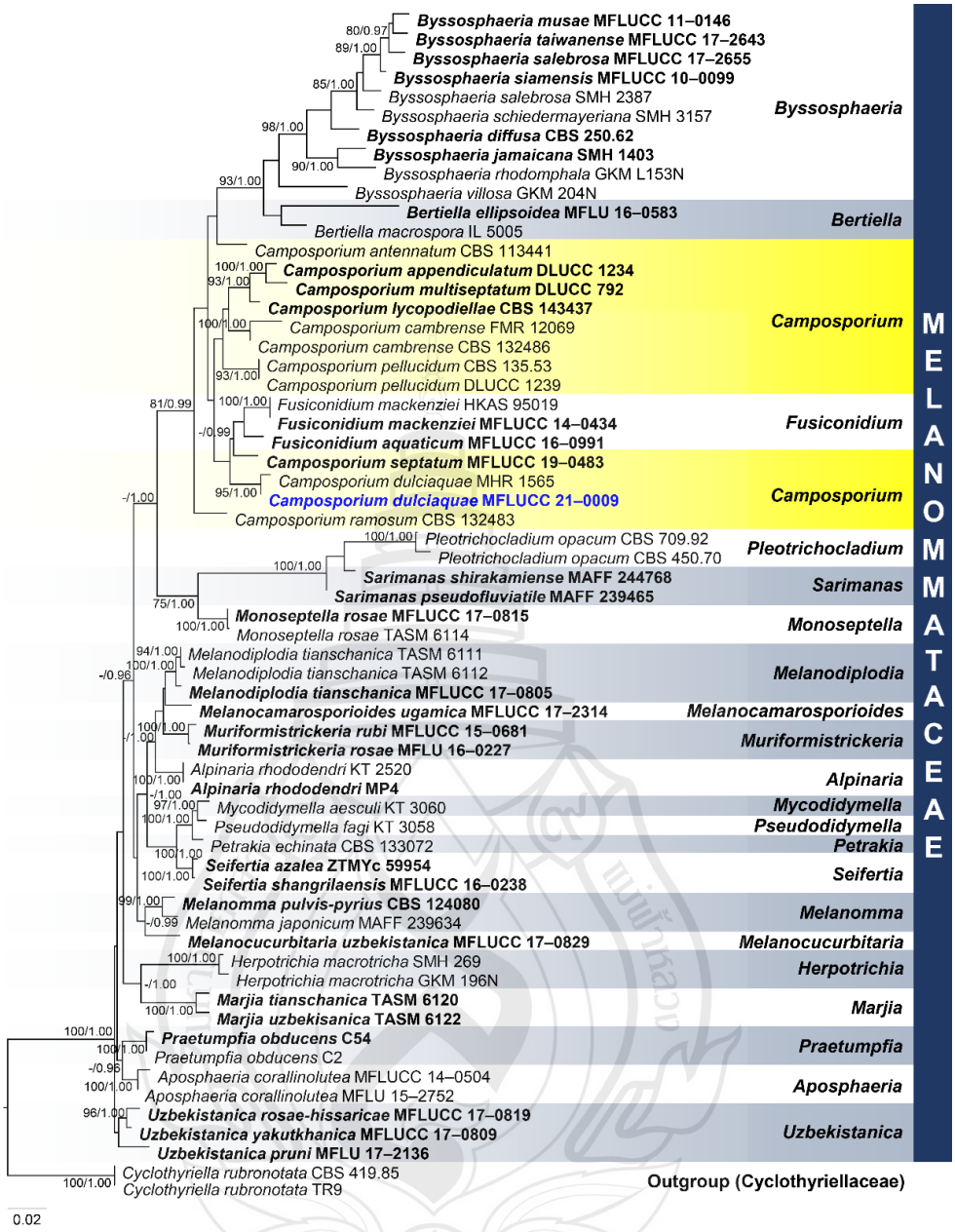


Figure 4.2 Phylogram Generated from Maximum Likelihood Analysis Based on Combined Large Subunit (LSU), Small Subunit (SSU), Internal Transcribed Spacers (ITS), and TEF1-α Sequence Data Representing the Species Of Melanommataceae. Related Sequences are Taken from Hyde et al. [57]. Sixty-two Taxa were Included in the Combined Analyses, which Comprised 3433 characters (LSU = 982 bp, SSU = 963 bp, ITS = 545 bp, TEF1-α = 943) After Alignment. The Best Scoring Raxml Tree

with a Final Likelihood Value of -18023.445951 is Presented. The Matrix had 1115 Distinct Alignment Patterns, with 44.01% of Undetermined Characters or Gaps. Estimated Base Frequencies were as Follows: A = 0.244338, C = 0.242233, G = 0.271538, T = 0.241891; Substitution Rates: AC = 1.712430, AG = 2.882169, AT = 1.678717, CG = 0.989358, CT = 10.389868, GT = 1.000000; Gamma Distribution Shape Parameter α = 0.154096. Bootstrap Support Values for ML Equal to or Greater Than 75% and BYPP Equal to or Greater Than 0.95 are Given Above the Nodes. *Cyclothyriella rubronotata* (CBS 419.85; TR9) in Cyclothyriellaceae were Used as the Outgroup Taxa. The Newly Generated Sequence is Indicated in Blue. The Ex-Type Strains are Indicated in Bold.

2) Occultibambusaceae D.Q. Dai & K.D. Hyde. Dai et al. [475] introduced Occultibambusaceae to accommodate *Neooccultibambusa, Occultibambusa, Seriascoma* and *Versicolorisporium. Brunneofusispora,* typified by *Brunneofusispora sinensis,* was introduced by Phookamsak et al. [476] as a new member of the family. The latest treatment of the family follows Hongsanan et al. [22] and Wijayawardene et al. [204] with 5 accepted genera in Occultibambusaceae.

A. *Brunneofusispora* S.K. Huang & K.D. Hyde, Fungal Diversity 95: 36 (2019). *Brunneofusispora*, typified by *B. sinensis*, was introduced by Phookamsak et al. [476]. Hongsanan et al. [22] discussed the key differences of *Brunneofusispora* to other genera in Occultibambusaceae and Wanasinghe et al. [477] observed the coelomycetous asexual morph of *B. sinensis* and amended the generic and species description. Two species, *B. sinensis* and *B. clematidis*, have molecular data and are accepted in this genus (Species Fungorum 2020; http://www.speciesfungorum.org/Names/Names.asp (accessed on 13 January 2021)). *Brunneofusispora sinensis* was described from undetermined terrestrial wood near in a river [476] and *Magnolia denudata* [477] in China, while *B. clematidis* was observed in *Clematis subumbellata* by Phukhamsakda et al. [478]. In this paper, one novel coelomycetous *Brunneofusispora* species from a freshwater habitat is introduced.

a. *Brunneofusispora hyalina* M.S. Calabon & K.D. Hyde, sp. nov. (Figure 4.3)

MycoBank number: MB838552; Facesoffungi number: FoF 09531

Etymology: refers to hyaline conidia

Holotype: MFLU 21–0016

Saprobic on decaying wood submerged in freshwater habitats. Sexual morph: Undetermined. Asexual morph: *Mycelium* mostly immersed, composed of septate, branched, hyphae. *Conidiomata* 260–435 × 110–205 μm ($\bar{x}$ = 347 × 175 μm, n = 10), black, pycnidial, solitary, immersed to semi-immersed, globose to subglobose, ostiolate. *Ostiole* circular, papillate, laterally or centrically located. *Conidiomatal wall* 10–20 μm wide ($\bar{x}$ = 16 μm, n = 15), composed of thick-walled, dark brown to hyaline cells of textura angularis. Conidiophores reduced to conidiogenous cells. *Conidiogenous cells* 5–11 μm × 2–4 μm ($\bar{x}$ = 8 μm, n = 20), hyaline, thin-walled, enteroblastic, phialidic, smooth, cylindrical, subcylindrical, ampulliform, pyriform, swollen at base, discrete, producing a single conidium at apex. *Conidia* 2–4 × 1.3–2.6 μm ($\bar{x}$ = 2.7 × 1.9 μm, n = 50), aseptate, oblong, cylindrical to ovoid, tapered to apices, hyaline, smooth-walled.

Culture characteristics: Conidia germinating on malt extract agar (MEA) within 24 h. Germ tubes produced from the basal and apical cells of the conidia. Colonies growing on MEA, reaching 40–45 mm in 4 weeks at 25 °C. Mycelia superficial, circular, with entire margin, flat, smooth, from above brown at the center, dark brown at the edge, from below dark brown.

Material examined: THAILAND, Chiang Mai Province, Mushroom Research Center (MRC), on decaying wood submerged in a stream, 13 September 2019, M.S. Calabon, WF03 (MFLU 21–0016, holotype), ex-type living culture, MFLUCC 21–0008.

GenBank accession numbers: LSU = MT860430, SSU = MW485613, ITS = MT864352, TEF1-α = MW512606, RPB2 = MW512609

Notes: Based on morphology, coupled with multi-loci phylogenetic analyses, the novel taxon was placed in *Brunneofusispora*. *Brunneofusispora hyalina* is similar *to B. sinensis* in conidiogenesis and conidial shape but differs in the size of conidiomata (260–435 × 110–205 μm diameter versus 120–160 μm × 80–120 μm diameter) and conidiogenous cells (5–11 μm × 2–4 μm

versus 6–7.5 μm × 2.5–3 μm) [477]. In the phylogenetic analysis, *Brunneofusispora hyalina* clustered as a sister taxon to *Brunneofusispora* sp. (X135) (Figure 3.4). The latter is named in GenBank as *Neooccultibambusa* sp. with an accession number MK304223 for the ITS gene region but there are no available description and photographic plate for this species, so we transferred this to *Brunneofusispora*. BLAST results of ITS and LSU sequence data were Pleosporales sp. E6910l (99% similarity) and *Neooccultibambusa thailandensis* MFLUCC 16–0274 (98% similarity), respectively. The TEF1-α sequence was 95% similar to *Brunneofusispora sinensis* (KUMCC 17–0030), *Occultibambusa fusispora* (MFLUCC 11–0127), and *Occultibambusa bambusae* (MFLUCC 13–0855), while RPB2 sequence data were 85.19% similar to *Occultibambusa fusispora* MFLUCC 11-0127. *Brunneofusispora hyalina* had 35 base pair differences (493 bp, 7.10%) in the ITS region when compared to *Brunneofusispora* sp. (X135). A comparison of ITS and TEF1-α sequence data of *B. hyalina* differed by 49 (9.25%, 530 bp) and 37 (6.41%, 577bp) base pairs with *B. clematidis*, respectively. *Brunneofusispora hyalina* differed by 41 (7.87%, 521 bp) and 44 base pairs (4.73%, 931 bp) in ITS and TEF1-α sequence data, respectively, when compared to *B. sinensis* (MFLUCC 17–2070).

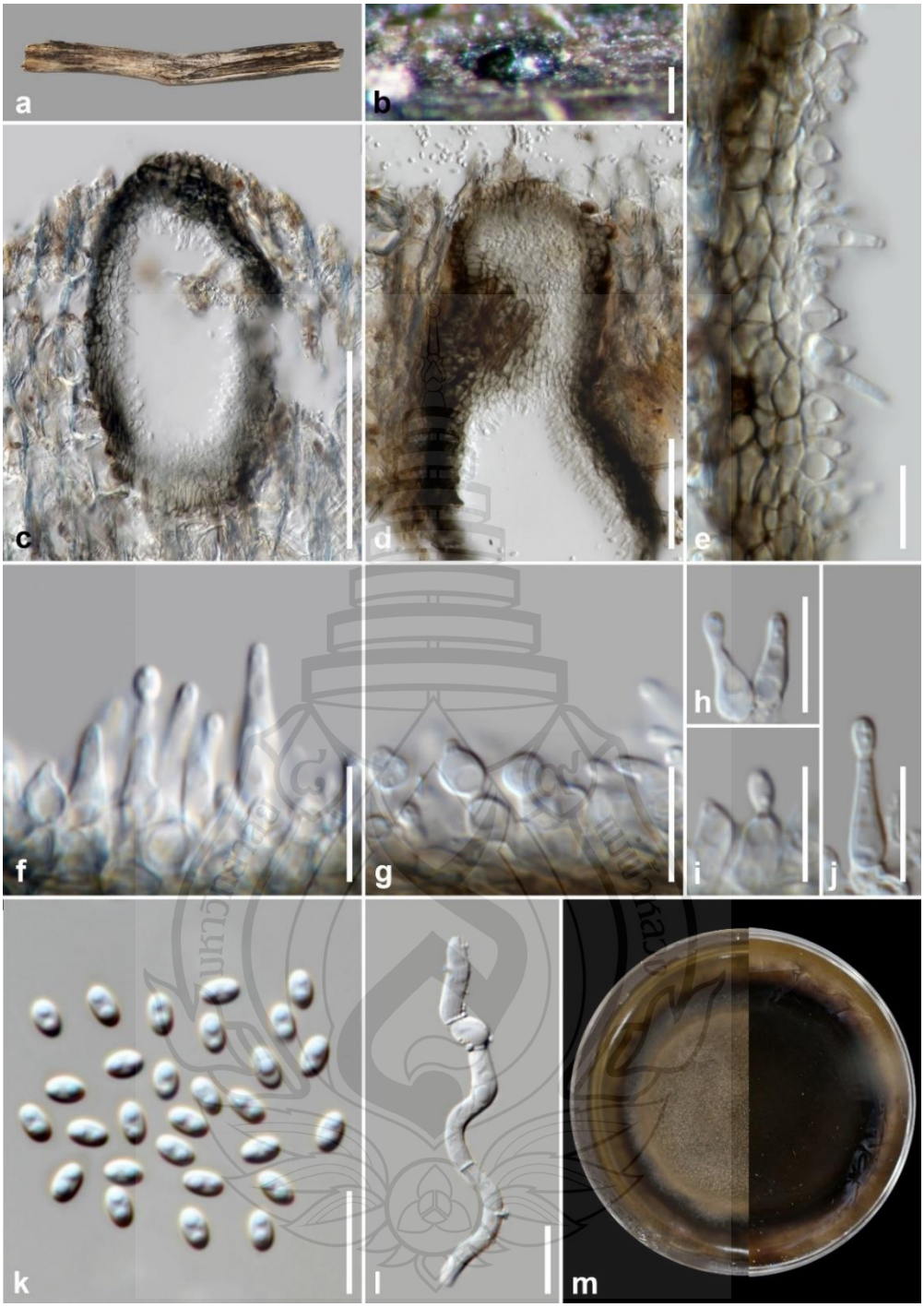


Figure 4.3 *Brunneofusispora hyalina* (MFLU 21–0016, holotype). (a) Host; (b) Black Conidiomata on the Host; (c,d) Vertical Section of Conidiomata; (e) vertical Section of Conidiomatal Wall.; (f–j) Conidiogenous Cells and Developing Conidia; (k) Conidia; (l) Germinated Conidium; (m) Culture on MEA. Scale Bars: (b,c) 100 µm; (d) 50 µm; (e–l) 10 µm

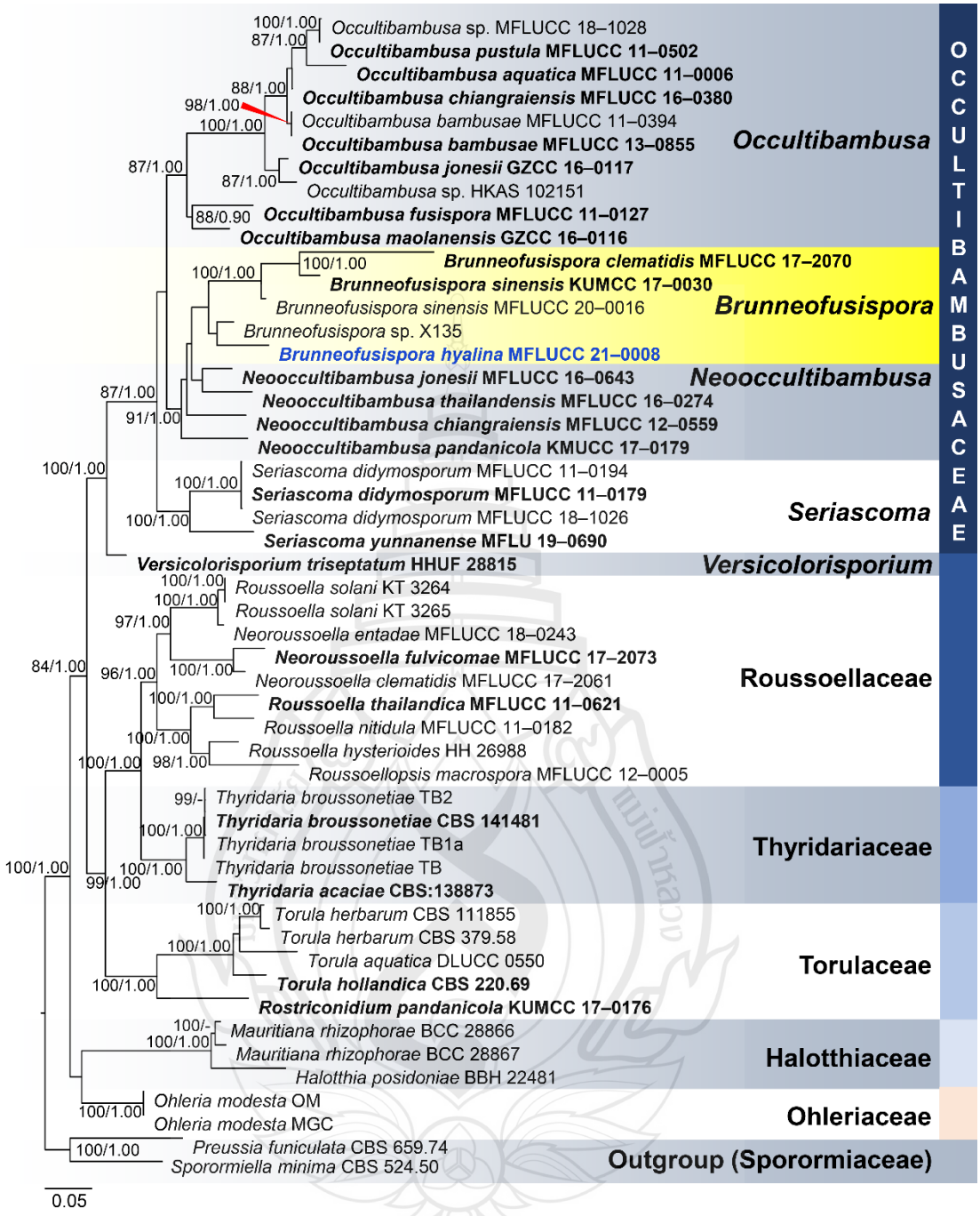


Figure 4.4 Phylogram Generated from Maximum Likelihood Analysis Based on Combined LSU, SSU, ITS, TEF1-α, and RPB2 Sequence Data Representing the Species of Pleosporales. Related Sequences are Taken From Tibpromma et al. [479]. Fifty Taxa were Included in the Combined Analyses, which Comprised 6314 Characters (LSU = 1116, SSU = 988, ITS = 2438, TEF1-α = 678, RPB2 = 1094) after Alignment. The Best

Scoring Raxml Tree with a Final Likelihood Value of −22606.054905 is Presented. The Matrix had 2273 Distinct Alignment Patterns, with 50.65% of Undetermined Characters or Gaps. Estimated Base Frequencies were as Follows: A = 0.249087, C = 0.252571, G = 0.272240, T = 0.226102; Substitution Rates: AC = 1.279443, AG = 3.002197, AT = 1.311809, CG = 1.122167, CT = 6.076550, GT = 1.000000; gamma Distribution Shape Parameter α = 0.234175. Bootstrap Support Values for ML Equal to or Greater Than 75% and BYPP Equal to or Greater Than 0.95 are Given Above the Nodes. *Preussia funiculata* CBS 659.74 and *Sporormiella minima* CBS 524.50 in Sporormiaceae were Used as the Outgroup Taxa. The Newly Generated Sequence is Indicated in Blue. The Ex-type Strains are Indicated in Bold.

4.3.1.2 Sordariomycetes O.E. Erikss. et Winka, Myconet 1: 10 (1997). The latest treatment of Sordariomycetes by Hyde, Norphanphoun, et al. [23] is followed with 45 orders, 167 families and 1499 genera (with 308 genera *incertae sedis*) listed and described. Three new species of freshwater Sordariomycetes are introduced and described in this paper.

1. Chaetosphaeriales Huhndorf, A.N. Mill. & F.A. Fernández, Mycologia 96(2): 378 (2004). Chaetosphaeriales was introduced by Huhndorf et al. [480]. The order comprises five families (Chaetosphaeriaceae, Helminthosphaeriaceae, Leptosporellaceae, Leptosporellaceae, and Linocarpaceae) with 55 genera recorded [204]. Sixty-nine species were recorded from freshwater habitats (Chaetosphaeriaceae: 59, Helminthosphaeriaceae: 6, Linocarpaceae: 4) [5].

1) Chaetosphaeriaceae Réblová, M.E. Barr & Samuels, Sydowia 51(1): 56 (1999). Forty-four genera constitute Chaetosphaeriaceae, wherein 12 genera (59 species) were recorded in freshwater habitats [5, 204, 481]. Freshwater *Dictyochaeta* is the most speciose genus in the family with 16 species recorded [5].

A. *Rattania* Prabhugaonkar & Bhat, Mycotaxon 108: 218 (2009). *Rattania* was introduced by Prabhugaonkar & Bhat [482] to accommodates *Rattania setulifera*, a species isolated from fresh leaves of rattan (*Calamus thwaitesii*) in India. Shenoy et al. [483] placed the genus in Chaetosphaeriales. *Rattania* is

characterized by sporodochial, setose conidiomata, monoblastic conidiogenous cells and slimy, fusiform, 0–5-septate, setulate conidia [482]. In this paper, a new *Rattania* species observed from submerged decaying wood in freshwater river in Thailand is introduced.

a. *Rattania aquatica* M.S. Calabon & K.D. Hyde, sp. nov. (Figure 4.5)

MycoBank number: MB838553; Facesoffungi number: FoF 09532

Etymology: in reference to the habitat where the fungus was collected

Holotype: MFLU 21–0013

Saprobic on decaying wood submerged in freshwater habitats. Sexual morph: Undetermined. Asexual morph: *Colonies* on the substrate effuse, scattered, dark brown to black. *Mycelium* mostly immersed, composed of branched, septate, smooth, thin-walled, brown hyphae. *Conidiomata* 170–270 × 55–150 μm ($\bar{x}$ = 210 μm, n = 10), superficial, synnematous, scattered, dark brown to black, funnel-shaped, sessile sporodochia with spore mass at the apex. *Setae* 290–475 × 3–14 μm ($\bar{x}$ = 340 × 9, n = 10), erect, straight to curved, flexuous, unbranched, irregular in length, cylindrical, tapering towards apex into an acute tip, 10–15 septate, smooth, thick-walled. *Conidiophores* up to 175 μm long, macronematous, brown, cylindrical, densely compacted along the synnematal axis, smooth-walled. *Conidiogenous cells* 2–4 μm long ($\bar{x}$ = 2.8 μm, n = 10), terminal, integrated or discrete, hyaline, smooth-walled. *Conidia* 22–27 × 3–5 μm ($\bar{x}$ = 24.9 × 3.9 μm, n = 30), hyaline, naviculate to fusiform, apex acute, base truncate, smooth, thin-walled, 0–1 septate, mostly aseptate, with a single filiform setula at both ends, 3.6–8.3 μm long, guttulate.

Culture characteristics: Conidia germinating on malt extract agar (MEA) within 24 h. Germ tubes produced from the basal and apical cell of conidia. Colonies growing on MEA, reaching 30–35 mm in 2 weeks at 25 °C. Mycelia superficial, circular, with entire margin, flat, smooth, from above white, from below white.

Material examined: THAILAND, Tak Province, Tha Sing Yang, Ban Mae Ja Wang on decaying wood submerged in a freshwater river, 17

October 2019, N. Padaruth, CC24 (MFLU 21–0013, holotype), ex-type living culture, MFLUCC 21–0006.

GenBank accession numbers: LSU = MW287235; ITS = MW260331

Notes: *Rattania aquatica* differs from the type species *R. setulifera* in conidiomatal morphology (synnemata versus sporodochia), shorter conidia (22–27 × 3–5 µm versus 5–50 um × 1.5–3.5) and conidial septation (0–1 versus 0–5) [482]. Based on the BLASTn search of ITS sequence data in GenBank, the closest matches are Chaetosphaeriaceae sp. TBA274 (96%) and Sordariomycetes sp. KO-2013 (95%). However, *Rattania setulifera* (GUFCC 15501) is the closest match for the LSU sequence data with 98% similarity. The multi-loci phylogenetic analyses show that *R. aquatica* is a distinct species and sister taxon to *R. setulifera* (GUFCC 15501) with 95% MP, 1.00 BYPP support (Figure 3.6). A comparison of ITS and LSU sequence data between *R. aquatica* and *R. setulifera* revealed 9.68% (46/475 bp) and 2.20% (18/820 bp) nucleotide base pair differences, respectively.

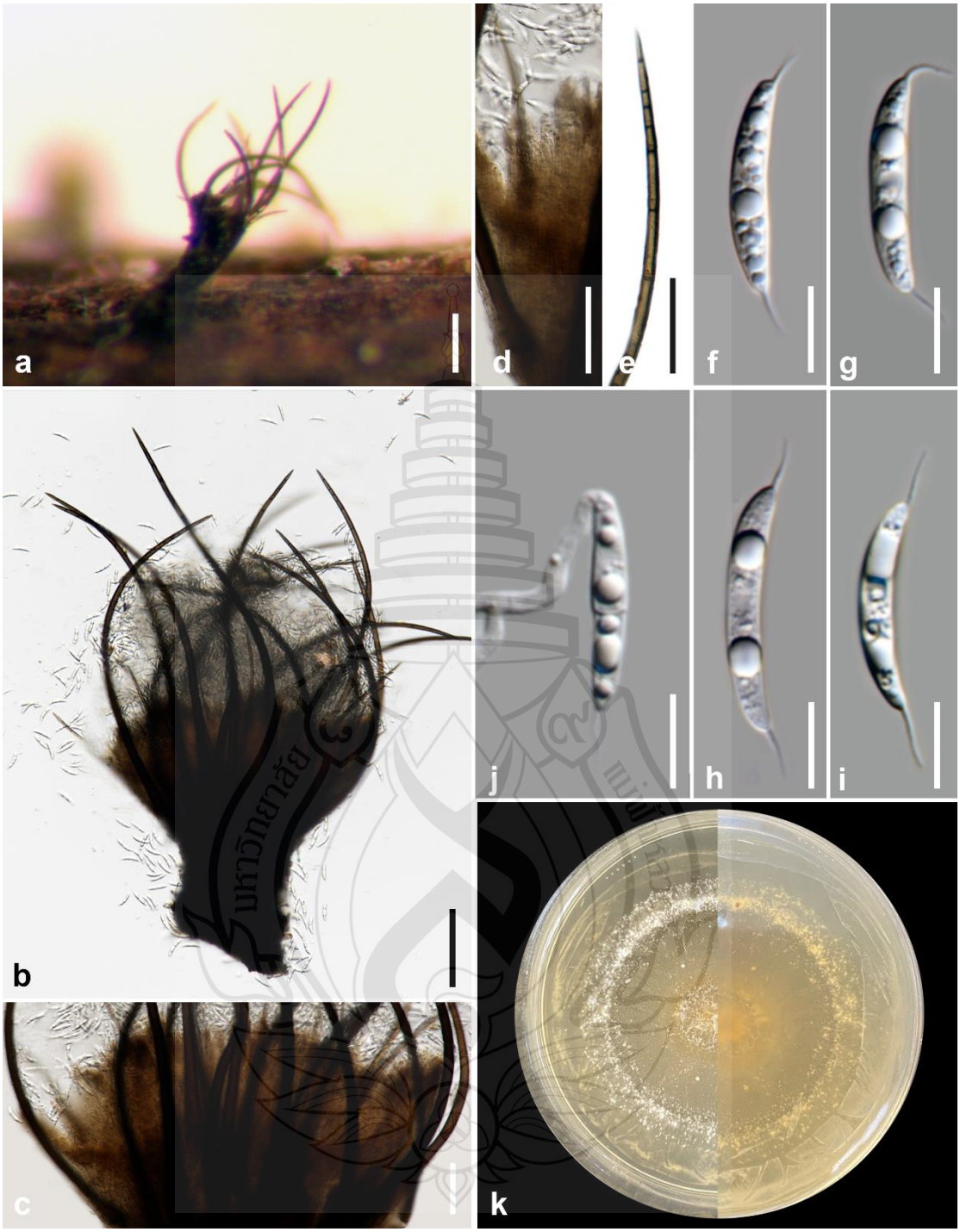


Figure 4. 5 *Rattania aquatica* (MFLU 21–0013, Holotype). (a) Appearance of Conidioma on Host; (b) Synnemata; (c,d) Closely Packed Conidiophores; (e) Setae; (f–i). Conidia; (j) Germinated Conidium; (k) Culture on MEA. Scale Bars: (a,b) 100 µm; (c–e) 50 µm; (f–j) 10 µm

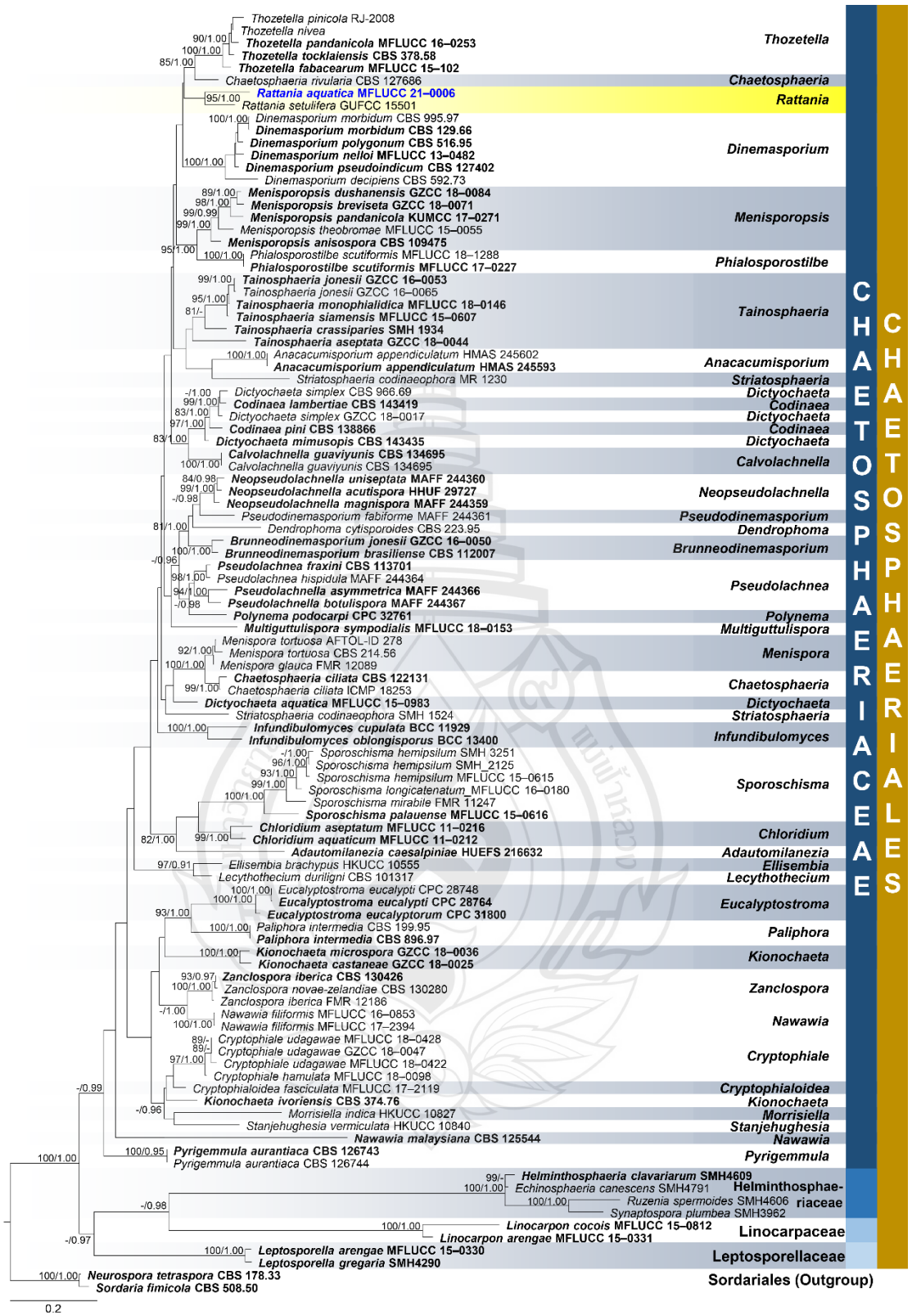

Thozetella pinicola RJ-2008
Thozetella nivea
Thozetella pandanicola MFLUCC 16–0253
Thozetella tocklaiensis CBS 378.58
Thozetella fabacearum MFLUCC 15–102
Thozetella
Chaetosphaeria rivularia CBS 127686
Chaetosphaeria
Rattania aquatica MFLUCC 21–0006
Rattania setulifera GUFCC 15501
Rattania
Dinemasporium morbidum CBS 995.97
Dinemasporium morbidum CBS 129.66
Dinemasporium polygonum CBS 516.95
Dinemasporium nelloi MFLUCC 13–0482
Dinemasporium pseudoindicum CBS 127402
Dinemasporium decipiens CBS 592.73
Dinemasporium
Menisporopsis dushanensis GZCC 18–0084
Menisporopsis breviseta GZCC 18–0071
Menisporopsis pandanicola KUMCC 17–0271
Menisporopsis theobromae MFLUCC 15–0055
Menisporopsis anisospora CBS 109475
Menisporopsis
Phialosporostilbe scutiformis MFLUCC 18–1288
Phialosporostilbe scutiformis MFLUCC 17–0227
Phialosporostilbe
Tainosphaeria jonesii GZCC 16–0053
Tainosphaeria jonesii GZCC 16–0065
Tainosphaeria monophialidica MFLUCC 18–0146
Tainosphaeria siamensis MFLUCC 15–0607
Tainosphaeria crassiparies SMH 1934
Tainosphaeria aseptata GZCC 18–0044
Tainosphaeria
Anacacumisporium appendiculatum HMAS 245602
Anacacumisporium appendiculatum HMAS 245593
Anacacumisporium
Striatosphaeria codinaeophora MR 1230
Striatosphaeria
Dictyochaeta simplex CBS 966.69
Dictyochaeta
Codinaea lambertiae CBS 143419
Codinaea
Dictyochaeta simplex GZCC 18–0017
Dictyochaeta
Codinaea pini CBS 138866
Codinaea
Dictyochaeta mimusopis CBS 143435
Dictyochaeta
Calvolachnella guaviyunis CBS 134695
Calvolachnella guaviyunis CBS 134695
Calvolachnella
Neopseudolachnella uniseptata MAFF 244360
Neopseudolachnella acutispora HHUF 29727
Neopseudolachnella magnispora MAFF 244359
Neopseudolachnella
Pseudodinemasporium fabiforme MAFF 244361
Pseudodinemasporium
Dendrophoma cytisporoides CBS 223.95
Dendrophoma
Brunneodinemasporium jonesii GZCC 16–0050
Brunneodinemasporium brasiliense CBS 112007
Brunneodinemasporium
Pseudolachnea fraxini CBS 113701
Pseudolachnea hispidula MAFF 244364
Pseudolachnella asymmetrica MAFF 244366
Pseudolachnella botulispora MAFF 244367
Pseudolachnea
Polynema podocarpi CPC 32761
Polynema
Multiguttulispora sympodialis MFLUCC 18–0153
Multiguttulispora
Menispora tortuosa AFTOL-ID 278
Menispora tortuosa CBS 214.56
Menispora glauca FMR 12089
Menispora
Chaetosphaeria ciliata CBS 122131
Chaetosphaeria ciliata ICMP 18253
Chaetosphaeria
Dictyochaeta aquatica MFLUCC 15–0983
Dictyochaeta
Striatosphaeria codinaeophora SMH 1524
Striatosphaeria
Infundibulomyces cupulata BCC 11929
Infundibulomyces oblongisporus BCC 13400
Infundibulomyces
Sporoschisma hemipsilum SMH 3251
Sporoschisma hemipsilum SMH_2125
Sporoschisma hemipsilum MFLUCC 15–0615
Sporoschisma longicatenatum_MFLUCC 16–0180
Sporoschisma mirabile FMR 11247
Sporoschisma palauense MFLUCC 15–0616
Sporoschisma
Chloridium aseptatum MFLUCC 11–0216
Chloridium aquaticum MFLUCC 11–0212
Chloridium
Adautomilanezia caesalpiniae HUEFS 216632
Adautomilanezia
Ellisembia brachypus HKUCC 10555
Ellisembia
Lecythothecium duriligni CBS 101317
Lecythothecium
Eucalyptostroma eucalypti CPC 28748
Eucalyptostroma eucalypti CPC 28764
Eucalyptostroma eucalyptorum CPC 31800
Eucalyptostroma
Paliphora intermedia CBS 199.95
Paliphora intermedia CBS 896.97
Paliphora
Kionochaeta microspora GZCC 18–0036
Kionochaeta castaneae GZCC 18–0025
Kionochaeta
Zanclospora iberica CBS 130426
Zanclospora novae-zelandiae CBS 130280
Zanclospora iberica FMR 12186
Zanclospora
Nawawia filiformis MFLUCC 16–0853
Nawawia filiformis MFLUCC 17–2394
Nawawia
Cryptophiale udagawae MFLUCC 18–0428
Cryptophiale udagawae GZCC 18–0047
Cryptophiale udagawae MFLUCC 18–0422
Cryptophiale hamulata MFLUCC 18–0098
Cryptophiale
Cryptophialoidea fasciculata MFLUCC 17–2119
Cryptophialoidea
Kionochaeta ivoriensis CBS 374.76
Kionochaeta
Morrisiella indica HKUCC 10827
Morrisiella
Stanjehughesia vermiculata HKUCC 10840
Stanjehughesia
Nawawia malaysiana CBS 125544
Nawawia
Pyrigemmula aurantiaca CBS 126743
Pyrigemmula aurantiaca CBS 126744
Pyrigemmula
Helminthosphaeria clavariarum SMH4609
Echinosphaeria canescens SMH4791
Ruzenia spermoides SMH4606
Synaptospora plumbea SMH3962
Helminthosphaeriaceae
Linocarpon cocois MFLUCC 15–0812
Linocarpon arengae MFLUCC 15–0331
Linocarpaceae
Leptosporella arengae MFLUCC 15–0330
Leptosporella gregaria SMH4290
Leptosporellaceae
Neurospora tetraspora CBS 178.33
Sordaria fimicola CBS 508.50
Sordariales (Outgroup)
0.2
CHAETOSPHAERIACEAE
CHAETOSPHAERIALES

Figure 4. 6 Phylogenetic Tree Generated from Maximum Likelihood (ML) Analysis Based on Combined LSU and ITS Sequence Data for the Species from Chaetosphaeriales. Related Sequences are Taken from Lin [481]. One-Hundred Three Taxa were Included in the Combined Analyses which Comprised 1329 Characters after Alignment Including Gaps. LSU: 789 bp, ITS: 540 bp. The RAxML Analysis of the Combined Dataset Yielded a Best Scoring Tree with a Final ML Optimization Likelihood Value of −19,119.372669. The Matrix had 730 Distinct Alignment Patterns, with 13.78% Undetermined Characters or Gaps. Estimated Base Frequencies were as Follows: A = 0.225668, C = 0.269306, G = 0.309464, T = 0.195562; Substitution Rates AC = 1.438984, AG = 1.899345, AT = 1.390083, CG = 0.832127, CT = 6.028381, GT = 1.000000; Gamma Distribution Shape Parameter α = 0.286425. Bootstrap Support Values for ML Equal to or Greater Than 75% and BYPP Equal to or Greater Than 0.95 are Given Above the Nodes. *Neurospora tetraspora* (CBS 178.33) and *Sordaria fimicola* (CBS 508.50) from Sordariales were Used as Outgroup Taxa. The Newly Generated Sequence is Indicated in Blue. The Ex-type Strains are Indicated in Bold.

2. Phyllachorales M.E. Barr, Mycologia 75: 11 (1983). Phyllachorales was formally described by Barr [484] but phyllachoraceous taxa were placed by several authors in various orders and families (see Mardones et al. [485]) for historical placement of phyllachoraceous fungi]. Four families (Phaeochoraceae, Phaeochorellaceae, Phyllachoraceae, Telimenaceae) and 60 genera were included in Phyllachorales [204]. The divergence time for the order is estimated as 168 MYA [23]. Phyllachoraceous taxa are biotrophic, obligate plant parasitic fungi, and saprobic on palms (Arecaceae) and submerged decaying wood [23].

1) Phyllachorales genera *incertae sedis*. Wijayawardene et al. [204] listed *Marinosphaera* under Phyllachorales genera *incertae sedis*. In this paper, a novel genus is introduced based on morphology and multi-loci phylogenetic analyses.

A. *Neoxylomyces* M.S. Calabon, Boonmee, E.B.G. Jones & K.D. Hyde, gen. nov.

MycoBank number: MB838554; Facesoffungi number: FoF 09533

Etymology: referring to the similarity to the genus *Xylomyces*

Saprobic on decaying wood submerged in freshwater habitats. Sexual morph: Undetermined. Asexual morph: *Colonies* on the substrate effuse, scattered, dark brown to black. *Mycelium* mostly immersed, composed of branched, septate, smooth, thin-walled, dematiaceous, anastomosing hyphae. *Conidiophores* and conidia not developed. *Chlamydospores* narrowly fusiform, cylindrical, intercalary, erect, mostly straight, slightly curved, solitary or in chains, occasionally branched, multiseptate, constricted at septa, brown, paler end cells, thick-walled with scarce irregular longitudinal striations.

Type species: *Neoxylomyces multiseptatus* M.S. Calabon, Boonmee, E.B.G. Jones & K.D. Hyde

Notes: *Neoxylomyces* is similar to *Xylomyces* in having brown, thick-walled, multiseptate chlamydospores [7, 24]. The latter, typified by *X. chlamydosporus*, is placed in Aliquandostipitaceae while *Neoxylomyces* clustered with other taxa of Phyllachorales with 100% ML, 1.00 BYPP support (Figure 3.7). In multi-loci phylogenetic analyses, *Neoxylomyces* shared the same clade with *Clathrosporium retortum* (CCIBt 4122; CCIBt 4123) with 100% ML, 1.00 BYPP support.

a. *Neoxylomyces multiseptatus* MS Calabon, Boonmee, E.B.G. Jones & K.D. Hyde, sp. nov. (Figure 4.8)

MycoBank number: MB838555; Facesoffungi number: FoF 09534

Etymology: In reference to the multiseptate chlamydo-spores

Holotype: MFLU 21–0014

Saprobic on decaying wood submerged in freshwater habitats. Sexual morph: Undetermined. Asexual morph: *Colonies* on the substrate effuse, scattered, dark brown to black. *Mycelium* mostly immersed, composed of

branched, septate, smooth, thin-walled, dematiaceous, anastomosing hyphae. Conidiophores and conidia not developed. Chlamydospores 111–378 × 8–13 μm ($\bar{x}$ = 255 × 10.2 μm, n = 30), narrowly fusiform, cylindrical, intercalary, erect, mostly straight, slightly curved, solitary or in chains, occasionally branched, with 7–45 septa, constricted at septa, brown, paler and truncated end cells, 3.28–5.93 μm wide ($\bar{x}$ = 4.39 μm), thick-walled with scarce irregular longitudinal striations.

Culture characteristics: Chlamydospores germinating on malt extract agar (MEA) within 24 h. Germ tubes produced from the basal and apical cell of conidia. Colonies growing on MEA, reaching 35–40 mm in 4 weeks at 25 °C. Mycelia superficial, circular, with entire margin, flat, smooth, from above ivory to pale brown at the margin, white at the center; reverse, dark brown at the center then becoming pale orange to light brown at the margin.

Material examined: THAILAND, Chiang Mai Province, Mae Teang District, Mushroom Research Center (M.R.C.), on decaying wood submerged in a stream, 11 February 2019, M.S. Calabon, MC02 (MFLU 21–0014, holotype), ex-type living culture, MFLUCC 21–0007.

GenBank accession numbers: LSU = MW287236, SSU = MW287239, ITS = MW260332, TEF1-α = MW512607

Notes: *Neoxylomyces multiseptatus* is similar to *Xylomyces giganteus* in having brown, long, multiseptate chlamydospores. The former differs in the number of septa (7–45 versus 6–85), size of the chlamydospores (111–378 × 8–13 μm versus (140) 190–575 × 25–50 μm), and absence of a mucilaginous coating to the chlamydospores [486, 487]. Furthermore, *Xylomyces* belongs to Aliquandostipitaceae (Jahnulales, Dothideomycetes) [204]. The closest match of the sequences based on BLASTn searches in NCBI GenBank database were *Clathrosporium*. *Clathrosporium retortum* (CCIBt 4123) was the closest species based on BLAST result of ITS (83% similarity) and LSU sequence data (95% similarity). The TEF1-α sequence was 91% similar to *Tolypocladium ophioglossoides* (NBRC:8992), *T. paradoxum* (NBRC:-106958), *Metarhizium granulomatis* (UAMH 11176), and *Hypomyces polyporinus* (ATCC 76479). The multi-loci phylogenetic analyses show that *N. multiseptatus* is a distinct species and sister taxon to *Clathrosporium retortum* (CCIBt 4123) with 100% MP, 1.00 BYPP support. The former has long, narrowly fusiform, multiseptate

chlamydospores while the latter has subglobose to irregular, hyaline to subhyaline conidia formed by branched, densely interwoven conidial filaments [488].

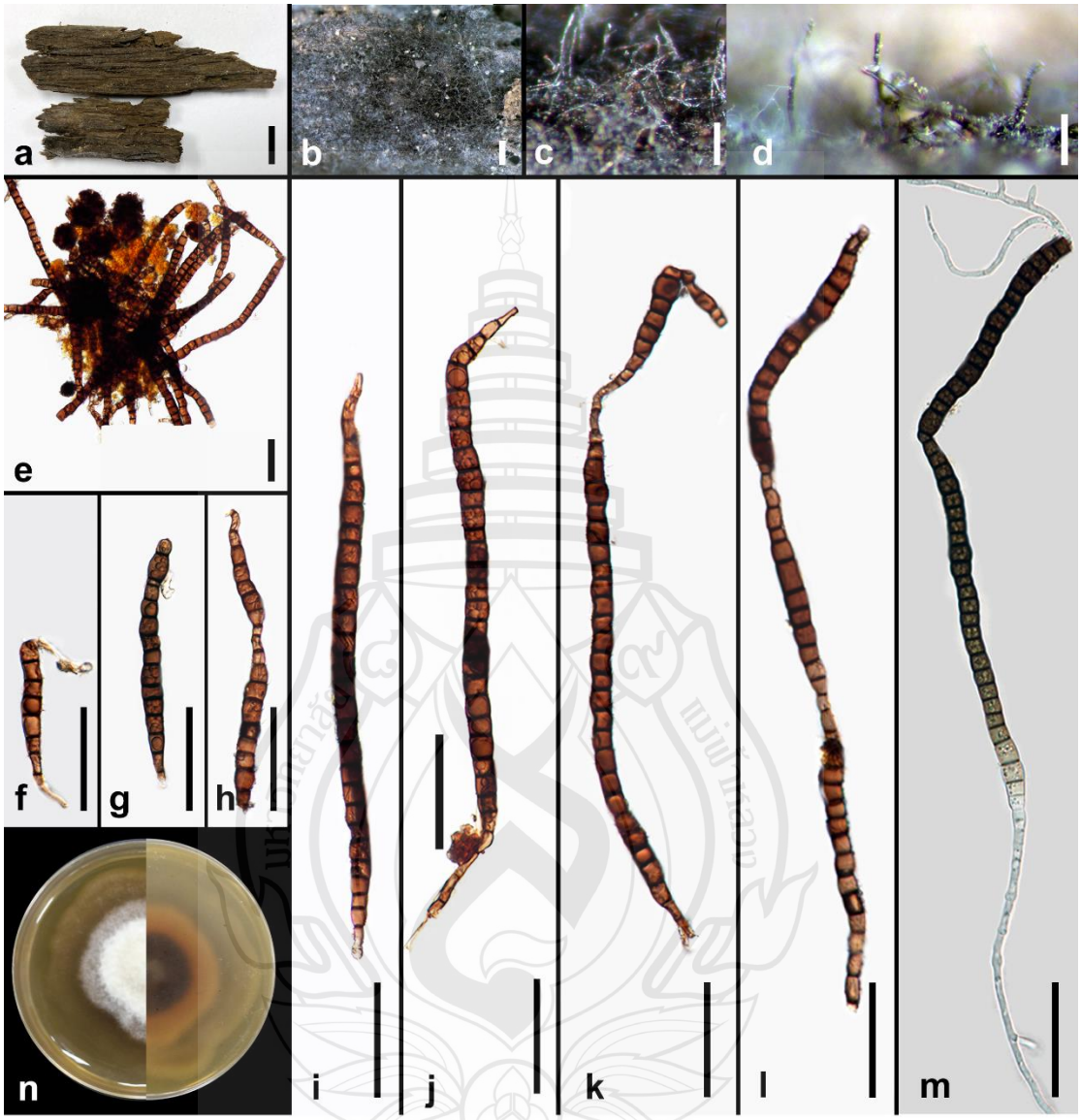


Figure 4.7 *Neoxylomyces multiseptatus* (MFLU 21–0014, Holotype). (a) Host; (b–e) Colonies on Wood; (f–l) Chlamydospores; (m) Germinated Chlamydospore; (n) Culture on MEA. Scale Bars: (a) 10 mm; (b,c) 500 µm; (d) 100 µm; (e–m) 50 µm.

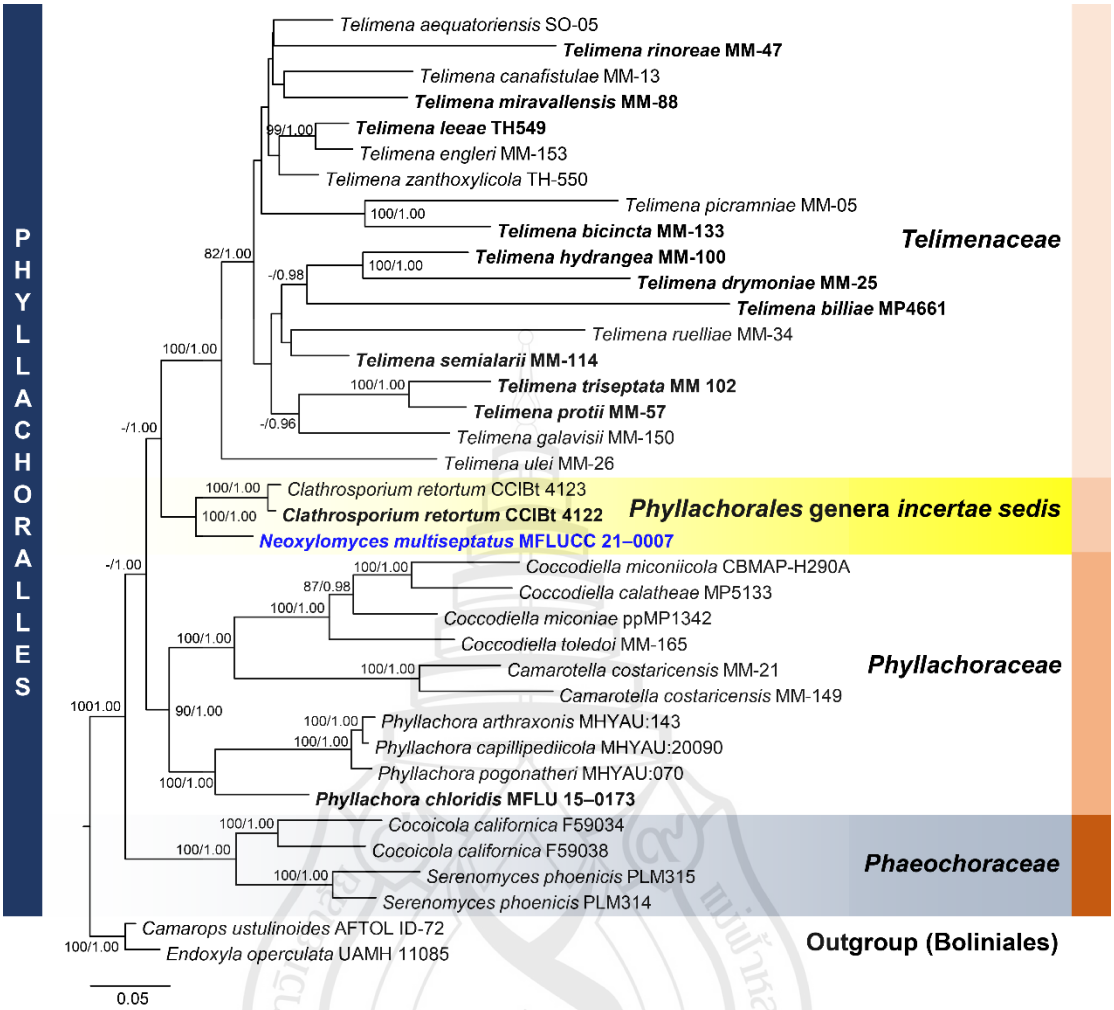


Figure 4.8 Phylogram Generated from Maximum Likelihood Analysis Based on Combined LSU, SSU, ITS, and TEF1-α Sequence Data Representing the Species of Phyllachorales and Related Taxa. Sequences are Taken from Dayarathne et al. [489] and Yang et al. [490]. Thirty-seven Taxa were Included in the Combined Analyses, which Comprised 3259 Characters (LSU = 863, SSU = 1175, ITS = 462, TEF1-α = 759) after Alignment. The Best Scoring RAxML Tree with a Final Likelihood Value of −32,589.920351 is Presented. The Matrix had 2136 Distinct Alignment Patterns, with 34.35% of Undetermined Characters or Gaps. Estimated Base Frequencies were as Follows: A = 0.248688, C = 0.249512, G = 0.274933, T = 0.226867; Substitution Rates: AC = 1.044099, AG = 1.599779, AT = 1.069911, CG = 1.048973, CT = 3.108380, GT =

1.000000; Gamma Distribution Shape Parameter α = 0.745075. Bootstrap Support Values for ML Equal to or Greater Than 75% and BYPP Equal to or Greater Than 0.95 are Given Above the Nodes. *Camarops ustulinoides* (AFTOL-ID 72) and *Endoxyla operculata* (UAMH 11085) were Used as the Outgroup Taxa. The Newly Generated Sequence is Indicated in Blue. The Ex-type Strains are Indicated in Bold.

3. Togniniales Senan., Maharachch. & K.D. Hyde, Fungal Diversity 72: 220 (2015). Maharachchikumbura et al. [29] introduced Togniniales to accommodate Togniniaceae based on multi-loci phylogenetic analyses. The monotypic order is characterized by perithecial ascomata and clavate, tiny asci with hyaline ascogenous hyphae, and cylindrical to allantoid ascospores [29, 491]. Hyde, Norphanphoun, et al. [23] estimated the divergence of the order as 138 MYA.

1) Togniniaceae Réblová, L. Mostert, W. Gams & Crous, Stud. Mycol. 50(2): 540 (2004). Réblová et al. [492] introduced Togniniaceae based on LSU and SSU sequence data of *Togninia* species. Togniniaceae has been referred to various orders Calosphaeriales [493]and Diaporthales [494], but Maharachchikumbura et al. [29] excluded it from Diaporthales and accommodated Togniniaceae in Togniniales. Two genera, *Conidiotheca* and *Phaeoacremonium*, constitute the family.

A. *Phaeoacremonium* W. Gams, Crous & M.J. Wingf., Mycologia 88: 789 (1996). Crous et al. [495] introduced *Phaeoacremonium* (=*Togninia*), with *P. parasiticum* as the type species. *Phaeoacremonium* was known to be the asexual morph of *Togninia*, a genus introduced by Berlese [496] with *T. minima* as the type species. *Togninia* was synonymized under *Phaeoacremonium* by Gramaje et al. [497] as the latter has the most species, widely used by mycologist, and some *Togninia* species already have names in *Phaeoacremonium*. Sixty-seven epithets of *Phaeoacremonium* are listed in Species Fungorum (2020; http://www.speciesfungorum.org/Names/Names.asp (accessed on 13 January 2021)).

a. *Phaeoacremonium thailandense* M.S. Calabon & K.D. Hyde, sp. nov. (Figure 4.9)

Mycobank number: MB838556; Facesoffungi number: FoF 09535

Etymology: In reference to the host location, Thailand, where the holotype was collected.

Holotype: MFLU 21–0012

Saprobic on decaying wood submerged in freshwater habitats. Sexual morph: *Ascomata* 170–280 µm ($\bar{x}$ = 212 µm, n = 10) diameter, perithecial, scattered to gregarious, immersed to semi-immersed, globose to subglobose, black, coriaceous. *Ascomatal wall* 15–45 µm thick ($\bar{x}$ = 28 µm, n = 10), membranous, comprising 8–10 layers, of outer dark brown to brown and inner hyaline cells of textura angularis. *Hamathecium* composed of 2–7 µm ($\bar{x}$ = 3.9 µm, n = 10) wide, hyaline, septate paraphyses, slightly constricted at septa and gradually narrowed towards apex, longer than asci. *Asci* 18–25 × 4–6 µm ($\bar{x}$ = 22 × 5, n = 20), 8-spored, unitunicate, clavate, apex truncate, apedicellate, with truncate bases. Ascogenous hyphae hyaline, septate, simple, smooth-walled, 2–3 µm at base. *Ascospores* 4.8–6.6 × 1.2–1.6 µm ($\bar{x}$ = 5.7 × 1.4 µm, n = 30), biseriate, reniform with rounded ends, unicellular, hyaline, thin-walled, smooth-walled, often containing small guttules at both ends. Asexual morph: Undetermined.

Material examined: THAILAND, Tak Province, Tha Sing Yang, Ban Mae Ja Wang, on decaying wood submerged in a freshwater river, 17 October 2019, N. Padaruth, CC12 (MFLU 21–0012, holotype), ex-type living culture, MFLUCC 21–0005.

Culture characteristics: Ascospores germinating on malt extract agar (MEA) within 24 h. Germ tubes produced from the basal and apical cell of conidia. Colonies growing on MEA, reaching 20–25 mm in 2 weeks at 25 °C. Mycelia superficial, circular, with entire margin, flat, smooth, transparent, spare, from above light brown; reverse, light brown.

GenBank numbers: LSU = MW287238, ITS = MW260334, TEF1-α = MW512608, TUB2 = MW512610, ACT = MW512611

Notes: *Phaeoacremonium thailandense* shares the same morphology with other sexual morphs of the genus, such as ascus formation in acropetal succession, ascal apex thickened without a discharge mechanism, hyaline ascogenous hyphae, and allantoid, reniform to oblong-cylindrical ascospores [23]. Currently, three species of *Phaeoacremonium* are reported in freshwater habitats: *P.*

aquaticum, P. ovale, and *P. thailandense* [5]. The novel species differs from *P. aquaticum* and *P. ovale* in the absence of an ostiolar neck, and longer asci (18–25 µm versus 18–21 µm versus 11–20 µm) [498, 499]. The closest match of the sequences based on BLASTn searches in GenBank is *Phaeoacremonium. Phaeoacremonium sicilianum* (CBS 123034) is the closest species based on BLAST result of ITS region with 92% similarity. The TEF1-α sequence was 94% similar to *P. minimum* strains (AFTOL-ID 924; UCRPA7), while TUB sequence was 80% similar to *P. silicianum* strains (KER-U-PMS4; KER-U-PMS5; KER-U-PMS6). The multi-loci phylogenetic analyses showed that *P. thailandense* is a distinct species and sister taxon to *P. silicianum* strains (CBS 123034; 123035) with 100% MP, 1.00 BYPP support (Figure 3.10). A comparison of ITS and ACT sequence data between *P. thailandense* and *P. silicianum* revealed 17.45% (41/235 bp) and 6.46% (39/604 bp) nucleotide base pair differences, respectively.

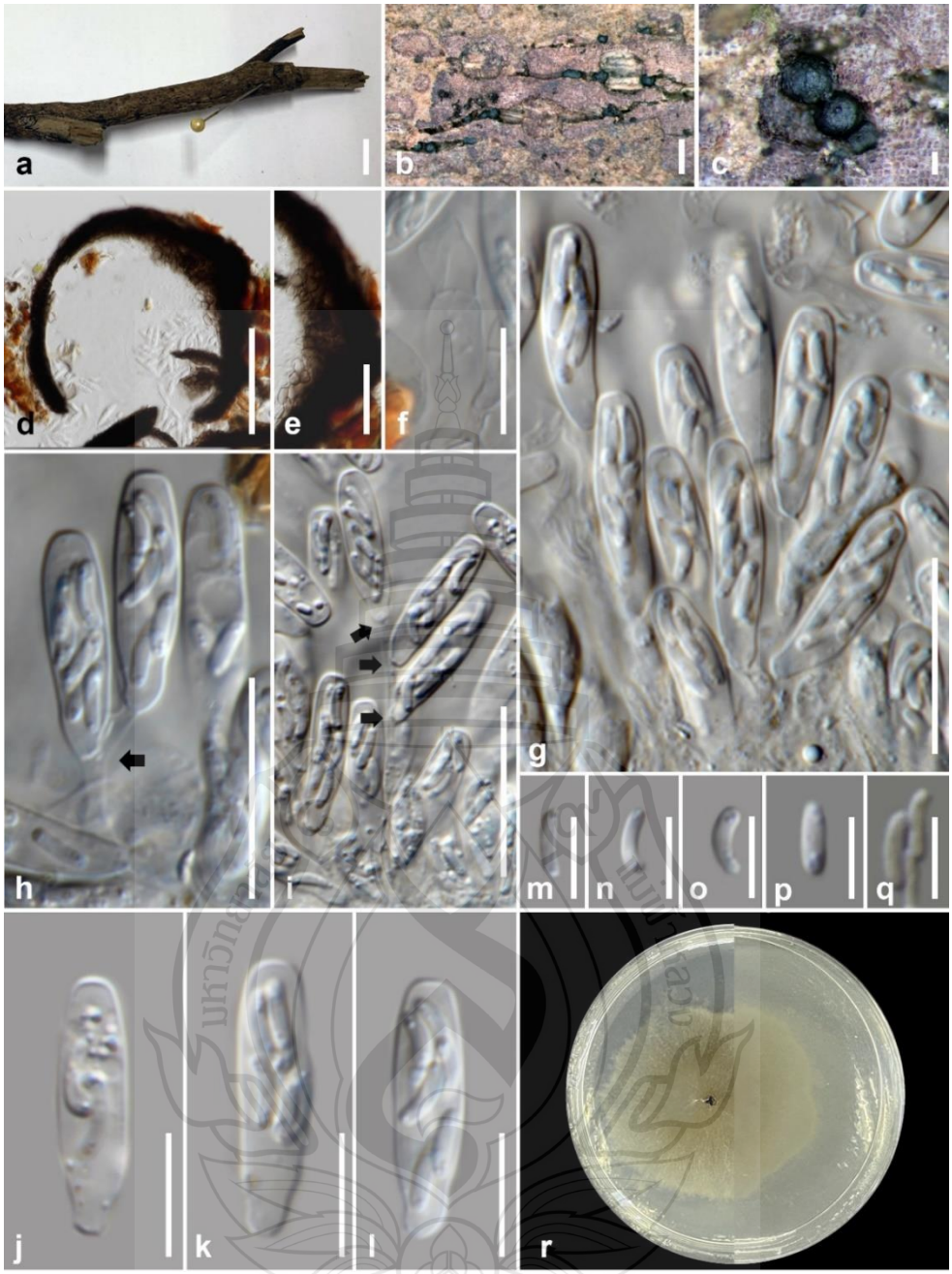


Figure 4.9 *Phaeoacremonium thailandense* (MFLU 21–0012, Holotype). (a) Host; (b,c) Ascomata on Submerged Wood; (d) Section of an Ascoma; (e) Ascomatal Wall; (f) Paraphyses; (g–i) Ascogenous Hyphae (Arrows); (j–l) Asci; (m–p) Ascospores; (q) Germinated Ascospores; (r) Culture on MEA from Surface and Reverse. Scale Bars: (a) 10 mm; (b) 500 µm; (c–e) 100 µm; (f,j–l) 10 µm; (g–i) 20 µm; (m–q) 5 µm

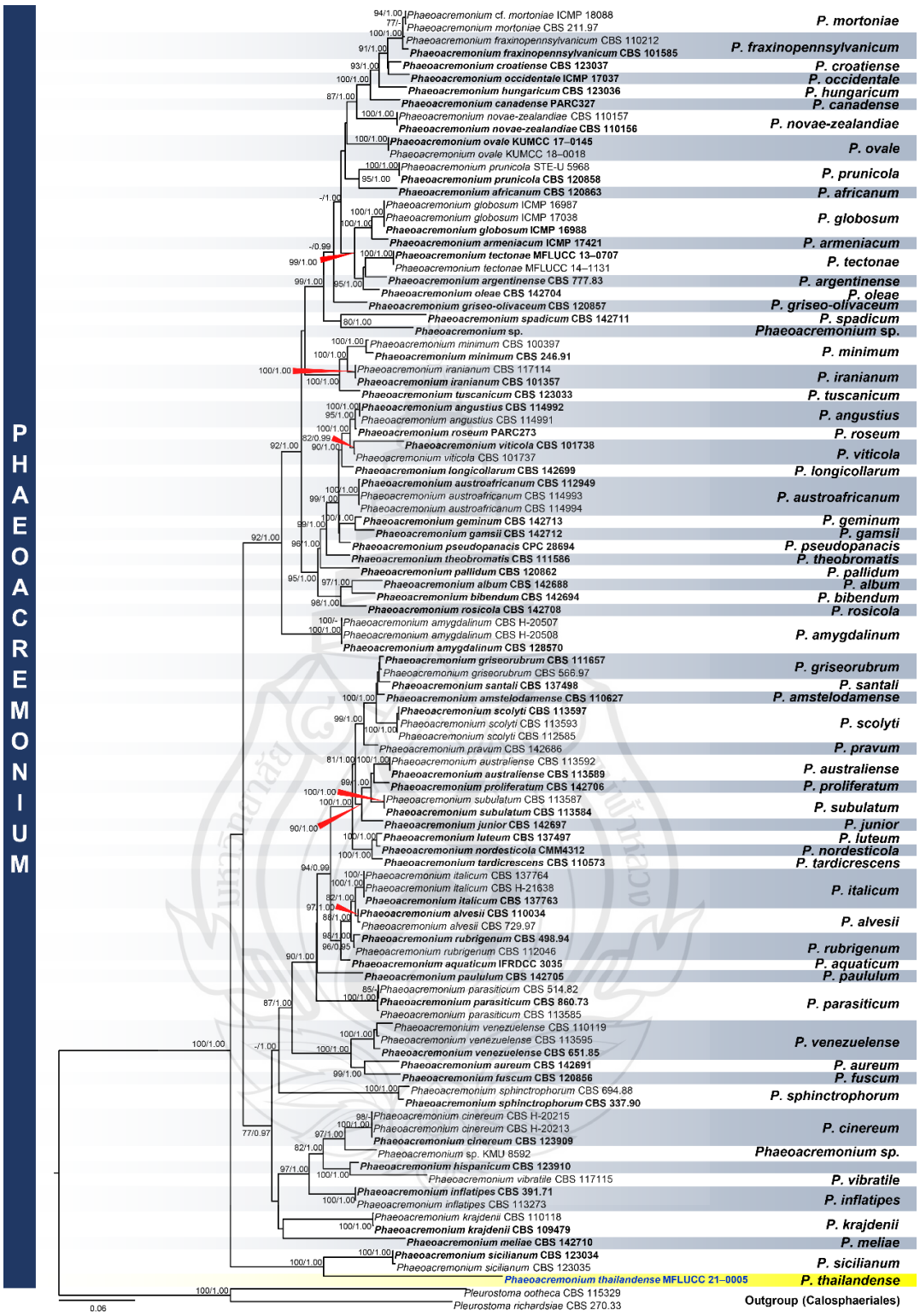


Figure 4.10 Phylogram Generated from Maximum Likelihood Analysis Based on combined LSU, SSU, ITS, TEF1-α, TUB2, and ACT Sequence Data

Representing the Species of Phyllachorales and Related Taxa. Sequences are Taken from Huang et al. [499]. One Hundred-Two Taxa were Included in the Combined Analyses, Which Comprised 2395 Characters (LSU: 892, ITS: 527, TEF1-α = 202; TUB2: 513; ACT: 261) after Alignment. The Best Scoring RAxML Tree with a Final Likelihood Value of −22707.720097 is Presented. The Matrix had 1011 Distinct Alignment Patterns, with 45.51% of Undetermined Characters or Gaps. Estimated Base Frequencies were as Follows: A = 0.228986, C = 0.288393, G = 0.253607, T = 0.229013; substitution rates: AC = 1.333048, AG = 3.557820, AT = 1.416942, CG = 1.385484, CT = 4.971984, GT = 1.000000; Gamma Distribution Shape Parameter α = 0.255190. Bootstrap Support Values for ML Equal to or Greater Than 75% and BYPP Equal to or greater Than 0.95 are Given Above the Nodes. *Pleurostoma ootheca* (CBS 115329) and *P. richardsiae* (CBS 270.33) were Used as the Outgroup Taxa. The Newly Generated Sequence is Indicated in Blue. The Ex-type Strains are Indicated in Bold.

4.4 Discussion

Mycologists in Thailand have initiated a number of projects to document the diversity of freshwater fungi, and this article is a continuation of these studies. Freshwater fungi are an ecological group and include all the major phyla that occur on a wide range of substrates [174]. The first account of Thai freshwater fungi was by Tubaki et al. [71], who listed 40 Ingoldian fungi from foam samples from north and central Thailand. In 1996, BIOTEC initiated a project on lignicolous freshwater fungi under its Fungal Biodiversity Programme, resulting in Sivichai and Boonyene [500] listing 613 freshwater taxa for Thailand. The accumulative annual records of freshwater from 1996–2004 are presented in Figure A1. Zhang et al. [82] listed 173 (in 112 genera) freshwater species (including 34 Ingoldian fungi) published up to the end of 2010. Research on freshwater fungi in China started in the 1920s [501–503],

and by 2013, Hu et al. [454] listed some 782 species, including 25 chytridiomycetes, 256 ascomycetes, 416 hyphomycetes, 63 oomycetes, and 22 zygomycetes.

We are constantly reminded that an estimated 39.4% of plants are now threatened with extinction, yet 1886 species of fungi were scientifically named for the first time in 2019 (Kew, Report State of the World's Plants and Fungi). In this article we have focused on the number of new taxa of freshwater fungi introduced over the past five years from samples collected in Thailand. This data shows that there seems no sign of it reaching a plateau [504].

Freshwater ascomycetes have been extensively studied over the past two decades [5, 7, 449], but it was only in early 2000 that molecular data was used to resolve species [73, 448, 449, 505–507]. Monographs and outlines of freshwater Dothideomycetes and Sordariomycetes have been provided by Dong, Wang, et al. [7] and Luo et al. [5]. One hundred and forty-five genera of freshwater Dothideomycetes (six orders, 43 families) were included, with 32% (46 genera) being unique to freshwater habitats [7, 449]. Luo et al. [5] listed 451 species under 160 genera of freshwater Sordariomycetes.

In the present paper, five novel freshwater ascomycetes were introduced based on multi-loci phylogenetic analyses showing the high undiscovered diversity of fungi in lotic habitats in Thailand. Two new freshwater Dothideomycetes, *Camposporium dulciaquae* and *Brunneofusispora hyalina*, add to the increasing number of pleosporalean taxa discovered from freshwater habitats in Thailand. Based on the published works from 2015–2020, 40 novel pleosporolean taxa were discovered: Aigialaceae (1 species) [508], Anteagloniaceae (1 species) [7], Astrosphaeriellaceae (2 species) [7], Dictyosporiaceae (7 species) [7, 345, 509–511], Latoruaceae (2 species) [7, 415], Lentitheciaceae (4 species) [299, 512, 513] , Ligninsphaeriaceae (1 species) [22], Lindgomycetaceae (3 species) [7, 514], Longipedicellataceae (3 species) [7], Lophiostomataceae (1 species) [7], Melanommataceae (1 species) [511], Morosphaeriaceae (3 species) [7, 515], Nigrogranaceae (1 species) [7], Occultibambusaceae (1 species) [310], Parabambusicolaceae (1 species) [7], Phaeosphaeriaceae (1 species) [516], Pleosporales genera *insertae sedis* (2 species) [7, 451], Pseudoastrosphaeriellaceae (1 species) [7], Tetraplosphaeriaceae (1 species) [7], Trematosphaeriaceae (1 species) [511], and Wicklowiaceae (2 species) [455, 457]. *Camposporium*

thailandicum is an addition to the known twelve *Camposporium* species recorded in freshwater habitats: *C. antennatum* [517–519], *C. appendiculatum* [403], *C. cambrense* [520–522], *C. fusisporum* [432], *C. hyalinum* [523], *C. japonicum* [520, 522], *C. marylandicum* [524–526], *C. multiseptatum* [403], *C. ontariense* [520], *C. pellucidum* [403, 519, 520, 522, 525–527], *C. quercicola* [432], and *C. septatum* [403]. *Brunneofusispora hyalina* is the only known species of the genus thriving in freshwater habitats, while other species were collected on different plant hosts like *Clematis subumbellata* in Thailand (*B. clematidis*) [478] and *Magnolia denudata*, and an unknown host in China (*B. sinensis*) [476, 477].

Forty new species of freshwater Sordariomycetes were discovered in Thailand over the past five years, and taxa were members of Amphisphaeriales [5], Annulatascales [23], Chaetosphaeriales [5, 511], Diaporthomycetidae genera *incertae sedis* [312, 476, 528], Distoseptisporales [5, 23, 511, 529, 530], Magnaporthales [5], Microascales [5, 302], Pleurotheciales [5, 312, 403, 514], Pseudodactylariales [403], Savoryellales [403], Sporidesmiales [310], and Xylariales [5]. Three novel Sordariomycetes (*Neoxylomyces multiseptatus*, *Phaeoacremonium thailandense*, and *Rattania aquatica*) are additions to these species thriving in freshwater habitats in Thailand. *Phaeoacremonium thailandense* is the first reported freshwater species of *Phaeoacremonium* in Thailand. Other freshwater *Phaeoacremonium* species were recorded in China [498, 499]. At present, five species, including the novel taxa, of *Phaeoacremonium* were recorded in Thailand and include *P. aureum*, isolated from mangrove plant *Rhizophora mucronata*, *P. parasiticum* causing human diseases [31, 531], *P. sphinctrophorum* on dead bamboo culms [475], and *P. tectonae* on *Tectona grandis* [516]. *Neoyxylomyces multiseptatus* is the fourth species under Phyllachorales recorded in freshwater habitats. Other species recorded were *Ascovaginospora stellipala*, *Phyllachora therophila*, and *Tamsiniella labiosa* [5, 449]. *Rattania aquatica* is the first member of the genus recorded from freshwater habitats and an addition to 59 species (12 genera) of freshwater Chaetosphaeriaceae.

Between the years 2015–2020, 129 novel species, dominated by Dothideomycetes with 86 species, followed by Sordariomycetes (40 species), have been discovered from freshwater habitats in Thailand (Figure C1, Table E1). Most of freshwater fungi were collected from streams, which reflects the ease of sampling in

these sites. All these freshwater taxa were saprobes in submerged decaying woods. Most have an asexual morph form, wherein 80 and 4 species were hyphomycetes and coelomycetes, respectively. Thirty-five species were sexual morphs, and 10 species had both sexual-asexual morphs. The discovery of five novel freshwater ascomycetes (1 sexual morph, 4 asexual morphs) add to the increasing number of fungi discovered in Thailand for the past six years (Figure D1). Future work needs to explore various lentic and lotic habitats and different substrates in freshwater environments of Thailand. While the Ascomycota dominate taxa recovered from freshwater habitats, much remains to be done to survey other major taxa and develop better techniques for their enumeration, such as members of the Basidiomycota (only 115 are listed by Jones et al. [174], Zygomycota, Mucoromycota, and microsporidians [174]. These groups must be covered so as to determine the overall diversity of freshwater fungi in Thailand.

4.5 Supplementary Materials

The following are available online at https://www.mdpi.com/2309-608X/7/2/-117/s1, Table E1: Freshwater fungi discovered from 2015–2020 in Thailand, Figure B1: Annual cumulative number of freshwater fungi recorded for Thailand from 1996–2004. (Adapted from Sivichai and Boonyene), Figure C1: Classification of novel freshwater fungi discovered from Thailand from 2015–2020, Figure D1: Total number of novel freshwater fungi discovered from Thailand from 2015–2020.

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CHAPTER 5

Mycoenterolobium aquadictyosporium sp. nov. (PLEOSPOROMYCETIDAE, DOTHIDEOMYCETES) FROM A FRESHWATER HABITAT IN THAILAND[4]

Abstract

A study of freshwater fungi in Thailand led to the discovery of *Mycoenterolobium aquadictyosporium* sp. nov. Evidence for the novelty and placement in *Mycoenterolobium* is based on comparison of morphological data. The new species differs from the type species, *M. platysporum*, in having shorter and wider conidia, and from *M. flabelliforme* in having much longer and wider conidia. The hyphomycetous genus *Mycoenterolobium* is similar to *Cancellidium* but differs in the arrangement of conidial rows of cells at the attachment point to the conidiophores. The conidia of the former are made up of rows of cells, radiating in a linear pattern from a single cell attached to the conidiophore, while in *Cancellidium*, adherent rows of septate branches radiate from the conidiophore. *Cancellidium* conidia also contain branched chains of blastic monilioid cells arising from the conidia, while these are lacking in *Mycoenterolobium*. At maturity in *Mycoenterolobium*, the two conidial lobes unite and are closely appressed. Phylogenetic analyses based on a combined LSU, SSU, ITS, TEF1-α, and RPB2 loci sequence data support the placement of *Mycoenterolobium aquadictyosporium* close to the family Testudinaceae within Pleosporomycetidae, Dothideomycetes. The novel species *Mycoenterolobium aquadictyosporium* is described and illustrated and is compared with other morphologically similar taxa.

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Keywords: 1 New Taxon, Freshwater Hyphomycete, Asian Mycology, Multi-Locus Analysis, Thailand

5.1 Introduction

The incorporation of molecular data in phylogenetic and evolutionary studies has revolutionized the current knowledge of fungal systematics [20, 26, 27, 532–536]. Natural taxonomic placements of taxa and development of backbone trees based on molecular phylogeny have been possible [5, 22, 23, 204, 537, 538]. The knowledge of fungal taxonomy and classification are however limited as only approximately 8% (120,000 described taxa) of the 2.2 to 3.8 million estimated global fungal species are described [539] and even fewer have been sequenced. Several authors have suggested areas as to where to find the "missing fungi," such as understudied countries and hosts, particularly in tropical regions and biodiversity hot spots, little explored habitats or niches, and cryptic species hidden under well-established names, see [190, 384, 539, 540].

The taxonomy and classification of Dothideomycetes have been comprehendsively studied, and considerable changes have occurred over the past decade [22, 24, 389]. Hyde et al. [24] listed 105 families under Dothideomycetes. Several published works have also focused on different ecological groups of Dothideomycetes that include terrestrial [541–547], rock-dwelling [548], freshwater [7, 73, 448], and marine habitats [3, 549]. Divergence time estimates using molecular data and fossil records have helped to confirm the establishment of higher-level taxa, such as families, orders, and classes.

Pleosporales is the largest order of Dothideomycetes [22, 24, 186, 390, 391] and comprises ascomycetes with bitunicate asci and ceolomycetous or hyphomycetous asexual morphs [546, 547, 550, 551]. Twenty-eight families and 175 genera (with 12 genera listed as genera *incertae sedis*) were included in the Pleosporales by Lumbsch and Huhndorf [552]. Wijayawardene et al. [553] updated the outline of Lumbsch and Huhndorf and included 75 families and 52 genera in Pleosporales genera incertae sedis. In the Outline of Fungi and fungus-like taxa, Wijayawardene et

al. [204] included 87 families and 533 genera, with 49 genera listed as genera *incertae sedis* in Pleosporales.

The asexual genus *Mycoenterolobium* was introduced by Goos [554] with *Mycoenterolobium platysporum* as the type species growing on decaying wood of Araucaria from Hawaii. Subsequently, Karandikar [555] introduced *Mycoenterolobium flabelliforme* from dead bark of *Tectona grandis* collected from Toranmal region of Maharashtra State, India. There is no sequence data for these two species; therefore, taxonomic placement of the genus was not possible until the current study.

In our survey of freshwater fungi in northern Thailand [461], we observed and isolated a saprobic hyphomycete from submerged wood. Phylogenetic analysis of combined LSU, SSU, ITS, TEF1-α, and RPB2 shows that the genus *Mycoenterolobium* groups close to Testudinaceae.

5.2 Materials and Methods

5.2.1 Sample Collection, Morphological Observation, and Fungal Isolation

Samples of submerged decayed wood were collected from a freshwater stream in Phitsanulok Province, Thailand. The samples were incubated for 5 days and observed using stereomicroscope for the presence of fruiting bodies. Macromorphological features were photographed using a Motic SMZ 168 Series dissection microscope for fungal structures on the woody substrate, while microscopic characters were documented using Nikon Eclipse 80i microscope. Single spore isolation was used to obtain pure cultures and colonial characteristics described. Herbarium-type specimen was deposited in Mae Fah Luang University (MFLU). Ex-type living culture was deposited at Mae Fah Luang University Culture Collection (MFLUCC). The new species was registered in Faces of Fungi (http://www.facesoffungi.org; [202] and MycoBank database (http://www.mycobank.org/).

5.2.2 DNA extraction, PCR amplification, and sequencing

Fungal mycelia from pure cultures grown in malt extract agar (MEA) for 30 days were scraped off using sterilized scalpel and kept in a 1.5 ml microcentrifuge tube. Genomic DNA was extracted using the Biospin Fungus Genomic DNA

Extraction kit (BioFlux®, China) following the manufacturer's protocol. Polymerase chain reaction (PCR) was used to amplify five genes: the large subunit (28SrDNA), small subunit (18SrDNA), internal transcribed spacers (ITS1-5.8S-ITS2), translation elongation factor 1-alpha (TEF1-α), and DNA dependent RNA polymerase II second largest subunit (RPB2). The 28S rDNA was amplified using the primers LROR and LR5 [416], while 18SrDNA was amplified using the primers NS1 and NS4 [417]. For ITS, primers ITS5 and ITS4 were used [417]. The TEF1-α was amplified using primers EF1–983F and EF1–2218R [464], while RPB2 was amplified using primers fRPB2-5F/fRPB2-7cR [556]. Polymerase chain reaction was performed in a volume of 25 µl, which contained 12.5 µl of 2× Power Taq PCR MasterMix (Bioteke Co., China), 1 µl of each primer (10 µM), 1 µl genomic DNA, and 9.5 µl deionized water. The PCR thermal cycle programs for LSU, SSU, and TEF1-α amplification were as follows: initial denaturing step of 94 °C for 3 min, followed by 40 cycles of denaturation at 94 °C for 45 s, annealing at 56 °C for 50 s, elongation at 72 °C for 1 min, and final extension at 72 °C for 10 min. The PCR thermal cycle program for the RPB2 was initial denaturing step of 95 °C for 5 min, followed by 40 cycles of denaturation at 95 °C for 1 min, annealing at 52 °C for 2 min, elongation at 72 °C for 90 s, and final extension at 72 °C for 10 min. Agarose gel electrophoresis was done to confirm the presence of amplicons at the expected molecular weight. PCR products were purified and sequenced with the primers mentioned above at a commercial sequencing provider (BGI, Shenzhen, China). A BLAST search of the newly generated sequences was carried out to exclude contamination and to search for related taxa in GenBank database (www.ncbi.nlm.nih.gov/blast/).

5.2.3 Phylogenetic analysis

The gene sequences of closely related strains were assembled based on the closest matches from the BLAST search results and from recently published data in Wanasinghe [557] and Dayarathne et al. [6]. Sequences generated from the three genes were analyzed along with other sequences retrieved from GenBank (Table 5.1). Five datasets, one for each gene, were aligned with MAFFT v. 7 using the web server (http://mafft.cbrc.jp/alignment/server; Katoh et al. [419]). Alignment was further refined manually, where necessary, using BioEdit v.7.0.9.0 [420]. Aligned sequences

were automatically trimmed using TrimAl v. 1.3 on the web server (http://phylemon.-bioinfo.cipf.es/utilities.html). The online tool “ALTER” [421] was used to convert the alignment file to phylip format. Phylogenetic analysis of both individual and combined gene data was performed using maximum likelihood (ML) and Bayesian inference (BI).

Maximum parsimony (MP) analyses were performed using the heuristic search option with 1000 random taxa addition and tree bisection and reconnection (TBR) as the branchswapping algorithm in PAUP in CIPRES web portal [228, 422]. All characters were unordered and of equal weight and gaps were treated as missing data. Maxtrees were unlimited, branches of zero length collapsed, and all multiple, equally parsimonious trees were saved. Clade stability was assessed using a bootstrap (BS) analysis with 1000 replicates, each with ten replicates of random stepwise addition of taxa [423]. Descriptive tree statistics for parsimony (tree length [TL], consistency index [CI], retention index [RI], relative consistency index [RC], and homoplasy index [HI]) were calculated for trees generated under different optimality criteria.

Maximum likelihood analysis was performed using RAxML v. 8 software on the CIPRES web portal [225–227] (http://www.phylo.org/portal2/; Miller et al. [228]). The GTR + GAMMA model of nucleotide evolution was used. RAxML rapid bootstrapping of 1000 replicates was performed. Bayesian inference analysis was performed using MrBayes v. 3.2.6 on XSEDE at the CIPRES web portal [229], using the parameter setting of 2 parallel runs and 4 chains, run for 4,000,000 generations at which point the standard deviation of split frequencies was below 0.01. Trees were sampled every 1000 generations, and all other parameters were left as default. Newly generated sequences have been deposited in GenBank (Table 5.1), and the finalized alignment and tree were deposited in TreeBASE, submission ID: 26361 (http://www.-treebase.org/).

Table 5.1 Taxa Used in this Study for the Analysis of Combined LSU, SSU, ITS rDNA, TEF1-α, and RPB2 Sequence Data and their GenBank Accession Numbers

Species	**Strain / Voucher Number**	**LSU**	**SSU**	**ITS**	***TEF1-α***	***RPB2***
Amniculicola immersa	CBS 123083	FJ795498	GU456295	–	GU456273	GU456358
Amniculicola parva	CBS 123092	GU301797	GU296134	MH863272	GU349065	–
Angustospora nilensis	MFLU 15-1511	NG_057091	NG_061219	–	–	–
Anteaglonium globosum	ANM925.2	GQ221911	–	–	GQ221919	–
Anteaglonium parvulum	MFLUCC 14–0817	KU922913	KU922914	–		–
Anteaglonium thailandicum	MFLUCC 14–0816	KU922909	KU922910	–	KU922920	–
Aquasubmersa japonica	KT2813	LC061586	LC061581	LC061591	LC194383	LC194420
Aquasubmersa japonica	KT2862	LC061587	LC061582	LC061592	LC194384	LC194421
Aquasubmersa japonica	KT2863	LC061588	LC061583	LC061593	LC194385	LC194422
Aquasubmersa mircensis	MFLUCC 11–0401	JX276955	JX276956	JX276954		
Atrocalyx acutispora	KT2436	LC194341	LC194299	LC194475	LC194386	LC194423
Atrocalyx lignicola	CBS122364	LC194342	LC194300	LC194476	LC194387	LC194424

Table 5.1 (continued)

Species	Strain / Voucher Number	LSU	SSU	ITS	*TEF1-α*	*RPB2*
Cryptoclypeus oxysporus	KT2772	LC194345	LC194303	LC194479	LC194390	LC194427
Cryptocoryneum brevicondensatum	yone152	LC194349	LC194307	LC096155	LC096137	LC194431
Cryptocoryneum japonicum	KT3300	LC194354	LC194312	LC096160	LC096142	LC194436
Cryptocoryneum pseudorilstonei	CBS113641	LC194364	LC194322	LC096170	LC096152	LC194446
Halotestudina muriformis	MFLUCC 18–0392	MN017894	MN017947	–	–	–
Halotestudina muriformis	MFLU 18–0524	MN017853	MN017919	–	–	MN077079
Halotestudina muriformis	MFLU 17–2634	MN017852	MN017918	–	MN077068	–
Halotestudina muriformis	MFLUCC 17–0395	MN017854	MN017920	–	–	–
Hermatomyces tectonae	MFLUCC 14–1141	KU764696	KU712466	KU144918	KU872758	–
Hermatomyces thailandica	MFLUCC 14–1143	KU764692	KU712468	KU144920	KU872754	KU712488
Lepidosphaeria nicotiae	CBS 101341	DQ678067	–	–	DQ677910	DQ677963
Ligninsphaeria jonesii	GZCC 15–0080	KU221038	–	–	–	–
Ligninsphaeria jonesii	MFLUCC 15–0641	NG_059642	–	–	–	–

Table 5.1 (continued)

Species	Strain / Voucher Number	LSU	SSU	ITS	*TEF1-α*	*RPB2*
Longicorpus striataspora	MFLUCC 17–2515	MK035990	MK035975	MK035967	MK034430	MK034438
Longicorpus striataspora	MFLUCC 17–2516	MK035991	MK035976	MK035968	MK034431	MK034439
Longicorpus striataspora	MFLUCC 18–0268	MK035989	MK035974	MK035966	MK034429	MK034437
Longicorpus striataspora	MFLUCC 18–0267	MK035988	MK035973	MK035965	MK034428	MK034436
Lophiostoma arundinis	CBS 621.86	DQ782384	DQ782383	AJ496633	DQ782387	DQ782386
Lophiostoma crenatum	CBS 629.86	DQ678069	DQ678017	–	DQ677912	DQ677965
Lophiotrema bambusae	RP0030	KX672154	KX672159	KX672149	KX672162	KX672161
Lophiotrema eburnoides	KT1424.1	LC001707	LC001706	LC001709	LC194403	LC194458
Lophiotrema fallopiae	KT2748	LC149915	LC149911	LC149913	LC194404	LC194459
Massarina albocarnis	CBS 119345	LC194379	LC194337	LC194503	LC194416	LC194471
Muristudina chiangraiensis	MFLUCC 17–2551	MG602248	MG602249	MG602247	MG602251	MG602250
Mycoenterolobium aquadictyosporium	**MFLUCC 19-0288**	**MT447877**	**MT465324**	**MT465427**	**MT461428**	**MT477863**
Neotestudina rosatii	CBS 331.78	MH872904	–	MH861143	–	–

Table 5.1 (continued)

Species	Strain / Voucher Number	LSU	SSU	ITS	*TEF1-α*	*RPB2*
Neotestudina rosatii	CBS 690.82	DQ384107	DQ384069	–	–	–
Polyplosphaeria fusca	KT1616	AB524604	AB524463	AB524789	–	–
Pseudoastrosphaeriella bambusae	MFLUCC 11–0205	KT955475	KT955455	–	KT955437	KT955414
Pseudoastrosphaeriella longicolla	MFLUCC 11–0171	KT955476	–	–	KT955438	KT955420
Pseudoastrosphaeriella thailandensis	MFLUCC 14–0038	KT955479	KT955458	–	KT955441	KT955409
Pseudocryptoclypeus yakushimensis	KT2186	LC194380	LC194338	LC194504	LC194417	LC194472
Pseudolophiotrema elymicola	KT1450	LC194381	LC194339	LC194505	LC194418	LC194473
Pseudotetraploa curviappendiculata	HC 4930	AB524608	AB524467	AB524792	AB524823	–
Quadricrura septentrionalis	HC 4983	AB524615	AB524474	AB524799	AB524830	–
Striatiguttula nypae	MFLUCC 17–2517	MK035993	MK035978	MK035970	MK034433	MK034441
Striatiguttula nypae	MFLUCC 17–2518	MK035994	MK035979	MK035971	MK034434	–
Striatiguttula nypae	MFLUCC 18–0265	MK035992	MK035977	MK035969	MK034432	MK034440

Table 5.1 (continued)

Species	Strain / Voucher Number	LSU	SSU	ITS	*TEF1-α*	*RPB2*
Striatiguttula phoenicis	MFLUCC 18–0266	MK035995	MK035980	MK035972	MK034435	MK034442
Tetraploa sasicola	KT 563	AB524631	AB524490	AB524807	AB524838	–
Trematosphaeria wegeliniana	CBS:123124	GU261722	GU261720	–	–	–
Triplosphaeria maxima	KT 870	AB524637	AB524496	AB524812	AB524843	–
Ulospora bilgramii	AFTOL-ID 1598	DQ678076	DQ678025	–	DQ677921	DQ677974
Ulospora bilgramii	CBS 101364	DQ678076	DQ678025	–	DQ677921	DQ677974
Ulospora bilgramii	CBS 333.78	MH872905	–	MH861144	–	–
Verruculina enalia	BCC 18401	GU479802	GU479770	–	GU479863	GU479835
Verruculina enalia	BCC 18402	GU479803	GU479771	–	GU479864	GU479836

5.3 Result

5.3.1 Phylogenetic Analysis

The concatenated dataset (LSU, SSU, ITS, TEF1-α, and RPB2 loci) was composed of 59 taxa from Testudinaceae and related families in Pleosporales (Amniculicolaceae, Anteagloniaceae, Aquasubmersaceae, Cryptocoryneaceae, Her-

matomycetaceae, Ligninsphaeriaceae, Lophiotremataceae, Pseudoastrosphaeriellaceae, Striatiguttulaceae, Tetraplosphaeriaceae), with *Lophiostoma arundinis* CBS 621.86 and *Lophiostoma crenatum* CBS 629.86 as outgroup taxa (Table 5.1).

The analyzed dataset, after trimming, comprised a total of 4214 characters including gaps (LSU = 830 bp; SSU = 1021; ITS = 474; TEF1-α = 866; RPB2 = 1007). The ML analysis for the combined dataset provided the best scoring tree (Figure 5.1) with a final ML optimization likelihood value of −32,311.80 (ln). The matrix had 1605 distinct alignment patterns and 24.63% proportion of gaps and completely undetermined characters. The best ML phylogram resulted with estimated base frequencies: A = 0.249042, C = 0.247668, G = 0.270573, T = 0.232717, substitution rates: AC = 1.439606, AG = 3.875210, AT = 1.434240, CG = 1.134209, CT = 8.381462, GT = 1.000000), and gamma distribution shape parameter: α = 0.195734. The Bayesian analysis resulted in 4002 trees after 4,000,000 generations. The first 1000 trees, representing the burn-in phase of the analyses, were discarded, while the remaining 3002 trees were used for calculating posterior probabilities in the majority rule consensus tree.

The maximum parsimonious dataset consisted of 4527 characters, of which 2732 were constant, 1193 parsimony informative (26.35%), and 289 parsimony uninformative. The parsimony analysis of the data matrix resulted in 15 equally most parsimonious trees with a length of 4356 steps (TL = 5935, CI = 0.396, RI = 0.641, RC = 0.254, HI = 0.604) in the first tree. The tree topologies resulted from three analyses are similar. Support values for ML and MP above 50% and Bayesian posterior probabilities (PP) greater than 0.95 are given at the nodes.

The ML phylogram generated based on sequence analysis of the combined dataset indicates that *Mycoenterolobium aquadictyosporium* formed a sister clade to *Lepidosphaeria nicotiae* (CBS 101341) with 54% ML and 0.99 PP statistical support (Figure 4.1). *Muristudina chiangraiensis* (MFLUCC 17–2551), *Neotestudina rosatii* (CBS 331.78; CBS 690.82), *Verruculina enalia* (BCC 18402; BCC 18401), *Ulospora bilgramii* (CBS 333.78; AFTOL-ID 1598; CBS 101364), *Trematosphaeria wegeliniana* (CBS 123124), *Angustospora nilensis* (MFLU 15–1511), and *Halotestudina muriformis* (MFLU 17–2634; MFLUCC 18–0392; MFLUCC 17–0395;

MFLU 18–0524) were grouped in Testudinaceae clade with 89% ML and 1.00 PP statistical support. The sequence data placed *Mycoenterolobium aquadictyosporium* close to the family Testudinaceae within Pleosporomycetidae, Dothideomycetes. However, the family Testudinaceae is heterogeneous morphologically and phylogenetically weakly supported, and the new taxon is referred to Pleosporales *incertae sedis* until further taxon sampling is undertaken.

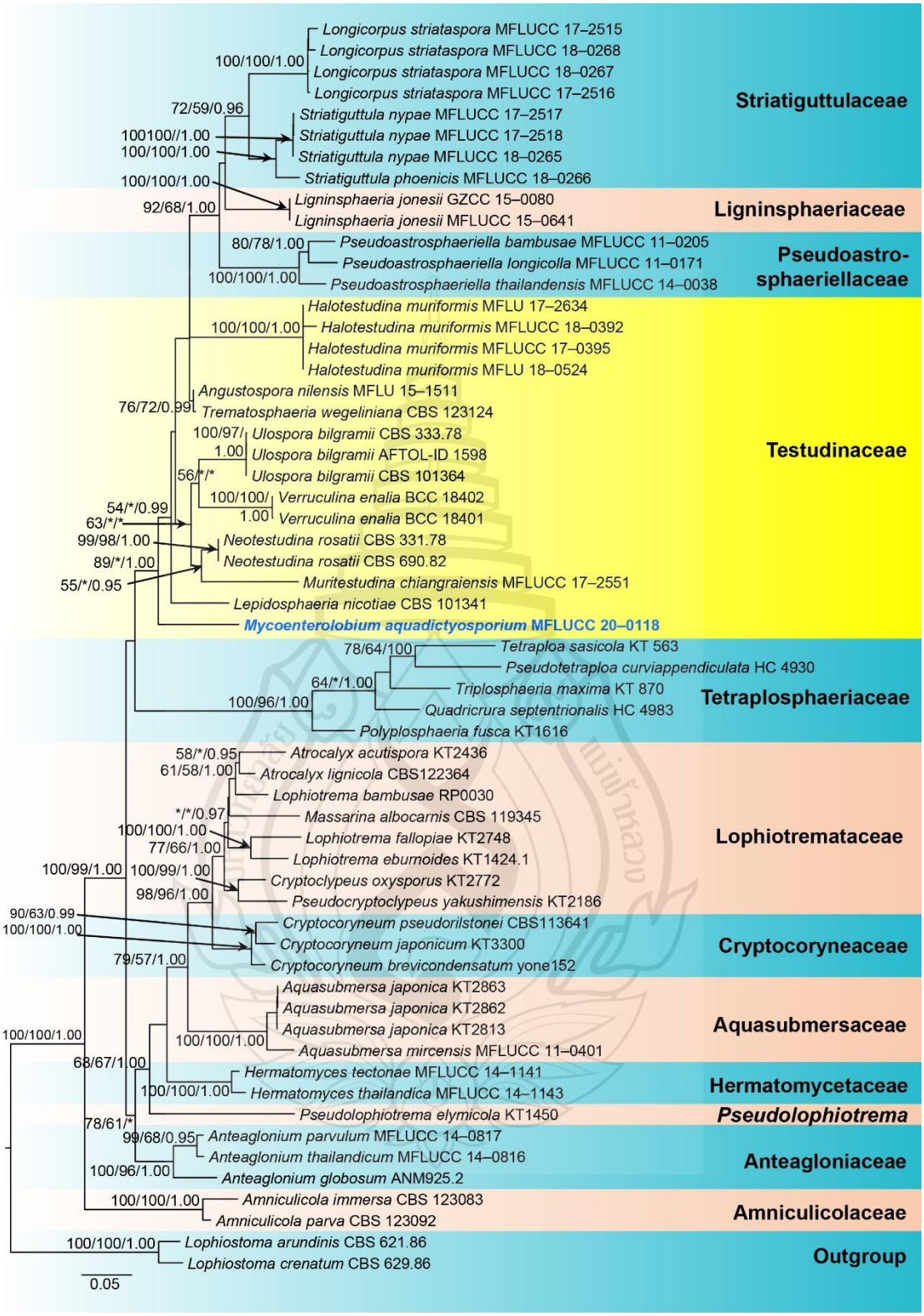

Longicorpus striataspora MFLUCC 17–2515
Longicorpus striataspora MFLUCC 18–0268
Longicorpus striataspora MFLUCC 18–0267
Longicorpus striataspora MFLUCC 17–2516
Striatiguttula nypae MFLUCC 17–2517
Striatiguttula nypae MFLUCC 17–2518
Striatiguttula nypae MFLUCC 18–0265
Striatiguttula phoenicis MFLUCC 18–0266
Striatiguttulaceae
Ligninsphaeria jonesii GZCC 15–0080
Ligninsphaeria jonesii MFLUCC 15–0641
Ligninsphaeriaceae
Pseudoastrosphaeriella bambusae MFLUCC 11–0205
Pseudoastrosphaeriella longicolla MFLUCC 11–0171
Pseudoastrosphaeriella thailandensis MFLUCC 14–0038
Pseudoastro-sphaeriellaceae
Halotestudina muriformis MFLU 17–2634
Halotestudina muriformis MFLUCC 18–0392
Halotestudina muriformis MFLUCC 17–0395
Halotestudina muriformis MFLU 18–0524
Angustospora nilensis MFLU 15–1511
Trematosphaeria wegeliniana CBS 123124
Ulospora bilgramii CBS 333.78
Ulospora bilgramii AFTOL-ID 1598
Ulospora bilgramii CBS 101364
Verruculina enalia BCC 18402
Verruculina enalia BCC 18401
Neotestudina rosatii CBS 331.78
Neotestudina rosatii CBS 690.82
Muritestudina chiangraiensis MFLUCC 17–2551
Lepidosphaeria nicotiae CBS 101341
Mycoenterolobium aquadictyosporium MFLUCC 20–0118
Testudinaceae
Tetraploa sasicola KT 563
Pseudotetraploa curviappendiculata HC 4930
Triplosphaeria maxima KT 870
Quadricrura septentrionalis HC 4983
Polyplosphaeria fusca KT1616
Tetraplosphaeriaceae
Atrocalyx acutispora KT2436
Atrocalyx lignicola CBS122364
Lophiotrema bambusae RP0030
Massarina albocarnis CBS 119345
Lophiotrema fallopiae KT2748
Lophiotrema eburnoides KT1424.1
Cryptoclypeus oxysporus KT2772
Pseudocryptoclypeus yakushimensis KT2186
Lophiotremataceae
Cryptocoryneum pseudorilstonei CBS113641
Cryptocoryneum japonicum KT3300
Cryptocoryneum brevicondensatum yone152
Cryptocoryneaceae
Aquasubmersa japonica KT2863
Aquasubmersa japonica KT2862
Aquasubmersa japonica KT2813
Aquasubmersa mircensis MFLUCC 11–0401
Aquasubmersaceae
Hermatomyces tectonae MFLUCC 14–1141
Hermatomyces thailandica MFLUCC 14–1143
Hermatomycetaceae
Pseudolophiotrema elymicola KT1450
Pseudolophiotrema
Anteaglonium parvulum MFLUCC 14–0817
Anteaglonium thailandicum MFLUCC 14–0816
Anteaglonium globosum ANM925.2
Anteagloniaceae
Amniculicola immersa CBS 123083
Amniculicola parva CBS 123092
Amniculicolaceae
Lophiostoma arundinis CBS 621.86
Lophiostoma crenatum CBS 629.86
Outgroup
0.05

Figure 5.1 Phylogenetic Tree Based on RAxML Analyses of Combined LSU, SSU, ITS, TEF1-α, and RPB2 Sequence Data. Bootstrap Support Values for ML and MP Higher Than 50% and PP Greater Than 0.95 are Indicated Above the Nodes as MP/ML/PP. The New Isolate is Represented in Blue. The Tree is Rooted to *Lophiostoma arundinis* (CBS 621.86) and *Lophiostoma crenatum* (CBS 629.86) (Lophiostomataceae). Bar = 0.05 Estimated Number of Nucleotide Substitutions Per Site Per Branch

5.3.2 Taxonomy

Mycoenterolobium aquadictyosporium M.S. Calabon, Boonmee, E.B.G. Jones & K.D. Hyde, sp. nov. (Figures. 5.2 and 5.3)

MycoBank number: MB835668; Faces of fungi number: FoF 08423

Etymology: referring to the aquatic habitat and shape of the conidia

Saprobic on decaying wood submerged in freshwater habitat. Sexual morph: undetermined. Asexual morph: hyphomycetous, on natural substrate, colonies effuse, black, shiny, uniformly spread, mycelium immersed. *Conidiophores* 7–22 × 2–8 μm ($\overline{x}$ = 11× 5 μm, n = 7), micronematous, inconspicuous, short or absent. *Conidiogenous cells* monoblastic, integrated, terminal, determinate, oval to irregularly shaped. *Conidia* when immature 19–52 × 14–38 μm ($\overline{x}$ = 30 × 25 μm, n = 15); at mature 45–92 × 43–104 μm, and 10–30 μm thick ($\overline{x}$ = 71× 70 × 20 μm, n = 30), acrogenous, solitary, dictyosporous, strongly flattened, fan shaped at maturity, composed of 15–25 rows of cells radiating from single cell at the point of attachment, dark brown, smooth-walled.

Culture characteristics: conidia germinating on MEA within 24 h and germ tubes produced from the basal part of the conidia. On MEA, colony circular with entire margin, reaching 10–15 mm in 25 days at 25 °C, dark brown to grayish brown from above, dark brown to black from below, surface smooth, opaque, dry, raised to becoming umbonate in old cultures, with dense mycelia. Sporulation in culture after 14 days of incubation.

Material examined: Thailand, Phitsanulok Province, Wang Thong District, Kaeng Sopha waterfall stream, on submerged wood, 25 July 2019, S. Boonmee, PSL/WT-17 (MFLU 20–0443, holotype), ex-type living culture 20–0118.

GenBank accession numbers: ITS = MT465427, LSU = MT447877, SSU = MT465324, TEF1-α = MT461428, RPB2=MT477863

Notes: *Mycoenterolobium*, typified by *M. platysporum* Goos, was isolated from decaying wood of *Araucaria* sp. (Araucariaceae) in Hawaii [554]. *Mycoenterolobium* is unique in the production of massive, flattened, fan-shaped conidia that resemble *Cancellidium* species. However, they differ in the arrangement of conidial rows of cells at the attachment point to the conidiophores. The conidia of *Mycoenterolobium* are made up of rows of cells, radiating in a linear pattern from a basal cell attached to the conidiophore, while *Cancellidium* is distinct in having parallel adherent rows of septate branches radiating from the conidiophore [554, 558, 559]. *Cancellidium* conidia also contain internal branched chains of blastic, cicatrized, and monilioid cells, developing from the base [560], and these are lacking in *Mycoenterolobium*. Dictyosporous hyphomycetes wherein conidial morphology differs from *Mycoenterolobium* include *Aquadictyospora, Dictyopalmispora, Dictyosporium, Dictyocheirospora*, *Digitodesmium*, *Jalapriya, Pseudodictyosporium*, and *Vikalpa* [22, 509–511, 561]. *Aquadictyospora* is characterized by broadly rounded conidia, composed of 4–6 compactly arranged rows with a basal, subglobose, hyaline cell. *Dictyopalmispora* has complanate conidia, with unique hairlike extensions produced from apical cells of all 4 rows. *Digitodesmium* has cheiroid, digitate conidia with apical gelatinous caps, while *Jalapriya* has cheiroid, euseptate conidia with 5–7 rows of cells, rows converging or not converging at apex, apical cells with or without appendages. *Dictyosporium* differs in having cheiroid, digitate, and complanate conidia without separating arms, while *Dictyocheirospora* is characterized by non-complanate conidia with arms arising from the basal cell and closely gathered at the apex and compact. *Pseudodictyosporium* has cheiroid conidia with 2–3 rows of cells, while *Vikalpa* has conidia with 3 rows of cells each in a different plane.

Three species are included in *Mycoenterolobium*: *M. aquadictyosporium, M. flabelliforme* K.G. Karand., P.N. Singh & S.K., Singh, and *M. platysporum* Goos [554, 555]. *Mycoenterolobium aquadictyosporium* can be distinguished from *M. platysporum* in having shorter but wider conidia (45–92 μm long, 43–104 μm wide vs. 110–130 μm long, 75–80 μm wide). The conidia of *Mycoenterolobium aquadictyosporium* are longer than in *M. flabelliforme* (45–92 μm long, 43–104 μm wide vs.

23.5–37.5 µm long, 24.5–45.5 µm wide). *Mycoenterolobium aquadictyosporium* is a freshwater species, *M. platysporum* and *M. flabelliforme* were collected from terrestrial trees of *Araucaria* sp. and *Tectona grandis* [554, 555], while *M. platysporum* has also been collected from submerged mangrove wood of *Rhizophora stylosa* [562].

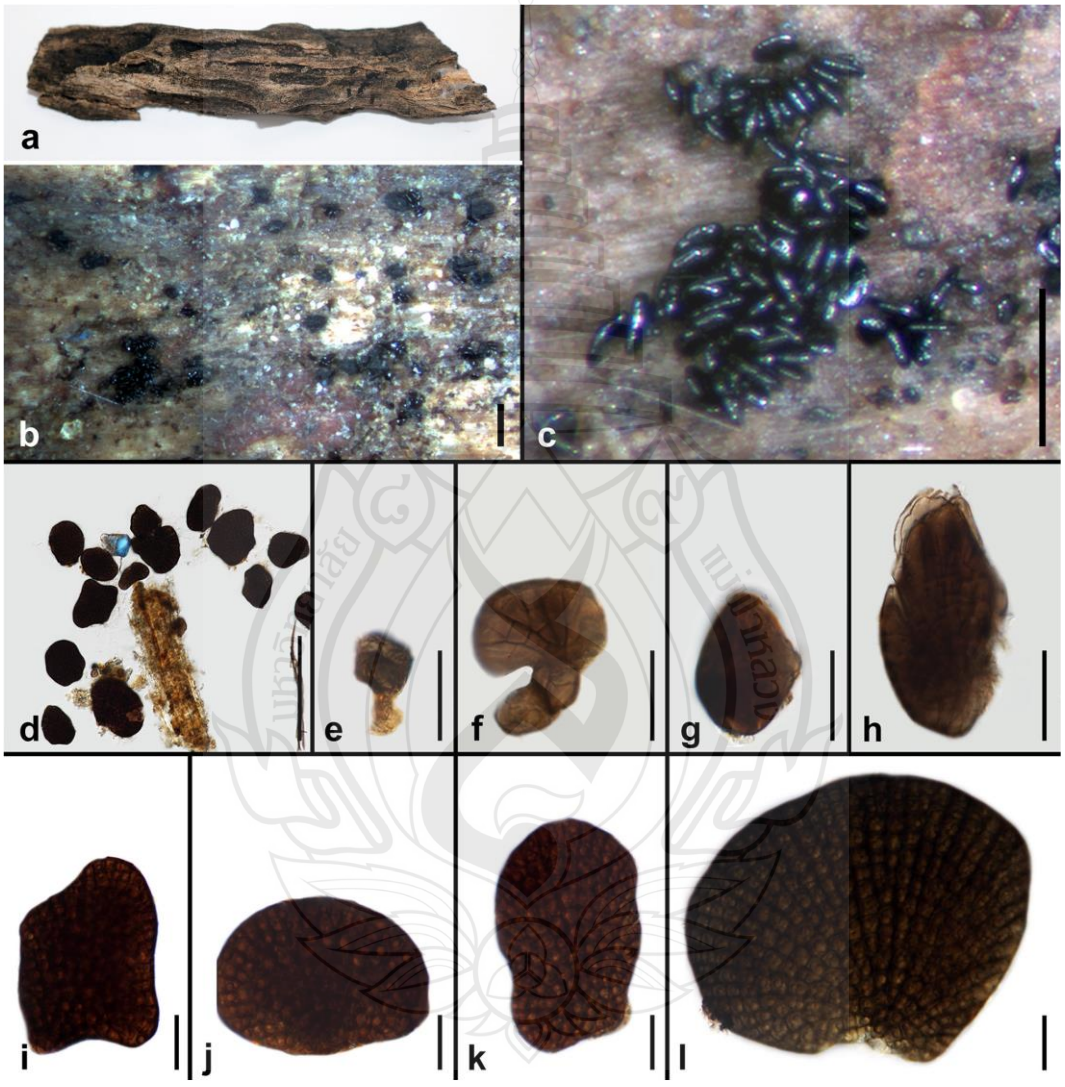


Figure 5.2 *Mycoenterolobium aquadictyosporium* (MFLUCC 20–0118, Holotype). (a) Host; (b,c) Appearance of Colonies in Natural Substrate; (d) Conidia; (e,f) Developing Conidia Attached to Conidiogenous Cells; (g,h) Immature Conidia; (i–l) Mature Conidia. Scale Bars: (b) 1 mm; (c,d) 200 µm; (e–l) 10 µm

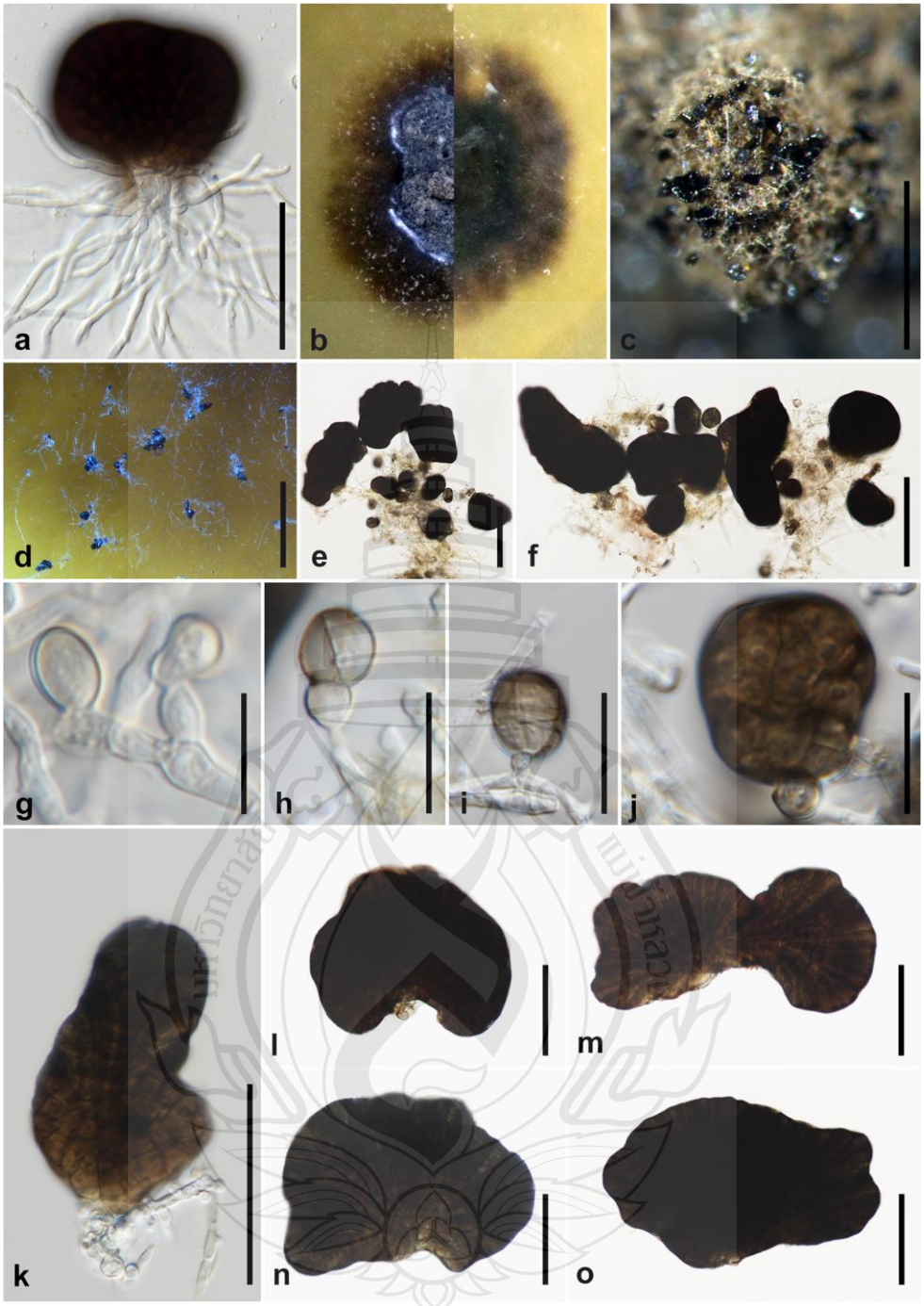


Figure 5.3 *Mycoenterolobium aquadictyosporium* (MFLUCC 20–0118, Holotype). (a) Germinated Conidium; (b) Colony on MEA from Above and Below; (c–f) Development of Conidia in Culture; (g–k) Developing Conidia Attach to Conidiogenous Cells; (l–o) Conidia. Scale bar: (a,k–o) 50 µm; (c,d) 1 mm; (e,f) 100 µm; (g–j) 15 µm



Figure 5.4 Fan-shaped Conidia of *Mycoenterolobium* and *Cancellidium*. (a,b) Conidia of *Mycoenterolobium aquadictyosporium* (MFLUCC 20–0118) Showing Rows of Cells Radiating in a Linear Pattern from a Basal Cell; (c,d) Conidia of *Cancellidium* sp. (MFLU 20–0429) with Parallel Adherent Rows of Septate Branches Radiating from the Point of Attachment to the Conidiophore; € Strings of Monilioid Cells of *Cancellidium* sp. (MFLU 20–0429). Scale bar: (a–e) 20 μm

5.4 Discussion

Phylogenetic results showed a close relationship between the new taxon and the family Testudinaceae, typified by *Testudina terrestris* Bizz. and established by von Arx [563] to accommodate *Argynna*, *Lepidosphaeria*, *Neotestudina*, *Pseudophaeotrichum*, and *Testudina*. *Argynna* was transferred to Argynnaceae by Shearer and Crane [564], and *Pseudophaeotrichum* was synonymized as *Neotestudina* [6, 22]. Currently, Testudinaceae includes nine genera, i.e., *Angustospora*, *Halotestudina*, *Lepidosphaeria*, *Lojkania*, *Muritestudina*, *Neotestudina*, *Testudina*, *Ulospora*, and *Verruculina* [3, 6, 204]. Members in Testudinaceae are mainly characterized by globose to subglobose ascomata, a peridium comprising cells of *textura angularis*, clavate to cylindrical asci with short pedicels and ellipsoidal, verrucose to verruculose ascospores with mostly one longitudinal septum. *Halotestudina*, *Lepidosphaeria*, and *Verruculina* were isolated from marine habitats, while *Angustospora* species are freshwater taxa [6, 24, 302, 565]. Doilom et al. [566] provided descriptions, illustrations, and notes for the type species of *Lepidosphaeria*, *Neotestudina*, and *Ulospora* from their type specimens. Wanasinghe et al. [557] and Dayarathne et al. [6] provided a synopsis and key to the genera in Testudinaceae.

In the phylogenetic analysis of Wanasinghe et al. [557], the placement of several genera within Testudinaceae was not congruent and varied between the estimated ML and MP trees. For instance, *Muritestudina chiangraiensis* grouped with *Neotestudina rosatii* in ML analysis but clustered with *Verruculina enalia* in MP analysis. The inconsistencies in the estimated trees may be due to weak phylogenetic signal of the analyzed multi-loci, unequal evolutionary rates and different genealogical histories [557]. Two fungal species from marine habitats, *Massarina ricifera* and *Quintaria lignatilis*, were clustered with other genera in Testudinaceae but with weak bootstrap support [3, 389]. Resolving the taxonomic placement of both marine species needs additional taxon sampling [24]. We therefore refer *Mycoenterolobium aquadictyosporium* to the Pleosporales *incertae sedis* until further taxon sampling is undertaken.

Mycoenterolobium aquadictyosporium is similar to *Cancellidium pinicola* in having dictyoseptate, muriform, strongly flattened, fan-shaped conidia that are wider at the apex and narrower at the base [33, 567]. *Mycoenterolobium aquadictyosporium* differs from the latter in the arrangement of conidial rows of cells at the attachment point to the conidiophores. The conidia of *Mycoenterolobium* are made up of rows of cells, radiating in a linear pattern from a basal cell attached to the conidiophore, while *Cancellidium* is distinct in having parallel adherent rows of septate branches radiating from the conidiophore [558, 559] (Figure 5.4). Furthermore, *Cancellidium* is not closely related to the Dothideomycetes as it belongs to Sordariomycetidae genera *incertae sedis* (Sordariomycetes) [23, 204], and a new order has been introduced to accommodate the genus [33]. The scanning electron micrograph study of [562] on conidium development of *Mycoenterolobium platysporum* contributed to the current knowledge on the septation of the lobes in the genus and its muriform morphology. *Mycoenterolobium platysporum* has a stipitate cup morphology at an early stage of conidial development then the opposing side of the cup elongates until it reaches both apical edges attaining a bivalve-like morphology. At maturity in *Mycoenterolobium*, the two conidial lobes unite and are closely appressed [559].

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CHAPTER 6

Wicklowia phuketensis (WICKLOWIACEAE, PLEOSPORALES), A NOVEL FRESHWATER TAXON FROM THAILAND[5]

Abstract

An investigation of aquatic fungi in Thailand resulted in the collection and isolation of a new species of *Wicklowia* (Wicklowiaceae) from submerged wood. *Wicklowia phuketensis* sp. nov. differs from known species in morphology and multigene phylogenetic analyses. Both *W. submersa* and *W. phuketensis* lack appendages at both ends, while *W. aquatica* has basal appendages. *Wicklowia phuketensis* differs from other species in the dimensions of the ascomata, asci and ascospores. The combined LSU and SSU sequence data placed the new species within Wicklowiaceae.

Keywords: 1 New Species, Aquatic Fungi, Dothideomycetes, Multi-Gene Analysis, Taxonomy, Tropical Mycology

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6.1 Introduction

Freshwater fungi are broadly defined as any species, which rely on freshwater for the entirety or part of their life cycle [39]. The number of freshwater fungal species has been estimated between 3,069–4,145 [174], which is lower when compared to marine fungi with an estimated 12,500 species [36, 190]. Freshwater fungi are likely to be more numerous than marine fungi as many habitats and substrates are not well-explored. Furthermore, underrepresentation of some taxa and cryptic species may further underestimate diversity of freshwater taxa [174]. In Thailand, 173 species belonging to 112 genera have been recorded from freshwater habitats as of 2010 [82]. Since then, many additional novel taxa have been described bringing the number even higher (see [5, 455, 481, 508, 528, 568].

Recently, a species from the genus *Wicklowia*, *W. submersa* Boonmee, Sorvongxay & K.D. Hyde, was discovered in Thailand [455]. This genus was introduced by Raja et al. [569] to accommodate *Wicklowia aquatica* Raja, A. Ferrer & Shearer collected from submerged wood in freshwater habitats. Based on the LSU sequence data along with supporting morphological characteristics, Raja et al. [569] placed the genus under Pleosporales family *incertae sedis*. Analysis of sequence data by Ariyawansa et al. [516] along with other closely related taxa showed that *Wicklowia* was a distinct lineage close to Lindgomycetaceae. Thus, the taxonomic placement was revised to assign *Wicklowia* to the new family Wicklowiaceae. Two species, *W. aquatica* and *W. submersa*, are currently included in this monotypic genus from freshwater habitats [455, 569], the former having basal appendages, while the latter lacks this character.

Fungal biodiversity in Thailand has been studied extensively in the past decade, but most of these studies focused mainly on macro- and microfungi from terrestrial habitats (see [384, 385, 479, 570–572]. In comparison, freshwater fungi remain relatively poorly sampled, although we are carrying out a survey of freshwater fungi along a north - south latitudinal gradient [461]. As we continue to explore rarely studied environments such as freshwater habitats, we can discover novel species that could help us elucidate the biodiversity of aquatic fungi.

This paper describes and illustrates a new *Wicklowia* species using LSU and SSU sequence data, and morphology. This is the second species of *Wicklowia* discovered from Thailand.

6.2 Materials and Methods

6.2.1 Sample Collection, Morphological Observation and Fungal Isolation

Samples of submerged decayed wood were collected from a freshwater stream in Phuket Province, southern Thailand. The samples were incubated for five days and observed using stereomicroscope for the presence of fruiting bodies. Micromorphological features were photographed using a Motic SMZ 168 Series dissection microscope for fungal structures on the woody substrate while microscopic characters were documented using Nikon Eclipse 80i microscope. Single spore isolation was used to obtain pure cultures and colonial characteristics were described based on the growth observed in MEA. Herbarium type specimens were deposited in Mae Fah Luang University (MFLU). Ex-type living cultures were deposited at Mae Fah Luang University Culture Collection (MFLUCC). The new species was registered in Facesoffungi [202] and Index Fungorum databases [573]

6.2.2 DNA Extraction, PCR Amplification, and Sequencing

Fungal mycelia from pure cultures grown in MEA for 30 days were scraped using sterilized scalpel and kept in a 1.5 mL microcentrifuge tube. Genomic DNA was extracted using the Biospin Fungus Genomic DNA Extraction kit (BioFlux, Hangzhou, China) following the manufacturer's protocol. Polymerase chain reaction (PCR) was used to amplify the two genes: the large subunit (28S rDNA, LSU) and small subunit (18S rDNA, SSU). The LSU was amplified using the primers LR0R and LR5 [416] while SSU was amplified using the primers NS1 and NS4 [417]. Polymerase chain reaction was performed in a volume of 25 μL, which contained 12.5 μL of 2× Power Taq PCR MasterMix (Bioteke Co., Jiangsu, China), 1 μL of each primer (10 μM), 1 μL genomic DNA, and 9.5 μL deionized water. The amplification conditions used were as follows: initial denaturation at 95 °C for 5 min, followed by 35 cycles of denaturation at 95 °C for 90 s, annealing at 55 °C (28S) and 48 °C (18S)

for 1 min, and final extension at 72 °C for 10 min. Agarose gel electrophoresis was done to confirm the presence of amplicons at the expected molecular weight. PCR products were purified and sequenced with the primers mentioned above at a commercial sequencing provider (BGI, Ltd., Shenzhen, China). A BLAST search of the newly generated sequences was carried out to exclude contamination and to search for related taxa in GenBank database (http://www.ncbi.nlm.nih.gov/blast/).

6.2.3 Phylogenetic Analysis

The taxa table was assembled based on the closest matches from the BLAST search results and from recently published data [455]. Sequences generated from the two gene regions were analyzed along with other sequences retrieved from GenBank (Table 6.1). Two datasets, one for each gene, were aligned with MAFFT v. 7 using the web server (http://mafft.cbrc.jp/alignment/server; Katoh et al. [419]). Alignment was further refined manually, where necessary, using BioEdit v.7.0.9.0 [420]. Aligned sequences were automatically trimmed using TrimAl v.1.3 on the web server (http://phylemon.bioinfo.cipf.es/utilities.html). The alignments were submitted to TreeBASE (submission ID: 26023). The online tool “ALTER” [421] was used to convert the alignment file to phylip format. Phylogenetic analysis of both individual and combined gene data was performed using maximum likelihood (ML) and Bayesian inference (BI).

Maximum likelihood analysis was performed using RAxML v. 8 software on the CIPRES web portal [225–227] (http://www.phylo.org/portal2/; Miller et al. [228]). The GTR+GAMMA model of nucleotide evolution was used. RAxML rapid bootstrapping of 1000 replicates was performed. Bayesian inference analysis was performed using MrBayes v. 3.2.6 on XSEDE at the CIPRES webportal [229], using the parameter setting of 2 parallel runs, 4 chains, run for 2,000,000 generations at which point the standard deviation of split frequencies was below 0.01. Trees were sampled every 1,000 generations and all other parameters were left as default. Newly generated sequences have been deposited in GenBank (Table 6.1).

Table 6.1 GenBank and Culture Collection Accession Numbers of Species Included in this Phylogenetic Study. The Newly Generated Sequences are shown in Bold

Species	Strain/Voucher Number	GenBank Accession No.	
		LSU	SSU
Amniculicola immersa	CBS 123083	FJ795498	GU456295
Amniculicola lignicola	CBS 123094	MH874798	–
Amniculicola lignicola	Ying01	EF493861	EF493863
Amniculicola parva	CBS 123092	GU301797	GU296134
Anguillospora longissima	ccm-F00980	AY204597	AY204598
Anguillospora longissima	CS869-1D	GU266240	GU266222
Arundellina typhae	MFLUCC 16–0309	KX274251	KX274256
Arundellina typhae	MFLUCC 16–0310	KX274252	KX274257
Clohesyomyces aquaticus	MFLUCC 11–0092	JX276950	JX276949
Delitschia chaetomioides	SMH 3253.2	GU390656	–
Delitschia winteri	AFTOL-ID 1599	DQ678077	DQ678026
Dothidea sambuci	DAOM 231303	NG_027611	NG_012432
Dothidea ribesia	MFLU 14-0040	KM388552	KM388549
Hongkongmyces pedis	HKU 35	NG_056287	KF314117
Hongkongmyces thailandica	MFLUCC 16–0406	KY771321	KY771323
Lindgomyces angustiascus	F60_1	JX508283	JX508284
Lindgomyces apiculatus	KT1108	JF419884	JF419886
Lindgomyces breviappendiculatus	KT1215	AB521748	AB521733
Lindgomyces carolinensis	G618	KX655800	KX655801
Lindgomyces cigarospora	G619	KX655804	KX655805
Lindgomyces cinctosporus	R56-3	GU266245	GU266238
Lindgomyces griseosporus	JFUCC200007	KC769693	–
Lindgomyces ingoldianus	ATCC 200398	NG_042321	NG_016531
Lindgomyces lemonweirensis	A632-1a	JF419888	JF419890

Table 6.1 (continued)

Species	Strain/Voucher Number	GenBank Accession No.	
		LSU	SSU
Lindgomyces madisonensis	G416b	KT207821	KT207823
Lindgomyces okinawaensis	KT3531	LC100027	LC100019
Lindgomyces pseudomadisonensis	KT 2742	LC149916	LC149912
Lindgomyces rotundatus	KT 966	AB521739	AB521722
Lolia aquatica	CBS H-22130	KU726001	–
Lolia aquatica	Egypt	HM367732	–
Lolia dictyospora	CBS H-22131	KU726000	KU725999
Lophiostoma nucula	CBS 627.86	GU301837	GU296167
Lophiostoma vagabundum	KH164	AB619022	AB618704
Murispora cardui	MFLUCC 13–0761	KT709176	KT709183
Murispora cicognanii	IT 1693	KT709178	KT709185
Murispora cicognanii	MFLUCC 14–0953	KT709179	KT709186
Murispora fagicola	MFLUCC 13–0600	KT709174	KT709181
Murispora galii	MFLUCC 13–0819	KT709175	KT709182
Murispora hawksworthii	MFLUCC 14–0918	KT709180	KT709187
Murispora medicaginicola	MFLUCC 13–0762	NG_059608	KT709184
Murispora rubicunda	CBS 291.56	AY849957	–
Murispora rubicunda	IFRD 2017	FJ795507	GU456308
Neomassariosphaeria typhicola	KT 667 / HHUF 27779	AB521747	AB521730
Phaeotrichum benjaminii	CBS 541.72	NG_057709	NG_062645
Preussia funiculata	CBS 659.74	GU301864	GU296187
Preussia lignicola	CBS 264.69	GU301872	GU296197
Preussia terricola	AFTOL-ID 282	AY544686	AY544726
Trichodelitschia bisporula	CBS 262.69	GU348996	GU296202
Trichodelitschia munkii	Kruys 201	DQ384096	DQ384070

Table 6.1 (continued)

Species	Strain/Voucher Number	GenBank Accession No.	
		LSU	SSU
Wicklowia aquatica	AF289-1	GU045446	–
Wicklowia aquatica	CBS 125634	MH875044	NG_061099
Wicklowia aquatica	F76-2	GU045445	GU266232
Wicklowia aquatica	ILL 40790	NG_059925	–
Wicklowia phuketensis	**MFLUCC 20–0109**	**MT068484**	**MT068490**
Wicklowia submersa	MFLUCC 18–0373	MK637644	MK637643

6.3 Result

6.3.1 Phylogenetic Analysis

The fifty-five taxa were included in the combined multigene analyses from Wicklowiaceae and related families (Amniculicolaceae, Delitschiaceae, Lindgomycetaceae, Lophiostomataceae, Phaeotrichaceae and Sporormiaceae), with *Dothidea ribesia* MFLU 14–0040 and *D. sambuci* DAOM 231303 as outgroup taxa (Table 6.1). The analyzed dataset, after trimming, comprised a total of 1889 characters including gaps (LSU = 942 bp; SSU = 947 bp) The ML analysis for the combined dataset provided the best scoring tree (Figure 6.1) with a final ML optimization likelihood value of -7599.97 (ln). The matrix had 551 distinct alignment patterns, with 13.88% of undetermined characters or gaps. Parameters for the GTR model of the combined LSU and SSU dataset are as follows: estimated base frequencies; A = 0.259080, C = 0.210951, G = 0.283351, T = 0.246618; substitution rates AC = 1.093774, AG = 2.685543, AT = 0.914901, CG = 1.365282, CT = 8.927762, GT = 1.000000; gamma distribution shape parameter $\alpha = 0.160409$.

Bayesian analysis resulted in 4002 trees after 2,000,000 generations. Phylogenetic analyses of the combined data matrix resulted in considerably high bootstrap support and well-resolved clades (Figure 6.1). In the phylogenetic analysis,

Wicklowia phuketensis (MFLUCC 20–0109) clustered with *W. submersa* and *W. aquatica* with maximum statistical support.

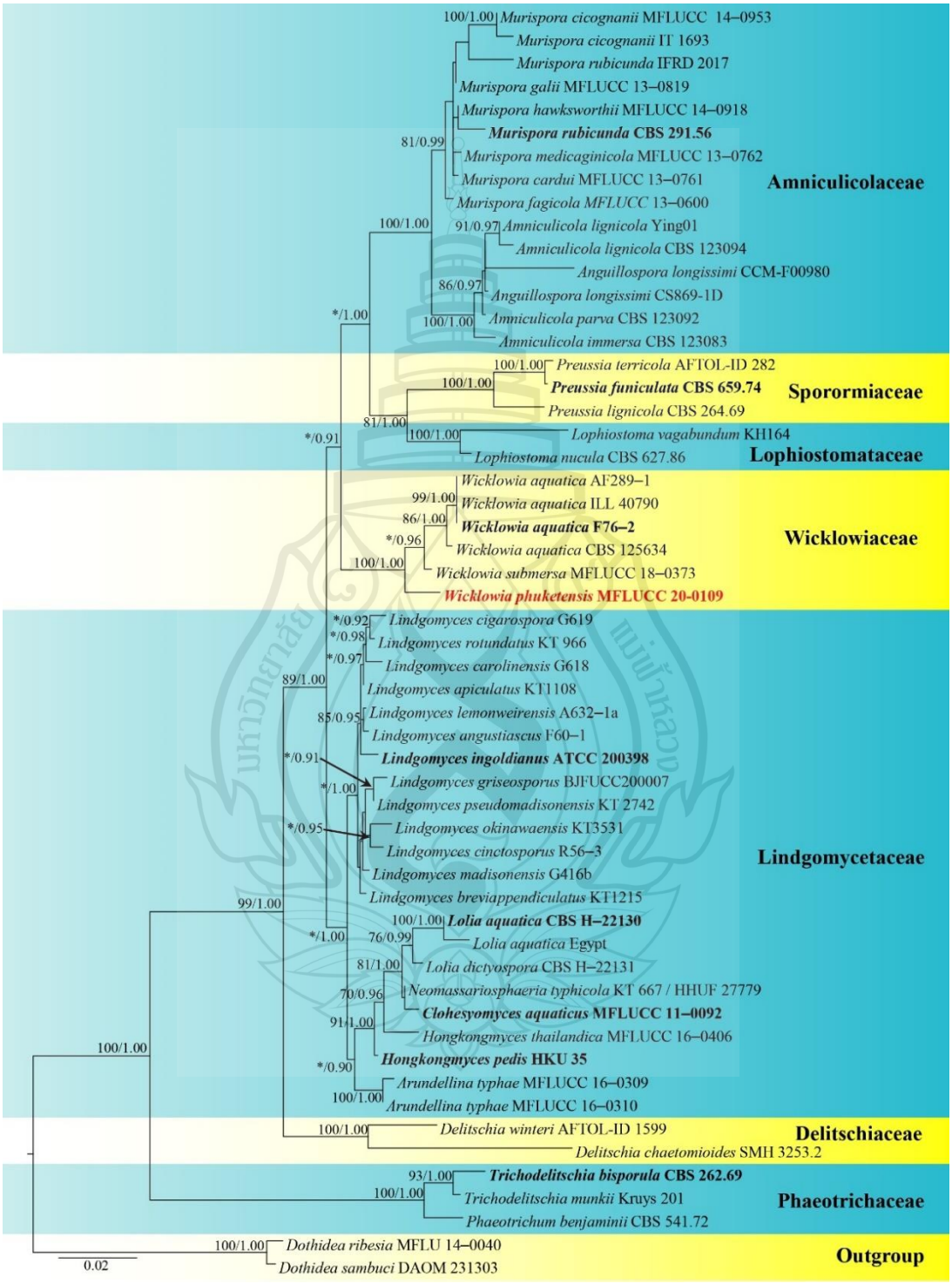


Figure 6.1 Maximum Likelihood Phylogenetic Tree Inferred from Combined Dataset of LSU and SSU of 55 Taxa. The Phylogenetic Tree was constructed Using GTR+GAMMA Model Using 1889 Nucleotides Including Gaps. Bootstrap Support Values for Maximum Likelihood (ML) Higher Than 70% and Bayesian Posterior Probabilities (BYPP) Greater Than 0.95 are Given Above Each Branch in that Order. The Tree is Rooted to *Dothidea sambuci* DAOM 231303 and *D. ribesia* MFLU 14–0040 (Dothideaceae). The Representative Type Species of Each Genus is Shown in Bold. The New Species is Shown in Bold and Red

6.3.2 Taxonomy

Wicklowia phuketensis M.S. Calabon, S. Boonmee, E.B.G Jones & K.D. Hyde, sp. nov. (Figure 6.2)

Index Fungorum number: IF557237, Facesoffungi number: FoF 07382

Etymology: The name "phuketensis" is derived from Phuket, a province located of southern Thailand from where the fungus was collected.

Holotype: MFLU 20–0143

Saprobic on decaying submerged wood in a freshwater stream. Sexual morph: *Ascomata* 217–273 × 206–312 μm ($\bar{x}$ = 247 × 241 μm), immersed to erumpent when mature, raising the host tissue, visible as dark with crater-like depression on host surface, uni- to biloculate, subglobose, dark brown, scattered, gregarious, ostiolate. *Ostiolar neck* pore-like opening, laterally compressed, 48–62 μm high, 80–95 μm wide, composed of 2–5 μm diam, globose to subglobose, brown to black cells, with hyaline periphyses *Peridium* 20–33 μm wide, thick-walled, composed of dark brown of pseudoparenchymatous cells, of *textura angularis*. *Hamathecium* comprising 1–3 μm wide, numerous, cylindrical, filiform, branched, septate, hyaline pseudoparaphyses. *Asci* 86–288 × 22–32 μm ($\bar{x}$ = 153 × 28 μm, n = 10) 8-spored, bitunicate, fissitunicate, cylindrical to clavate, rounded at the apex, with an ocular chamber when immature, sessile or short pedicellate. *Ascospores* 34–43 × 9–12 μm ($\bar{x}$ = 40 × 11 μm, n = 20), biseriate, partially overlapping, ellipsoidal to oblong with rounded ends, slightly inequilateral, symmetrical to asymmetrical, upper cell wider, slightly curved, hyaline, 1-septate, constricted at the septum, guttulate when immature, surrounded by

a thin mucilaginous sheath, without any appendages, smooth-walled. Asexual morph: Undetermined.

Culture characteristics: Ascospores germinated on MEA within 24 h. Colonies on MEA, reaching 26 × 30 mm diameter in 14 d at 25°C. Mycelium superficial, initially light grey, becoming dark brown with age, hairy, effuse with wavy edge; reverse dark brown.

Material examined: THAILAND, Phuket Province, Thalang District, Sa Khu, elev. 800–1000 m, 8.097345ºN, 98.355000ºE, on decaying submerged wood of an unidentified host, in freshwater stream, 06 May 2019, MS Calabon, FWAS1: MFLU 20–0143, holotype; ex-type living culture, MFLUCC 20-0109.

GenBank: SSU: MT068490; LSU:MT068484.

Notes: *Wicklowia phuketensis* (MFLUCC 20–0109) is morphologically similar to *W. aquatica* and *W. submersa* in its uni to biloculate, dark oval, immersed ascomata, crater-like depression on host surface, bitunicate, fissitunicate, cylindrical-clavate asci and regularly 1-septate, hyaline ascospores, surrounded by a mucilagenous sheath. Both *Wicklowia phuketensis* and *W. submersa* lack appendages at both ends, while *W. aquatica* has basal appendages. *Wicklowia phuketensis* has larger ascomata, asci and ascospores as compared to *W. aquatica* and *W. submersa* (Table 6.2). The multi-gene phylogenetic analyses (LSU and SSU) show that *W. phuketensis* is a distinct species with high bootstrap support (100% ML, 1.00 BYPP). Based on the LSU gene sequence data, *W. phuketensis* differs by 26 (3.12%, 833 bp) and 17 (2.03%, 837 bp) base pairs with *W. aquatica*, type species of the genus, and the closely related species *W. submersa*, respectively.

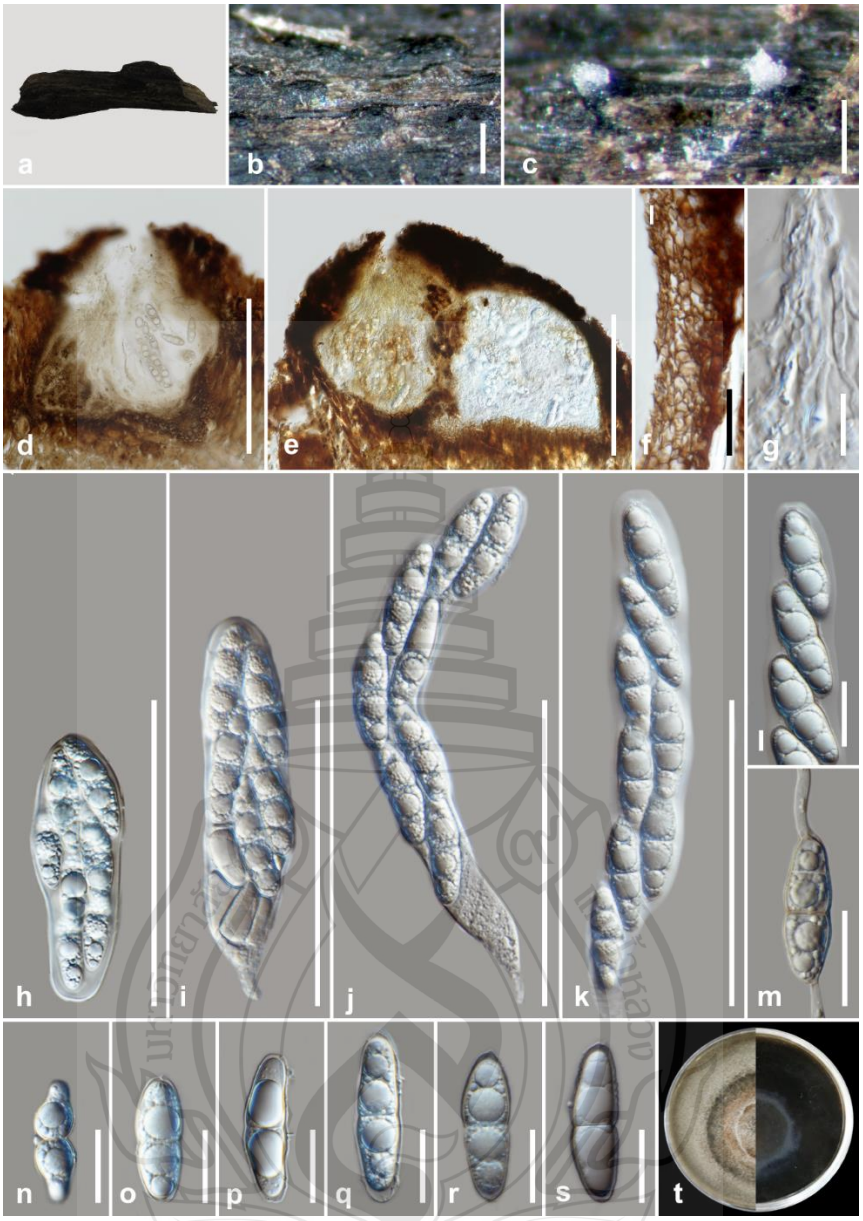


Figure 6.2 *Wicklowia phuketensis* (MFLUCC 20–0109, Holotype). (a) Host Material; (b) Appearance of Ascomata on Host; (c) Spores Released at the Tip of Ascomata; (d,e) Cross Sections of Ascomata; (f) Section of Peridium; (g) Pseudoparaphyses; (h–l) Asci; (m) Germinated Ascospore; (n–q) Ascospores with Distinct Mucilaginous Sheath; (r,s) Ascospores Stained in Nigrosin Reagent; (t) Colony on MEA from Above and Below (25 d Old). Scale bars: (b,c) 500 μm; (d,e) 200 μm; (f,l–s) 20 μm; (g) 10 μm; (h–k) 100 μm

6.4 Discussion

Wicklowia is characterized by subglobose, immersed to erumpent ascomata, at maturity, black with hyaline, one-septate ascospores surrounded by a mucilaginous sheath with or without appendages [455, 569]. Three species are currently included in the genus i.e., *W. aquatica* [569], *W. submersa* [455] and *W. phuketensis* (in this study). In contrast to W. aquatica, which has basal appendages, *W. submersa* and *W. phuketensis* lack appendages at both ends. Appendages and mucilaginous sheaths in fungi are considered adaptations for attachment on substrata and dispersal in aquatic habitats [574]. The new species differs from the other two *Wicklowia* species in having larger ascomata with uni- to biloculate, and longer asci and ascospores.

Phylogenetic analysis showed that Wicklowiaceae is basal to Amniculicolaceae, Sporormiaceae and Lophiostomataceae with good statistical support (1.00 BYPP). Wicklowiaceae shares common characters with Lindgomycetaceae in having immersed to erumpent, brown ascomata and ascospores usually with a gelatinous sheath, but the latter differs in ascospore morphology e.g., shape (fusiform to cylindrical), septation (uni- to multiseptate) and pigmentation (from hyaline to brown) [516]. The family Wicklowiaceae is currently represented by the monotypic genus *Wicklowia*, which is sparsely populated with only three known species and all of which are recorded from freshwater habitats.

Table 6.2 Synopsis of Characters of *Wicklowia* Species

Species	Ascomata	Asci	Ascospores	Reference
Wicklowia aquatica	140–145 × 265–270 µm	60–95 × 18–26 µm	25–30 × 7–9 µm, 1-septate, hyaline, guttulate, with a mucilaginous sheath and appendages	[569]
Wicklowia submersa	128–143 × 175–215 µm	66–84 × 19–23 µm	24–27 × 7–9 µm, 1-septate, hyaline, guttulate when immature only, with a mucilaginous sheath, lacking appendages	[455]
Wicklowia phuketensis	217–273 × 206–312 µm	86–288 × 22–32 µm	34–43 × 9–12 µm (40 × 11 µm), 1-septate, guttulate when immature, surrounded by a thin mucilaginous sheath, without any appendages	This study

6.5 Acknowledgments

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CHAPTER 7

FRESHWATER FUNGAL NUMBERS[6]

Abstract

A comprehensive account of fungal classification from freshwater habitats is outlined and discussed in the present review based on literature of biodiversity studies and recent morpho-phylogenetic analyses. A total of 3,870 freshwater fungal species are listed with additional details on the isolation source, habitat, geographical distribution, and molecular data. The Ascomycota (2,968 species, 1,018 genera) dominated the freshwater fungal taxa wherein Sordariomycetes (823 species, 298 genera) had the largest number, followed by Dothideomycetes (677 species, 229 genera), Eurotiomycetes (276 species, 49 genera), and Leotiomycetes (260 species, 83 genera). Other phyla included in the updated classification of freshwater fungi are: Chytridiomycota (333 species, 97 genera), Rozellomycota (221 species, 105 genera), Basidiomycota (218 species, 100 genera), Blastocladiomycota (47 species, ten genera), Monoblepharomycota (29 species, six genera), Mucoromycota (19 species, ten genera), Aphelidiomycota (15 species, three genera), Entomophthoromycota (six species, four genera), Mortierellomycota (five species, three genera), Olpidiomycota (four species, one genus), Zoopagomycota (three species, two genera), and Sanchytriomycota (two species, two genera). The freshwater fungi belong to 1,361 genera, 386 families and 145 orders. The Pleosporales and Laboulbeniaceae are the largest freshwater fungal order and family comprised of 391 and 185 species, respectively. The most speciose genera are *Chitonomyces* (87, Laboulbeniomycetes), *Verrucaria* (50, Eurotiomycetes), *Rhizophydium* (52, Rhizophydiomycetes), *Penicillium* (47, Eurotiomycetes), and *Candida* (42, Saccharomycetes).

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Keywords: Fungal Classification, Fungal Taxonomy, Freshwater Fungi, Higher Fungi, Molecular Taxonomy, Basal Clades

7.1 Introduction

It has been over 140 years since Saccardo [575] described the first freshwater hyphomycetes, *Heliscus lugdunensis* (≡ *Neonectria lugdunensis*). This was followed by the discovery of four novel taxa [*Tetracladium marchalianum*, *Clavariopsis aquatica*, *Lemonniera aquatica*, *Anguillospora longissima* (≡ *Amniculicola longissima*)] by de Wildeman [12, 45, 576] from different freshwater habitats and on different substrates. Ingold's [13] documentation of 16 freshwater hyphomycetous species, of which 10 are novel species, and identification of the typical habitat of freshwater fungi served as an impetus for further studies on the occurrence of fungal taxa, both sexual and asexual, in freshwater habitats [5, 7, 68–71, 81, 459, 577–580, 17, 57, 58, 63–67].

The classical methods used to document freshwater fungal composition have been significantly improved by recent developments in fungal identification using molecular techniques. In the classification of freshwater fungi, incorporation of molecular data in the analysis of extant and novel species provides a better understanding of the phylogenetic relationships of freshwater taxa (e.g., generic boundaries delimitation of polyphyletic taxa, resolving species complexes, linking asexual-sexual morphs, or synasexual morphs). Furthermore, continuous exploration of freshwater habitats led to introduction of many novel taxa [173, 456, 459, 581]. For instance, novel species from China and Thailand totaled 298 novel species from 2015 to 2020. Unfortunately, for almost two decades of morpho-phylogenetic taxonomy of freshwater fungi, there are no published information on the overall known number of taxa unlike those of fungi in marine habitats wherein the marine fungal numbers stand as 1901 species under 769 genera [36]. The available published information includes biodiversity studies in particular geographical areas [62, 82, 454, 582–584], selected hosts [88, 177, 584], or of species within taxonomic [5, 7, 33, 88, 437, 459, 584–587] or morphological groups [17, 38, 57, 588–590]. The scattered data on freshwater

fungi are currently compiled in an online database, https://freshwaterfungi. org/, but since the website only started in early 2020 and in the process of collating all the freshwater fungal data, there are no definite numbers given yet [449]. The only information in the literature so far is the estimated number of freshwater fungi to be around 3069–4145, of which, Chytridiomycota (500–1289 species) and Ascomycota (622 species) have the greatest number of taxa [174]. These figures were considered as an underestimate as there is little data for many of the aquatic groups, and many microhabitats, substrates, and geographical areas are unexplored or underexplored and yet to be surveyed.

This paper presents an up-to-date classification of freshwater fungi and the number of taxa recorded in freshwater habitats. The classification scheme follows [204] unless the taxonomy has been updated recently. The text is divided into three main sections: (1) *Classification of freshwater Ascomycota*, (2) *Basidiomycota*, and (3) *Freshwater fungal basal clades*. For *Ascomycota* section, a special section *Freshwater lichens* is included in order to discuss and enumerate lichenicolous and lichen-like taxa from Arthoniomycetes, Candelariomycetes, Coniocybomycetes, Dothideomycetes, Eurotiomycetes, Lecanoromycetes, Lichinomycetes, and Sordariomycetes. After the section on the Basidiomycota, the section on *Freshwater yeasts* was included with a discussion on their taxonomic classification. Furthermore, since Ingold's contribution in freshwater mycology is momentous, a special section on *Ingoldian fungi* with a taxonomic outline of taxa from freshwater habitats is included in the present review. Every table dealing with the taxonomic classification of freshwater fungi include the taxon name, isolation source, and its geographical distribution. Freshwater fungi with molecular data, including the country where the taxa were isolated, are in bold.

7.2 Origin of Freshwater Fungi

Molecular evidence suggests that fungi first appeared about 1.5 billion years ago and evolved from one common ancestor [591]. The ancestral fungi may have lived in water and had flagella, like the members of Chytridiomycota [27, 592, 593].

Molecular studies of Liu et al. [593] showed that the major fungal phyla, Ascomycota, Basidiomycota, and Zygomycota formed a well-supported clade, and they lacked flagella, while Chytridiomycota are mainly flagellated, and it formed a basal and early diverging clade within the fungal kingdom. The loss of a flagellum has occurred only one time, leading to derived fungal phyla (Zygomycota, Basidiomycota and Ascomycota) to adapt from the aquatic environment to terrestrial habitats [592, 593].

Fungi colonized the land probably during the Cambrian, over 500 million years ago (MYA), however, the fungal territorialization times are still a matter of debate as the land fungal fossil records are reported from the Devonian [594, 595]. Fungal hyphae and spore cysts in a stem of *Asteroxylon mackiei* were also discovered in the Rhynie chert from the Devonian (419.2 to 358.9 MYA). The earliest land plants appeared around 470 MYA [596, 597], while oomycetes had already colonized terrestrial habitats at that time [598, 599]. Microorganisms became abundant within plant fossils since their territorialization [598, 599]. A rich terrestrial fungal fossil (e.g., fossil chytrids, Glomales and fossil hyphae associated with wood decay) have been found during the Devonian, around 400 MYA [598, 600–604] and terrestrial fungal fossils were reported as arbuscular mycorrhizal-like symbioses [605, 606]. Simon et al. [605] investigated the origin of arbuscular mycorrhizal fungi and their results showed that these fungi diverged 353–462 MYA, which is consistent with the fossil records, indicating establishment of arbuscular mycorrhizal-like symbiosis between fungi and plant roots as a major event in the colonization of land.

Ascomycota and Basidiomycota diverged at a similar time with fungal territorialization, around 500–650 MYA, and mainly saprobic on vascular plants [607, 608]. Studies showed that they had a terrestrial origin [33, 591–593]. Fungal adaption to terrestrial habitats requires a variety of ecological strategies to obtain nutrients, such as saprotrophism, parasitism, humification, and the development of mutual relationships. Ascomycota and Basidiomycota are the largest groups in the fungal kingdom, and have been reported as endophytes, pathogens, and saprobes of plants/animals, indicating rapid diversification on land through different nutritional modes.

Around 250 MYA fungi rapidly increased in numbers and became abundant as the result of the Permian–Triassic extinction event. Following this event, numerous

plants and animals evolved and provided abundant hosts for fungi [609, 610]. Molecular analyses showed that the subclasses and some orders of the two classes Sordariomycetes and Dothideomycetes diverged at 150–250 MYA [20, 22, 23, 611]. Several studies indicate that after the Cretaceous-Tertiary extinction (65 MYA), fungi dramatically increased in numbers [612]. Recent molecular clock analyses also support this view, with many species diverged after 65 MYA [22, 536, 611]

At present, the origin, evolution, and taxonomy of fungi are better understood with the use of molecular analyses for their study. Early studies of the fungi placed them in the plant kingdom, and later separated from the plant kingdom as the fifth kingdom [613]. Earlier, the true fungi comprised four phyla viz. Ascomycota, Basidiomycota Chytridiomycota, and Zygomycota [613]. While, presently, the fungal kingdom comprises 20 phyla [204, 614]. Among them, eight phyla viz. Aphelidiomycota, Ascomycota, Basidiomycota, Blastocladiomycota, Chytridiomycota, Monoblepharomycota, Mortierellomycota and Rozellomycota include freshwater fungi [174, 204, 615]. Freshwater fungi have multiple origins and evolve separately through different lineages [38]. Chytridiomycota are likely to have evolved from marine ancestors, while Ascomycota and Basidiomycota originated from terrestrial habitats [591, 616]. Ascomycota are the dominant phylum of freshwater fungi. Freshwater ascomycetes probably are immigrants from terrestrial environments and mainly through three evolutionary pathways [33, 38, 616].

7.3 Classification of freshwater fungi

Our comprehensive review of published data of biodiversity studies and/or single or multi-species taxonomic studies, resulted in an updated classification of freshwater fungi under thirteen phyla (45 classes), and documentation of 3,870 species from freshwater habitats: Ascomycota 2,968 (1,018 genera), Chytridiomycota 333 (97 genera), Rozellomycota 221 (105 genera), Basidiomycota 218 (100 genera), Blastocladiomycota 47 (ten genera), Monoblepharomycota 29 (six genera), Mucoromycota 19 (ten genera), Aphelidiomycota 15 (three genera), Entomophthoromycota six (four genera), Mortierellomycota five (three genera), Olpidiomycota four (one

genus), Zoopagomycota three (two genera), and Sanchytriomycota two (two genera) (Table 7.1). For Ascomycota, Sordariomycetes has the highest number of taxa which accounts for 27.68% (823 species in 298 genera), followed by Dothideomycetes (677 species, 229 genera). Chytridiomycetes dominated the taxa under Chytridiomycota with 181 species recorded while 201 taxa are under Microsporidea (Rozellomycota). The freshwater yeasts constitute taxa from Ascomycota and Basidiomycota with 163 species each. The total freshwater fungal number, 3,870 species, included in this review is within the estimated range of Jones et al. [174] which is around 3,069–4,145 species. The present review lists all the fungal taxa in freshwater habitats. Some species, including their occurrence and host substrates, will inevitably be missed in the process of searching the published literatures. All the updates will be added on the website, www.freshwaterfungi.org [449].

Table 7.1 Taxonomic Classification and Numbers of Freshwater Fungi

Class	Order	Family	Number of species
Classification of freshwater Ascomycota			
Arthoniomycetes	Arthoniales	Arthoniaceae	3
		Chrysotrichaceae	2
		Lecanographaceae	1
		Opegraphaceae	1
		Roccellaceae	5
Candelariomycetes	Candelariales	Candelariaceae	4
Coniocybomycetes	Coniocybales	Coniocybaceae	4
Dothideomycetes	Asterinales	Morenoinaceae	1
	Botryosphaeriales	Botryosphaeriaceae	3
		Phyllostictaceae	1
	Capnodiales	Teratosphaeriaceae	2
		Mycosphaerellaceae	5
		Neodevriesiaceae	6

Table 7.1 (continued)

Class	Order	Family	Number of species
	Collemopsidiales	Xanthopyreniaceae	3
	Dothideales	Saccotheciaceae	2
	Dyfrolomycetales	Pleurotremataceae	1
	Hysteriales	Hysteriaceae	1
		Hysteriales genus *incertae sedis*	1
	Jahnulales	Aliquandostipitaceae	37
	Kirschsteiniotheliales	Kirschsteiniotheliaceae	6
		Kirschsteiniotheliales genera *incertae sedis*	6
	Lichenotheliales	Lichenotheliaceae	2
	Microthyriales	Microthyriales genera *incertae sedis*	1
	Minutisphaerales	Acrogenosporaceae	13
		Minutisphaeraceae	5
	Monoblastiales	Monoblastiaceae	1
	Natipusillales	Natipusillaceae	4
	Pleosporales	Acrocalymmaceae	3
		Aigialaceae	27
		Amniculicolaceae	2
		Anteagloniaceae	2
		Aquasubmersaceae	2
		Astrosphaeriellaceae	24
		Bambusicolaceae	1
		Corynesporascaceae	4
		Cucurbitariaceae	2

Table 7.1 (continued)

Class	Order	Family	Number of species
		Cyclothyriellaceae	2
		Delitschiaceae	3
		Dictyosporiaceae	55
		Didymosphaeriaceae	6
		Dothidotthiaceae	5
		Hermatomycetaceae	1
		Latoruaceae	2
		Lentitheciaceae	15
		Leptosphaeriaceae	6
		Lindgomycetaceae	25
		Longipedicellataceae	5
		Lophiostomataceae	20
		Lophiotremataceae	2
		Massarinaceae	6
		Melanommataceae	20
		Morosphaeriaceae	13
		Mycoporaceae	1
		Neopyrenochaetaceae	3
		Nigrogranaceae	2
		Occultibambusaceae	5
		Parabambusicolaceae	3
		Periconiaceae	8
		Phaeoseptaceae	2
		Phaeosphaeriaceae	16
		Pleomassariaceae	4
		Pleomonodictydaceae	1
		Pleosporaceae	19

Table 7.1 (continued)

Class	Order	Family	Number of species
		Pseudoastrosphaeriellaceae	6
		Pseudoberkleasmiaceae	1
		Pyrenochaetopsidaceae	1
		Roussoellaceae	5
		Sporormiaceae	7
		Striatiguttulaceae	1
		Teichosporaceae	1
		Testudinaceae	1
		Tetraplosphaeriaceae	13
		Thyridariaceae	1
		Torulaceae	15
		Trematosphaeriaceae	9
		Wicklowiaceae	3
		Pleosporales genera *incertae sedis*	10
	Trypetheliales	Polycoccaceae	1
		Trypetheliaceae	1
	Tubeufiales	Tubeufiaceae	133
		Wiesneriomycetaceae	12
	Venturiales	Venturiaceae	1
	Dothideomycetes families *incertae sedis*	Endosporiaceae	1
		Argynnaceae	2
		Trichothyriaceae	1
		Pseudorobillardaceae	2
	Dothideomycetes	Dothideomycetes genera	31

Table 7.1 (continued)

Class	Order	Family	Number of species
	genera *incertae sedis*	*incertae sedis*	
Eurotiomycetes	Arachnomycetales	Arachnomycetaceae	1
	Chaetothyriales	Cyphellophoraceae	4
		Herpotrichiellaceae	40
		Chaetothyriales genera *incertae sedis*	2
	Chaetothyriomyce-tidae family *incertae sedis*	Rhynchostomataceae	1
	Eurotiales	Aspergillaceae	67
		Thermoascaceae	1
		Trichocomaceae	8
	Mycocaliciales	Mycocaliciaceae	9
	Onygenales	Arthrodermataceae	4
		Onygenaceae	7
	Sclerococcales	Dactylosporaceae	5
	Verrucariales	Adelococcaceae	1
		Verrucariaceae	126
Laboulbeniomycetes	Laboulbeniales	Ceratomycetaceae	73
		Laboulbeniaceae	185
	Pyxidiophorales	Pyxidiophoraceae	1
Lecanoromycetes	Acarosporales	Acarosporaceae	4
	Arctomiales	Arctomiaceae	1
	Baeomycetales	Baeomycetaceae	1
		Hymeneliaceae	4
		Protothelenellaceae	1

Table 7.1 (continued)

Class	Order	Family	Number of species
		Protothelenellaceae	1
		Trapeliaceae	6
		Xylographaceae	1
	Caliciales	Caliciaceae	4
		Physciaceae	21
	Lecanorales	Pilocarpaceae	4
		Catillariaceae	1
		Cladoniaceae	13
		Haematommataceae	1
		Lecanoraceae	18
		Parmeliaceae	13
		Psoraceae	1
		Ramalinaceae	10
		Scoliciosporaceae	2
		Stereocaulaceae	1
	Lecideales	Lecideaceae	8
	Ostropales	Coenogoniaceae	1
		Graphidaceae	1
		Gyalectaceae	2
		Porinaceae	8
	Peltigerales	Collemataceae	13
		Lobariaceae	2
		Massalongiaceae	1
		Peltigeraceae	9
		Placynthiaceae	4
	Pertusariales	Megasporaceae	6
		Microcaliciaceae	1

Table 7.1 (continued)

Class	Order	Family	Number of species
		Ochrolechiaceae	1
		Pertusariaceae	1
	Rhizocarpales	Rhizocarpaceae	3
	Teloschistales	Teloschistaceae	14
	Umbilicariales	Ophioparmaceae	1
		Umbilicariaceae	1
	Ostropomycetidae genera *incertae sedis*	Ostropomycetidae genera *incertae sedis*	1
Leotiomycetes	Helotiales	Discinellaceae	24
		Gelatinodiscaceae	3
		Helotiaceae	19
		Helotiales genera *incertae sedis*	19
		Hyaloscyphaceae	18
		Hydrocinaceae	13
		Lachnaceae	5
		Loramycetaceae	3
		Mitrulaceae	2
		Mollisiaceae	27
		Ploettnerulaceae	9
		Solenopeziaceae	33
		Vibrisseaceae	12
	Lauriomycetales	Lauriomycetaceae	3
	Leotiales	Leotiales genera *incertae sedis*	5
	Rhytismatales	Rhytismataceae	4

Table 7.1 (continued)

Class	Order	Family	Number of species
		Mollisiaceae	27
	Thelebolales	Thelebolales genera *incertae sedis*	2
	Leotiomycetes families *incertae sedis*	Calloriaceae	34
		Cenangiaceae	1
		Hamatocanthoscyphaceae	3
		Pezizellaceae	3
		Rutstroemiaceae	1
		Sclerotiniaceae	2
	Leotiomycetes genera *incertae sedis*	Leotiomycetes genera *incertae sedis*	15
Lichinomycetes	Lichinales	Lichinaceae	21
		Peltulaceae	3
Orbiliomycetes	Orbiliales	Orbiliaceae	19
Pezizomycetes	Pezizales	Ascobolaceae	2
		Pezizaceae	7
		Pyronemataceae	2
		Rhizinaceae	2
Saccharomycetes	Saccharomycetales	Debaryomycetaceae	21
		Dipodascaceae	7
		Lipomycetaceae	1
		Metschnikowiaceae	4
		Phaffomycetaceae	7
		Pichiaceae	12

Table 7.1 (continued)

Class	Order	Family	Number of species
		Saccharomycetaceae	30
		Saccharomycetales genera *incertae sedis*	50
		Saccharomycodaceae	6
		Saccharomycopsidaceae	5
		Trichomonascaceae	5
		Wickerhamomycetaceae	10
Sordariomycetes	Annulatascales	Annulatascaceae	36
		Aquapteridosporaceae	4
	Atractosporales	Atractosporaceae	7
	Barbatosphaeriales	Barbatosphaeriaceae	1
	Cancellidiales	Cancellidiaceae	7
	Ceratolentales	Bullimycetaceae	3
	Conlariales	Conlariaceae	4
	Diaporthales	Diaporthaceae	3
		Gnomoniaceae	4
		Diaporthales genera *incertae sedis*	1
		Sydowiellaceae	1
	Diaporthomycetidae family *incertae sedis*	Acrodictyaceae	6
		Junewangiaceae	21
		Papulosaceae	7
		Pseudoproboscisporaceae	5
		Pseudostanjehughesiaceae	2
		Woswasiaceae	1

Table 7.1 (continued)

Class	Order	Family	Number of species
	Diaporthomycetidae genera *incertae sedis*	Diaporthomycetidae genera *incertae sedis*	10
	Distoseptisporales	Distoseptisporaceae	22
	Jobellisiales	Jobellisiaceae	3
	Magnaporthales	Ceratosphaeriaceae	5
		Magnaporthaceae	5
		Ophioceraceae	11
		Pseudohalonectriaceae	6
		Pyriculariaceae	3
	Myrmecridiales	Myrmecridiaceae	4
	Ophiostomatales	Ophiostomataceae	1
	Parasympodiellales	Parasympodiellaceae	1
	Phomatosporales	Phomatosporaceae	7
	Rhamphoriales	Rhamphoriaceae	2
	Sporidesmiales	Sporidesmiaceae	22
	Tirisporellales	Tirisporellaceae	2
	Togniniales	Togniniaceae	4
	Trichosphaeriales	Trichosphaeriaceae	4
	Xenospadicoidales	Xenospadicoidaceae	21
	Coronophorales	Bertiaceae	1
		Chaetosphaerellaceae	1
		Coronophorales genera *incertae sedis*	2
		Nitschkiaceae	1
	Glomerellales	Australiascaceae	2
		Glomerellaceae	1
		Plectosphaerellaceae	2

Table 7.1 (continued)

Class	Order	Family	Number of species
		Reticulascaceae	8
	Hypocreales	Bionectriaceae	5
		Hypocreaceae	4
		Hypocreales genera *incertae sedis*	4
		Nectriaceae	57
		Niessliaceae	2
		Sarocladiaceae	1
		Stachybotryaceae	7
	Hypocreomycetidae genera *incertae sedis*	Hypocreomycetidae genera *incertae sedis*	5
	Microascales	Gondwanamycetaceae	1
		Halosphaeriaceae	42
		Microascaceae	2
		Microascales genera *incertae sedis*	1
		Triadelphiaceae	5
	Torpedosporales	Juncigenaceae	1
	Vermiculariopsiellales	Vermiculariopsiellaceae	5
	Pisorisporiales	Pisorisporiaceae	2
	Conioscyphales	Conioscyphaceae	13
	Fuscosporellales	Fuscosporellaceae	15
	Pleurotheciales	Pleurotheciaceae	32
	Pseudodactylariales	Pseudodactylariaceae	4
	Savoryellales	Savoryellaceae	34

Table 7.1 (continued)

Class	Order	Family	Number of species
	Sordariomycetes genera *incertae sedis*	Sordariomycetes genera *incertae sedis*	31
	Chaetosphaeriales	Chaetosphaeriaceae	131
		Helminthosphaeriaceae	10
		Linocarpaceae	8
	Coniochaetales	Coniochaetaceae	8
	Cordanales	Cordanaceae	5
	Phyllachorales	Phyllachoraceae	3
		Phyllachorales genera *incertae sedis*	1
	Sordariales	Chaetomiaceae	16
		Lasiosphaeriaceae	19
		Podosporaceae	1
		Sordariaceae	1
		Sordariales genera *incertae sedis*	5
	Sordariomycetidae genera *incertae sedis*	Sordariomycetidae genera *incertae sedis*	3
	Amphisphaeriales	Amphisphaeriaceae	4
		Apiosporaceae	4
		Beltraniaceae	7
		Pseudomassariaceae	2
		Sporocadaceae	7
	Xylariales	Castanediellaceae	2
		Clypeosphaeriaceae	2

Table 7.1 (continued)

Class	Order	Family	Number of species
		Clypeosphaeriaceae	2
		Diatrypaceae	1
		Hyponectriaceae	7
		Hypoxylaceae	2
		Microdochiaceae	2
		Oxydothidaceae	10
		Xylariaceae	5
		Vamsapriyaceae	2
		Zygosporiaceae	3
		Xylariales genera *incertae sedis*	13
	Xylariomycetidae family *incertae sedis*	Cainiaceae	1
		Myelospermataceae	1
Ascomycota genera *incertae sedis*	Ascomycota genera *incertae sedis*	Ascomycota genera *incertae sedis*	252
Pezizomycotina genera *incertae sedis*	Pezizomycotina genera *incertae sedis*	Pezizomycotina genera *incertae sedis*	2
		Total	**2968**
Classification of freshwater Basidiomycota			
Agaricomycetes	Agaricales	Limnoperdaceae	2
		Niaceae	2
		Physalacriaceae	2
		Agaricales genera *incertae sedis*	2

Table 7.1 (continued)

Class	Order	Family	Number of species
	Atheliales	Atheliaceae	6
	Cantharellales	Hydnaceae	4
		Ceratobasidiaceae	2
	Agaricomycetes genera *incertae sedis*	Agaricomycetes genera *incertae sedis*	8
Agaricostilbomycetes	Agaricostilbales	Agaricostilbaceae	1
Atractiellomycetes	Atractiellales	Phleogenaceae	1
Bartheletiomycetes	Polyporales	Polyporales genera *incertae sedis*	1
	Sebacinales	Sebacinaceae	3
	Trechisporales	Hydnodontaceae	1
Classiculomycetes	Classiculales	Classiculaceae	2
Cystobasidiomycetes	Cystobasidiales	Cystobasidiaceae	7
	Erythrobasidiales	Erythrobasidiaceae	7
Exobasidiomycetes	Doassansiales	Doassansiaceae	2
		Rhamphosporaceae	1
	Exobasidiales	Brachybasidiaceae	1
	Georgefischeriales	Gjaerumiaceae	1
		Tilletiariaceae	1
	Microstromatales	Microstromatales genera *incertae sedis*	1
Microbotryomycetes	Kriegeriales	Camptobasidiaceae	1
		Kriegeriaceae	1
	Leucosporidiales	Leucosporidiaceae	6
	Microbotryales	Ustilentylomataceae	1
	Sporidiobolales	Sporidiobolaceae	27

Table 7.1 (continued)

Class	Order	Family	Number of species
	Microbotryomycetes families *incertae sedis*	Chrysozymaceae	1
		Colacogloeaceae	1
	Microbotryomycetes genera *incertae sedis*	Microbotryomycetes genera *incertae sedis*	5
Moniliellomycetes	Moniliellales	Moniliellaceae	1
Tremellomycetes	Cystofilobasidiales	Cystofilobasidiaceae	5
		Mrakiaceae	9
	Filobasidiales	Filobasidiaceae	15
		Holtermanniaceae	1
		Piskurozymaceae	4
	Tremellales	Bulleraceae	1
		Bulleribasidiaceae	12
		Cryptococcaceae	10
		Naemateliaceae	1
		Phaeotremellaceae	1
		Rhynchogastremaceae	8
		Tremellaceae	1
		Trimorphomycetaceae	2
		Tremellales genera *incertae sedis*	1
	Trichosporonales	Trichosporonaceae	10
Ustilaginomycetes	Urocystidales	Doassansiopsidaceae	10
	Ustilaginales	Anthracoideaceae	1
		Ustilaginaceae	14
		Ustilaginales genera *incertae sedis*	5

Table 7.1 (continued)

Class	Order	Family	Number of species
Agaricomycotina *incertae sedis*	Agaricomycotina *incertae sedis*	Agaricomycotina *incertae sedis*	1
Basidiomycota genera *incertae sedis*	Basidiomycota genera *incertae sedis*	Basidiomycota genera *incertae sedis*	4
		Total	**218**
Classification of freshwater fungal basal clades			
Aphelidiomycota			
Aphelidiomycetes	Aphelidiales	Aphelidiaceae	15
Blastocladiomycota			
Blastocladiomycetes	Blastocladiales	Blastocladiaceae	36
		Catenariaceae	3
		Paraphysodermataceae	1
	Catenomycetales	Catenomycetaceae	1
		Coelomomycetaceae	5
	Blastocladiomycetes genus *incertae sedis*	Blastocladiomycetes genus *incertae sedis*	1
		Total	**47**
Chytridiomycota			
Chytridiomycetes	Chytridiales	Asterophlyctaceae	4
		Chytridiaceae	35
		Chytriomycetaceae	57
		Phlyctochytriaceae	21
		Pseudorhizidiaceae	1
		Scherffeliomycetaceae	1
		Chytridiales genus *incertae sedis*	1
	Polyphagales	Polyphagaceae	9

Table 7.1 (continued)

Class	Order	Family	Number of species
	Zygophlyctidales	Zygophlyctidaceae	4
	Zygorhizidiales	Zygorhizidiaceae	4
	Chytridiomycetes family *incertae sedis*	Sparrowiaceae	1
	Chytridiomycetes genera *incertae sedis*	Chytridiomycetes genera *incertae sedis*	43
Cladochytriomycetes	Cladochytriales	Catenochytridiaceae	2
		Cladochytriaceae	15
		Endochytriaceae	26
		Nowakowskiellaceae	2
		Septochytriaceae	2
		Cladochytriales genera *incertae sedis*	4
Lobulomycetes	Lobulomycetales	Alogomycetaceae	1
		Lobulomycetaceae	2
Mesochytriomycetes	Gromochytriales	Gromochytriaceae	1
	Mesochytriales	Mesochytriaceae	1
Polychytriomycetes	Polychytriales	Arkayaceae	1
		Polychytriaceae	7
Rhizophlyctidomycetes	Rhizophlyctidales	Borealophlyctidaceae	1
		Rhizophlyctidaceae	3
Rhizophydiomycetes	Rhizophydiales	Alphamycetaceae	3
		Angulomycetaceae	1
		Aquamycetaceae	1
		Collimycetaceae	1

Table 7.1 (continued)

Class	Order	Family	Number of species
		Coralloidiomycetaceae	1
		Globomycetaceae	2
		Gorgonomycetaceae	1
		Halomycetaceae	3
		Kappamycetaceae	1
		Pateramycetaceae	1
		Protrudomycetaceae	1
		Rhizophydiaceae	52
		Staurastromycetaceae	2
		Terramycetaceae	2
Spizellomycetes	Spizellomyceta-les	Spizellomycetaceae	1
Synchytriomycetes	Synchytriales	Synchytriaceae	4
		Synchytriales genus *incertae sedis*	4
Chytridiomycota genera *incertae sedis*			3
		Total	**333**
Entomophthoromycota			
Entomophthoromycetes	Entomophthora-les	Ancylistaceae	2
		Entomophthoraceae	4
Monoblepharomycota			
Hyaloraphidiomycetes	Hyaloraphidiales	Hyaloraphidiaceae	1
Monoblepharidomycetes	Monoblepharida-les	Gonapodyaceae	4
		Harpochytriaceae	12

Table 7.1 (continued)

Class	Order	Family	Number of species
		Monoblepharidaceae	10
		Oedogoniomycetaceae	1
		Telasphaerulaceae	1
		Total	**29**
Sanchytriomycota			
Sanchytriomycetes	Sanchytriales	Sanchytriaceae	2
Mortierellomycota			
Mortierellomycetes	Mortierellales	Mortierellaceae	5
Mucoromycota			
Endogonomycetes	Endogonales	Endogonaceae	1
Mucoromycetes	Mucorales	Choanephoraceae	1
		Cunninghamellaceae	3
		Lichtheimiaceae	1
		Mucoraceae	10
		Rhizopodaceae	2
		Syncephalastraceae	1
		Total	**19**
Olpidiomycota			
Olpidiomycetes	Olpidiales	Olpidiaceae	4
Rozellomycota			
Microsporidea	Amblyosporida	Amblyosporidae	49
		Caudosporidae	5
		Gurleyidae	24
		Amblyosporida genera *incertae sedis*	2
	Glugeida	Glugeidae	12

Table 7.1 (continued)

Class	Order	Family	Number of species
		Spragueidae	7
		Thelohaniidae	10
		Unikaryonidae	6
		Glugeida genus *incertae sedis*	1
	Neopereziida	Berwaldiidae	4
		Neopereziidae	12
		Neopereziida genera *incertae sedis*	3
	Nosematida	Enterocytozoonidae	1
		Mrazekiidae	6
		Nosematidae	6
		Ordosporidae	1
		Nosematida genera *incertae sedis*	4
	Microsporidea families *incertae sedis*	Fibrillasporidae	2
		Cougourdellidae	2
		Duboscqiidae	3
		Microfilidae	2
		Neonosemoidiidae	1
		Pleistophoridae	10
		Toxoglugeidae	1
		Tuzetiidae	7
	Microsporidea genera *incertae sedis*	Microsporidea genera *incertae sedis*	20

Table 7.1 (continued)

Class	Order	Family	Number of species
Rozellomycota genera *incertae sedis*	Rozellomycota genera *incertae sedis*	Rozellomycota genera *incertae sedis*	20
		Total	**221**
Zoopagomycota Zoopagomycetes	Zoopagales	Zoopagaceae	3
		Overall total	**3870**

7.3.1 Classification of Freshwater Ascomycota

The freshwater Ascomycota comprises thirteen classes namely Arthoniomycetes, Candelariomycetes, Coniocybomycetes, Dothideomycetes, Eurotiomycetes, Laboulbeniomycetes, Lecanoromycetes, Leotiomycetes, Lichinomycetes, Orbiliomycetes, Pezizomycetes, Saccharomycetes, and Sordariomycetes. Ascomycota genera *incertae sedis* totaled to 252 species (in 141 genera) and two species listed under Pezizomycotina genera *incertae sedis* (*Pyrenocollema strontianense*, *Psammina stipitata*). Taxonomic classification of freshwater Candelariomycetes, Coniocybomycetes, Lecanoromycetes, and Lichinomycetes were listed in "*Freshwater lichens*" section as members of these classes are lichens and lichenicolous taxa.

7.3.1.1 Arthoniomycetes

Arthoniomycetes is the largest taxonomic group of primarily lichenized fungi outside of Lecanoromycetes. The taxa are mostly tropical and subtropical microlichens with bitunicate asci in ascohymenial apothecia [617]. Multi-locus phylogenetic analysis shows that Arthoniomycetes is monophyletic and sister class to Dothideomycetes [618]. On the latest outline of fungi and fungus-like taxa, Wijayawardene et al. (2020) listed two orders under Arthoniomycetes: Arthoniales (116 genera) and Lichenostigmatales (3 genera). Few freshwater Arthoniomycetes have been recorded from freshwater habitats [619–621] and the taxa listed in Table

7.2 accounts for twelve species (in 8 genera) but undoubtedly there are more taxa to be discovered. The additional information on freshwater lichenicolous taxa is discussed in "*Freshwater Lichens*" section.

Table 7.2 Classification of Freshwater Arthoniomycetes with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Distribution	Reference
ASCOMYCOTA			
ARTHONIOMYCETES			
Arthoniales			
Arthoniaceae			
Arthonia caudata	River watershed	Canada	[622]
Arthonia helvola	River watershed	Canada	[622]
Arthonia radiata	River watershed	Canada	[622]
Chrysotrichaceae			
Chrysothrix caesia	River watershed	Canada	[622]
Chrysothrix granulosa	River	Canada	[619]
Lecanographaceae			
Alyxoria varia	River watershed	Canada	[622]
Opegraphaceae			
Cresponea chloroconia	River watershed	Canada	[622]
Roccellaceae			
Enterographa osagensis	Creek	Central North	[620]

Table 7.2 (continued)

Taxon	Substrate	Distribution	Reference
		America	[620]
Enterographa zonata	Waterfall	Canada	[619]
Gyrographa gyrocarpa		North America	[623]
Pseudoschismatomma rufescens	River watershed	Canada	[622]
Schismatomma cretaceum	Nature Reserve	Ukraine	[621]

7.3.1.2 Dothideomycetes

Freshwater Dothideomycetes is a large taxonomic unit referring to fungal species having bitunicate asci, often with fissitunicate dehiscence, with many collected from freshwater. The ecology of freshwater fungi has not been systematically studied due to the variability and uncertainty of the host habitat, especially the specimens collected from the rainy or drought seasons. Thus, the numbers of freshwater Dothideomycetes are counted based on the fungi reported from biodiversity studies and/or single or multi-species taxonomic studies from freshwater habitats [7]. Dong, Wang, et al. [7] is the key reference for a comprehensive taxonomic account of freshwater Dothideomycetes, including morphological descriptions, multi-locus phylogenetic analysis, notes with dichotomous keys of taxa, and mapped freshwater distributions with references for each species.

According to recent statistics, freshwater dothideomycetous species reside in six orders, 43 families and 145 genera, while 46 genera are exclusively documented from freshwater environments [7]. In this paper, freshwater Dothideomycetes are distributed in 18 orders, 75 families and 229 genera. Pleosporales is the largest freshwater order with 391 freshwater species, followed by Tubeufiales and Jahnulales with 145 and 37 freshwater species, respectively (Table 7.3, Figure 7.1). Few taxa are reported in Minutisphaerales, Capnodiales, and Kirschsteiniotheliales with 18, 13, and 12 freshwater species, respectively. Representative Dothideomycetes taxa are

illustrated in Figure 7.2. Natipusillales is the only order in which all species are from freshwater habitats. In total, 677 dothideomycetous species are reported in this study from freshwater habitats.

Table 7.3 Classification of Freshwater Dothideomycetes with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	Reference
ASCOMYCOTA			
DOTHIDEOMYCETES			
Asterinales			
Morenoinaceae			
Morenoina palmicola	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Botryosphaeriales			
Botryosphaeriaceae			
Dothiorella uruguayensis	Submerged decaying wood (stream)	China	[624]
Lasiodiplodia theobromae	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Tiarosporella paludosa	Submerged decaying wood (reservoir, river, stream, lake)	Australia, Brunei, China, Malaysia, Philippines	[432, 583, 625–627]
Neodevriesiaceae			
Tripospermum camelopardus	Foam (rivulet, river, stream), submerged leaf litter of *Alnus glutinos*a (stream)	Austria, Canada, France, Ireland, UK	[588, 628–632]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Tripospermum infalcatum	Rainwater: building roofs, needles of *Pinus densiflora*	Japan, Poland	[633, 634]
Tripospermum limneticum	Submerged decaying leaves	India	[635]
Tripospermum myrti	Foam (rivulet, stream), submerged leaf litter of *Alnus glutinos*a (stream), stemflow and throughfall of tree canopies, water-filled treeholes	Austria, Brazil, Canada, France, Hungary, India, Malaysia	[577, 588, 628, 630, 631, 636–639]
Tripospermum prolongatum	Stemflow and throughfall of tree canopies, submerged decaying leaves (stream), foam (stream)	India, USA	[636, 640]
Tripospermum sinense	Submerged decaying leaves of dicotyledon (stream)	China	[641]
Phyllostictaceae			
Guignardia manokwaria	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Capnodiales			
Mycosphaerellaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Mycosphaerella aspidii	*Equisetum fluviatile*	Austria	[642]
Mycosphaerella equisetina	*Equisetum fluviatile*	Austria	[642]
Mycosphaerella equiseticola	*Equisetum fluviatile*	Austria	[642]
Mycosphaerella perexigua	*Carex rostrata, Eriophorum angustifolium*	Austria	[642]
Stigmidium rivulorum	River	Bulgaria	[643]
Teratosphaeriaceae			
Apenidiella foetida	Submerged plant debris (river)	**Spain**	[644]
Apenidiella strumelloidea	Leaf of *Carex* sp. (stagnant water)	**Russia**	[429]
Collemopsidiales			
Xanthopyreniaceae			
Collemopsidium japonicum	Nature reserves	Japan	[645]
Collemopsidium monense	Stream	UK	[646]
Zwackhiomyces lacustris	Stream and lake margin	Europe	[647]
Dothideales			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Saccotheciaceae			
Aureobasidium melanogenum	Ground- and tapwater	**Slovenia**	[648]
Aureobasidium pullulans	Water (lake, pond), glacial meltwater river	Slovakia, **Argentina**	[649–651]
Dyfrolomycetales			
Pleurotremataceae			
Melomastia aquatica	Submerged decaying wood (river)	China, South Africa	[652]
Hysteriales			
Hysteriaceae			
Gloniopsis calami	Submerged decaying wood (pond)	**Thailand**	[653]
Hysteriales genus *incertae sedis*			
Graphyllium planispora	*Scirpus, Typha*	USA	[654]
Jahnulales			
Aliquandostipitaceae			
Aliquandostipite crystallinus	Submerged decaying wood (river)	Costa Rica, Panama, Peru, **USA**, Venezuela	[655–657]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Aliquandostipite khaoyaiensis	Submerged decaying wood (stream)	Costa Rica, USA, **Thailand**	[7, 655, 656]
Aliquandostipite manochiae	Submerged decaying wood (lake)	Thailand	[345]
Aliquandostipite minuta	Submerged decorticated wood (swamp)	USA	[656, 658]
Aliquandostipite separans	Submerged decaying branches	Egypt	[659]
Aliquandostipite siamensiae	Submerged decaying wood	**Thailand**, USA	[656, 659]
Ascagilis bipolaris	Submerged decaying wood (river, stream, waterfall)	Australia, China, **Costa Rica**, Malaysia, Peru, **Thailand**, USA	[72, 583, 656, 657, 660–665]
Ascagilis guttulaspora	Submerged decaying wood (stream)	**China**	[514]
Ascagilis queenslandica	Submerged decaying wood (stream)	**Australia**	[511]
Ascagilis seychellensis	Submerged decaying wood (river)	Brazil, **Costa Rica**, Seychelles	[661, 664, 666]
Ascagilis submersa	Submerged decaying wood (stream)	**Thailand**	[7]
Ascagilis sunyatsenii	Submerged decaying wood (stream)	**China**	[659, 667]
Ascagilis thailandensis	Submerged decaying wood (stream)	**Thailand**	[7]
Brachiosphaera jamaicensis	Submerged decaying wood	Jamaica, China, Poland	[668, 669]
Brachiosphaera tropicalis	Submerged decaying herbaceous, wood	Brazil, China, Malaysia, Panama, Peru,	[71, 519, 656,

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
	(river, stream, waterfall); foam (river); water	Thailand, USA, Venezuela	657, 665, 669–672]
Jahnula apiospora	Submerged decorticated wood (creek)	Canada	[673]
Jahnula appendiculata	Submerged decaying wood (e.g. (*Azadirachta indica* var. *siamensis, Erythrophleum teysmannii, Melaleuca cajuputi, Shorea obtusa, S. roxburghii, Wrightia tomentosa, Xylia xylocarpa, Zollingeria dongnaiensis* (river), *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	Peru, **Thailand**	[62, 584, 657, 674, 675]
Jahnula aquatica	Submerged decaying wood (e.g., *Salix* sp.) (creek, lake, stream, waterfall)	China, France, Germany, Malaysia, South Africa, Thailand, **USA**	[583, 656, 661, 664, 676–680]
Jahnula bipileata	Submerged decorticated wood (lake)	**Ecuador, USA**	[664]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Jahnula granulosa	Submerged decaying wood (lake)	China, South Africa, **Thailand**	[661, 665, 670]
Jahnula morakotii	Submerged *Azadirachta indica* test block (peat swamp)	Thailand	[675]
Jahnula poonythii	Submerged decaying wood (lake)	China, Mauritius, Mexico	[627, 661, 670, 681]
Jahnula purpurea	Submerged decorticated branch (river)	Martinique	[682]
Jahnula rostrata	Submerged decaying wood (lake, stream)	**China**, **USA**	[7, 656, 664]
Jahnula sangamonensis	Submerged decorticated wood (river)	USA	[656, 664]
Jahnula seychellensis	Submerged decaying wood and twig (stream, river)	Brazil, Philippines, Seychelles	[432, 661, 683]
Jahnula systyla	Submerged decaying wood (river)	Australia, China, Malaysia	[583, 661, 676]
Megalohypha aqua-dulces	Submerged decaying wood (river)	**Panama**, Thailand	[684]
Neojahnula australiensis	Submerged decaying wood (river)	Australia, Brunei, China, Peru, **Thailand**, USA	[7, 583, 656, 657, 665, 685]
Pseudojahnula potamophila	Submerged decaying wood (river)	Australia, Costa Rica, **USA**	[656, 661, 664]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Xylomyces acerosisporus	Submerged decaying leaves (river)	Brazil	[686]
Xylomyces aquaticus	Submerged decaying woods (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) and leaves, foam (stream), water (river), submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp), water-filled treeholes	Austria, Brazil, Hungary, Poland, Spain, Thailand, Ukraine, **UK**, USA	[62, 70, 474, 584, 628, 638, 683, 687–689]
Xylomyces chlamydosporus	Submerged decaying wood (lake, river, stream, waterfall)	Australia, Brazil, Brunei, China, Seychelles, Thailand, USA	[78, 486, 521, 627, 656, 683, 690–694]
Xylomyces foliicola	Submerged decaying wood and leaves (e.g., *Calophyllum brasiliense*) (stream)	Brazil	[683, 695]
Xylomyces giganteus	Submerged decaying wood (river)	Australia, China, South Africa	[486, 487, 696]
Xylomyces punctatus	Submerged decaying wood (river)	China	[78, 486]
Xylomyces pusillus	Submerged decaying wood and leaf (lake, river)	Brazil, China	[78, 486, 670, 697]
Kirschsteiniotheliales			
Kirschsteiniotheliaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Kirschsteiniothelia aquatica	Submerged decaying wood (stream)	**China**	[683, 698]
Kirschsteiniothelia atra	Submerged decaying wood	Brazil, **China**	[699]
Kirschsteiniothelia cangshanensis	Submerged decaying wood (river)	**China**	[698]
Kirschsteiniothelia fluminicola	Submerged decaying wood (river)	**China**	[698]
Kirschsteiniothelia rostrata	Submerged decaying wood (stream)	**China**, **Thailand**	[514, 698]
Kirschsteiniothelia submersa	Submerged decaying wood (stream)	**China**	[699]
Kirschsteiniotheliales genera *incertae sedis*			
Brachysporiella gayana	Submerged decaying wood (reservoir, stream, waterfall), submerged decaying *Eleiodoxa conferta* (peat swamp)	Brazil, China, Thailand	[62, 521, 626, 683]
Brachysporiella pulchra	Submerged decaying twig (stream)	Brazil	[683]
Brachysporiella rhizoidea	Submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta*	China, Thailand	[584, 700, 62]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
	(peat swamp)		
Brachysporiella setosa	Submerged decaying wood (stream)	Brunei, China	[583]
Taeniolella longissima	Submerged Scots pine test block (water-cooling tower)	UK	[701]
Taeniolella phialosperma	Sediment	**Korea**	[702]
Microthyriales			
Microthyriales genera *incertae sedis*			
Heliocephala elegans	Submerged decaying leaves (stream)	Brazil	[683]
Lichenotheliales			
Lichenotheliaceae			
Endococcus rugulosus	Stream and lake margin	Europe	[647]
Endococcus verrucisporus	Stream and lake margin	Europe	[647]
Monoblastiales			
Monoblastiaceae			
Acrocordia cavata	River watershed	Canada	[622]
Microthyriales			
Microthyriales genera *incertae sedis*			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Heliocephala elegans	Submerged decaying leaves (stream)	Brazil	[683]
Minutisphaerales			
Acrogenosporaceae			
Acrogenospora aquatica	Submerged decaying wood (stream)	**China**	[173]
Acrogenospora basalicellularispora	Submerged decaying wood (stream)	**China**	[173]
Acrogenospora ellipsoidea	Submerged decaying wood (stream)	China	[703]
Acrogenospora guttulatispora	Submerged decaying wood (stream)	**China**	[173]
Acrogenospora obovoidspora	Submerged decaying wood (stream)	**China**	[173]
Acrogenospora olivaceospora	Submerged decaying wood (stream)	**China**	[173]
Acrogenospora ovalis	Submerged decaying wood (reservoir)	China	[704]
Acrogenospora sphaerocephala	Submerged decaying wood (river, stream, waterfall), bamboo, leaves (stream), decaying *Metroxylon sagu* (peat swamp), submerged *Phragmites* (river)	Brazil, Brunei, China, Philippines, Seychelles, USA, UK	[432, 511, 626, 662, 683, 690, 693, 705, 706]
Acrogenospora submersa	Submerged decaying wood (river)	**China**	[173]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Acrogenospora subprolata	Submerged decaying wood (river, stream)	**China**	[78, 173, 704]
Acrogenospora thailandica	Submerged decaying wood (stream)	**Thailand**	[511]
Acrogenospora verrucispora	Submerged decaying wood (stream)	**China**	[173]
Acrogenospora yunnanensis	Submerged decaying wood (stream)	**China**	[173]
Minutisphaeraceae			
Minutisphaera aquaticum	Submerged decorticated wood river)	**Thailand**	[707]
Minutisphaera aspera	Submerged decorticated wood (stream)	**USA**	[708]
Minutisphaera fimbriatispora	Submerged decorticated wood (pond)	**USA**	[709, 710]
Minutisphaera japonica	Submerged decorticated *Fraxinus excelsior*, *Salix* sp. (brook)	**Japan, France**	[708, 710]
Minutisphaera parafimbriatispora	Submerged decorticated wood (swamp)	**USA**	[708]
Natipusillales			
Natipusillaceae			
Natipusilla bellaspora	Submerged decaying wood (river, stream))	**Peru**	[657, 711]
Natipusilla decorospora	Submerged corticated wood (swamp)	**Ecuador**	[709]
Natipusilla limonensis	Submerged decaying wood (river, stream)	**Costa Rica,** Peru	[657, 709]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Natipusilla naponensis	Submerged corticated wood (swamp)	**Ecuador**	[709]
Pleosporales			
Acrocalymmaceae			
Acrocalymma aquaticum	Submerged decaying wood (stream)	**Thailand**	[712]
Acrocalymma bipolare	Submerged decaying wood (river)	**Egypt**	[7]
Acrocalymma medicaginis	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Aigialaceae			
Fissuroma neoaggregatum	Submerged decaying wood	**Thailand**	[7]
Neoastrosphaeriella aquatica	Submerged decaying wood	**Thailand**	[508]
Amniculicolaceae			
Amniculicola aquatica	Submerged decaying wood	**China**	[511]
Amniculicola guttulata	Submerged decaying wood	**China**	[7, 511]
Amniculicola longissima	Submerged decaying wood (*Alnus glutinosa*, *Acer pseudoplatanus*, *Corylus avellana*, *Fraxinus excelsior*, *Fagus sylvatica*, *Ulmus* sp.) (stream), foam (stream, spring, river, lake), submerged decaying leaves of *Salix*	**Austria**, Brazil, **Czech Republic**, France, **Germany**, India, Ireland,	[13, 63, 637, 639, 687, 713–719, 65, 720–724, 519, 588,

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
	spp., *Populus* spp., *Betula glandulosa*, *Alnus tenuifolia*, *A. glutinosa* (stream, river), water (river, stream), scum (stream), sediment (dam, stream), stemflow and throughfall of tree canopies and palm species	Jamaica, Nigeria, Poland, UK, **USA**, Venezuela	628, 630–632, 636]
Amniculicola immersa	Submerged *Salix* sp. wood	Denmark	[725]
Amniculicola lignicola	Partly submerged wood of *Fraxinus excelsior*	**France**	[726]
Amniculicola parva	Submerged wood of *Alnus glutinosa*	**France**	[725]
Anguillospora crassa	Scum (stream), foam (stream, river), submerged decaying leaves of *Alnus glutinosa, A. tenuifolia Salix* spp., *Populus* spp., *Betula glandulosa* (stream), sediment (dam), stemflow and throughfall of tree canopies, water (river, stream)	Austria, Brazil. Canada, **Czech Republic**, France, **Germany**, India, Ireland, Japan, Jamaica, **Poland**, Portugal, **Slovakia**, UK, USA Venezuela	[65, 519, 715, 717, 718, 721, 722, 724, 727–730, 588, 731–736, 628, 630–632, 636, 637, 639]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Anguillospora curvula	Submerge decayed leaves of Poaceae (river), foam (river)	Ireland, UK	[632, 737]
Anguillospora filiformis	Foam (stream), submerged decaying leaves (stream), water (river, stream)	**Australia**, Austria, Brazil, **Canada**, **Italy**, **Poland**, **Portugal**, **Spain**, USA, Venezuela	[519, 628, 637, 639, 728, 729, 736, 738]
Anguillospora furtiva	Foam (stream, river)	**Austria**, Ireland, **Slovakia**, UK	[628, 632, 724, 736]
Anguillospora gigantea	Water (river, spring), decaying unidentified leaves (spring), submerged decaying leaves of *Populus* sp. (irrigation ditch)	Cuba, Poland, USA	[63, 65, 687, 739]
Anguillospora mediocris	Submerged decaying leaves of *Alnus glutinosa* (stream)	**Hungary**	[736, 740]
Anguillospora pseudolongissima	Submerged decaying leaves of *Salix* (rivulet), foam (river)	Brazil, USA	[63, 65, 723]
Anguillospora pulchella	Foam	USA	[741]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Anguillospora rosea	Foam (stream, river, waterfalls), apothecium of *Orbilia* on submerged branch of tree, submerged decorticated twigs	Austria, Ireland, **UK**	[628, 632, 736, 742]
Anguillospora rubescens	Submerged decaying grass blades (river)	**Belarus**	[743]
Anguillospora virginiana	Foam	USA	[741]
Fouskomenomyces cupreorufescens	Submerged decaying leaves of *Alnus glutinosa* (oligotropic peat bog)	**Austria**	[744] [745]
Fouskomenomyces mimiticus	Submerged decaying plant debris	**Spain**	[745]
Murispora aquatica	Submerged decaying wood (stream)	**China**	[746]
Murispora cicognanii	Submerged decaying wood (stream)	**China**	[511]
Murispora fagicola	Submerged decaying wood (river)	**China**	[746]
Murispora fissilispora	Submerged decaying plant debris	**Spain**	[745]
Murispora asexualis	Submerged decaying plant debris	**Spain**	[745]
Murispora navicularispora	Submerged decaying plant debris	**Spain**	[745]
Murispora rubicunda	Submerged dead herbaceous stem (*Dipsacus*?)	Austria, **France**	[391, 747]
Neomassariosphaeria typhicola	Submerged culm of *Phragmites* and stems of *Typha*	**Denmark**, Pakistan, USA	[390, 748, 749]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
	latifolia (lake), submerged decaying branches		
Anteagloniaceae			
Flammeascoma bambusae	Submerged bamboo stem	**Thailand**	[345]
Purpureofaciens aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Aquasubmersaceae			
Aquasubmersa japonica	Submerged decaying wood (river)	**Japan**	[516]
Aquasubmersa mircensis	Submerged decaying wood (stream)	**Thailand**	[712]
Astrosphaeriellaceae			
Aquatospora cylindrica	Submerged decaying wood (stream)	**Thailand**	[7]
Astrosphaeriella angustispora	Submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	Thailand	[62, 584]
Astrosphaeriella aquatica	Submerged rachides of *Livistona* (river), submerged decaying *Eleiodoxa conferta* and *Licuala longicalycata* (peat swamp)	Papua New Guinea, Ecuador, Thailand	[585, 750, 751]
Astrosphaeriella exorrhiza	Submerged roots of *Iriartea* (stream)	Ecuador	[751]
Astrosphaeriella floridana	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Astrosphaeriella fronsicola	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Astrosphaeriella lophiostomopsis	Decaying *Licuala longicalycata* and *Metroxylon sagu* (peat swamp)	Thailand	[585]
Astrosphaeriella malayensis	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Astrosphaeriella maquilingiana	Submerged decaying wood (stream)	Australia	[752]
Astrosphaeriella papuana	Submerged decaying wood and bamboo (river)	Papua New Guinea, Philippines	[432, 751]
Astrosphaeriella seychellensis	Submerged decaying wood (river)	Seychelles	[693]
Astrosphaeriella stellata	Submerged decaying wood and bamboo (lake, river, stream, waterfall); decaying culms of *Thysanolaena maxima*	China, Philippines, Thailand	[432, 521, 580, 627, 753, 754]
Astrosphaeriella thailandensis	Submerged decaying wood (stream)	Thailand	[755]
Caryospora aquatica	Submerged decaying wood (stream, waterfall)	**China**, **Thailand**	[7, 516]
Caryospora aquatica	Submerged decaying wood (stream, waterfall)	**China**, **Thailand**	[7, 516]
Caryospora minima	Submerged decaying wood and bamboo (lake, stream, reservoir)	China, Philippines, South Africa	[432, 626, 627, 662, 696]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Caryospora obclavata	Submerged decorticated woody debris	USA	[756]
Caryospora quercus	Submerged decaying wood	**Thailand**	[7]
Caryospora submersa	Submerged decaying wood	**Thailand**	[7]
Pithomyces elaeidicola	Submerged decaying wood (stream)	Brazil	[683]
Pithomyces flavus	Submerged decaying wood (lake)	China	[454, 670]
Pithomyces niger	Submerged decaying wood (stream)	Brazil	[683]
Pithomyces obscuriseptatus	Rainwater from building roofs	Poland	[633]
Xenoastrosphaeriella tornata	Submerged decaying wood and bamboo (river)	Philippines	[432]
Xenoastrosphaeriella trochus	Submerged decaying wood (stream)	Australia, China, South Africa	[662, 670, 752]
Bambusicolaceae			
Bambusicola aquatica	Submerged decaying wood (stream)	**China**	[7]
Corynesporascaceae			
Corynespora aquatica	Submerged decaying leaves (stream)	Mexico	[757]
Corynespora cubensis	Rainwater from building roofs	Poland	[633]
Corynespora lignicola	Submerged decaying wood (river)	**China**	[653]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Corynespora submersa	Submerged decaying wood (river)	**China**	[653]
Cucurbitariaceae			
Neocucurbitaria aquadulcis	Submerged plant debris	**Spain**	[758]
Neocucurbitaria variabilis	Submerged plant debris	**Spain**	[758]
Cyclothyriellaceae			
Massariosphaeria scirpina	*Typha* leaves	USA	[654]
Massariosphaeria websteri	Submerged decaying culms of cf. *Phragmites karka*	Pakistan	[748]
Delitschiaceae			
Delitschia bispora	Water-cooling towers	UK	[759–761]
Delitschia fasciatispora	Submerged branch (river)	Mauritius	[762]
Delitschia palmietensis	Submerged bark (river)	Mauritius	[762]
Dictyosporiaceae			
Aquadictyospora lignicola	Submerged decaying wood (stream)	**China**	[763]
Aquaticheirospora lignicola	Submerged decaying wood (stream)	**Thailand**	[764]
Cheirosporium triseriale	Submerged decaying wood (stream)	China	[765]
Cheirosporium vesiculare	Submerged decaying wood (river)	Egypt	[766]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Dendryphiella vinosa	Submerged decaying wood (stream)	**Thailand**	[7]
Dictyocheirospora aquadulcis	Submerged decaying wood (stream)	**Thailand**	[511]
Dictyocheirospora aquatica	Submerged decaying wood (river)	**China**	[767]
Dictyocheirospora garethjonesii	Submerged decaying wood (river)	**China**	[767]
Dictyocheirospora gigantica	Submerged decaying wood (e.g., submerged test block of *Anisoptera oblonga*) (river, stream)	South Africa, Thailand	[768]
Dictyocheirospora heptaspora	Submerged decaying wood (lake) and bamboo (river)	China, Philippines	[432, 627]
Dictyocheirospora indica	Submerged decaying wood (stream)	**Thailand**	[509]
Dictyocheirospora musae	Submerged decaying wood (lake)	China	[627]
Dictyocheirospora rotunda	Submerged decaying wood (river, stream))	**China**, **Thailand**	[7, 510, 767]
Dictyocheirospora tetraploides	Submerged decaying wood (stream)	China	[769]
Dictyocheirospora thailandica	Submerged decaying wood (stream)	**Thailand**	[7]
Dictyocheirospora vinaya	Submerged decaying wood (stream)	**Thailand**	[510]
Dictyosporium alatum	Submerged decaying wood (stream), decaying *Metroxylon sagu* (peat swamp)	Brunei, Thailand	[583, 585]
Dictyosporium aquaticum	Submerged decaying date palm (river)	**Egypt**	[345]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Dictyosporium biseriale	Submerged decaying wood (stream)	China	[703]
Dictyosporium brahmaswaroopii	Submerged decaying wood (river)	China	[768]
Dictyosporium canisporum	Submerged decaying wood (stream)	China	[769]
Dictyosporium digitatum	Submerged decaying wood (e.g., *Anisoptera oblonga*, *Dipterocarpus alatus*, *Machilus velutina*, *Pinus massoniana*, *Xylia dolabriformis* test blocks) (reservoir, river, stream) and leaves (stream)	Australia, Brazil, Brunei, China, Thailand	[70, 626, 662, 768, 770]
Dictyosporium elegans	Submerged decaying leaves and petiole (stream), submerged test blocks of *Anisoptera oblonga*, *Dipterocarpus alatus*, *Machilus velutina*, *Pinus massoniana* (stream)	Brazil, China, Thailand	[70, 583, 683]
Dictyosporium lakefuxianense	Submerged decaying wood (lake)	China	[627, 771]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Dictyosporium muriformis	Submerged decaying wood (stream)	**China**	[403]
Dictyosporium nigroapice	Submerged decaying wood (e.g., *Dipterocarpus alatus* test block) (stream)	China, Thailand	[70, 509, 768]
Dictyosporium olivaceosporum	Submerged decaying twigs (stream)	**Japan**	[772]
Dictyosporium palmae	Submerged decaying fronds of *Phoenix dactylifera* (river)	**Egypt**	[766]
Dictyosporium pelagicum	Submerged decaying wood (river)	USA	[773]
Dictyosporium polystichum	Submerged decaying wood (lake)	China	[627]
Dictyosporium stellatum	Submerged decaying wood (lake)	**Ontario**	[774]
Dictyosporium subramanianii	Submerged decaying wood (e.g., *Dipterocarpus alatus* test block) (river, stream, waterfall)	Thailand	[70, 521]
Dictyosporium tetraseriale	Submerged decaying wood (e.g., *Machilus velutina*, *Pinus massonaina* wood baits) (stream)	Brunei, China	[768]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Dictyosporium tetrasporum	Submerged decaying wood (stream)	China	[775]
Dictyosporium thailandicum	Submerged decaying wood (stream)	**Thailand**	[345]
Dictyosporium tratense	Submerged decaying wood (stream)	**Thailand**	[509]
Dictyosporium triramosum	Submerged decaying stem (river)	Buenos Aires	[776]
Dictyosporium tubulatum	Submerged decaying wood (stream)	**Thailand**	[509]
Dictyosporium yunnanense	Submerged decaying wood	China	[771]
Dictyosporium zhejiangense	Submerged decaying wood (stream)	**China**	[777]
Digitodesmium bambusicola	Submerged bamboo culms (river)	Philippines	[431]
Digitodesmium heptasporum	Submerged decaying wood (stream)	China	[769]
Digitodesmium recurvum	Submerged decaying wood (stream)	China	[778]
Jalapriya apicalivaginatum	Submerged decaying wood (stream)	**China**	[779]
Jalapriya aquatica	Submerged decaying wood (stream)	**China**	[779]
Jalapriya pulchra	Submerged decaying wood (stream)	**China**	[772]
Pseudocoleophoma typhicola	Submerged stems of *Typha latifolia* (lake)	**UK**	[310]
Pseudodictyosporium wauense	Submerged decaying wood (stream)	**China**	[763]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Vikalpa lignicola	Submerged decaying wood (stream)	China	[772]
Didymellaceae			
Calophoma complanata	Submerged decaying wood (stream)	China	[583]
Didymella castillejae	Submerged decaying wood (river)	Malaysia	[583, 660]
Didymella glacialis	*Carex rostrata*	Austria	[642]
Didymella hellebori	Submerged decaying wood (river)	Malaysia	[660]
Microsphaeropsis olivacea	Submerged decaying wood (stream)	Brunei	[583]
Nothophoma spiraeae	Submerged plant litter	**Korea**	[702]
Didymosphaeriaceae			
Didymosphaeria bisphaerica	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[584]
Didymosphaeria pittospora	Submerged beech test blocks in storage tank and water in cooling tower	India	[780]
Paraphaeosphaeria michotii	*Typha leaves*	UK	[781]
Paraphaeosphaeria schoenoplecti	Senescent culms of *Schoenoplectus litoralis*	China	[782]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Paraconiothyrium fuckelii	Submerged decaying wood	USA	[773]
Pseudotrichia allequashensis	Submerged, partially decomposed grass stem	USA	[749]
Dothidotthiaceae			
Mycocentrospora acerina	Foam (lake, spring, stream, river), submerged decaying leaves of *Alnus* sp. (stream), stemflow and throughfall of tree canopies	Austria, Brazil, Canada, India, Spain, Switzerland, USA, Venezuela	[519, 588, 628, 636, 637, 716, 730, 783, 784]
Mycocentrospora angulata	Submerged decaying leaves of *Prunus* and unidentified angiosperm leaves, foam (stream, lake, spring, river)	USA	[65, 716]
Mycocentrospora aquatica	Foam (stream), submerged decaying wood and leaves(stream)	Canada, UK	[588, 729, 737]
Mycocentrospora clavata	Submerged decaying leaves (stream)	Canada	[729]
Mycocentrospora varians	Submerged decaying leaves (stream)	USA	[640]
Hermatomycetaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Hermatomyces sphaericus	Submerged decaying stream (stream)	Brazil	[683]
Latoruaceae			
Pseudoasteromassaria aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Pseudoasteromassaria spadicea	Submerged decaying wood (stream)	**Thailand**	[415]
Lentitheciaceae			
Halobyssothecium bambusicola	Sumerged decaying wood (stream)	**Thailand**	[299]
Halobyssothecium cangshanense	Submerged decaying wood (stream)	**China**	[407]
Halobyssothecium carbonneanum	Submerged decaying branch of *Populus* sp. (lake)	**France**	[408]
Halobyssothecium kunmingense	Submerged decaying wood (stream)	**China**	[7]
Halobyssothecium obiones	*Phragmites australis* culms and stems, *Typha* leaves (river, swamps)	UK, USA	[706, 781, 785, 786]
Halobyssothecium unicellulare	Submerged decaying wood (river)	**Egypt**	[310]
Keissleriella linearis	Submerged dead stems of *Phragmites* sp. (lake)	**France**	[393]
Lentithecium clioninum	Submerged decaying wood (river)	**Japan**	[406]
Lentithecium pseudoclioninum	Submerged twigs of woody plant (pond)	**Japan**	[398]
Poaceascoma aquaticum	Submerged decaying bamboo (stream)	**Thailand**	[512]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Setoseptoria arundinacea	Submerged decaying wood; submerged stems of *Phragmites* sp. (lake)	China, Denmark, UK	[393, 627, 785]
Setoseptoria magniarundinacea	Submerged dead herbaceous stems (river)	Japan	[787]
Tingoldiago clavata	Submerged decaying wood	**Thailand**	[513]
Tingoldiago hydei	Submerged decaying wood	**Thailand**	[513]
Tingoldiago graminicola	Submerged culms of *Phragmites australis* and *P. japonica* (river)	**Japan**, UK	[405]
Leptosphaeriaceae			
Leptosphaeria acuta	*Scirpus*, *Typha* (lake)	USA	[654]
Leptosphaeria albopunctata	Submerged decaying wood (river), *Phragmites australis* stems and leaves	USA, UK	[690] [690, 786, 788, 789]
Leptosphaeria culmifraga	*Phragmites australis* culms	UK	[785]
Leptosphaeria eustomoides	*Phragmites australis* leaves	UK	[789]
Leptosphaeria modesta	*Typha* leaves	UK	[781]
Leptosphaeria sepalorum	*Juncus filiformis* (lake)	Austria	[642]
Lindgomycetaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Aquimassariosphaeria kunmingensis	Submerged decaying wood (stream)	**China**	[7]
Aquimassariosphaeria typhicola	Submerged, partially decomposed stems of *Typha latifolia* and unidentified grass stem (lake)	USA	[749]
Arundellina typhae	Submerged dead stem of *Typha* sp. (river)	**UK**	[310]
Clohesyomyces aquaticus	Submerged decaying wood and bamboo (river, stream)	Australia, China, Thailand	[7, 435, 625, 712]
Hongkongmyces aquaticus	Submerged decaying wood (stream)	**Thailand**	[7]
Hongkongmyces brunneisporus	Submerged decaying wood (stream, lake)	**China**	[790]
Hongkongmyces pedis	Freshwater (river)	**Korea**	[791]
Hongkongmyces snookiorum	Submerged detritus (fen)	**USA**	[408]
Lindgomyces angustiascus	Submerged decorticated wood (lake)	USA	[792]
Lindgomyces apiculatus	Submerged twigs of woody plant (pond)	**Japan**	[793]
Lindgomyces aquaticus	Submerged decaying wood (stream)	**Thailand**	[7]
Lindgomyces breviappendiculatus	Submerged decaying wood (river)	Japan	[405, 406]
Lindgomyces carolinensis	Submerged decaying wood (lake)	**USA**	[794]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Lindgomyces cigarosporus	Submerged decaying wood (lake)	**USA**	[794]
Lindgomyces cinctosporus	Submerged decaying wood of *Salix* sp. and branchlet of *Fagus sylvatica* (brook, stream)	**France**, Spain, **USA**	[405, 795]
Lindgomyces griseosporus	Submerged wood and twig of *Alnus glutinosa, Fraxinus excelsior, Rhamnus cathartica, Frangula alnus, Salix* sp., and submerged dead root of *Platanus* sp. (stream)	**France**, Spain	[795]
Lindgomyces ingoldianus	Submerged woody debris (e.g., *Dipterocarpus alatus, Platanus* sp., *Xylia dolabriformis* test blocks) (reservoir, stream); submerged herbaceous stem (*Scirpus brevicaudatus, S. validus, S. atrovirens, Typha latifolia*) (lake)	Australia, Brunei, China, France, Japan, Malaysia, Thailand, USA	[70, 405, 626, 662, 749, 795–797]
Lindgomyces lemonweirensis	Submerged, decorticated wood (river)	**USA**	[793]
Lindgomyces madisonensis	Submerged decaying wood (creek)	**USA**	[798]
Lindgomyces okinawaensis	Submerged dead twigs (river)	**Japan**	[302]
Lindgomyces pseudomadisonensis	Submerged dead twigs of woody plant (river)	**Japan**	[310]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Lindgomyces pseudomadisonensis	Submerged dead twigs of woody plant (river)	**Japan**	[310]
Lindgomyces rotundatus	Submerged decaying wood (e.g., *Salix* sp.) (pond, river)	**Japan**, USA	[405]
Lolia aquatica	Decayed stem of *Phragmites australis* (irrigation canal)	**Egypt**	[799, 800]
Lolia dictyospora	Submerged decayed rachis of *Phoenix dactylifera* (river)	**Egypt**	[800]
Neolindgomyces submersus	Submerged decaying wood (river)	Australia	[801]
Longipedicellataceae			
Longipedicellata aptrootii	Submerged decaying wood and bamboo (river, stream, river)	China, Malaysia, Philippines, **Thailand**	[7, 432, 521, 626, 802, 803]
Longipedicellata aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Pseudoxylomyces aquaticus	Submerged decaying wood (stream)	**Thailand**	[7]
Pseudoxylomyces elegans	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks); twigs; bark	Australia, Brazil, China, India, **Japan**, Seychelles, **Thailand**, USA	[7, 70, 398, 486, 663, 705, 804–807]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Submersispora variabilis Lophiostomataceae	Submerged decaying wood (stream)	**Thailand**	[7]
Biappendiculispora japonica	Submerged decaying wood (stream)	**China**	[460]
Crassiclypeus aquaticus	Submerged decaying wood (pond)	**Japan**	[808]
Pseudocapulatispora longiappendiculata	Submerged decaying wood (stream)	**China**	[7]
Flabellascoma aquaticum	Submerged decaying wood (river)	**China**	[460]
Lentistoma aquaticum	Submerged decaying wood	**Thailand**	[7]
Lentistoma bipolare	Submerged decaying wood (lake, river, reservoir, stream, waterfall), submerged decaying *Licuala longicalycata* and *Metroxylon sagu* (peat swamp)	Australia, Brunei, China, **Japan**, Malaysia, Philippines Seychelles, South Africa, Thailand, USA	[70, 432, 693, 705, 797, 808–810, 446, 583–585, 626, 627, 656, 662]
Lophiostoma amphibium	*Equisetum fluviatile, Carex rostrata, C. nigra*	Austria	[642]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Lophiostoma appendiculatum	Submerged *Salix* wood (lake)	USSR	[788]
Lophiostoma aquaticum	Submerged decaying wood (river, stream)	Brunei, Malaysia, South Africa. UK	[583, 696, 797, 811]
Lophiostoma frondisubmersum	Submerged rachides of *Livistona*, submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp), submerged decaying wood (stream, river, waterfall) and bamboo (river)	New Guinea, Philippines, Thailand, USA	[62, 432, 521, 584, 656, 750]
Lophiostoma lunisporum	Submerged decaying wood (lake)	Australia	[447]
Lophiostoma maquilingense	Submerged decaying wood (stream)	Philippines	[797]
Lophiostoma proprietunicatum	Submerged decaying wood (lake)	China	[627, 812]
Lophiostoma purpurascens	Submerged decaying wood (river, stream)	Australia, China, New Guinea	[662, 797]
Neotrematosphaeria biappendiculata	Submerged decaying wood (pond)	**Japan**	[813]
Neovaginatispora fuckelii	Submerged decaying wood (stream)	**China**	[460]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Sigarispora arundinis	*Phragmites australis*	USSR	[788]
Sigarispora clavata	Submerged decaying wood	**China**	[460]
Vaginatispora aquatica	Submerged decaying wood (stream)	Australia, China, **Thailand**	[662, 814, 815]
Vaginatispora armatispora	Submerged decaying wood (waterfall)	**Thailand**	[460, 511, 816]
Lophiotremataceae			
Lophiotrema culmifragum	*Schoenoplectus lacustri*	USSR	[788]
Lophiotrema rubi	Submerged, partially decomposed wood (lake)	USA	[749]
Massarinaceae			
Byssothecium circinans	Submerged decaying wood (stream)	Hungary	[817, 818]
Byssothecium flumineum	Twigs of *Prunus serotina* (creek)	USA	[819]
Helminthosporium aquaticum	Submerged decaying wood (stream)	**China**	[820]
Helminthosporium velutinum	Submerged decaying wood (stream)	**China**	[820]
Massarina australiensis	Submerged decaying wood (waterfalls)	Australia	[72]
Massarina eburnea	Submerged decaying wood (lake)	USA	[749]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Melanommataceae			
Bertiella ellipsoidea	Submerged decaying wood (stream)	**Thailand**	[312]
Byssosphaeria schiedermayeriana	Submerged decaying wood (river)	Seychelles	[693]
Byssosphaeria siamensis	Submerged decaying wood (stream)	**Thailand**	[312]
Camposporium appendiculatum	Submerged decaying wood (river)	**China**	[403]
Camposporium antennatum	Foam (stream), water (stream)	Hungary, Venezuela	[519, 722]
Camposporium cambrense	Submerged decaying wood (river, stream, waterfall)	Thailand	[521]
Camposporium dulciaquae	Submerged decaying wood (stream)	**Thailand**	[386]
Camposporium fusisporum	Submerged decaying wood (river)	Philippines	[432]
Camposporium hyalinum	Submerged cupules of *Fagus sylvatica* (stagnant water)	UK	[523]
Camposporium marylandicum	Submerged decaying wood (river)	USA	[524]
Camposporium multiseptatum	Submerged decaying wood (river)	**China**	[403]
Camposporium pellucidum	Submerged decaying wood (stream, reservoir), foam (stream), water-filled treeholes	Austria, Brazil, **China**, Hungary, India, Ireland, UK,	[17, 403, 519, 628, 631, 637, 638, 719, 722,

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
		Venezuela	821]
Camposporium quercicola	Submerged decaying bamboo (river)	Philippines	[432]
Camposporium septatum	Submerged decaying wood (stream)	**Thailand**	[403]
Herpotrichia dalisayi	Submerged decaying wood (stream)	Philippines	[822]
Mamillisphaeria dimorphospora	Submerged decaying wood (stream)	Australia, Brunei, Malaysia	[583, 660, 752, 823, 824]
Melanomma australiense	Submerged decaying wood (stream)	Australia	[752, 801]
Phragmocephala atra	Submerged decaying wood (stream)	**China**	[825]
Phragmocephala garethjonesii	Submerged decaying wood (stream)	**China**	[825]
Phragmocephala glanduliformis	Water-filled treeholes	Hungary	[638]
Tumularia aquatica	Foam (rivulet, stream), submerged decaying leaves of broad-leaved trees and shrubs, water (river), submerged leaf litter of *Alnus glutinosa* (stream)	Austria, Brazil, Canada, Cuba, **Czech Republic**, France, India, **Poland**, UK, USA	[63, 588, 739, 826, 827, 628, 630, 631, 637, 713, 714, 728, 736]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Tumularia tuberculata	Foam (stream), submerged leaves of *Alnus glutinosa*, *Alnus* sp., *Quercus*, and *Fagus sylvatica*, stemflow and throughfall of tree canopies, water (stream)	Austria, Canada, France, Hungary, India, Spain	[588, 628, 630, 636, 783, 828, 829]
Morosphaeriaceae			
Aquihelicascus songkhlaensis	Submerged decaying wood (stream)	**Thailand**	[7]
Aquihelicascus thalassioideus	Submerged decaying wood (lake, river, stream, waterfall), bamboo (river), twigs	Australia, Brunei, China, Martinique, Peru, Japan, Philippines, **Thailand**	[7, 398, 432, 521, 583, 627, 657, 662, 797, 830]
Aquihelicascus yunnanensis	Submerged decaying wood (stream)	**China**	[7]
Neohelicascus aquaticus	Submerged decaying wood (pond, stream)	**China**, **Japan**, **Thailand**	[7, 398, 830, 831]
Neohelicascus chiangraiensis	Submerged decaying wood (pond)	**Thailand**	[515]
Neohelicascus egyptiacus	Submerged decaying dicotyledonous wood (river)	**Egypt**	[830]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Neohelicascus elaterascus	Submerged decaying wood (stream, river) and bamboo (river); twigs (lake)	Brunei, Chile, China, Japan, Peru, Philippines, South Africa, **Thailand**, USA	[7, 398, 696, 832, 432, 583, 626, 627, 653, 656, 657, 662]
Neohelicascus gallicus	Submerged wood of *Alnus glutinosa, Corylus avellana, Robinia pseudoacacia, Fraxinus excelsior, Salix* sp. (brook)	**France**	[833]
Neohelicascus submersus	Submerged decaying wood (river)	**China**	[7]
Neohelicascus unilocularis	Submerged decaying wood (river)	**Martinique**	[833, 834]
Neohelicascus uniseptatus	Submerged decaying wood (stream)	**Thailand**	[515]
Mycoporaceae			
Mycoporum antecellens	Twig (waterfall)	Canada	[619]
Neopyrenochaetaceae			
Neopyrenochaeta asexualis	Submerged plant debris	**Spain**	[758]
Neopyrenochaeta glabra	Submerged plant debris	**Spain**	[758]
Neopyrenochaeta submersa	Submerged plant debris	**Spain**	[758]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Pyrenochaetopsidaceae			
Pyrenochaetopsis aquatica	Submerged plant debris	**Spain**	[758]
Nigrograna ceae			
Nigrograna aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Nigrograna cangshanensis	Submerged decaying wood (stream)	**China**	[415]
Occultibambusaceae			
Brunneofusispora hyalina	Submerged decaying wood (stream)	**Thailand**	[386]
Occultibambusa aquatica	Submerged decaying bamboo (waterfall)	**Thailand**	[310]
Occultibambusa kunmingensis	Submerged decaying bamboo (stream)	**China**	[7]
Occultibambusa pustula	Submerged decaying wood (stream)	**China**	[7]
Seriascoma didymosporum	Submerged decaying wood (stream)	**China**	[7]
Parabambusicolaceae			
Aquastroma magniostiolatum	Submerged decaying wood (pond, stream)	**Japan**, **Thailand**	[7, 398]
Parabambusicola aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Paramonodictys solitarius	Submerged decaying wood (stream)	**Thailand**	[7]
Periconiaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Periconia aquatica	Submerged decaying wood (river)	**China**	[514]
Periconia byssoides	Submerged decaying wood (lake)	USA, China	[627, 773]
Periconia cookei	Submerged decaying wood (stream)	**China**	[312]
Periconia digitata	Submerged decaying wood (lake)	China	[627]
Periconia minutissima	Submerged decaying wood (stream, river)	Brazil, **China,** Philippines	[432, 514, 627, 670, 683]
Periconia pseudobyssoides	Submerged decaying wood (stream)	**China**	[312]
Periconia pseudodigitata	Dead culms of *Phragmites australis*, submerged stems of unidentified herbaceous plant (river)	**Japan**	[398]
Periconia submersa	Submerged decaying wood (river)	**China**	[514]
Phaeoseptaceae			
Phaeoseptum aquaticum	Submerged branch of *Robinia pseudoacacia*; driftwood of *Salix* sp	**France**	[835]
Pleopunctum pseudoellipsoideum	Submerged decaying wood	**China**	[7]
Phaeosphaeriaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Didymocyrtis pseudeverniae	Nature Reserve	Ukraine, UK	[621]
Juncaceicola alpina	*Carex rostrata, Equisetum fluviatile*	Austria	[642]
Leptospora rubella	Submerged decaying wood (lake)	**UK**	[310]
Ophiobolus typhae	Submerged decaying leaves of *Typha latifolia*	UK	[59]
Ophiosphaerella herpotricha	*Typha* sheath	UK	[781]
Phaeosphaeria caricis	Submerged decaying grass (lake)	USA	[749]
Phaeosphaeria caricinella	*Carex rostrata, C. paupercula* subspec. *irrigua, Juncus filiformis*	Austria	[642]
Phaeosphaeria culmorum	*Carex rostrata, Equisetum fluviatile, Glyceria fluitans*	Austria	[642]
Phaeosphaeria eustoma	Submerged decaying wood (river), *Typha* leaves, *Scirpus*	UK, USA	[836] [654, 781]
Phaeosphaeria halima	*Phragmites australis* stem	UK	[786]
Phaeosphaeria herpotrichoides	Submerged beech wood, *Carex rostrata*	Austria, UK	[642, 760]
Phaeosphaeria juncicola	*Scirpus, Typha*	USA	[654]
Phaeosphaeria licatensis	*Typha* leaves	UK	[781]
Phaeosphaeria microscopica	*Phragmites australis* leaves and steam	UK	[786, 789]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Phaeosphaeria sowerbyi	*Typha* leaves	USA	[654]
Phaeosphaeria vilasensis	Submerged decaying *Juncus* stem (lake)	USA	[837]
Pleomassariaceae			
Beverwykella cerebriformis	Submerged decaying angiospermic leaves (stream)	Malaysia	[838]
Beverwykella clathrata	Submerged decaying leaves of *Pinus serotina* and evergreen broad-leaved shrubs (puddles), *Calophyllum brasiliense* (stream)	Brazil, USA	[88, 839]
Beverwykella pulmonaria	Decaying leaves (tin can filled with rainwater), rainwater from building roofs, blackened leaf (pond), submerged *Fagus* leaves (stream), water-filled treeholes	Hungary, Ireland, Netherlands, Poland, UK	[633, 638, 719, 840]
Splanchnonema britzelmayrianum	Submerged decaying wood (stream)	Hungary	[817]
Pleomonodictydaceae			
Pleomonodictys capensis	Submerged decaying wood (stream)	Brunei, **China**	[583, 590]
Pleosporaceae			
Alternaria alternata	Water (river)	**Poland**	[728]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Clathrospora permunda	*Scirpus, Typha* (lake)	USA	[654]
Comoclathris typhicola	Submerged *Typha* leaves	UK	[781]
Curvularia eragrostidis	Submerged decaying wood (stream)	**China**	[825]
Curvularia geniculata	Submerged leaf	Brazil	[697]
Curvularia muehlenbeckiae	Submerged decaying twig	**Korea**	[841]
Curvularia pseudobrachyspora	Submerged decaying plant material	**Korea**	[841]
Curvularia verruculosa	Submerged decaying wood (stream)	**China**	[825]
Decorospora gaudefroyi	Submerged decaying wood	UK	[318]
Platysporoides tirolensis	*Carex rostrata* (lake)	Austria	[642]
Pleospora hydrophila	*Salix* wood	USSR	[788]
Pleospora incerta	*Carex rostrata*	Austria	[642]
Pleospora palustris	*Scirpus maritimus*	UK	[318]
Pleospora pelagica	Submerged decaying wood (stream)	China	[624]
Pleospora phaeospora	*Equisetum fluviatile* (lake)	Austria	[642]
Pleospora scirpicola	Submerged decaying *Scirpus validus* stems	UK, USA, USSR	[61, 749, 788]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
	(lake), *Schoenoplectus lacustris* stalks (lake)		
Pleospora submersa	Submerged decaying *Salix* twigs	UK	[318]
Stemphylium majusculum	Submerged decaying wood (stream)	Brunei	[583]
Typhicola typharum	Submerged decaying *Typha latifolia* stem and leaves (lake)	USA, UK	[654, 749, 781, 842]
Pseudoastrosphaeriellaceae			
Carinispora nypae	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Pseudoastrosphaeriella africana	Dead bamboo stems (waterfall)	**Thailand**	[843]
Pseudoastrosphaeriella aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Pseudoastrosphaeriella bambusae	Submerged dead branches of bamboo and wood (stream)	**Thailand**	[7, 843]
Pseudoastrosphaeriella longicolla	Submerged dead branches of bamboo	**Thailand**	[843]
Pseudoastrosphaeriella papillata	Submerged decaying wood and bamboo (lake)	Brunei, China, Philippines	[432, 627, 751]
Pseudoberkleasmiaceae			
Pseudoberkleasmium chiangmaiense	Submerged decaying wood (river)	**China**	[590]
Roussoellaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Roussoella aquatica	Submerged decaying wood (stream)	**China**	[7]
Roussoella intermedia	Submerged, partially decomposed bark (lake)	USA	[749]
Roussoella minutella	Submerged decaying wood and bamboo (river)	Philippines	[432]
Neoroussoella bambusae	Submerged decaying wood (stream)	**China**	[7]
Neoroussoella leucaenae	Submerged decaying wood (stream)	**China**	[7]
Sporormiaceae			
Sporormiella minima	Submerged wood (water-cooling towers)	UK	[760]
Sporormiella minimoides	Submerged decaying wood (lake)	China	[627]
Westerdykella aquatica	Endophytic in *Acorus calamus* (pond), mud (rice field), sediment	**China, Korea**	[702, 844]
Westerdykella aurantiaca	Sediment	**Korea**	[702]
Westerdykella dispersa	Sediment	**Korea**	[702]
Westerdykella multispora	Beech wood	UK	[761]
Westerdykella purpurea	Submerged decaying wood (stream)	**Thailand**	[807]
Striatiguttulaceae			
Longicorpus striatisporus	Submerged decaying wood (river, stream, waterfall)	Thailand	[521]
Teichosporaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Chaetomastia clavigera	*Schoenoplectus lacustris*	USSR	[788]
Testudinaceae			
Angustospora nilensis	Submerged decaying wood (river)	**Egypt**	[302]
Tetraplosphaeriaceae			
Aquatisphaeria thailandica	Submerged decaying wood (stream)	**Thailand**	[845]
Ernakulamia cochinensis	Submerged decaying wood and leaf (stream)	Brazil, **Thailand**	[7, 697]
Shrungabeeja aquatica	Submerged decaying wood (stream)	**Thailand**	[7]
Shrungabeeja vadirajensis	Submerged decaying wood (stream)	**Thailand**	[7]
Tetraploa abortiva	Decaying leaf litter (river)	Argentina	[589]
Tetraploa aquatica	Submerged decaying wood (river)	**China**	[846]
Tetraploa aristata	Decaying palm leaflets, submerged branches, roots of *Ctenanthe oppenheimiana* and *Stromanthe sanguinea*, stemflow and throughfall of tree canopies, submerged decaying woods (stream, waterfall, river), foam (stream), decaying *Metroxylon sagu* (peat swamp)	Argentina, Brazil, China, Hungary, India, Japan, Malaysia, Peru, Thailand	[78, 521, 585, 589, 636, 731, 847–849]
Tetraploa ellisii	Leaf lesions of *Oryza sativa* (river)	Peru	[589]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Tetraploa puzheheiensis	Submerged decaying wood (wetland)	**China**	[7]
Tetraploa scheueri	Decaying leaves, *Carex acutiformis*	UK	[850]
Tetraploa thailandica	Submerged decaying wood	**Thailand**	[590]
Tetraploa yunnanensis	Submerged decaying wood (werland)	**China**, Thailand	[7]
Triplosphaeria acuta	Submerged bamboo culms (stream)	**Japan**	[851]
Thyridariaceae			
Thyridaria triseptata	Submerged decaying wood (lake)	USA	[749]
Torulaceae			
Dendryphion aquaticum	Submerged decaying wood (stream)	**China**	[699]
Dendryphion comosum	Submerged leaves	Brazil	[697]
Dendryphion fluminicola	Submerged decaying wood	**China**	[852]
Dendryphion nanum	Submerged decaying wood (river, stream))	**China,** USA	[699]
Dendryphion submersum	Submerged decaying wood (stream)	**China**	[699]
Neotorula aquatica	Submerged decaying wood (stream)	**China**	[699]
Neotorula submersa	Submerged decaying wood (river)	**China**	[310]
Rostriconidium aquaticum	Submerged decaying wood (river)	**China**	[852]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Rostriconidium cangshanense	Submerged decaying wood (stream)	**China**	[853]
Rostriconidium pandanicola	Submerged decaying wood (river)	**China**	[853]
Torula aquatica	Submerged decaying wood (lake, river)	**China**	[852]
Torula herbarum	Submerged decaying wood (stream, lake)	Brazil, China	[627, 683]
Torula fici	Submerged decaying wood (river)	**China**	[852]
Torula gaodangensis	Submerged decaying twig (river)	**China**	[312]
Torula masonii	Submerged decaying wood (lake)	**China**	[852]
Trematosphaeriaceae			
Falciformispora aquatica	Submerged decaying wood (waterfall)	**Thailand**	[511]
Falciformispora lignatilis	Submerged decaying wood	USA	[656]
Falciformispora uttaraditensis	Submerged decaying twigs (creek)	**Thailand**	[403]
Hadrospora fallax	Submerged decaying wood (lake, river)	China, USA	[582, 627]
Trematosphaeria callicarpa	Submerged decaying wood (lake) and bamboo (river)	China, Philippines, USA	[432, 627]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Trematosphaeria confusa	Submerged decaying wood (stream)	Australia, Malaysia	[583, 809]
Trematosphaeria hydrela	Decaying wood	Union of Soviet Socialist Republics	[854]
Trematosphaeria lineolatispora	Submerged decaying wood	USA	[656]
Trematosphaeria pertusa	Submerged decaying wood (water-cooling tower)	Hungary, Japan, UK	[398, 760, 817, 855]
Wicklowiaceae			
Wicklowia aquatica	Submerged decorticated debris (river)	**USA**	[569]
Wicklowia phuketensis	Submerged decaying wood (stream)	**Thailand**	[457]
Wicklowia submersa	Submerged decaying wood (stream)	**Thailand**	[455]
Pleosporales genera *incertae sedis*			
Ascorhombispora aquatica	Submerged bamboo (stream)	China	[856]
Fusiformiseptata crocea	Submerged decaying wood (stream)	**Thailand**	[7]
Isthmosporella pulchra	Submerged decorticated wood (lake)	USA	[857]
Mycoenterolobium aquadictyosporium	Submerged decaying wood (stream)	**Thailand**	[451]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Mycoenterolobium platysporum	Submerged decaying wood (stream)	Brazil	[683]
Scolecobasidium anellii	Foam and submerged decaying leaf litter (stream)	India	[722]
Scolecobasidium dendroides	Submerged decaying wood (stream)	Brunei	[583]
Scolecobasidium flagelliferum	Rainwater from building roofs	Poland	[633]
Rebentischia unicaudata	Submerged decaying wood (swamp)	USA	[706]
Repetophragma fasciatum	Submerged decaying leaves (stream)	Brazil	[683]
Trypetheliales			
Polycoccaceae			
Polycoccum sp.	Stream and lake margin	Europe	[647]
Trypetheliaceae			
Arthopyrenia fallaciosa	River watershed	Canada	[622]
Tubeufiales			
Tubeufiaceae			
Acanthohelicospora aurea	Submerged decaying wood (stream)	Thailand	[858]
Acanthohelicospora guianensis	Submerged decaying wood (stream, reservoir), stemflow	China, India, Thailand	[626, 727, 858]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Acanthophiobolus helicosporus	*Carex paniculata*	Denmark	[859]
Aquaphila albicans	Submerged decaying wood (lake, river, stream, waterfall), bamboo (river)submerged rotting wood of angiosperm	Australia, Brunei, China, Malaysia, Philippines, **Thailand**	[7, 310, 432, 521, 583, 627, 860]
Berkleasmium aquaticum	Submerged decaying wood (stream)	**China**	[861]
Berkleasmium corticola	Submerged decaying wood (stream)	Brazil, China	[583, 683]
Berkleasmium guangxiense	Submerged decaying wood (stream)	**China**	[861]
Berkleasmium latisporum	Submerged decaying wood (stream)	**Thailand**	[7, 861]
Berkleasmium longisporum	Submerged decaying wood (stream)	**Thailand**	[459]
Berkleasmium micronesiacum	Submerged decaying *Eleiodoxa conferta* and *Nenga pumila* (peat swamp)	Thailand	[62, 585]
Berkleasmium monilicellulare	Submerged decaying bamboo (river)	Philippines	[432]
Berkleasmium moriforme	Submerged decaying wood (stream)	Malaysia	[583, 660]
Berkleasmium thailandicum	Submerged decaying wood (stream)	**Thailand**	[861]
Berkleasmium typhae	Submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	Thailand	[584] [62]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Berkleasmium zhejiangense	Submerged decaying wood (stream)	China	[862]
Boerlagiomyces grandisporus	Submerged decaying wood (river)	Philippines	[432, 863]
Boerlagiomyces lacunosisporus	Submerged decaying wood (river)	Australia	[864]
Boerlagiomyces websteri	Submerged decorticated wood (river)	USA, Thailand	[500, 865]
Camporesiomyces vaccinii	Stemflow and throughfall of palm species	India	[727]
Chlamydotubeufia chlamydospora	Submerged twig (creek)	Panama	[866]
Chlamydotubeufia cylindrica	Submerged decaying wood (stream)	**Thailand**	[459]
Chlamydotubeufia huaikangplaensis	Submerged decaying wood (stream)	**Thailand**	[514]
Chlamydotubeufia krabiensis	Submerged decaying wood (stream)	**Thailand**	[514]
Dematiohelicoma perelegans	Submerged decaying wood (stream)	Thailand	[858]
Dematiohelicomyces helicosporus	Submerged decaying wood (stream)	**Thailand**	[310, 459]
Dictyospora thailandica	Submerged decaying wood	**Thailand**	[459, 867]
Helicoarctatus aquaticus	Submerged decaying wood (stream)	**Thailand**	[459]
Helicoarctatus thailandicus	Submerged decaying wood (stream)	**Thailand**	[868]
Helicodochium amazonicum	Submerged decaying wood	Brazil	[869]
Helicodochium aquaticum	Submerged decaying wood (stream)	**Thailand**	[459]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Helicohyalinum aquaticum	Submerged decaying wood	**Thailand**	[867]
Helicoma ambiens	Stemflow and throughfall of tree canopies	India	[636]
Helicoma atroseptatum	Submerged decaying wood (stream)	Thailand	[858]
Helicohyalinum infundibulum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicoma aquaticum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicoma gigasporum	Submerged decaying wood, decaying *Licuala longicalycata* (peat swamp)	China. Thailand	[585, 700]
Helicoma guttulatum	Submerged decaying wood, bamboo (river)	Philippines, **Thailand**	[310]
Helicoma hongkongense	Submerged decaying wood (stream)	China, **Thailand**	[459, 700]
Helicoma longisporum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicoma multiseptatum	Submerged decaying wood (stream)	**China**	[459]
Helicoma nematosporum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicoma pannosum	Submerged decaying wood (stream, river)	Malaysia, Thailand	[583, 660, 858]
Helicoma resinae	Submerged decaying wood (stream)	Thailand	[858]
Helicoma septoconstrictum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicomyces ambiguous	Submerged decaying wood (river)	USA	[690]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Helicomyces bellus	Water-filled treeholes	Hungary	[638]
Helicomyces chiayiensis	Submerged decorticated wood (stream)	**China**	[870]
Helicomyces colligatus	Submerged decaying wood, stemflow and throughfall of tree canopies, foam (stream)	India, **Thailand**, Venezuela	[459, 519, 636]
Helicomyces geniculatus	Submerged decaying wood (stream)	**China**	[870]
Helicomyces hyalosporus	Submerged decaying wood (stream)	**China**	[459]
Helicomyces macrofilamentosus	Submerged decaying wood (stream)	Thailand	[858]
Helicomyces roseus	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (lake, stream, river, waterfall), stemflow and throughfall of tree canopies and palm species, leaves (stream), foam (stream)	Australia, Brazil, Brunei, China, India, Malaysia, Thailand	[70, 446, 858, 521, 583, 627, 636, 683, 691, 722, 727]
Helicomyces scandens	Stemflow and throughfall of tree canopies	India	[636]
Helicomyces torquatus	Submerged decaying wood (stream), twig, foam (stream), stemflow and throughfall of palm species	Brunei, **China**, India, Malaysia, Panama, **Thailand**,	[459, 519, 583, 727, 871, 872]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
		Venezuela	
Helicosporium aquaticum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicosporium flavidum	Submerged decaying culms of *Miscanthus floridulus* (stream)	**China**	[581]
Helicosporium flavisporum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicosporium flavum	Submerged decaying wood	**Thailand**	[867]
Helicosporium gracile	Submerged decaying wood (wood)	Thailand	[858]
Helicosporium lumbricopsis	Submerged decaying wood (wood)	Thailand	[858]
Helicosporium murinum	Stemflow and throughfall of palm species	India	[727]
Helicosporium panachaeum	Submerged decaying wood (wood)	Thailand	[858]
Helicosporium setiferum	Submerged decaying wood (stream)	**Thailand**	[459]
Helicosporium thailandense	Submerged decaying wood (stream)	**Thailand**	[7]
Helicosporium vesicarium	Submerged decaying wood (stream)	**Thailand**	[459]
Helicotruncatum palmigenum	Submerged decaying wood (stream)	**Thailand**	[7]
Helicotubeufia guangxiensis	Submerged decaying wood (stream)	**China**	[568]
Helicotubeufia jonesii	Submerged decaying wood (stream)	**China**	[568]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Muripulchra aquatica	Submerged decaying wood (stream)	**China**	[458]
Neochlamydotubeufia fusiformis	Submerged decaying wood (stream)	**Thailand**	[459]
Neochlamydotubeufia khunkornensis	Submerged decaying wood (stream)	**Thailand**	[459]
Neohelicomyces aquaticus	Submerged decaying wood (river)	**China**	[458]
Neohelicomyces dehongensis	Submerged decaying wood (stream)	**China**	[7]
Neohelicomyces grandisporus	Submerged decaying wood (river)	**China**	[458]
Neohelicomyces hyalosporus	Submerged decaying wood (stream)	**China**	[459]
Neohelicomyces longisetosus	Submerged decaying culms of *Miscanthus floridulus* (stream)	**China**	[581]
Neohelicomyces submersus	Submerged decaying wood (stream)	**China**	[458]
Neohelicomyces thailandicus	Submerged decaying wood (stream)	**Thailand**	[7]
Neohelicosporium acrogenisporum	Submerged decaying wood (stream)	**Thailand**	[459]
Neohelicosporium aquaticum	Submerged decaying wood (stream)	**China**	[873]
Neohelicosporium astrictum	Submerged decaying wood (stream)	**Thailand**	[459]
Neohelicosporium ellipsoideum	Submerged decaying wood (stream)	**Thailand**	[459]
Neohelicosporium guangxiense	Submerged decaying wood (stream)	**China**	[873]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Neohelicosporium griseum	Submerged decaying wood (wood, reservoir, river)	Brunei, China, Malaysia, Thailand	[583, 626, 660, 858]
Neohelicosporium hyalosporum	Submerged decaying wood (stream)	**China**	[873]
Neohelicosporium irregulare	Submerged decaying wood (stream)	**Thailand**	[459]
Neohelicosporium krabiense	Submerged decaying wood (stream)	**Thailand**	[459]
Neohelicosporium parvisporum	Submerged decaying wood (stream)	**China**	[873]
Neohelicosporium submersum	Submerged decaying wood (stream)	**Thailand**	[7]
Neohelicosporium sympodiophorum	Submerged decaying culm of *Miscanthus floridulus* (stream)	China	[581]
Neohelicosporium taiwanense	Submerged decaying wood (stream)	**China**	[870]
Neohelicosporium thailandicum	Submerged decaying wood (stream)	**Thailand**	[873]
Neotubeufia krabiensis	Submerged decaying wood (stream)	**Thailand**	[874]
Parahelicomyces talbotii	Submerged decaying wood (stream)	**China, Thailand**	[459, 581]
Parahelicomyces aquaticus	Submerged decaying wood (stream)	**Thailand**	[459]
Parahelicomyces hyalosporus	Submerged decaying wood (stream)	**China**	[458]
Pseudohelicoon gigantisporum	Submerged decaying wood (stream), water (river)	Australia, **Poland**,	[728, 858, 875]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
		Thailand	
Pseudohelicoon subglobosum	Submerged decaying wood (stream)	**China**	[876]
Thaxteriellopsis lignicola	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia abundata	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia aquatica	Submerged decaying wood (stream)	**China, Thailand**	[7, 458, 459]
Tubeufia brevis	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia brunnea	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia cerea	Foam, submerged decaying leaf litter (stream)	India	[722]
Tubeufia chlamydospora	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia claspisphaeria	Submerged decaying wood, submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	China, Thailand	[62, 584, 877]
Tubeufia cylindrothecia	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (stream)	**China, Thailand**	[7, 70, 458, 459]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Tubeufia dictyospora	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia eccentrica	Submerged decaying wood (stream)	**China**	[459]
Tubeufia fangchengensis	Submerged decaying wood (stream)	**China**	[459]
Tubeufia filiformis	Submerged decaying wood (stream)	**Thailand**	[459, 878]
Tubeufia geniculata	Submerged decaying wood (stream)	**China**	[459]
Tubeufia guangxiensis	Submerged decaying wood (stream)	**China**	[459, 874]
Tubeufia hechiensis	Submerged decaying wood (stream)	**China**	[459]
Tubeufia hyalospora	Submerged decaying wood (stream)	**Thailand**	[310]
Tubeufia inaequalis	Submerged decaying wood (stream)	**China, Thailand**	[459]
Tubeufia krabiensis	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia latispora	Submerged decaying wood (stream)	**Thailand**	[878]
Tubeufia laxispora	Submerged decaying wood (stream)	**Thailand**	[459, 878]
Tubeufia mackenziei	Submerged decaying wood (stream)	**Thailand**	[878]
Tubeufia palmarum	Submerged decaying wood (stream, river)	Brunei, Malaysia	[583, 660]
Tubeufia parvispora	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia rubra	Submerged decaying wood (stream)	**China**	[459]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Tubeufia sympodihylospora	Submerged decaying wood (stream)	**China**	[459]
Tubeufia sympodilaxispora	Submerged decaying wood (stream)	**China**	[459]
Tubeufia sympodiophora	Submerged decaying wood	China	[446]
Tubeufia taiwanensis	Submerged decaying wood (stream)	**China**	[459]
Tubeufia tectonae	Submerged decaying wood (stream)	**Thailand**	[7, 310, 459]
Tubeufia tratensis	Submerged decaying wood (stream)	**Thailand**	[459]
Tubeufia xylophila	Submerged decaying wood (stream)	**China**	[459]
Xenosporium africanum	Submerged decaying culms of *Miscanthus floridulus* (stream)	**China**	[879]
Xenosporium formosiforme	Submerged decaying culms of *Miscanthus floridulus* (stream)	**China**	[879]
Xenosporium parvulum	Submerged decaying culms of *Miscanthus floridulus* (stream)	**China**	[879]
Wiesneriomycetaceae			
Phalangispora bharathensis	Throughfall of palm species	India	[727]
Phalangispora constricta	Foam (stream, river), sediment (dam, stream), stemflow and throughfall of tree canopies	India, Malaysia, Thailand, Venezuela	[519, 636, 718, 727, 827, 880, 881]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Phalangispora nawawii	Submerged decaying leaves (river), foam (stream)	India, Malaysia, Venezuela	[519, 827, 882]
Phalangispora sinensis	Submerged decaying leaves (stream)	**China**	[883]
Setosynnema isthmosporum	Submerged decaying leaves (stream)	Papua New Guinea, Thailand	[884, 885]
Setosynnema limnetica	Submerged leaves (river)	India	[886]
Setosynnema yunnanense	Submerged decaying dicotyledonous leaves (river)	China	[887]
Speiropsis hyalospora	Submerged leaves of *Coffea arabica* (stream), foam (stream)	India	[827, 888] [722]
Speiropsis pedatospora	Rainwater from building roofs, submerged leaves of *Coffea arabica* (stream), foam (stream, rivulet), stemflow and throughfall of tree canopies	Austria, India, Poland, Thailand	[500, 631, 633, 636, 827, 888]
Speiropsis scopiformis	Submerged decaying angiospermous leaves (stream)	Brazil, Malaysia	[683, 889]
Wiesneriomyces conjunctosporus	Submerged decaying wood	Malaysia	[1394]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Wiesneriomyces laurinus	Rainwater from building roofs, submerged decaying *Licuala longicalyca*ta (peat swamp), submerged decaying leaves (stream), foam (stream)	Brazil, India, Malaysia, Poland, Thailand	[584, 585, 633, 683, 722, 890] [585, 890]
Venturiales			
Venturiaceae			
Magnohelicospora fuscospora	Submerged decaying leaves and twigs of *Salix* (reservoir)	Ireland	[719]
Dothideomycetes families *incertae sedis*			
Argynnaceae			
Lepidopterella palustris	Submerged decaying wood (swamp)	USA	[564, 656]
Lepidopterella tangerina	Submerged decaying wood (river)	USA	[656, 756]
Pseudorobillardaceae			
Pseudorobillarda phragmitis	Water (river), foam (rivulet, stream)	Austria, India, Poland	[631, 687, 722]
Pseudorobillarda sojae	Submerged decaying wood, decaying *Licuala longicalycata* (peat swamp)	**Thailand**	[585, 891]
Trichothyriaceae			

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Lichenopeltella nigroannulata	*Carex nigra, C. rostrata, Equisetum fluviatile, Eriophorum angustifolium, Juncus filiformis* (lake)	Austria	[642]
Dothideomycetes genera *incertae sedis*			
Alascospora evergladensis	Submerged petiole of *Nymphaea odorata*	USA	[892]
Ascominuta lignicola	Submerged decaying wood, submerged decaying *Licuala longicalycata* and *Nenga pumila* (peat swamp)	China, Thailand	[584, 585, 816, 893]
Ascominuta ovalispora	Submerged decaying wood (stream)	Thailand	[703]
Bactrodesmium aquaticum	Submerged decaying wood (river, reservoir)	India	[894]
Bactrodesmium indicum	Submerged beech test block (cooling tower)	India	[895]
Bactrodesmium spilomeum	Submerged decaying wood (river)	UK	[688]
Clavariopsis aquatica	Submerged decaying wood (*Alnus glutinosa, Acer pseudoplatanus, Corylus avellana, Tilia cordata, Salix* spp., *Populus* spp., *Betula glandulosa,* and *Alnus tenuifolia*) (stream), submerged decaying leaves of *Coffea arabica* and *Hevea brasiliensis* (stream), foam (stream, rivulet, river, spring, lake), water (river, stream), scum (stream), sediment	Austria, Canada, **Czech Republic**, France, India, Ireland, Japan, **Poland**, Portugal, Spain, UK, USA, Venezuela	[13, 63, 687, 713–718, 721, 728, 729, 519, 731, 732, 736, 783, 888, 588, 628, 630–632,

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
	(dam), stemflow and throughfall of tree canopies		636, 639]
Clavariopsis azlanii	Submerged decaying leaves, foam (stream)	India, Malaysia, Venezuela	[519, 722, 896]
Clavariopsis brachycladia	Submerged leaf of *Acer*	Japan	[64]
Clavariopsis bulbosa	Foam (stream)	India	[722]
Gibbera myrtilli	Submerged decaying leaves of *Vaccinium macrocarpon, V. oxycoccus, Ledum groenlandicum* (lake)	USA	[749]
Lucidascocarpa pulchella	Submerged decaying wood (river)	Costa Rica, Ecuador, Peru	[657, 897]
Monodictys abuensis	Submerged decaying wood (stream)	China	[583]
Monodictys castaneae	Submerged decaying wood (river)	USA	[773]
Monodictys cruciseptata	Submerged decaying wood	USA	[898]
Monodictys fluctuata	Submerged decaying wood	Thailand	[816]
Monodictys levis	Submerged decaying wood and bamboo (river)	Philippines	[432]
Monodictys melanocephaloides	Submerged decaying wood (reservoir)	China, Thailand	[626, 816]
Monodictys pandani	Submerged decaying wood (lake, river)	Australia, China	[447]

Table 7.3 (continued)

Taxon	Substrate	Country	Reference
Monodictys paradoxa	Submerged decaying wood	Thailand	[816]
Monodictys peruviana	Submerged decaying wood (stream)	China	[583]
Monodictys putredinis	Submerged decaying wood (stream), water-filled treeholes	Brazil, China, Hungary, South Africa	[78, 638, 662, 696]
Monodictys sessilis	Submerged decaying wood (river, stream)	China	[78, 662]
Monodictys striata	Submerged decaying wood (stream)	China	[662]
Monodictys trichocladiopsis	Submerged decaying wood (reservoir)	China	[626]
Ocala scalariformis	Submerged decorticated wood (lake)	**USA**	[899]
Oncopodiella trigonella	Water-filled treeholes	Hungary	[638]
Quintaria aquatica	Submerged decaying wood (river)	Australia	[801]
Quintaria microspora	Submerged wood of *Fraxinus excelsior* (stream)	France	[900]
Wettsteinina moniliformis	Submerged decaying leaf sheath (lake)	Denmark	[300]
Wettsteinina niesslii	Submerged decaying wood and *Phragmites australis* culms (lake, river)	UK, USA	[61, 773, 785, 786]

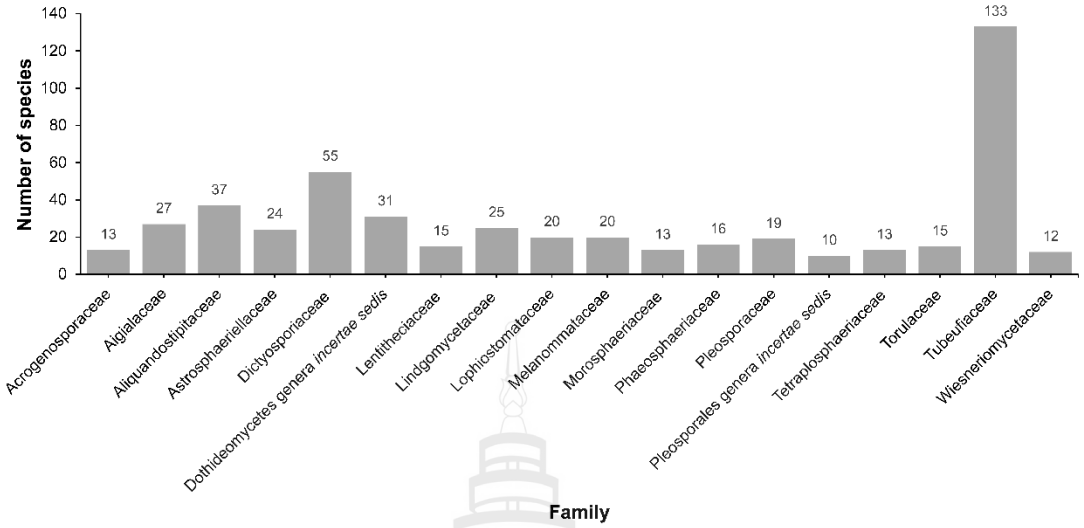


Figure 7.1 Major Families of Dothideomycetes Taxa from Freshwater Habitats

The taxonomic studies on freshwater fungi have greatly advanced with molecular data resulting in a rapid increase in fungal numbers [173, 437, 460, 698]. However, large numbers of fungi are yet to be documented in poorly studied regions as shown in Dong et al. [7]. Furthermore, the identities of some earlier proposed fungi need to be reappraised with molecular data to confirm their taxonomical status. Fungal numbers are often related to the numbers of researchers working on specific fungal groups. It is a challenge indeed for mycologists and/or taxonomists to classify and document this huge number of fungi before they become extinct.

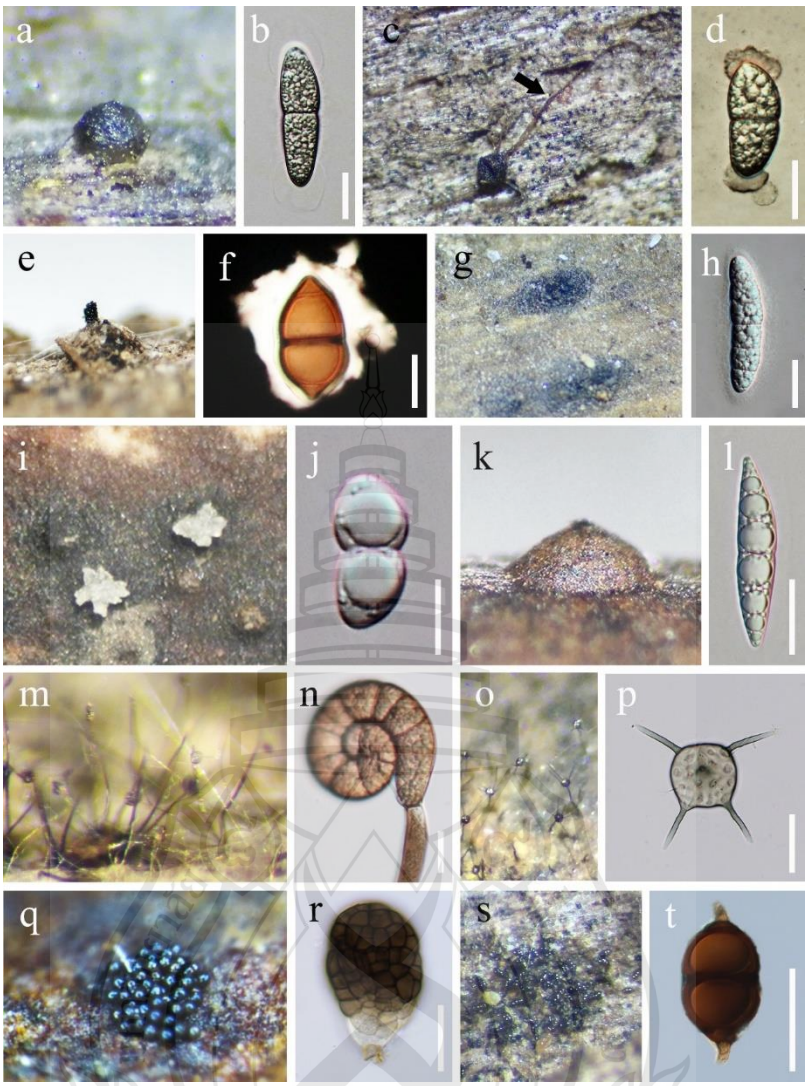


Figure 7.2 Freshwater Dothideomycetes. (a,b) *Aliquandostipite khaoyaiensis* (MFLU 18-1573); (c,d) *Ascagilis submersa* (MFLU 18-1527); (c) Ascoma on Host with Associated Appendages (Arrow); (e,f) *Caryospora aquatica* (MFLU 18-1202); (g,h) *Parabambusicola aquatica* (MFLU 18-1524); (i,j) *Longipedicellata aptrootii* (MFLU 18-1000); (k,l) *Caryospora submersa* (MFLU 18-1539); (m,n) *Helicotruncatum palmigenum* (MFLU 15-2715); (o,p) *Shrungabeeja aquatica* (MFLU 18-0978); (q,r) *Pleopunctum pseudoellipsoideum* (HKAS 102147); (s,t) *Pseudoxylomyces elegans* (MFLU 17-1712). Scale bar: (b,d,f,h,l,r) 20 µm; (j,n) 10 µm; (p) 30 µm; (t) 50 µm

7.3.1.3 Eurotiomycetes

Eurotiomycetes was established by Eriksson and Winka [901] and presently consists of six subclasses: Chaetothyriomycetidae, Coryneliomycetidae, Cryptocaliciomycetidae, Eurotiomycetidae, Mycocaliciomycetidae, and Sclerococcomycetidae [902–906]. The microcolonies of Eurotiomycetes formed under natural conditions do not have much morphological differences leading to difficulty morphologically in distinguishing species. The incorporation of molecular techniques in the fungal taxonomy made the classification of fungi more objective, accurate, and comprehensive [5, 7, 204, 903, 905, 906]. Wijayawardene et al. [204] provided an outline of the classification of the fungi and fungus-like taxa, and counted all legally published species, with a total of 3,994 Eurotiomycetes species.

The Eurotiomycetes are medically and industrially important group (e.g., producers of toxic and potentially useful metabolites, fermentation agents in food and enzymes production, pathogens of humans and animals) [907–909]. Eurotiomycetes includes mostly saprophytic species occurring in various substrates (e.g., wood, compost, dung, decaying plant material, foodstuffs, soil), and some have parasitic and/or commensal associations with other fungi [909–913].

Most species of Eurotiomycetes are reported in terrestrial environments, and freshwater environments account for only a small part [7, 74, 914] (Figure 7.3). Currently known freshwater Eurotiomycetes are mostly saprophytes on submerged wood, decaying leaves, branches, and plant debris in lakes and streams [74, 915–917]. Some taxa grow on inundated stones and isolated from sediments in freshwater habitats, and even from drinking water [918–920].

Table 7.4 lists 276 species of freshwater Eurotiomycetes fungi, but this number is undoubtedly underestimated. The data includes common taxa in freshwater environments, i.e., *Aspergillus*, *Penicillium*, *Thelidium*, *Verrucaria*., and most of this data comes from cultivable fungi. In this paper, freshwater Eurotiomycetes are documented from seven orders, thirteen families and 49 genera. Verrucariales is the largest freshwater order with 127 freshwater species, followed by Eurotiales and Chaetothyriales with 76 and 46 freshwater species, respectively (Table 7.4). Representative freshwater Eurotiomycetes are illustrated in Figure 7.3. The most speciose genus is *Verrucaria* with 50 freshwater species, followed by *Penicillium* (47

species), *Thelidium* (22 species), *Aspergillus* (18 species), *Exophiala* (17 species), and *Staurothele* (16 species). Many freshwater Eurotiomycetes are uncultivable, and some groups are misidentified without the help of molecular data as morphologically, they are indistinguishable. In addition, some species will inevitably be missed in the process of searching the published literature.

Table 7.4 Classification of Freshwater Eurotiomycetes with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	Reference
EUROTIOMYCETES			
Chaetothyriomycetidae			
Chaetothyriales			
Cyphellophoraceae			
Anthopsis microspora	Scum (stream)	Japan	[921]
Cyphellophora oxyspora	Water (swimming pool)	**Germany**	[922]
Cyphellophora catalaunica	Sediments (river)	**Spain**	[920]
Kumbhamaya jalapriya	Submerged roots of *Hopea ponga* (stream)	India	[923]
Herpotrichiellaceae			
Aculeata aquatica	Submerged decaying wood (river)	**Thailand**	[916]
Exophiala cancerae	Water	**Germany**	[919]
Exophiala castellani	Drinking water	**Germany**	[919]
Exophiala dermatitidis	Groundwater, water (river)	**Poland, Slovenia**	[648, 728]
Exophiala equina	Drinking water	Netherlands	[924]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Exophiala lecanii-corni	Tapwater	**Slovenia**	[648]
Exophiala mesophila	Waterlines, tapwater	**USA, Slovenia**	[648, 925]
Exophiala oligosperma	Tapwater	**Slovenia**	[648]
Exophiala phaeomuriformis	Tapwater	**Slovenia**	[648]
Exophiala pisciphila	Swimming pool	Germany	[926]
Exophiala psychrophila	From Atlantic salmon smolt	–	[927]
Exophiala salmonis	Cut-throat trout (*Oncorhynchus clarkii*), fingerling lake trout (*Salvelinus namaycush*)	Alberta, Canada	[928]
Exophiala angulospora	Drinking well water	Japan	[918]
Exophiala lacus	Lake	**Netherlands**	[919]
Exophiala opportunistica	Drinking water	**Germany**	[919]
Exophiala xenobiotica	Tapwater	**Slovenia**	[648]
Minimelanolocus aquaticus	Submerged decaying wood (stream)	**China**	[74]
Minimelanolocus aquatilis	Submerged decaying wood (stream)	**Brazil**	[87]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Minimelanolocus clavatus	Submerged decaying wood (stream)	**China**	[914]
Minimelanolocus nujiangensis	Submerged decaying wood (river)	**China**	[914]
Minimelanolocus submersus	Submerged decaying wood (lake)	**China**	[310]
Phialophora reptans	Drinking water	**Germany**	[922]
Phialophora aurantiaca	Water	UK	[929]
Phialophora benthica	Sediment (lake)	Canada	[930]
Rhinocladiella amoena	Submerged decaying twig	**Spain**	[931]
Rhinocladiella similis	Groundwater, tapwater	**Slovenia**	[648]
Thysanorea melanica	Submerged decaying wood (stream)	**China**	[74]
Thysanorea obscura	Submerged decaying wood (stream)	**China**	[74]
Thysanorea papuana	Submerged decaying wood (stream)	**Thailand**	[917]
Thysanorea thailandensis	Submerged decaying wood (river)	**Thailand**	[916]
Thysanorea aquatica	Submerged decaying wood (river)	**Thailand**	[916]
Thysanorea asiatica	Submerged decaying wood (stream)	**China**	[74]
Thysanorea curvata	Submerged decaying wood (stream)	**China**	[74]
Thysanorea nonramosa	Submerged decaying wood (stream)	**Thailand**	[917]
Thysanorea uniseptata	Submerged decaying wood (stream)	**Thailand**	[511]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Thysanorea yunnanensis	Submerged decaying wood (stream)	**Thailand**	[74]
Veronaea aquatica	Submerged decaying wood (stream)	China	[932]
Veronaea botryosa	Submerged decaying wood (river)	Thailand	[916]
Chaetothyriales genera *incertae sedis*			
Uncispora sinensis	Submerged decaying leaves (river)	**China**	[933]
Uncispora wuzhishanensis	Submerged decaying leaves (stream)	**China**	[915]
Adelococcaceae			
Sagediopsis lomnitzensis	Stream and lake margin	Europe	[647]
Verrucariales			
Verrucariaceae			
Agonimia allobata	Stream	Lithuania	[934]
Agonimia tristicula	Stream	UK	[935]
Clavascidium lacinulatum	Stream	UK	[646]
Catapyrenium lachneum	Stream	UK	[646]
Catapyrenium squamulosum	River watershed	Canada	[622]
Catillaria cf. *chalybeia*	Stream	Gwynedd	[646]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Dermatocarpon arnoldianum	River and stream	Europe	[936]
Dermatocarpon intestiniforme	Stream	UK	[643, 646]
Dermatocarpon leptophyllodes	Stream	UK	[646]
Dermatocarpon luridum	Stream	Poland	[934]
Dermatocarpon meiophyllizum	Stream	UK	[646]
Dermatocarpon miniatum	River	Bulgaria	[643]
Dermatocarpon rivulorum	Submerged siliceous rock (stream)	Italy	[937]
Endocarpon adscendens	Stream	UK	[646]
Hydropunctaria orae	Stream	-	[938, 939]
Hydropunctaria rheitrophila	Stream, submerged carbonic rock (stream)	Italy, Poland	[934, 937]
Hydropunctaria scabra	Siliceous rock (stream)	Bulgaria	[940]
Phaeospora lemaneae	Parasitic on *Lemanea* sp.	UK	[61]
Placopyrenium cinereoatratum	Siliceous rocks (brook, lake, river, stream)	Bulgaria, **Finland**, Norway, Sweden, **UK**	[941]
Placopyrenium formosum	Rock (river)	**Finland, Iceland, UK**	[941]
Polyblastia ardesiaca	-	Italy	[942]
Psoroglaena stigonemoides	Twig (waterfall)	Canada	[619]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Sporodictyon cruentum	River and streams	Alpine Australia, Italy, UK	[646, 942–944]
Thelidium aethioboloides	Splash water zone (creek)	**Germany**	[945]
Thelidium aquaticum	Stream	Poland	[934]
Thelidium circumspersellum	Limestone (rivulet)	Romania	[945]
Staurothele acarosporoides	Nature reserves	Northern Vietnam	[946]
Staurothele arenaria	Nature reserves	Northern Vietnam	[946]
Staurothele chlorospora	Nature reserves	Northern Vietnam	[946]
Staurothele clopimoides	River	Italy, USA	[942, 947]
Staurothele fauriei	Nature reserves	Northern Vietnam	[946]
Staurothele fissa	Lakes and Streams	Europe	[646, 942, 948, 949]
Staurothele fuscocuprea		Italy	[942]
Staurothele honghensis	Nature reserves	Northern Vietnam	[946]
Staurothele iwatsukii	River	Japan	[950]
Staurothele kwapiensis	Nature reserves	Northern Vietnam	[946]
Sagediopsis lomnitzensis	Stream and lake margin	Europe	[647]
Staurothele muliensis	Nature reserves	Northern Vietnam	[946]
Staurothele ochroplaca	Nature reserves	Northern Vietnam	[946]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Staurothele pachystroma	Nature reserves	Northern Vietnam	[946]
Staurothele paraguayensis	Nature reserves	Northern Vietnam	[946]
Staurothele sinensis	Nature reserves	Northern Vietnam	[946]
Staurothele succedens	Stream	UK, Italy	[646, 942]
Staurothele yunnanica	Nature reserves	Northern Vietnam	[946]
Thelidium carbonaceum	Nature reserves	Australia	[951]
Thelidium circumspersellum	Stream	Poland	[952]
Thelidium epomphalum	Creek and River	Europe	[953]
Thelidium carbonaceum	Nature reserves	Australia	[945]
Thelidium fontigenum	Waterfall, amphibious on limestone, lime-containing sandstone, silt-impregnated wood, and on mica schist	Austria, Germany, Switzerland	[945]
Thelidium klementii	Calcareous rocks	Germany	[945]
Thelidium lahmianum	Inundated granite boulders	Poland	[945]
Thelidium methorium	Rocks (brook, creek, river)	Austria, Czech Republic, Estonia, **Italy**, Norway, **Slovakia**, Sweden, Switzerland	[945]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Thelidium minutulum	splash water zone, limestone or basic siliceous rocks (creeks, rivers)	**Austria**, Czech Republic, Germany	[945]
Thelidium nigricans	Siliceous rocks (creek's splash water zone)	Switzerland	[945]
Thelidium papulare	Rocks (creek)	Austria, Germany	[945]
Thelidium pertusatii	Rocks (river)	**Italy**	[945]
Thelidium pluvium	Sandstone, schist (creek, river)	**Austria**, Germany	[945]
Thelidium rehmii	Sandstone rocks (creek)	**Germany**	[945]
Thelidium rivulicolum	Carbonaceous rock (creek, stream)	France, Germany	[945]
Thelidium spadanum	–	Europe	[945]
Thelidium sublacteum	–	Europe	[945]
Thelidium submethorium	Rocks (creek, river)	**Italy**, Germany	[945]
Thelidium suzaeanum	Limestone rock (river)	Slovakia	[945]
Thelidium zahlbruckneri	Stream	Poland	[934]
Thelidium zwackhii	Stream	Italy, **Germany**, Poland	[934, 945]
Verrucaria aeithiobola	Stream	Italy and UK	[936, 942]
Verrucaria alpicola		Bulgaria	[940]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Verrucaria amnica	Mountain stream	New Zealand	[954]
Verrucaria aquatilis	Nature reserve, River, Stream	Italy, alpine Australia, UK	[646, 943, 955]
Verrucaria austroalpina	Creeks and rivers	Eastern Australia	[956]
Verrucaria basaltica	Streams and lakes	Poland	[957]
Verrucaria capitulata	Submerged rocks (stream)	Japan	[958]
Verrucaria cernaensis	Stream	Poland	[934]
Verrucaria consociata	Stream	Great Britain	[959]
Verrucaria conturmatula	Stream and lake margin	Europe	[647]
Verrucaria cootapatambensis	River	Alpine Australia	[943]
Verrucaria craterigera	Friable rocks by stream in a gorge	Japan	[958]
Verrucaria devensis	Stones (river)	Germany, **UK**	[960]
Verrucaria dolosa	Stream	Poland, UK	[646, 951]
Verrucaria elaeina	Stream	Poland	[951]
Verrucaria elaeomelaena	Submerged carbonatic rock (stream)	Italy	[937]
Verrucaria funckii	Stream, submerged siliceous rock (stream)	Italy, Poland	[934, 937]
Verrucaria glaucina	Stream	UK	[646]
Verrucaria gongshanensis	Non-calcareous rocks in a stream	China	[961]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Verrucaria honghensis	Riverside rocks	China	[962]
Verrucaria humida	Wet stones in bed of streamlet in *Picea abies* forest	Germany	[934]
Verrucaria hydrela	Inundated and submerged siltstone	**UK**	[938]
Verrucaria hydrophila	Shaded stone by stream in woodland	**UK**	[938]
Verrucaria igii	River	Alpine Australia	[943]
Verrucaria inconstans	Aquatic limestone	Australia	[956]
Verrucaria latebrosa	Submerged siliceous rock (stream)	Germany, Italy, **Slovakia**, **Switzerland**	[937, 945]
Verrucaria luchunensis	Riverside rocks	China	[962]
Verrucaria maas-geesterani	Lake	Switzerland	[963]
Verrucaria madida	Sloping siliceous rocks, shallowly submerged in stream	France	[962]
Verrucaria margacea	Freshwater	Australian	[956]
Verrucaria morosa	River	Alpine Australia	[943]
Verrucaria mundula	Aquatic slate	Australia	[956]
Verrucaria nodosa	Unshaded rock in stream	**UK**	[938]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Verrucaria nujiangensis	Submerged stones in stream	China	[962]
Verrucaria pachyderma	Stream	Australia, Italy, Europe	[957, 963]
Verrucaria phaeoderma	Aquatic basalt	Australia	[956]
Verrucaria placida	Stone in shaded streamlet in woodland	Norway, Germany, **UK**	[938]
Verrucaria praetermissa	Freshwater	Australian	[956]
Verrucaria puncticulata	Inundated and submerged siltstone	Australia	[956]
Verrucaria ruttneri	River	Alpine Australia	[943]
Verrucaria rosula	Siliceous rocks and stones (reservoir, stream)	France, **UK**	[938]
Verrucaria rhizicola	Bark of roots of *Alnus glutinosa* irregularly submersed in stream	France	[964]
Verrucaria sublobulata	Stream	**Poland**	[934]
Verrucaria submauroides	Stream	**Poland**	[934]
Verrucaria submersella	Stream	**Poland**	[934]
Verrucaria takagoensis	Non-calcareous rocks submerged in stream	Japan	[965]
Verrucaria tasmanica	Aquatic dolerite	Australia	[956]
Verrucaria tholocarpa	Aquatic limestone	Australia	[956]
Verrucaria yoshimurae	Rock (gorge)	Japan	[966]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Verrucaria tholocarpa	Aquatic limestone	Australia	[956]
Willeya australis	Nature reserves	Northern Vietnam	[946]
Willeya diffractella	Nature reserves	Northern Vietnam	[946]
Willeya fusca	Nature reserves	Northern Vietnam	[946]
Willeya iwatsukii	Nature reserves, river	Japan, Northern Vietnam	[946, 950]
Willeya japonica	Nature reserves	Northern Vietnam	[946]
Willeya laevigata	Nature reserves	Northern Vietnam	[946]
Willeya malayensis	Nature reserves	Northern Vietnam	[946]
Willeya microlepis	Nature reserves	Northern Vietnam	[946]
Willeya pallidipora	Nature reserves	Northern Vietnam	[946]
Willeya protrudens	Nature reserves	Northern Vietnam	[946]
Chaetothyriomycetidae family *incertae sedis*			
Rhynchostomataceae			
Rhynchostoma pyriforme	On rotten wood in river	Dominica	[967]
Eurotiomycetidae			
Arachnomycetales			
Arachnomycetaceae			

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Arachnomyces pilosus	River sediment	Spain	[968]
Eurotiales			
Aspergillaceae			
Aspergillus aculeatus	Freshwater	UK	[969]
Aspergillus affinis	Submerged riparian decomposing leaves	**Italy**	[970]
Aspergillus candidus	River	Egypt	[971]
Aspergillus clavatus	Freshwater	UK	[969]
Aspergillus flavus	Freshwater	**Korea**	[972]
Aspergillus fumigatus	Water (river)	**Poland**	[728]
Aspergillus israelensis	Isolated from evaporation pond	**Israel**	[973]
Aspergillus japonicas	Freshwater	**Korea**	[972]
Aspergillus niger	Water (river)	**Korea**, **Poland**	[728, 972]
Aspergillus ochraceous	River	Egypt	[971]
Aspergillus parasiticus	River	Egypt	[971]
Aspergillus parvulus	Freshwater	UK	[969]
Aspergillus sydowii	River	Egypt	[971]
Aspergillus tamarii	River	Egypt	[971]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Aspergillus terreus	Lake	India	[974]
Aspergillus tubingensis	Freshwater	**Korea**	[972]
Aspergillus versicolor	Lake	India	[974]
Aspergillus wentii	Lake	India	[974]
Monascus pallens	Sediment	Iraq	[975]
Monascus sanguineus	Sediment	Iraq	[975]
Penicillium acidum	Plant debris in pond	**Korea**	[571]
Penicillium aquaticum	Plant debris in pond	**Korea**	[571]
Penicillium aurantiogriseum	Freshwater	UK	[969]
Penicillium brasilianum	Freshwater	**Korea**	[972]
Penicillium brevicompactum	Lake	Turkey	[976]
Penicillium capsulatum	River	Egypt	[971]
Penicillium camemberti	Lake	India	[974]
Penicillium chrysogenum	Lake	India	[974]
Penicillium citrinium	River	Egypt, UK	[969, 971]
Penicillium citrogenium	River	Egyptian	[971]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Penicillium commune	Lake	India, UK	[969, 974]
Penicillium corylophilum	Freshwater	UK	[969]
Penicillium crustosum	Freshwater	**Korea**	[972]
Penicillium dimorphosporum	Lake	India	[974]
Penicillium echinulatum	Freshwater	UK	[969]
Penicillium echinulonalgiovense	Freshwater	**Korea**	[977]
Penicillium expansum	Freshwater	**Korea**	[972]
Penicillium flabrum	Freshwater	UK	
Penicillium funiculosum	Water (lake, river)	India, **Poland**	[728, 974]
Penicillium glabrum	Lake	**Turkey**, UK	[969, 976]
Penicillium globosum	Freshwater	**Korea**	[977]
Penicillium griseofulvum	Freshwater	UK	[969]
Penicillium griseoroseum	Lake	Turkey	[976]
Penicillium guanacastense	Stream soil	**Korea**	[977]
Penicillium hirsutum	Freshwater	UK	[969]
Penicillium janczewskii	Freshwater	UK	[969]
Penicillium lilacinum	Lake	India	[974]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Penicillium miczynskii	Lake	**Turkey**	[976]
Penicillium miniophilum	Freshwater	UK	[969]
Penicillium ochrosalmoneum	Freshwater	UK	[969]
Penicillium onobense	Freshwater	**Korea**	[977]
Penicillium olivicolor	Lake	India	[974]
Penicillium oxalicum	Freshwater	**Korea**	[972]
Penicillium pinophilum	Freshwater	UK	[969]
Penicillium piscarium	Freshwater	**Korea**	[972]
Penicillium piscium	Internal organs of freshwater Osteichthyes	–	[978]
Penicillium puberulum	Lake	Turkey	[976]
Penicillium purpurogenum	Freshwater	UK	[969]
Penicillium raistrickii	Freshwater	UK	[969]
Penicillium saturniforme	River soil	**Korea**	[979]
Penicillium scabrosum	Stream soil, water	**Korea**	[979, 980]
Penicillium simplicissimurn	Freshwater	UK	[969]
Penicillium solitum	Freshwater	UK	[969]
Penicillium spinulosum	Freshwater	UK	[969]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Penicillium variable	River	Egypt	[971]
Penicillium verrucosum	Lake	Turkey	[976]
Penicillium waksmanii	Freshwater	UK	[969]
Penicillium wandoens	Freshwater	Korea	[511]
Penicillium yunnanense	Freshwater	**Korea**	[977]
Thermoascaceae			
Paecilomyces lilacinus	Freshwater	UK	[969]
Trichocomaceae			
Talaromyces flavus	Submerged decaying leaf litter (swamp), sand (creek)	Australia, USA	[706, 981]
Talaromyces gwangjuensis	Freshwater (reservoir)	**Korea**	[982]
Talaromyces koreanus	Freshwater (reservoir)	**Korea**	[982]
Talaromyces liani	Freshwater	**Korea**	[983]
Talaromyces pinophilus	Freshwater	**Korea**	[972]
Talaromyces siamensis	Freshwater	**Korea**	[984]
Talaromyces teleomorphus	Freshwater (reservoir)	**Korea**	[982]
Talaromyces versatilis	Freshwater	**Korea**	[972]
Onygenales			

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Arthrodermataceae			
Arthroderma insingulare	Water (river)	**Poland**	[728]
Microsporum gypseum	Water (river)	**Poland**	[728]
Trichophyton mentagrophytes	Water	Poland	[985]
Trichophyton violaceum	Water (river)	**Poland**	[728]
Onygenaceae			
Aphanoascus keratinophilus	Water (river)	**Poland**	[728]
Chrysosporium fluviale		**Spain**	[986]
Chrysosporium minutisporosum	Sediment (river)	**Spain**	[987]
Chrysosporium pseudomerdarium	Sediment	**Korea**	[702]
Chrysosporium sanyaense	Sediment	**Korea**	[702]
Chrysosporium submersum	Sediment (river)	**Spain**	[987]
Chrysosporium undulatum	Sediment (river)	**Spain**	[988]
Mycocaliciomycetidae			
Mycocaliciales			
Mycocaliciaceae			
Chaenothecopsis debilis	River watershed	Canada	[622]

Table 7.4 (continued)

Taxon	Substrate	Country	Reference
Chaenothecopsis haematopus	Rainwater from building roofs	Poland	[633]
Chaenothecopsis pusiola	River watershed	Canada	[622]
Chaenothecopsis savonica	River watershed	Canada	[622]
Phaeocalicium curtisii	River watershed	Canada	[622]
Phaeocalicium polyporaeum	River watershed	Canada	[622]
Phaeocalicium populneum	River watershed	Canada	[622]
Sphinctrina anglica	River watershed	Canada	[622]
Stenocybe pullatula	River watershed	Canada	[622]
Sclerococcomycetidae			
Sclerococcales			
Dactylosporaceae			
Cylindroconidiis aquaticus	Freshwater	**Thailand**	Yu et al. 2018
Pseudobactrodesmium aquaticum	Submerged decaying wood (stream)	China	[456]
Pseudobactrodesmium chiangmaiensis	Submerged decaying wood (stream)	Thailand	[456]
Pseudobactrodesmium longisporum	Submerged decaying wood (stream)	Australia, Thailand	[456, 752]
Pseudobactrodesmium stilboideum	Submerged decaying wood (stream, river)	Brazil, Philippines, Thailand	[432, 989]

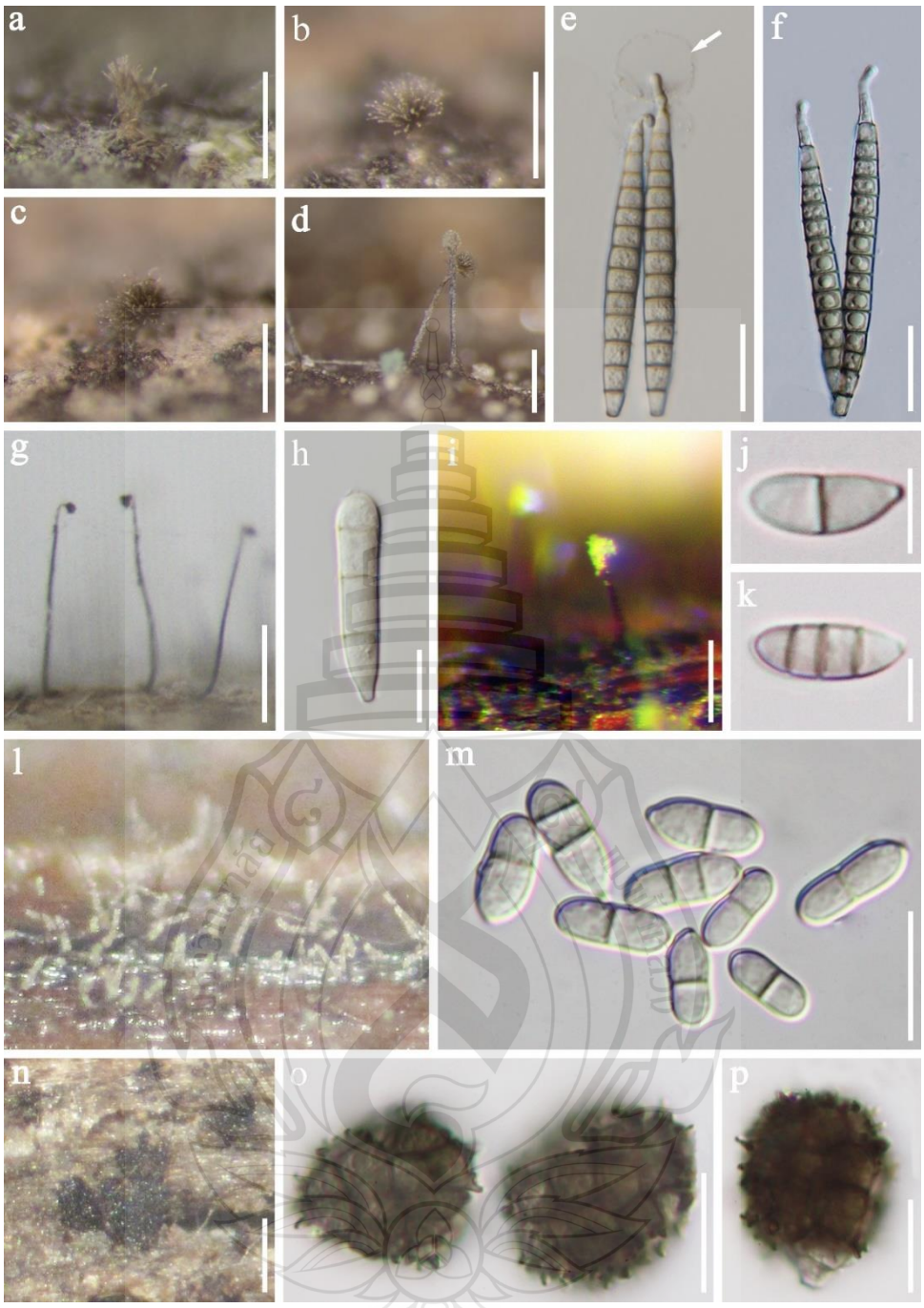


Figure 7.3 Freshwater Eurotiomycetes. (a–f) *Pseudobactrodesmium* spp.; (g–h) *Minimelanolocus* sp.; (i–k) *Thysanorea thailandensis*; (l,m) *Veronaea botryose*; (n–p) *Aculeata aquatica*. Scale bar: (a–d,g,n) 200 µm; (e,f) 20 µm; (h,m) 10 µm; (i) 100 µm; (j,k) 5 µm; (o,p) 15 µm

7.3.1.4 Laboulbeniomycetes

The Laboulbeniomycetes includes about 2100 species, most of which belong to the order Laboulbeniales [990, 991]. The latter are all obligate biotrophs associated with arthropods, therefore it is possible to define “Freshwater Laboulbeniales” as species occurring on arthropods (which in this case are all insects) that live or spend most of their time in the aquatic environment. Insect ecology is not the “questionable” subject of this paper, and we rely on the definitions contained in a paper dealing with this topic [992]. After this clarification, we can report that the “freshwater” Laboulbeniales total about 258 species and represent the 12% of the described species in this order of fungi. These 258 species are found in 25 genera, of which 20 include only aquatic species, while the other 4 are mainly composed of species that live in other ecosystems (Table 7.5). Figure 7.4 illustrates Laboulbeniomycetes from freshwater habitats.

These numbers are entirely provisional. Freshwater Laboulbeniales have received little attention in recent years, with only 7 species described during the last six years [989, 993–996]. On the other hand, molecular analysis confirmed the presence of dimorphic species in the largest genus *Chitonomyces* [997]: which is something that will certainly affect the taxonomy (and the numbers) of this and other genera.

Table 7.5 Classification of Freshwater Laboulbeniomycetes with Information on the Type of Habitats, Hosts, and Geographical Distribution of Fungal Taxa

Taxon	Substrate *(family of host-insects)*	Country	Reference
ASCOMYCOTA			
LABOULBENIOMYCETES			
Laboulbeniales			
Ceratomycetaceae			
Autoicomyces acuminatus	Hydrophilidae	USA	[501]
Autoicomyces aquatilis	Hydrochidae, Dytiscidae	Cuba, Europe, USA	[998]
Autoicomyces bicornis	Hydrophilidae	Argentina, South Korea	[999]
Autoicomyces chinensis	Hydrophilidae	China	[1000]
Autoicomyces contortus	Hydrophilidae	USA	[1001]
Autoicomyces costaricensis	Hydrophilidae	USA	[1001]
Autoicomyces crassus	Hydrophilidae	Europe	[1002]
Autoicomyces falcatus	Hydrophilidae	Brazil, Trinidad, **USA**	[991]
Autoicomyces falcifer	Hydrophilidae	Asia, Europe, Sierra Leone	[1003]
Autoicomyces fragilis	Hydrophilidae	Italy	[1004]
Autoicomyces furcatus	Hydrophilidae	Cameroon, USA	[1005]
Autoicomyces helocharalis	Hydrophilidae	Asia, Cameroon	[1005]
Autoicomyces humilis	Hydrophilidae	Asia, Italy, USA	[1005]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Autoicomyces incurvatus	Hydrophilidae	Philippines	[1005]
Autoicomyces latens	Hydrophilidae	Taiwan, Philippines	[1006]
Autoicomyces longipes	Hydrophilidae	Philippines	[1005]
Autoicomyces marginalis	Hydrophilidae	Argentina	[1001]
Autoicomyces marginicola	Hydrophilidae	Asia, Spain	[1002]
Autoicomyces minusculus	Hydrophilidae	South and North America	[1001]
Autoicomyces occidentalis	Hydrophilidae	USA	[1001]
Autoicomyces occultatus	Hydrophilidae	USA	[1005]
Autoicomyces ornitocephalus	Hydrophilidae	USA	[501]
Autoicomyces recurvatus	Hydrophilidae	**USA**	[991]
Autoicomyces semiopacus	Hydrophilidae	Trinidad	[1001]
Autoicomyces siamensis	Hydrophilidae	Thailand	[1007]
Autoicomyces trinitatis	Hydrophilidae	Trinidad	[1005]
Ceratomyces ansatus	Hydrophilidae	South and North America	[1008]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Ceratomyces brasiliensis	Hydrophilidae	Brazil	[501]
Ceratomyces californicus	Hydrophilidae	USA	[501]
Ceratomyces camptosporus	Hydrophilidae	USA	[1009]
Ceratomyces cladophorus	Hydrophilidae	Ecuador, USA	[1010]
Ceratomyces confusus	Hydrophilidae	USA	[1009]
Ceratomyces curvatus	Hydrophilidae	Venezuela	[501]
Ceratomyces filiformis	Hydrophilidae	Central, North, South America	[1005]
Ceratomyces floridanus	Hydrophilidae	USA	[501]
Ceratomyces hyalinus	Hydrochidae	China	[1011]
Ceratomyces intermedius	Hydrophilidae	Argentina	[1005]
Ceratomyces longicornis	Hydrophilidae	USA	[1005]
Ceratomyces mexicanus	Hydrophilidae	Mexico	[501]
Ceratomyces mirabilis	Hydrophilidae	Central and South America, **USA**	[991]
Ceratomyces platensis	Hydrophilidae	Argentina	[1005]
Ceratomyces procerus	Hydrophilidae	Brazil	[501]
Ceratomyces pyrenaeus	Hydrophilidae	Spain	[1012]
Ceratomyces rhizophorus	Hydrophilidae	Argentina	[1005]
Ceratomyces spiniger	Hydrophilidae	Costa Rica,	[501]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
		Mexico	
Ceratomyces spiralis	Hydrophilidae	Spain, Poland	[998]
Ceratomyces sternolophi	Hydrophilidae	Indonesia	[1005]
Ceratomyces ventriosus	Hydrophilidae	Argentina	[1005]
Drepanomyces malayanus	Hydrophilidae	Asia	[1013]
Eusynaptomyces africanus	Hydrophilidae	East Africa	[1005]
Eusynaptomyces benjaminii	Hydrophilidae	Germany, Poland	[998]
Eusynaptomyces borealis	Hydrophilidae	USA	[1005]
Eusynaptomyces cornutus	Hydrophilidae	Spain	[1014]
Eusynaptomyces enochri	Hydrophilidae	Europe	[998]
Eusynaptomyces hydrobii	Hydrophilidae	Poland	[998]
Helodiomyces elegans	Dryopidae	Algeria, Europe	[1015]
Phurmomyces obtusus	Hydrophilidae	China, Indonesia, Taiwan	[1000]
Plectomyces gracilis	Hydrophilidae	Philippines, China	[1000]
Rhynchophoromyces amphiopsis	Hydrophilidae	Cameroon	[1005]
Rhynchophoromyces anacaenae	Hydrophilidae	Europe	[1016]
Rhynchophoromyces denticulatus	Hydrophilidae	Asia, Guam	[1000]
Rhynchophoromyces elephanthnus	Hydrophilidae	USA	[1000]
Rhynchophoromyces helophorii	Hydrophilidae	Spain	[1012]
Rhynchophoromyces minor	Hydrophilidae	Argentina, Philippines, **USA**	[991]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Rhynchophoromyces rostratus	Hydrophilidae	Asia, North, Central and South America, Europe	[993]
Rhynchophoromyces sperchopsis	Hydrophilidae	USA	[1005]
Rhynchophoromyces unguicola	Hydrophilidae	China, Indonesia	[1000]
Synaptomyces argentinus	Hydrophilidae	Argentina	[1005]
Thaumasiomyces bipedalis	Hydrophilidae	Indonesia	[1005]
Thaumasiomyces scabellularius	Hydrophilidae	Cameroon	[1005]
Thaumasiomyces scaurus	Hydrophilidae	Cameroon	[1005]
Thripomyces italicus	Hydraenidae	Italy, Spain	[1017]
Thripomyces tessinensis	Hydraenidae	Poland	[1018]
Laboulbeniaceae			
Blastichomyces fastigiatus	Hydrophilidae	China, Indonesia	[1000]
Cantharomyces aquaticus	Hydrochidae	USA	[1005]
Cantharomyces bruchii	Dryopidae	Argentina	[1019]
Cantharomyces denigratus	Dryopidae	Europe	[1005]
Cantharomyces flagellatus	Dryopidae	Trinidad	[1005]
Cantharomyces italicus	Dryopidae	Europe	[1015]
Cantharomyces permasculus	Dryopidae	Argentina	[1005]
Cantharomyces platensis	Dryopidae	Argentina	[1005]
Capillistichus tenellus	Hydrophilidae	Spain	[1020]
Chaetarthriomyces coelostomalis	Hydrophilidae	Cameroon, China, Malaysia	[1000]
Chaetarthriomyces crassiappendicatus	Hydrophilidae	Europe	[1021]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Chaetarthriomyces flexatus	Hydrophilidae	Indonesia	[1005]
Chitonomyces aculeifer	Dytiscidae, Haliplidae	Argentina, China, Europe	[1022]
Chitonomyces acuminatus	Gyrinidae	Cameroon	[1023]
Chitonomyces aethiopicus	Gyrinidae	Africa	[1023]
Chitonomyces affinis	Dytiscidae	**USA**	[997]
Chitonomyces africanus	Dytiscidae	Cameroon	[1023]
Chitonomyces amoyensis	Dytiscidae	China	[1023]
Chitonomyces appendiculatus	Dytiscidae	Central and South America, **USA**	[997]
Chitonomyces arcuatus	Dytiscidae	Cameroon	[1023]
Chitonomyces argentinensis	Noteridae	Argentina	[1019]
Chitonomyces aripensis	Dytiscidae	Trinidad	[1024]
Chitonomyces atricornis	Gyrinidae	Cameroon	[1023]
Chitonomyces aurantiacus	Dytiscidae	Brazil, USA	[1025]
Chitonomyces auriculatus	Gyrinidae	Cameroon	[1023]
Chitonomyces australasiae	Dytiscidae	China, Fiji	[1000]
Chitonomyces bakeri	Dytiscidae	Asia, Greece, Spain	[1000]
Chitonomyces benjaminii	Dytiscidae	Sierra Leone	[1026]
Chitonomyces bicolor	Dytiscidae	Grenada, Trinidad	[1024]
Chitonomyces bidessarius	Dytiscidae	Asia, USA	[998]
Chitonomyces bilabiatus	Gyrinidae	Cameroon	[1023]
Chitonomyces borealis	Dytiscidae	USA	[1024]
Chitonomyces bullardii	Haliplidae	Spain, USA	[1002]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Chitonomyces cerviculatus	Dytiscidae	Grenada, Trinidad	[1024]
Chitonomyces chinensis	Dytiscidae	Asia, Sierra Leone	[1016]
Chitonomyces conditus	Gyrinidae	Cameroon	[1023]
Chitonomyces copelati	Dytiscidae	Cameroon	[1023]
Chitonomyces corniculatus	Dytiscidae	China	[1000]
Chitonomyces cornucopioides	Gyrinidae	Cameroon	[1023]
Chitonomyces dextricola	Gyrinidae	Cameroon	[1023]
Chitonomyces elegans	Dytiscidae	Cameroon, Indonesia	[1027]
Chitonomyces elongatus	Dytiscidae	Italy, Spain	[1002]
Chitonomyces ensifer	Dytiscidae	Italy, Poland, Spain	[998]
Chitonomyces excavatus	Dytiscidae	China	[1000]
Chitonomyces floridanus	Haliplidae	USA	[1024]
Chitonomyces furcatus	Dytiscidae	China	[1000]
Chitonomyces gracilipes	Dytiscidae	China	[1000]
Chitonomyces grenadae	Dytiscidae	Grenada	[1024]
Chitonomyces helicophorus	Dytiscidae	Trinidad	[1024]
Chitonomyces hyalinus	Dytiscidae	Central and South America, **USA**	[997]
Chitonomyces hydrocanthi	Dytiscidae	Sierra Leone	[1028]
Chitonomyces hydropori	Dytiscidae	Europe, Philippines, USA	[998]
Chitonomyces incisus	Dytiscidae	Fiji	[1024]
Chitonomyces indentatus	Dytiscidae	Philippines, China	[1000]
Chitonomyces inflatus	Dytiscidae	Philippines	[1023]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Chitonomyces intermedius	Dytiscidae	Asia	[1000]
Chitonomyces interpositus	Gyrinidae	Cameroon	[1023]
Chitonomyces introversus	Dytiscidae	Grenada, USA	[1024]
Chitonomyces irimotensis	Dytiscidae	Asia, Spain	[993]
Chitonomyces italicus	Dytiscidae	Europe	[1022]
Chitonomyces japanensis	Dytiscidae	China, Japan, Thailand	[1007]
Chitonomyces javanicus	Dytiscidae	Asia	[1007]
Chitonomyces laboulbenioides	Haliplidae	China	[1000]
Chitonomyces latens	Gyrinidae	Cameroon	[1023]
Chitonomyces ligulatus	Haliplidae	China	[1023]
Chitonomyces longirostratus	Dytiscidae	Trinidad, Japan	[1024]
Chitonomyces manubriolatus	Dytiscidae	Grenada, Thailand, Trinidad	[1007]
Chitonomyces melanurus	Dytiscidae	Africa, Asia, Europe	[1029]
Chitonomyces obtusus	Gyrinidae	Cameroon	[1023]
Chitonomyces occultus	Haliplidae	USA	[501]
Chitonomyces oedipus	Dytiscidae	Grenada, Trinidad	[1024]
Chitonomyces ordinatus	Dytiscidae	Asia	[1029]
Chitonomyces orectogyri	Gyrinidae	Africa	[501]
Chitonomyces orientalis	Dytiscidae	China, Japan, South Korea	[1000]
Chitonomyces paradoxus	Dytiscidae	Asia, Central America, Europe, Sierra Leone, **USA**	[997]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Chitonomyces pilicola	Gyrinidae	Cameroon	[1023]
Chitonomyces prolongatus	Dytiscidae	Brazil, USA	[1025]
Chitonomyces psittacopsis	Dytiscidae	Asia, North and Central America, Sierra Leone	[1016]
Chitonomyces pullus	Haliplidae	China	[1023]
Chitonomyces recurvatus	Dytiscidae	China	[1023]
Chitonomyces reynoldsii	Dytiscidae	Venezuela	[1023]
Chitonomyces rhyncostoma	Dytiscidae	Trinidad, **USA**	[997]
Chitonomyces rugosus	Dytiscidae	Fiji, Thailand	[1007]
Chitonomyces seticola	Dytiscidae	Grenada	[1024]
Chitonomyces sigmoideus	Gyrinidae	Cameroon	[1023]
Chitonomyces simplex	Dytiscidae	Brazil**,** Central America, Sierra Leone, **USA**	[1030]
Chitonomyces sinistricola	Gyrinidae	Cameroon	[1023]
Chitonomyces spinosus	Dytiscidae	Asia, Spain	[1000]
Chitonomyces striatus	Dytiscidae	Grenada	[1024]
Chitonomyces strictus	Dytiscidae	China	[1023]
Chitonomyces subterminalis	Gyrinidae	Cameroon	[1023]
Chitonomyces tarsicola	Haliplidae	China	[1023]
Chitonomyces thaxteri	Dytiscidae	Thailand, Trinidad	[1007]
Chitonomyces tricornis	Dytiscidae	Cameroon	[1023]
Chitonomyces tylopus	Dytiscidae	Spain	[1031]
Chitonomyces uncinulatus	Dytiscidae	Trinidad	[1024]
Chitonomyces venezuelae	Dytiscidae	Venezuela	[1023]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Chitonomyces yunnanensis	Dytiscidae	China	[1000]
Chitonomyces zonatus	Dytiscidae	Asia	[1000]
Coreomyces acuminatus	Corixidae	Chile	[1032]
Coreomyces arcuatus	Corixidae	Europe, Jamaica	[1018]
Coreomyces argentinensis	Corixidae	Argentina	[1019]
Coreomyces australis	Corixidae	Argentina	[1019]
Coreomyces bicolor	Corixidae	Jamaica	[1005]
Coreomyces chinensis	Corixidae	China	[1005]
Coreomyces confusus	Corixidae	**Sweden**, Denmark	[996]
Coreomyces corixae	Corixidae	Asia, Europe, North and South America, **Sweden**, **Turkey**	[996]
Coreomyces curvatus	Corixidae	China, Italy, Jamaica, USA	[1000]
Coreomyces dextrorsus	Corixidae	Denmark, **Sweden**	[996]
Coreomyces elongatus	Corixidae	Europe	[1018]
Coreomyces fastigiatus	Corixidae	Chile	[1005]
Coreomyces javanicus	Corixidae	Indonesia	[1033]
Coreomyces macropus	Corixidae	Europe, Jamaica, **Sweden**	[996]
Coreomyces micronectae	Corixidae	Asia	[1000]
Coreomyces minor	Corixidae	China, Philippines	[1000]
Coreomyces orientalis	Corixidae	China, Indonesia	[1000]
Coreomyces ramosus	Corixidae	USA	[1005]
Coreomyces recurvatus	Corixidae	Asia	[1034]
Coreomyces sigmoideus	Corixidae	Jamaica	[1005]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
***Coreomyces* sp.**	Corixidae	**South Africa**	[991]
Coreomyces subdivisus	Corixidae	Chile	[1005]
Coreomyces thaxteri	Corixidae	Ethiopia	[1005]
Hydraeomyces halipli	Haliplidae	Asia, Europe, North and South America,	[1035]
Hydrophilomyces aduncus	Hydraenidae	Spain	[1014]
Hydrophilomyces arcuatus	Hydraenidae	Finland	[1036]
Hydrophilomyces atroseptatus	Hydraenidae	Poland, Spain	[1002]
Hydrophilomyces coneglianensis	Hydrophilidae	Europe	[1037]
Hydrophilomyces deflexus	Hydraenidae	Spain	[995]
Hydrophilomyces digitatus	Hydraenidae	Europe	[1002]
Hydrophilomyces gracilis	Hydrophilidae	Belgium, Greece, Poland	[1018]
Hydrophilomyces hamatus	Hydrophilidae	Europe, Sierra Leone	[1018]
Hydrophilomyces hydraenae	Hydraenidae	USA	[989]
Hydrophilomyces limnebii	Hydraenidae	Europe	[1018]
Hydrophilomyces lumbricoides	Hydrophilidae	Argentina	[1001]
Hydrophilomyces major	Hydrophilidae	Argentina	[1005]
Hydrophilomyces pusillus	Hydrophilidae	Poland	[998]
Hydrophilomyces reflexus	Hydrophilidae	Argentina, USA	[501]
Hydrophilomyces rhynchophorus	Hydrophilidae	Central and South America, **USA**	[991]
Hydrophilomyces rhytidopus	Hydrophilidae	Argentina,	[1005]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
		Trinidad	
Hydrophilomyces riberae	Hydraenidae	Spain	[995]
Laboulbenia afrogyri	Gyrinidae	Africa	[1038]
Laboulbenia anomala	Gyrinidae	Africa	[501]
Laboulbenia aquatica	Gyrinidae	Bolivia, Venezuela	[1008]
Laboulbenia bicornis	Gyrinidae	Africa, Asia	[1039]
Laboulbenia birmanica	Gyrinidae	Myanmar	[1004]
Laboulbenia borealis	Gyrinidae	Asia, North and Central America, Madagascar	[1000]
Laboulbenia coarctata	Gyrinidae	India	[501]
Laboulbenia constricta	Gyrinidae	Africa	[1038]
Laboulbenia crassipes	Gyrinidae	Myanmar	[1004]
Laboulbenia cubensis	Gyrinidae	Cuba	[501]
Laboulbenia dactylophora	Gyrinidae	Africa	[1038]
Laboulbenia denticulata	Gyrinidae	Australia	[501]
Laboulbenia desgodii	Gyrinidae	Africa	[1038]
Laboulbenia dineutis	Gyrinidae	Asia, Africa, Papua New Guinea	[1039]
Laboulbenia drepanalis	Gyrinidae	Panama, “Amazon”	[501]
Laboulbenia fallax	Gyrinidae	Brazil, Panama, Trinidad	[1040]
Laboulbenia fennica	Gyrinidae	Europe	[1035]
Laboulbenia franciscoloi	Gyrinidae	Sierra Leone	[1038]
Laboulbenia funeralis	Gyrinidae	North, Central, and South America	[1040]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
Laboulbenia guerinii	Gyrinidae	North, Central, and South America	[501]
Laboulbenia gyrinicola	Gyrinidae	Algeria, Europe, Morocco	[1035]
Laboulbenia gyrinidarum	Gyrinidae	Mexico, North America	[501]
Laboulbenia heterocheila	Gyrinidae	"Timor"	[501]
Laboulbenia leathsi	Gyrinidae	Chile	[1019]
Laboulbenia leptopus	Gyrinidae	Argentina	[1019]
Laboulbenia oberthuri	Gyrinidae	Madagascar	[1009]
Laboulbenia orectochili	Gyrinidae	Asia	[501]
Laboulbenia orectochilicola	Gyrinidae	Myanmar	[1004]
Laboulbenia pachystoma	Gyrinidae	Argentina, Brazil	[1025]
Laboulbenia rotundata	Gyrinidae	Indonesia	[501]
Laboulbenia satanas	Gyrinidae	Philippines	[1041]
Laboulbenia songhaiensis	Gyrinidae	Sierra Leone	[1038]
Laboulbenia strangulata	Gyrinidae	Asia	[1029]
Laboulbenia valida	Gyrinidae	Indonesia	[1004]
Limnaiomyces amphiopsis	Hydrophilidae	Cameroon	[1023]
Limnaiomyces hydrocharis	Hydrophilidae	USA	[501]
Limnaiomyces tropisterni	Hydrophilidae	Mexico	[501]
Rickia admirabilis	Hydrophilidae	Cameroon, Sierra Leone	[1042]
Rickia coelostomalis	Hydrophilidae	Indonesia, Japan,	[1000]

Table 7.5 (continued)

Taxon	Substrate *(family of host-insects)*	Country	Reference
		China	
Scepastocarpus peritheciiformis	Hydrochidae	Spain	[1020]
Zodiomyces modae	Hydrophilidae	Japan	[1043]
Zodiomyces rhizophorus	Hydrophilidae	Trinidad	[993]
Zodiomyces subseriatus	Hydrophilidae	Asia, Poland	[1020]
Zodiomyces vermiformis	Hydrophilidae	Ecuador	[994]
Zodiomyces vorticellarius	Hydrophilidae	Africa, Asia, Central and South America, Europe, **USA**	[991]
Pyxidiophorales			
Pyxidiophoraceae			
Pyxidiophora spinulorostrata	Submerged decaying *Quercus* (river)	UK	[1044]

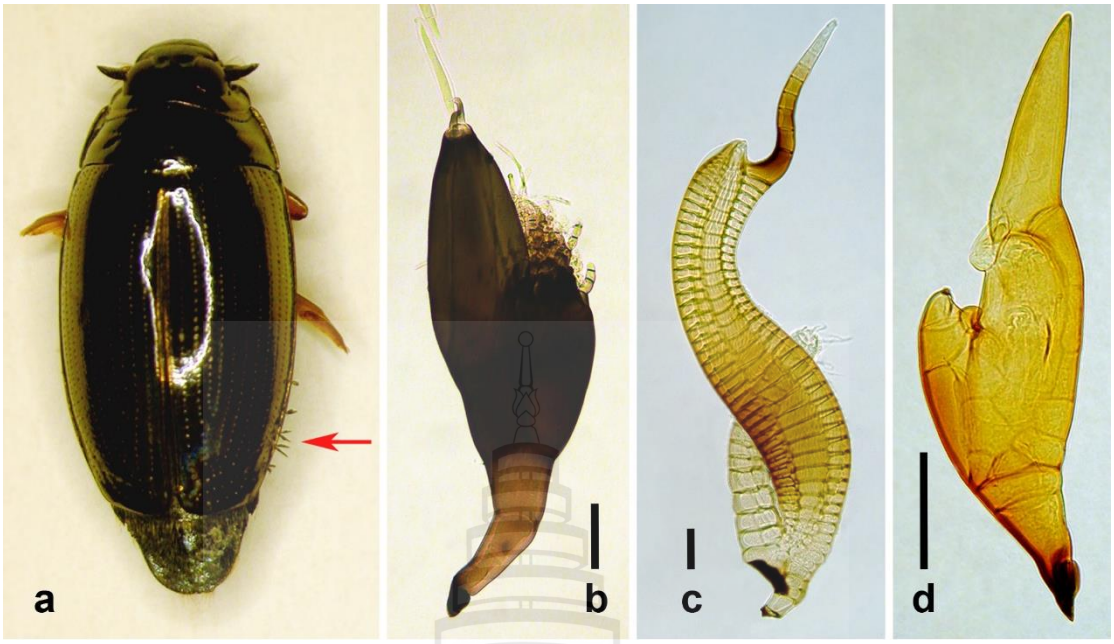


Figure 7.4 Freshwater Laboulbeniales. (a) Whirligig Beetle (*Gyrinus caspius*) Bearing Several Thalli of *Laboulbenia gyrinicola* (Arrow). b *Laboulbenia gyrinicola*. c *Ceratomyces cladophorus*. d *Chitonomyces paradoxus*. Scale bars: b–d = 50 μm

7.3.1.5 Leotiomycetes

Leotiomycetes, the most diverse ascomycetous class in Pezizomycotina, encompasses hyphomycetes with undetermined sexual morphs and apothecial or cleistothecial-bearing fungal members that are either distinctively growing on the substrates or immersed in stromatic tissues [1045–1047]. Freshwater Leotiomycetes thrives on various submerged substrates or floating objects either in static or running waters [38, 39, 69]. Freshwater Leotiomycetes have been found in various environments: ponds, rainfall, melting ice [1048], lakes [60], springs [1049], swamps [706, 1050], a polluted lake [627], rivers [1051], water distribution system [1052] and on various substrates: herbaceous and woody substrates [662, 754], dead cryptogamic plants [60], scums trapped by woody debris in streams (Ingold 1974), and isolated from stream spume [642, 1046].

In previous studies on fungal discoveries, freshwater Leotiomycetes were listed along with other classes under freshwater ascomycetes [38, 205, 616, 1053] or

documented exclusively as discomycetes [60, 1054–1056], as hyphomycetes [788, 826, 1046, 1048, 1057, 1058], Ingoldian fungi [13, 83], and aero-aquatic fungi [1059, 1060]. Studies documenting the overall freshwater fungal members within Leotiomycetes are lacking [1046].

Previous discoveries on new taxa and sexual morph association of freshwater Leotiomycetes were solely based on morphological observation [13, 38, 1056, 1061–1063]. However, the advance of sequencing technology introduced deeper morpho-phylogenetic insights on novel species and holomorph revelation of freshwater Leotiomycetes from various regions and substrates [736, 1046, 1060, 1064–1067]. Additionally, evolutionary lineages of freshwater fungi began to unfold. Studies on evolutionary freshwater fungi based on 18S rRNA data revealed that terrestrial fungi were the common ancestors of freshwater Leotiomycetes along with other classes (Dothideomycetes, Orbiliomycetes, Sordariomycetes) [616, 736]. Hence, providing freshwater fungi with DNA molecular data is important not only for basic taxonomic justification but also to answer unsolved evolutionary links within Leotiomycetes. This study provides a list of freshwater Leotiomycetes including information about the availability of sequence data of the listed fungal species.

Some 260 freshwater Leotiomycetes are listed in Table 7.6, but this figure is underestimated. Based on the results in Table 7.6, Helotiales has the largest freshwater fungal members with 187 species across 12 families including Helotiales genera incertae sedis. Few taxa under Lauriomycetales (3 species), Leotiales (5 species), Rhytismatales (4 species), and Thelebolales (2 species) are reported in freshwater habitats. Forty-four species are members of Leotiomycetes families *incertae sedis* while 15 species are under Leotiomycetes genera *incertae sedis*. Based on the current revisions of the Leotiomycetes [204], many species of freshwater Leotiomycetes have been updated and we refer to the currently accepted names. Freshwater Leotiomycetes listed in the Table 7.6 includes aero-aquatic species, Ingoldian fungi, meiosporic ascomycetes (discomycetes) and hyphomycetes. *Helicocentralis hyalina* found in Thailand, *Pseudaegerita conifera and P. websteri* both from Spain, were documented as new species of aero-aquatic fungi within Leotiomycetes and mostly found on submerged lignocellulose materials [1060, 1068]. Aero-aquatic fungi are equipped with aerially release propagules and air trapping

elements which are distinctive to freshwater hyphomycetes. Freshwater hyphomycetous Leotiomycetes consist of semiterrestrial aquatic and Ingoldian fungi which are important as decomposers with slight difference in substrate specialization and sporulation. *Dactylaria*, a semi-terrestrial hyphomycetes can sporulate underwater and play a role as decomposers of plant materials [580, 1069, 1070]. Ingoldian fungi were mostly isolated from floating foam or associated with leaf substrates and often found as asexual morphs with unique conidial shapes i.e., branched forms (*Varicosporium*) [1065], tetraradiate (*Alatospora, Articulaspora, Tetracladium, Tricladium*) and sigmoid (*Flagellospora*) [44]. Ingoldian fungi are chiefly leaf decomposers in freshwater ecosystems [1071], by producing exoenzymes that increases leaf litters' palatability for invertebrate diets [1072, 1073].

Members of freshwater Leotiomycetes, especially discomycetes, are considered responsible for degrading woody substrates in water bodies, even though their roles are not as significant as Sordariomycetes and Dothideomycetes [461, 1071]. Wood, plant materials composed of lignin, cellulose, and hemicellulose, are difficult to break down even in freshwater ecosystems. Hence, colonization of freshwater ascomycetes including discomycetes are capable to secrete enzymes for ligno-cellulose degradation on woody substrates and play a prominent role in nutrient cycling and energy transfer between trophic elements in freshwater ecosystems [1074, 1075].

Freshwater Leotiomycetes biodiversity and prevalence can be affected by substrate availability and pollution. A study has been undertaken on the effect of substrate preferences on freshwater Leotiomycetes. For nutrition reasons, *Alastospora acuminata* and *Tetrachaetum elegans* were found mostly on *Acacia* and *Eucalyptus* leaves, respectively [1076]. Hyphomycetes fungi, *Dactylaria* spp. were the only freshwater Leotiomycetes less affected by organic pollution [627]. However, other studies reported that diversity of hyphomycetous and ascomycetous fungi were greatly reduced in polluted environments [770, 1077]. The combination of macroclimate and microclimate may also affect freshwater fungal prevalence in general, including Leotiomycetes species in certain regions either in temperate or tropical zones [57]. While similar climate in different continents resulted parallel comparison in species assemblages of freshwater ascomycetes [656], microclimate

such as temperature, pH, and altitude may be related to Ingoldian fungal prevalence in particular areas [1078].

Table 7.6 Classification of Freshwater Leotiomycetes with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	Reference
ASCOMYCOTA			
LEOTIOMYCETES			
Leotiomycetidae			
Leotiomycetes families *incertae sedis*			
Calloriaceae			
Cistella graminicola	*Carex rostrata, Equisetum fluviatile*	Austria	[1079]
Dactylaria africana	Submerged decaying wood (river)	Philippines	[432]
Dactylaria appendiculata	Submerged decaying wood (river)	Brazil	[1080]
Dactylaria aquatica	Water	India	[1081]
Dactylaria aspirensis	Grass	China	[754]
Dactylaria belliana	Submerged leaves	Brazil	[697]
Dactylaria biguttulata	Submerged decaying wood (reservoir)	China	[626]
Dactylaria botulispora	Submerged decaying twig (stream)	Brazil	[683]
Dactylaria candidula	Submerged decaying twig (stream)	Brazil	[683]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Dactylaria fecundissima	Submerged decaying wood	China	[1082]
Dactylaria flammulicornuta	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Dactylaria fusifera	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Dactylaria fusiformis	Submerged decaying balsa wood (river) and leaves (stream)	Brazil, USA	[582, 683]
Dactylaria hemibeltranioidea	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Dactylaria hoogi	Submerged decaying wood (lake)	China	[627, 670]
Dactylaria irregularis	Submerged decaying wood (stream)	China	[676]
Dactylaria longidentata	Grass, submerged bamboo (lake), wood (river)	China, Philippines	[627]
Dactylaria lunata	Rainwater from building roofs	Poland	[633]
Dactylaria malaysianum	Submerged wood	China	[662]
Dactylaria mucronulata	Submerged wood	China	[1082]
Dactylaria naviculiformis	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Dactylaria obscuriseptata	Submerged decaying wood (reservoir)	China	[626]
Dactylaria obtriangularia	Water-filled treeholes	Hungary	[638]
Dactylaria plovercovensis	Submerged decaying wood (lake, reservoir)	China	[626]
Dactylaria saccardoana	Submerged decaying leaves (stream)	Brazil	[683]
Dactylaria splendida	Grass, submerged decaying wood (lake)	China	[627]
Dactylaria triseptata	Grass, submerged decaying wood (lake)	Brunei, China	[583, 627]
Dactylaria uliginicola	Submerged petiole of *Eleiodoxa conferta* (peat swamp)	Thailand	[62, 584]
Diplonaevia emergens	*Juncus filiformis*, *Eriophorum angustifolium*	Austria	[1079]
Diplonaevia seriata	*Carex rostrata*	Austria	[1079]
Mycoarthris corallina	Foam (stream), freshwater	UK, **Korea**	[984, 1046]
Rodwayella citrinula	*Phragmites australis* stems and leaves, wood	UK, Soviet Union	[786, 788, 789, 1083]
Roseodiscus equisetinus	*Equisetum fluviatile*	Austria	[1079]
Stamnaria persoonii	*Equisetum fluviatile*	Austria	[1079, 1084]
Cenangiaceae			

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Moellerodiscus advenulus	Submerged decaying *Picea mariana* needles (lake)	USA	[749]
Hamatocanthoscyphaceae			
Chalara aotearoae	Submerged wood	China	[1082]
Chalara siamense	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Chalara ungeri	Grass	China	[754]
Pezizellaceae			
Calycina citrina	Submerged decaying wood (swamp)	USA	[706, 1084]
***Calycina parilis* (*Chalara* state)**	Submerged decaying wood	Scotland	[1085]
Chalara alabamensis	Submerged decaying petioles (stream)	Brazil	[683]
Rutstroemiaceae			
Lambertella tubulosa	Submerged decaying twigs of *Acer pseudoplatanus*, *Fagus* sp. (stream, pond), water-filled treeholes	Hungary, Ireland, UK	[638, 719, 1086, 1087]
Sclerotiniaceae			
Monilia aquatilis	Water	Germany	[1088]
Leotiomycetes genera *incertae sedis*			
Aquadiscula appendiculata	*Acer rubrum* leaves	USA	[706, 1089]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Coleosperma lacustre	Submerged decaying stalks of *Schoenoplectus lacustris* (lake)	UK	[60]
Coronellaria caricinella	*Carex nigra, Carex echinata*	Austria	[1079]
Flagellospora curvula	Foam (stream, river, rivulet), leaves, submerged wood (*Alnus glutinosa, Corylus avellana, Fraxinus excelsior, Fagus sylvatica, Tilia cordata*), submerged leaves of *Alnus glutinosa*, *Coffea arabica* and *Hevea brasiliensis* (stream, river), water (river, stream), scum (stream), sediment (dam, stream), stemflow and throughfall of tree canopies	Austria, Brazil. Canada, China, France, Ghana, India, Ireland, Jamaica, Nigeria, **Poland**, Spain, South Africa, Sweden, Switzerland, Uganda, UK, USA, Venezuela	[13, 63, 637, 639, 713, 714, 717, 718, 720, 721, 728, 734, 83, 783, 784, 828, 888, 1046, 1057, 1090–1093, 519, 1094, 1095, 588, 628, 630–632, 636]
Flagellospora fusarioides	Submerged leaf of *Crataegus monogyna*, foam (stream)	Austria, UK	[628, 1046]
Flagellospora leucorhynchos	Foam (stream)	Czech Republic	[1046]
Flagellospora minuta	Submerged decaying leaves	Pakistan	[1096]
Flagellospora saccata	Foam (stream)	Canada, India	[722, 1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Flagellospora stricta	Submerged decaying leaves, water from melting ice (river)	Poland, Sweden	[1048, 1097]
Hysteronaevia advena	*Eriophorum angustifolium*	Austria	[1079]
Hysteronaevia olivacea	*Eriphorum vaginatum, Carex rostrata, C. paupercula, C. Nigra, Juncus filiforme*	Austria	[1079]
Hysteropezizella diminuens	*Carex rostrata, C. paupercula*	Austria	[1079]
Hysteropezizella fuscella	*Carex nigra, C. rostrata*	Austria	[1079]
Hysteropezizella phragmitina	*Carex rostrata*	Austria	[1079]
Helotiales			
Discinellaceae			
Cladochasiella divergens	Culture contaminant	Czech Republic	[1046]
Fontanospora alternibrachiata	Submerged decaying leaves (river), water (stream)	France, USA	[639, 828, 1098]
Fontanospora eccentrica	Foam (river, stream), submerged decaying leaves of *Quercus* (spring), water (stream)	Canada, Cuba, Ireland, Japan, **Portugal**, USA	[65, 632, 639, 731, 732, 739, 1046, 1066, 1098]
Fontanospora fusiramosa	Foam (stream)	Czech Republic	[1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Gyoerffyella craginiformis	*Liriodendron tulipifera,* decaying leaves	Netherland, USA	[65, 1046]
Gyoerffyella entomobryoides	*Rosa* sp.	Netherland	[1046]
Gyoerffyella gemellipara	Submerged decaying leaves (river), foam (stream, rivulet)	Austria, Czech Republic	[628, 631, 1046, 1099]
Gyoerffyella myrmecophagiformis	River, foam (stream), melted ice (river)	Austria, Poland	[628, 1048]
Gyoerffyella rotula	Foam (stream, river, rivulet)	Austria, Czech Republic, Ireland, New Zealand, UK	[631, 632, 1046, 1100]
Gyoerffyella speciosa	Foam (stream)	Canada, Japan	[588, 1101, 1102]
Gyoerffyella tatrica	Foam (tidal ditch)	UK	[1103]
Gyoerffyella tricapillata	Decaying leaf *Punus* and *Rosa* sp. in a pond, rainwater from building roofs	Poland, UK	[633, 1046, 1104]
Lemonniera alabamensis	Submerged wood of *Betula nigra* (stream), submerged decaying *Alnus glutinosa* leaves (stream), decaying submerged leaf litter of	Brazil, China, France, India, **Portugal**, Spain, USA	[630, 640, 676, 723, 783, 1066, 1105]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
	Polygonum nepalensis and *Nerium* sp., foam (stream)		
Lemonniera aquatica	Water (pond, river, stream), scum (stream), spring on flower petals of *Malus sylvestris, Prunus* spp, *Pyrus communis*, foam (stream, rivelet), submerged wood (*Alnus glutinosa, Acer pseudoplatanus, Corylus avellana, Fraxinus excelsior, Fagus sylvatica, Tilia cordata, Ulmus* sp.), submerged decaying leaves of *Salix* spp., *Populu s* spp., *Betula glandulosa*, and *Alnus tenuifolia*, (stream), foam (lake, spring, stream, river), stemflow and throughfall of tree canopies	Australia, Austria, Brazil, Canada, China, **Czech Republic**, Estonia, **France**, Germany, India, Ireland, Japan, Norway, **Poland**, Portugal, Romania, Russia, South Africa, Spain, Sweden, **Switzerland** UK, Ukraine, USA	[13, 63, 713, 716, 717, 724, 728, 729, 732, 783, 828, 1048, 588, 1066, 1086, 1105–1107, 628, 630–632, 636, 637, 687]
Lemonniera centrosphaera	Water (pond, river), foam (stream, river, rivulet), submerged leaf litter of *Alnus glutinosa* (stream), scum (stream)	Austria, Canada, China, Czech Republic, France, Ireland, Japan, **Poland**, UK, Ukraine	[588, 630–632, 728, 1048, 1067, 1101, 1106, 1108]
Lemonniera cornuta	Submerged decaying leaves and twigs of *Alnus* sp., *Salix* sp. and *Quercus kellogi*, submerged decaying leaves and twigs of dicots (river, stream), foam (stream, spring, river, lake),	China, France, India, Japan, Spain, UK, Ukraine, USA	[63, 67, 1106, 1109, 1110, 636, 714, 716, 737, 783,

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
	water (river. stream), stemflow and throughfall of tree canopies		828, 1058, 1064]
Lemonniera cornuta	Submerged decaying leaves and twigs of *Alnus* sp., *Salix* sp. and *Quercus kellogi*, submerged decaying leaves and twigs of dicots (river, stream), foam (stream, spring, river, lake), water (river. stream), stemflow and throughfall of tree canopies	China, France, India, Japan, Spain, UK, Ukraine, USA	[63, 67, 1106, 1109, 1110, 636, 714, 716, 737, 783, 828, 1058, 1064]
Lemonniera filiformis	Pond, foam (stream), water (stream), throughfall	Austria, Canada, China, India, Germany, Poland, Russia, Ukraine, USA	[67, 588, 628, 727, 737, 1048, 1064, 1110–1112]
Lemonniera pseudofloscula	Submerged decaying leaves (river) water (stream), foam (river), throughfall of palm species	Brazil, India, USA	[639, 723, 727, 735, 1064, 1106]
Lemonniera terrestris	Foam (pond, stream, river, rivulet), submerged leaves (pond, stream, river), leaf baits (stream), scum (stream), submerged decaying leaves of *Salix* spp., *Populus* spp., *Betula glandulosa*, *Alnus glutinosa*, and *Alnus tenuifolia* (stream), water (river,	Australia, Austria, Canada, China, Cuba, **Czech Republic**, France, Germany, Hungary, India, Ireland,	[588, 630, 739, 1048, 1067, 1090, 631, 636, 639, 714, 715, 717,

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
	stream), submerged decaying woods, stemflow and throughfall of tree canopies	Japan, Poland, Russia, **Slovakia**, South Africa, Spain, Sweden, UK, Ukraine, USA	724, 735]
Lemonniera yulongensis	Submerged decaying leaves (river)	China	[1113]
Margaritispora aquatica	Pond, foam (stream, rivulet), submerged decaying leaves of *Salix* spp., *Populus* spp., *Betula glandulosa*, and *Alnus tenuifolia, A. glutinosa* (stream)	Austria, Brazil, Canada, **Korea**, Poland, UK, USA	[13, 588, 628, 631, 637, 713, 715, 1048, 1067, 1114]
Margaritispora monticola	Rainwater in forest, foam (stream), bedrock, decaying angiosperm leaves (brook, stream, river), submerged leaf litter of *Alnus glutinosa* (stream), water (stream)	**Australia**, Austria, **Canada**, Czech Republic, France, New Zealand, **Portugal**, Slovakia, UK, USA	[628, 630, 736, 738, 828, 1098, 1115]
Pezoloma rhodocarpum	Plant debris	Malawi	[1116]
Tetrachaetum elegans	Water (river, stream), foam (rivulet, river, stream, spring, lake), submerged decaying leaves of *Alnus*	Austria, Brazil, Canada, **France**, **Germany**, India, Japan, Poland,	[13, 63, 714–716, 722, 731,

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
	glutinosa, A. tenuifolia, *Salix* spp., *Populus* spp., *Betula glandulosa* (stream)	Portugal, Spain, UK, USA	732, 736, 783, 828, 1048, 66, 1051, 1086, 1117, 588, 628, 630, 631, 637, 639, 713]
Gelatinodiscaceae			
Dimorphospora foliicola	*Castanea* leaf, stream, submerged decaying leaves of *Alnus glutinosa* (stream, river), water-filled treeholes	France, **Germany**, Hungary, Japan, **Portugal**, UK	[630, 638, 714, 736, 1046]
Fluminispora ovalis	Submerged decaying leaves of *Alnus glutinosa*	UK	[735]
Helotiaceae			
Articulospora atra	*Picea abies* twiglet (stream), foam (river)	Czech Republic, UK	[1046, 1118]
Articulospora moniliformis	Submerged *Alnus and Salix*	New Zealand, USA	[63, 65, 1115]
Articulospora prolifera	Submerged leaves of *Phragmites communis* (river)	Poland, Spain	[1048, 1067]
Articulospora tetracladia	Foam, foam/water (stream)	**Canada, Korea, France**, **Portugal**, USA, Venezuela	[519, 639, 732, 736, 1114]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Cudoniella indica	Foam (river)	South Africa	[1063, 1086]
Cudoniella clavus	Ash, alder, oak twigs	UK	[1119]
Dimorphospora foliicola	Water (stream)	USA	[639]
Helicocentralis hyalina	Submerged decaying wood (peat swamp)	**Thailand**	[1060]
Helicodendron triglitziense	Submerged leaves of *Salix* (reservoir), water-filled treeholes	Germany, Hungary, Ireland, Netherlands, USA	[638, 719, 1120–1122]
Helicodendron westerdijkiae	Water-filled treeholes	Hungary	[638]
Crocicreas megalosporum	*Carex rostrata*	Austria	[1079]
Hymenoscyphus africanus	Alder twigs	UK	[1123]
Hymenoscyphus imberbis	Submerged decaying twig (stream)	**Slovakia**	[1124]
Hymenoscyphus foliicola	*Acer pseudoplatanus* twigs	UK	[1125]
Hymenoscyphus malawiensis	Plant debris	Malawi	[1116]
Hymenoscyphus paradoxus	Willow twigs	Switzerland	[1126]
Hymenoscyphus phyllophilus	Skeletal leaves	Soviet Union	[788]
Hymenoscyphus scutula	Submerged decaying stems of *Scirpus atrovirens* (lake)	USA	[749]
Hymenoscyphus splendens	Beech cupules	UK	[1125]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Hymenoscyphus tetracladius	Beech and willow leaves (stream, lake), submerged wood (*Alnus glutinosa*, *Corylus avellana*, *Tilia cordata*, *Ulmus* sp.) (stream), foam (stream, rivulet, river), submerged decaying leaves of *Alnus glutinosa*, *A. tenuifolia*, *Salix* spp., *Populus* spp., *Betula glandulosa* (stream, river), water (river), scum (stream)	Austria, Brazil, Canada, France, Ireland, India, Japan, Nigeria, Spain, Switzerland, UK, USA	[13, 63, 717, 719–723, 729, 783, 784, 1125, 65, 588, 628, 630, 632, 713–715]
Hyaloscyphaceae			
Arbusculina fragmentans	Spume (river), flower petal by spring, pond and river	Slovakia, Slovenia, Poland	[1046, 1049, 1127]
Arbusculina irregularis	Roof top rainwater, submerged debris (creek), foam (stream)	India, Poland, USA	[66, 633, 827, 1048]
Brocchiosphaera brocchiata	Submerged decaying *Licuala longicalycata* (peat swamp), submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (lake, stream, river, reservoir) and bamboo (river)	Brazil, Brunei, China, Japan, Malaysia, Philippines, Thailand	[432, 583, 584, 626, 627, 683, 858, 1128]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Brocchiosphaera microspora	Submerged decaying woods (stream), submerged leaves of *Calophyllum brasiliense* (stream)	Brazil, Thailand	[858]
Clathrosphaerina zalewskii	On decaying leaves of *Betula i*n water	Netherland	[719, 1086, 1129]
Clavidisculum karstenii	Submerged Umbelliferae stem (stream)	UK	[1130]
Clavidisculum graminicola	*Carex rostrata, Equisetum fluviatile*	Austria	[1079]
Dematioscypha dematiicola	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Hyaloscypha albohyalina	Twigs, rainwater from building roofs, Decaying wood of *Nothofagus fusca* (stream, waterfall)	Poland, New Zealand, UK	[633, 1059, 1086]
Hyaloscypha spinulosa	Submerged decaying leaves of *Alnus* and *Betula* (brook, ponds, rainwater-filled bombcrater, treeholes), decaying leaves of *Nothofagus*	Argentina, Hungary, Ireland, Japan, Netherlands, Switzerland, UK	[638, 1129, 1131–1134]
Hyaloscypha zalewskii	Catkins of *Alnus*, spine of *Castanea sativa* (stream), decaying stems of *Endymion non-scriptus* (river), *Quercus* cupule, *Alnus glutinosa* strobilus (river), submerged roots, rainwater from building roofs	Ireland, Netherland, Poland, UK	[633, 1135]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Pseudaegerita caffra	Dead twig (stream)	Japan	[1136]
Pseudaegerita conifera	Submerged needles of *Pinus halepensis* (river)	Spain	[1068]
Pseudaegerita corticalis	River, submerged decaying wood (stream)	Poland, Thailand	[858, 1048, 1086]
Pseudagaerita foliicola	Oak leaf (lake)	UK	[1137]
Pseudaegerita ossiformis	Decaying twig of *Quercus* (river)	Italy	[1138]
Pseudaegerita viridis	River, water-filled treeholes, submerged decaying wood (stream)	Brazil, Hungary, Poland	[638, 1048, 1139, 1140]
Pseudaegerita websteri	Submerged decaying wood, decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, Spain	[88, 1068]
Hydrocinaceae			
Clathrosporium intricatum	Submerged decaying angiosperm and unidentified leaves (stream)	Malaysia, Thailand	[744, 858, 1141]
Clathrosporium retortum	From leaf litter submerged in fresh water	Brazil	[488]
Hydrocina chaetocladia	Submerged alder and oak twigs (stream)	UK	[1086, 1142, 1143]
Varicosporium aquaticum	Water (river)	Rusia	[1144]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Varicosporium delicatum	Submerged of rotting leaves of *Acer pseudoplatanus*, foam (rivulet, river, stream), water (river)	Austria, Canada, Ireland, **Poland**, **Portugal**	[588, 631, 632, 728, 1048, 1066]
Varicosporium elodeae	Foam (rivulet, stream, spring, river, lake), submerged decaying leaves of *Alnus glutinosa* (stream), submerged decaying leaves of broad-leaved trees, shrubs, and angiosperms, stemflow and throughfall of tree canopies, water-filled treeholes, water (river, stream)	Austria, Brazil, Canada, **Czech Republic**, France, Hungary, India, Ireland, Japan, New Zealand, **Poland**, **Slovakia**, Sweden, UK, USA	[13, 64, 638, 713, 716, 724, 728, 729, 783, 828, 1048, 1086, 67, 1093, 1095, 1145, 588, 628, 630–632, 636, 637]
Varicosporium giganteum	Foam (stream, spring, river, lake), submerged decaying leaves (stream)	Canada, China, Ireland, New Zealand, Thailand, USA	[588, 632, 716, 729, 881, 1058, 1065]
Varicosporium helicosporium	Foam (river)	Malaysia	[1146]
Varicosporium macrosporum	Foam (river)	Malaysia, Thailand	[881, 1146]
Varicosporium scoparium	Foam (river)	Spain	[1046]
Varicosporium tricladiiforme	Submerged leaves of *Salix atrocinerea*, foam (stream)	Austria, Spain	[628, 1147]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Varicosporium trimosum	Foam (stream)	Canada, Czech Republic	[1046, 1148]
Lachnaceae			
Lachnum calycioides	*Eriophorum vaginatum* *Juncus filiformis*	Austria	[1079]
Lachnum controversum	Stems of *Phragmites australis*	UK, Germany	[38]
Lachnum cf. *virgineum*	wood	USA	[690]
Lachnum imbecille	*Eriophorum angustifolium*	Austria	[1079, 1149]
Lachnum nudipes	Stems of *Phragmites australis*	UK	[786, 1150]
Loramycetaceae			
Loramyces juncicola	Dead stalks of *Scirpus, Eleocharis, Equisetum, Juncus*	UK, USA	[61, 1086, 1151]
Loramyces macrosporus	Internodes of *Equisetum fluviatile*	UK	[1046, 1152]
Obtectodiscus aquaticus	*Carex rostrata*	Austria, Switzerland	[1061, 1079, 1086]
Mitrulaceae			
Mitrula alba	Submerged leaves	UK	[1153]
Mitrula paludosa	Submerged leaves, wood	UK	[1086, 1154]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Mollisiaceae			
Belonopsis guestphalicum	Submerged decaying *Phragmites* stem, *Schoenoplectus lacustris* stalks, *Typha angustifolia* leaf bases (lake)	UK	[60]
Mollisia casaresiae	Submerged birch dowel	UK	[1062]
Mollisia cinerea *Belonium excelsior*	Wood, *Typha latifolia*	Soviet Union	[788, 1155]
Mollisia gigantea	*Picea* twigs	Finland	[1126]
Mollisia hydrophila	*Phragmites*	Czechoslovakia, Denmark, UK, Finland, France, Germany, Poland, Scotland, Sweden, Switzerland	[1155, 1156]
Mollisia mediella	*Phragmites*, *Schoenoplectus lacustris*	UK, Finland, France, Germany, Ireland, Sweden, Switzerland	[1156]
Mollisia melaleuca	Wood	Soviet Union	[788]
Mollisia pilosa	*Carex*, *Schoenoplectus lacustris*	UK, Soviet Union	[788, 1086, 1154]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Mollisia pulla	Submerged decaying *Carex, Eleocharis, Juncus, Phragmites, Phalaris* (lake)	UK	[1086, 1154]
Mollisia retincola	*Phragmites, Carex,Typha*	UK, Finland, France, Germany, Ireland, Sweden, Switzerland	[1156]
Mollisia uda	Wood	UK	[38]
Nimbomollisia eriophori	*Carex rostrata, Eriophorum vaginatum, Juncus filiformis*	Austria	[747]
Nimbomollisia melatephroides	*Carex rostrata*	Austria	[747]
Niptera bispora	*Carex rostrata*	Austria	[1079]
Niptera guestphalica	*Schoenoplectus lacustris, Typha* leaf bases	UK	[60]
Niptera lacustris	*Schoenoplectus lacustris, Scirpus, Phragmites*	UK, Scandinavia	[38]
Niptera melanophae	*Schoenoplectus lacustris*	Soviet Union	[788]
Niptera tephromelas	*Typha*	Italy	[1156]
Phialocephala fluminis	Submerged decaying balsa wood (river)	USA	[1157]
Phialocephala xalapensis	Submerged decaying wood (stream)	Brunei, China	[583]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Scutomollisia morvernensis	*Carex rostrata, Equisetum fluviatile, Eriophorum angustifolium, Glyceria fluitans, Juncus filiformis*	Austria	[1079]
Scutomollisia punctum	*Carex rostrata*	Austria	[1079]
Tapesia kneiffii	*Phragmites* stalks	UK	[60]
Trichobelonium kneiffii	*Phragmites, Carex, Typha*	Czech Republic, UK, Finland, France, Germany Ireland, Sweden, Switzerland	[1156]
Trimmatostroma betulinum	Leaves	China	[1086, 1158]
Variocladium giganteum	Submerged decaying leaves of *Crataegus monogyna* and Poaceae, foam (stream)	Canada, UK	[588, 1046]
Variocladium rangiferinum Ploettnerulaceae	Foam (river)	UK	[1118]
Variocladium rangiferinum	Foam (river)	UK	[1118]
Belonium excelsior	Submerged decaying *Phragmites*	Finland UK	[60–61]
Cadophora novi-eboraci	Freshwater	**Korea**	[984]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Collembolispora aristata	Foam (stream)	**Czech Republic**	[1159]
Collembolispora barbata	Foam (stream)	Portugal	[1160]
Pyrenopeziza arundinaceae	*Phragmites australis* leaves	UK	[789]
Pyrenopeziza huetteri	*Carex rostrata*	Austria	[1079]
Pyrenopeziza perminuta	*Carex rostrata*	Austria	[1079]
Volucrispora aurantiaca	Foam (rivulet, stream)	Austria, Canada, UK	[628, 631, 1161, 1162]
Volucrispora graminea	Foam (river, rivulet, stream), water (river), stemflow and throughfall of tree canopies and palm species	Austria, Canada, India, Ireland, **Poland**, Portugal, UK	[588, 628, 1163, 631, 632, 636, 714, 727, 728, 1046, 1148]
Solenopeziaceae			
Geniculospora grandis	Decomposing plant litter, foam (stream), water (river), submerged decaying leaves (stream)	**Australia**, Austria, Canada, Poland, **Portugal**, **Spain,** Thailand	[628, 687, 729, 736, 738, 884, 1160]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Geniculospora inflata	Foam (river, stream), submerged decaying leaves of *Alnus glutinosa* (stream), water (river, stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Austria, Brazil, France, Ireland, Portugal, Spain, UK, USA	[88, 628, 783, 630, 632, 639, 687, 713, 714, 730, 732]
Graddonia coracina	Wood	UK	[1085, 1154]
Mycofalcella calcarata	Submerged branch of *Quercus*, water (stream)	France, Portugal, **UK**, USA	[639, 732, 828, 1046]
Mycofalcella iqbalii	Submerged decaying culm of *Saccharum munja* (canal)	Pakistan	[1164]
Trichopezizella hystricula	*Carex rostrata*	Austria	[1079]
Tricladium aciculum	Foam (river, stream), submerged decaying leaves	Malaysia, Thailand	[847, 881, 1165]
Tricladium alaskense	Stream	USA	[1046]
Tricladium angulatum	Pond water, foam (stream, spring, river, lake), submerged decaying leaves of *Alnus glutinosa*, *A. tenuifolia*, *Salix* spp., *Populus* spp., *Betula glandulosa* (stream), water (river), scum (stream)	Austria, **Canada**, **Czech Republic**, **Germany**, **Poland**, **Switzerland**, UK, **USA**, Venezuela	[13, 63, 717, 724, 728, 736, 784, 1048, 1066, 1067, 1166, 65, 519, 588,

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
			628, 687, 713, 715, 716]
Tricladium anomalum	On submerged decaying leaves of *Typha latifolia*, river, foam and scum	Poland, UK, USA	[730, 1048, 1167]
Tricladium attenuatum	Foam (rivulet, stream)	Austria, Canada, Czech Republic, **Portugal**	[588, 631, 1046, 1066]
Tricladium biappendiculatum	Foam (rivulet, stream), submerged decaying leaves (stream)	Austria, Canada, Czech Republic, UK	[628, 631, 729, 826, 1046, 1065]
Tricladium brunneum	Foam (river)	India, Japan, Malaysia	[731, 827, 1146]
Tricladium castaneicola	Foam (stream, river), water-filled treeholes	Czech Republic, Hungary, Ireland	[632, 638, 1046]
Tricladium caudatum	Foam (rivulet, stream)	Austria, Canada, Czech Republic	[628, 631, 1046, 1148]
Tricladium chaetocladium	Water (stream, river), submerged decaying leaves (e.g., *Alnus glutinosa*, *Alnus* sp. (stream, river), foam (stream)	**Australia**, Canada, **France**, Malaysia, **Portugal**, **Spain**, USA	[577, 588, 1051, 630, 639, 732, 736, 738, 783, 828, 1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Tricladium curvisporum	Foam (rivulet, river, stream)	Austria, Brazil, Ireland, UK	[628, 631, 632, 1046, 1168, 1169]
Tricladium fallax	Foam (river, stream)	Brazil, Czech Republic	[723, 1170]
Tricladium fuscum	Rotten leaves and foam (stream)	Malaysia	[1165]
Tricladium gracile	Pond, submerged decaying leaves, water (river), foam (rivulet, stream, spring, river, lake)	Austria, Canada, Ireland, Poland, UK, USA	[63, 65, 588, 631, 632, 713, 714, 716]
Tricladium indicum	Foam, on submerged rotten leaves of *Pinus roxburghii*	China, India, Malaysia, USA	[583, 660, 1046]
Tricladium intermedium	On submerged of rotting twigs, submerged decaying angiosperm leaves, foam (river, stream, spring, lake)	USA	[65, 716]
Tricladium kelleri	Stream	USA	[1046]
Tricladium marylandicum	Foam (pond, lake, stream, spring, river), submerged decaying angiosperm leaves	Poland, USA	[716, 1048]
Tricladium minutum	*Juncus* culms, foam (stream)	Canada, UK	[588, 1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Tricladium obesum	Foam (stream)	Czech Republic	[1046, 1171]
Tricladium patulum	Foam (rivulet, river, stream), submerged leaf litter of *Alnus glutinosa* (stream)	Austria, Canada, Czech Republic, **France**, Ireland, **Poland**	[588, 628, 630–632, 728, 736, 1046]
Tricladium procerum	Submerged dead stem of *Juncus*, rainwater from building roofs	Poland, Slovenia	[633, 1046, 1127]
Tricladium robustum	In mountain stream, on rotten leaf of *Fagus sylvatica*, foam (stream)	Austria, Czech Republic, Spain	[628, 1170, 1172]
Tricladium splendens	Foam (rivulet, stream, river, spring, lake), submerged decaying leaves of *Alnus glutinosa, A. tenuifolia, Salix* spp., *Populus* spp., *Betula glandulosa* (stream), foam (stream), stemflow and throughfall of tree canopies, water (stream)	Austria, Brazil, **Canada**, **Czech Republic**, France, India, Ireland, Japan, **Poland**, **Slovakia**, Switzerland, UK, **USA**, Venezuela	[13, 63, 637, 713, 715, 716, 724, 728, 731, 736, 760, 784, 65, 828, 1046, 1166, 519, 588, 628, 630–632, 636]
Tricladium terrestre	Foam (stream)	Ireland, Portugal	[1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Tricaldium varicosporoides	Twigs, submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blokcs)	Japan, Thailand	[70, 1047, 1173]
Tricladium varium	Submerged decaying wood of *Pinus sylvestris* and *Fagus sylvatica* (water-cooling towers)	UK	[1174]
Vibrisseaceae			
Gorgoniceps boltonii	Submerged decaying *Equisetum fluviatile* Stems (lake)	Austria, UK	[60, 1079]
Leucovibrissea obconica	Alder twigs	Scandinavia	[1175]
Vibrissea decolorans	Twigs	Sweden, Norway	[1175]
Vibrissea dura	*Eucalyptus* logs	Australia	[1055]
Vibrissea filisporia	Submerged alder, willow and *Corylus* twigs (stream)	UK, Hungary, France, Norway, Sweden	[817, 1083, 1175, 1176]
Vibrissea flavovirens	Submerged decaying wood and leaves (stream, river)	UK	[1176–1178]
Vibrissea guernisacii	Twigs, water (river, lake)	Poland, UK, USA	[60, 687, 690]
Vibrissea leptospora	*Prunus, Rosa, Ribes, Salix*	Sweden, UK,	[1176]
Vibrissea norvegica	*Phragmites australis*	Norway	[1179]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Vibrissea sporogyra	Submerged decaying stalks of *Equisetum, Carex, Eleocharis* (lake)	UK	[60]
Vibrissea truncorum	Maple, alder, birch willow, juniper branches	Scandinavia	[1054, 1155]
Vibrissea vibrisseoides	Wood	Scandinavia	[1054, 1155]
Helotiales genera *incertae sedis*			
Aquapoterium pinicola	Submerged *Pinus* needles (swamp)	USA	[1050]
Chlorovibrissea bicolor	Wood	Australia	[1056]
Chlorovibrissea melanochlora	*Eucalyptus* logs	Australia	[1055]
Chlorovibrissea tasmanica	*Eucalyptus* logs	Australia	[1055]
Filosporella annelidica	Foam (river, stream), water, submerged decaying leaves of *Platanus occidentalis* and *Acer saccharinum* (river)	Austria, Spain, UK, USA	[628, 1046, 1180]
Filosporella aquatica	Ssubmerged decaying leaves of *Pandanus helicopus*	Malaysia	[1181]
Filosporella exilis	*Equisetum fluviatile*	Belarus	[1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Filosporella fistucella	Submerged roots of *Alnus glutinosa*	UK	[1046]
Filosporella pinguis	Foam (stream)	Canada	[1182]
Filosporella versimorpha	Submerged roots of *Alnus glutinosa*	UK	[1046]
Tetracladium apiense	Plant debris (stream), foam (stream)	South Africa, Spain	[1046, 1183]
Tetracladium breve	Leaf *Frangula* cf. *alnus*, foam (stream), water (river)	Austria, Brazil, **Poland**, Spain	[628, 728, 1046, 1183]
Tetracladium furcatum	Leaves, foam (river, stream), water (river, stream)	Austria, China, **Poland**, Portugal, UK	[628, 723, 728, 732, 1046, 1058, 1168]
Tetracladium globosum	Freshwater	**Korea**	[984]
Tetracladium marchalianum	Water (pond, river, stream), submerged decaying wood (*Alnus glutinosa, Acer pseudoplatanus, Corylus avellana, Fraxinus excelsior, Fagus sylvatica, Tilia cordata, Ulmus* sp., submerged decaying leaves of *Salix* spp., *Populus* spp., *Betula glandulosa*, and *Alnus tenuifolia*, (stream), foam (stream, river, rivulet),	**Austria**, Canada, Cuba, **Czech Republic**, France, **Germany**, India, Jamaica, Nigeria, **Poland**, Portugal, Spain, Switzerland, UK, USA, Venezuela	[13, 63, 715, 717, 718, 721, 724, 728, 729, 732, 739, 783, 519, 784, 828, 1048, 1183, 1184, 588,

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
	sediment (dam, stream)		628, 630, 631, 687, 713, 714]
Tetracladium maxiliforme	Water (pond, river), submerged decaying wood (*Alnus glutinosa*) in stream, foam (stream, rivulet), foam (stream)	Austria, Canada, France, New Zealand, **Poland**, USA, Venezuela	[65, 519, 588, 628, 630, 631, 728, 1048, 1067, 1100]
Tetracladium nainitalense	Root endophyte riparian plants, foam (stream)	Brazil, India	[723, 1185]
Tetracladium setigerum	Water (pond, river), foam (stream), submerged leaves of *Salix atrocinerea* (river) and *Alnus glutinosa* leaves (stream), sediment (stream)	Austria, Canada, France, India, Jamaica, Malaysia, Poland, Portugal, Spain, Switzerland, Thailand, UK, USA, Venezuela	[13, 63, 718, 732, 784, 1048, 1086, 1183, 65, 519, 577, 588, 628, 630, 637, 713]
Lauriomycetales			
Lauriomycetaceae			
Lauriomyces heliocephalus	Submerged decaying leaf	Brazil	[697]
Lauriomyces pulcher	Submerged decaying wood (stream)	Hong Kong	[676]
Lauriomyces sakaeratensis	Submerged decaying leaves (stream)	Brazil	[683]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Leotiales			
Leotiales genera *incertae sedis*			
Alatospora acuminata	Unpolluted water (stream), foam (stream, river, rivulet), submerged decaying wood and leaves (*Alnus glutinosa, Acer pseudoplatanus, Corylus avellana, Fraxinus excelsior, Fagus sylvatica, Picea abies, Tilia cordata, Ulmus* sp.), submerged leaves (*Coffea arabica* and *Hevea brasiliensis*) (stream), water (river), scum (stream), sediment (dam), stemflow and throughfall of tree canopies and palm species, water-filled treeholes	Austria, Brazil, **Canada**, **Czech Republic**, France, Hungary, India, Ireland, Jamaica, Japan, **Netherlands**, New Zealand, **Poland**, **Portugal**, Rhodesia, Uganda, South Africa, Spain, Sweden, Switzerland, **UK**, USA, Venezuela	[13, 63, 638, 713, 714, 717, 718, 721, 723, 724, 727, 728, 64, 729, 730, 732, 736, 783, 784, 828, 985, 1051, 1066, 519, 1086, 1090–1093, 1095, 1115, 1117, 1186, 1187, 588, 628, 630–632, 636]
Alatospora crassipes	Submerged decaying leaves of *Fagus sylvatica* in (river)	Czech Republic	[1188]
Alatospora flagellata	*Fagus sylvatica* leaf (stream), foam (stream, rivulet), submerged leaf litter of *Alnus glutinosa* (stream), water	Austria, Canada, Czech Republic, France, Hungary,	[588, 628, 630, 631, 728, 1046, 1117]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
	(river)	**Poland**	
Alatospora pulchella	Leaves (stream), foam (stream, rivulet), submerged decaying leaves of *Alnus* (stream), water (stream), stemflow and throughfall	**Australia**, Austria, China, Czech Republic, France, India, **Italy**, **Netherlands**, **Portugal**, Spain, UK, USA	[628, 630, 631, 639, 727, 783, 1046, 1066, 1117, 1158]
Rhytismatales			
Rhytismataceae			
Hypoderma alpinum	*Carex nigra*	Austria	[1079]
Hypohelion scirpinum	Submerged decaying stalks of *Carex nigra*	UK	[60]
Lophodermium licualae	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Lophodermium macci	Water	China	[1189]
Thelebolales			
Thelebolaceae			
Geomyces sp.	Water distribution system	Polland	[1052]
Thelebolales genera *incertae sedis*			
Gorgomyces honrubiae	Foam (stream)	Spain	[1046]

Table 7.6 (continued)

Taxon	Substrate	Country	Reference
Miniancora allisoniensis	Foam (stream)	Canada	[1046]

7.3.1.6 Orbiliomycetes

Orbiliaceae was previously assigned to Helotiales but it was raised to a class rank based on morpho-phylogenetic analysis. Wijayawardene et al. [204] accepted twelve genera in Orbiliaceae while *Microdochiella* (*M. fusarioides*) and *Mycoceros* (*M. antennatissimus*) are members of Orbiliales genus *incertae sedis* and Orbiliomycetes genus *incertae sedis*, respectively. Baral et al. [1190] provided a list of generic names of Orbiliomycetes while Baral et al. [1191] provided a comprehensive taxonomic account of the class and its geographical distribution. Orbiliomycetes are collected in various habitats (hygric, semi-aquatic, xeric). Nineteen species, in ten genera, (*Arthrobotrys, Hyalorbilia, Dactylella, Dicranidion, Helicoon, Monacrosporium, Orbilia, Orbiliella, Trinacrium, Vermispor*a), are listed in Table 7.7.

Table 7.7 Classification of Freshwater Orbiliomycetes with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	References
ASCOMYCOTA			
ORBILIOMYCETES			
Orbiliales			
Orbiliaceae			
Arthrobotrys dactyloides	Submerged twig	Brazil	[697]
Arthrobotrys oligosporus	Water (river), Submerged decaying leaves (stream), decaying *Licuala longicalycata* (peat swamp)	Brazil, Poland, Thailand	[683, 687] [585]
Dactylella microaquatica	Submerged decaying of unidentified leaves and *Shiia sieboldii*,	Cuba, Japan, Philippines, USA	[65, 432, 639, 739]

Table 7.7 (continued)

Taxon	Substrate	Country	References
	submerged decaying wood (river), water (stream)		
Dactylella submersa	Submerged decaying leaves of *Quercus*, foam (stream), stemflow and throughfall of palm species	Cuba, India, Ireland, Poland, UK	[713, 722, 727, 739, 985, 1192]
Dactylella yunnanensis	Submerged leaf	Brazil	[697]
Dicranidion fissile	rainwater from *Quercus myrsinaefolia* leaves	Japan	[634]
Dicranidion gracile	Stemflow and throughfall of tree canopies	India	[636]
Helicoon myosuroides	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88, 1140]
Helicoon pluriseptatum	Rainwater from building roofs, leaves in water, submerged decaying *Quercus* leaves (lake)	Ireland, Netherlands, Poland	[633, 719, 840]
Hyalorbilia oviparasitica	Foam (stream)	India	[722, 827]
Monacrosporium tentaculatum	Foam (stream, river), submerged leaves	India, Thailand, USA	[730, 827, 881]
Orbilia ellipsospora	Submerged decaying twigs and leaves (stream), *Calophyllum brasiliense*	Brazil	[88, 683]
Orbilia luteorubella	Submerged decaying wood (river)	USA	[690]

Table 7.7 (continued)

Taxon	Substrate	Country	References
Orbiliella armeniaca	Twigs	USA	[1193]
Trinacrium incurvum	Foam (river), stemflow and throughfall of palm species	Brazil, India	[723, 727]
Trinacrium indicum	Submerged decaying leaves of *Coffea arabica* (stream)	India	[1194]
Trinacrium robustum	Stemflow and throughfall of tree canopies and palm species	India	[636, 727]
Trinacrium subtile	Rainwater from building roofs, leaves in water, stemflow and throughfall of tree canopies and palm species	India, Netherlands, Poland	[633, 636]
Vermispora cauveriana	Foam (stream), submerged decaying leaves of *Ficus religiosa* (river)	India	[722] [1195]

7.3.1.7 Pezizomycetes

Pezizomycetes thrive mostly in terrestrial habitats, such as burnt land, deserts, forests, sand, steppe, and on different substrates (dung, leaves, soil, wood) [1196–1198]. However, Pezizomycetes are rarely reported from freshwater habitats. Jones et al. [174] recorded eight species from freshwater. Currently, ten species are included in the Freshwater Ascomycetes Database (http://fungi.life.illinois.edu/). We reviewed the number of freshwater fungi in this class (Table 7.8), and there are 13

species from four families. All known freshwater Pezizomycetes are found on woody substrates. Within these aquatic species, almost half of them from *Pachyella* and *Psilopezia*. Species of both genera are usually from wet habitats, however not all species were found and exclusively described on the water-soaked wood [1199–1201]. *Saccobolus beckii* is usually reported on animal dung [1202, 1203]. One interesting account reports them from water cooling tower [1204]. In addition, another unknown *Peziza* species has been reported from a water-cooling tower [836]. Hu et al. [1205] proposed a new genus *Aquapeziza* and placed in Pezizaceae based on the morphology and phylogeny *of Aquapeziza globispora* on submerged wood. The operculate asci, which is main feature of Pezizomycetes, are obvious in all freshwater Pezizomycetes except *A. globispora* with no distinct ascus [1205]. *Peziza oliviae* is the latest report associated with freshwater habitat within Pezizomycetes [1206].

Table 7.8 Classification of Freshwater Pezizomycetes with information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	References
PEZIZOMYCETES			
Pezizales			
Ascobolaceae			
Saccobolus beckii	Pine bark	India	[1204]
Thecotheus rivicola	Twigs and wood of *Prunus*	Czech Republic, USA	[1200]
Pezizaceae			
Adelphella babingtonii	Twigs	England; USA, France, Hungary	[60, 1197, 1201]
Aquapeziza globispora	Wood	China	[1205]
Pachyella adnata	Wood	USA, Japan	[1201]
Paclzyella clypeata	Wood	USA, Japan	[1201]

Table 7.8 (continued)

Taxon	Substrate	Country	References
Pachyella punctispora	Wood	USA	[1201]
Pachyella violaceonigra	Wood	Ukraine	[788]
Peziza oliviae	Wood	USA	[1206]
Peziza sp.	Wood	England	[836]
Pyronemataceae			
Miladina lecithina	Wood, foam (stream)	Austria, England, USA	[628, 1207, 1208]
Scutellinia scutellata	Wood	Ukraine	[788]
Rhizinaceae			
Psilopezia deligata	Poplar log or unidentified wood	USA, Argentina	[1200]
Psilopezia nummularia	Wood	USA	[1200]

7.3.1.8 Sordariomycetes

The Sordariomycetes is one of the largest classes of Ascomycota that comprises a highly diverse range of fungi mainly characterized by perithecial ascomata and inoperculate unitunicate asci [23, 25]. In freshwater habitats, Sordariomycetes is one of the major and important fungal groups with a vital role in ecosystems. Members of this class are known to produce bioactive compounds [174, 1209]. The latest systematic study of freshwater Sordariomycetes was carried out by Luo et al. [5] with taxonomic accounts for each genus. Furthermore, all taxa recorded from freshwater habitats are outlined with important ecological (freshwater distribution) and taxonomic (morphology, holotype, available molecular data) notes of each species [5, 449].

Luo et al. [5] included six subclasses, 30 orders, 56 families and 160 genera of Sordariomycetes thriving in freshwater habitats, and representative taxa are illustrated in Figure 7.5. From the review of published works on freshwater Sordariomycetes, a total 823 freshwater species were reported from freshwater habitats, and distributed in 40 orders, 85 families, and 298 genera (Table 7.9, Figure

7.6). Among the 40 orders, Chaetosphaeriales has the highest number of taxa with 149 freshwater species recorded.

The use of DNA sequence data coupled with phylogenetic analyses has significantly improved our understanding of the phylogeny and evolution of freshwater ascomycetes [616]. Most of the new taxa of freshwater fungi published in the past decade are supported with molecular data [386, 699, 1210–1212]. However, there are still taxa of freshwater fungi with no sequence data [1213, 1214]. The taxonomic placements of many freshwater Sordariomycetes are currently uncertain and suffers from lack of living cultures and type sequences. Therefore, to better understand the phylogeny of freshwater Sordariomycetes in a natural classification system, further investigations are needed. Future studies should put high priority to obtain living cultures.

Table 7.9 Classification of Freshwater Sordariomycetes with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	Reference
ASCOMYCOTA			
SORDARIOMYCETES			
Diaporthomycetidae			
Annulatascales			
Annulatascaceae			
Annulatascus apiculatus	Submerged decaying wood (stream)	Brazil	[1215]
Annulatascus aquaticus	Submerged decaying wood (stream)	China	[1216]
Annulatascus chiangmaiensis	Submerged decaying wood (stream)	**Thailand**	[587]
Annulatascus fusiformis	Submerged decaying wood (stream)	Australia, China, Philippines	[77, 435, 616]
Annulatascus hongkongensis	Submerged decaying wood (reservoir)	China	[1217]
Annulatascus joannae	Submerged decaying wood (river)	China	[1218]
Annulatascus lacteus	Submerged decaying wood (river)	China	[1218]
Annulatascus liputii	Submerged decaying bamboo (river)	Philippines	[430]
Annulatascus menglensis	Submerged decaying wood (stream)	China	[1219]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Annulatascus nakhonensis	Submerged decaying wood (stream)	**Thailand**	[587]
Annulatascus palmietensis	Submerged decaying wood (river)	Brunei, South Africa	[692, 696, 1220]
Annulatascus saprophyticus	Submerged decaying wood (stream)	**Thailand**	[1221]
Annulatascus songkhlaensis	Submerged decaying wood (stream)	**Thailand**	[587]
Annulatascus thailandensis	Submerged decaying wood (stream)	**Thailand**	[23]
Annulatascus tropicalis	Submerged decaying wood (stream)	China	[1218]
Annulatascus velatisporus	Submerged decaying wood (stream, river, waterfall) and bamboo (river), submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	**Australia**, Brazil, Brunei, China, Philippines, India, Japan, Malaysia, South Africa, Thailand	[30, 62, 432, 583, 584, 660, 666, 696, 816, 1222–1225]
Annulusmagnus triseptatus	Submerged decaying wood (river, stream)	Australia, Brunei, Canada, **China**, Malaysia, USA, Venezuela	[583, 1222, 1226]
Aqualignicola hyalina	Submerged decaying wood (river)	China, India	[1224, 1227]
Aqualignicola vaginata	Submerged decaying wood (stream)	China	[1219]
Ascitendus aquaticus	Submerged decaying wood (river)	Australia	[312]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Ascitendus austriacus	Submerged decaying wood	Australia, Canada, USA, Venezuela	[1226, 1228]
Ayria appendiculata	Submerged decaying wood	USA	[656]
Ayria nubispora	Submerged decaying wood (lake, stream)	Costa Rica, USA	[899]
Cataractispora appendiculata	Submerged decaying wood (river, stream)	Australia, Brunei, Seychelles	[1229]
Cataractispora aquatica	Submerged decaying wood (river, stream, waterfall)	Australia, Brunei, Malaysia, Seychelles	[521, 1229]
Cataractispora bipolaris	Submerged decaying wood (river, stream)	Australia, Brunei, Malaysia, USA	[583, 656, 1225]
Cataractispora receptaculorum	Submerged decaying wood and bamboo (reservoir)	China	[436]
Cataractispora viscosa	Submerged decaying wood (stream)	Australia, China, Malaysia, Mauritius	[583, 1229]
Chaetorostrum quincemilense	Submerged decaying wood (stream)	Peru	[1230]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Fusoidigranularius nilensis	Submerged decaying wood (*Phragmites australis*) (river)	**Egypt**	[1231]
Longivarius aquatorbae	Submerged decaying wood (*Erythrophleum teysmannii*)	**Thailand**	[1232]
Longicollum biappendiculatum	Submerged decaying wood (stream)	Brazil, Costa Rica, Peru, USA	[1233]
Submersisphaeria aquatica	Submerged decaying wood, submerged decaying *Licuala longicalycata* (peat swamp)	Australia, France, Thailand, USA	[584, 1234–1236]
Submersisphaeria palmae	Submerged decaying *Eleiodoxa conferta* petiole and rachis, *Nenga pumila* rachis, *Licuala longecalycata* trunk and petiole, (peat swamp)	Thailand	[62]
Vertexicola ascoliberatus	Submerged decaying wood (stream)	Costa Rica	[666]
Vertexicola caudatus	Submerged decaying wood	China	[1237]
Aquapteridosporaceae			
Aquapteridospora aquatica	Submerged decaying wood (stream)	**Thailand**	[587]
Aquapteridospora bambusinum	Submerged decaying wood	**Thailand**	[590]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Aquapteridospora lignicola	Submerged decaying wood (stream)	**Thailand**	[1238]
Aquapteridospora fusiformis	Submerged decaying wood (stream)	**China**	[5]
Atractosporales			
Atractosporaceae			
Atractospora aquatica	Submerged decaying wood (stream)	**China**	[5]
Atractospora decumbens	Submerged decaying wood (stream)	**France**	[1239]
Atractospora ellipsoidea	Submerged decaying wood	Brunei, **China**, USA	[587, 692, 1226, 1240]
Atractospora reticulata	Submerged decaying *Sambucus nigra* wood (stream)	**France**	[1239]
Atractospora thailandensis	Submerged decaying wood (river)	**Thailand**	[437]
Atractospora verruculosa	Submerged decaying wood	France	[1239]
Rubellisphaeria abscondita	Submerged decaying wood	France	[1239]
Jobellisiales			
Jobellisiaceae			
Jobellisia guangdongensis	Submerged decaying wood (stream)	**China**	[807, 1241]
Jobellisia luteola	Submerged decaying wood	USA	[656]
Jobellisia viridifusca	Submerged decaying wood (river)	China	[1227]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Barbatosphaeriales			
Barbatosphaeriaceae			
Barbatosphaeria lignicola	Submerged decaying wood (stream)	**China**	[5]
Cancellidiales			
Cancellidiaceae			
Cancellidium applanatum	Submerged decaying wood of *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks, unidentified wood (stream), submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	Brazil, Perú, Thailand	[62, 70, 584, 683, 858, 1242]
Cancellidium atrobrunneum	Submerged decaying wood (stream)	**Thailand**	[33, 587]
Cancellidium cinereum	Submerged decaying wood (stream)	**China**	[33]
Cancellidium griseonigrum	Submerged decaying wood (stream)	**Thailand**	[33]
Cancellidium thailandense	Submerged decaying wood (stream)	**Thailand**	[587]
Obliquiminima hyalina	Submerged decaying wood (stream)	**Thailand**	[587]
Ceratolentales			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Bullimycetaceae			
Bullimyces aurisporus	Submerged decaying wood (stream)	**Costa Rica**	[1243]
Bullimyces communis	Submerged decaying wood (reserve, stream)	**Costa Rica**	[1243]
Bullimyces costaricensis	Submerged decaying wood (stream)	**Costa Rica**	[1243]
Conlariales			
Conlariaceae			
Conlarium aquaticum	Submerged decaying wood (river, stream)	**China**, **Thailand**	[437, 587]
Conlarium dupliciascosporum	Submerged decaying wood (stream)	China	[1241]
Conlarium subglobosum	Submerged decaying wood (stream)	**Thailand**	[587]
Riomyces rotundus	Submerged decaying wood (stream)	**Costa Rica**	[1243]
Diaporthales			
Diaporthaceae			
Diaporthe aquatica	Submerged decaying wood (ditch)	**China**	[498]
Diaporthe beckhausii	Submerged decaying wood (stream)	China	[583]
Diaporthe longicolla	Freshwater	**Korea**	[841]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Gnomoniaceae			
Ambarignomonia petiolorum	Submerged partially decomposed *Acer rubrum* leaves (lake)	USA	[749]
Gnomonia papuana	Submerged leaves	Papua New Guinea	[1244]
Gnomoniella microspora	Submerged decaying wood (stream)	Malaysia	[583]
Gnomoniella rubicola	Submerged decaying wood (stream)	Brunei	[583]
Sydowiellaceae			
Sillia ferruginea	Submerged decaying wood	UK	[760, 836]
Diaporthales genera *incertae sedis*			
Phruensis brunneispora	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[80, 584]
Distoseptisporales			
Distoseptisporaceae			
Distoseptispora appendiculata	Submerged decaying wood (stream)	**Thailand**	[5]
Distoseptispora aquatica	Submerged decaying wood (stream)	**China**	[699]
Distoseptispora cangshanensis	Submerged decaying wood (stream)	**China**	[1245]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Distoseptispora fasciculata	Submerged decaying wood (stream)	**Thailand**	[587]
Distoseptispora fluminicola	Submerged decaying wood (stream)	**China**	[699]
Distoseptispora guttulata	Submerged decaying wood (stream)	**Thailand**	[5, 1212]
Distoseptispora lignicola	Submerged decaying wood (waterfall)	**Thailand**	[5]
Distoseptispora martinii	Submerged decaying wood (stream)	Brazil	[683]
Distoseptispora multiseptata	Submerged decaying wood (stream)	**Thailand**	[5, 310]
Distoseptispora neorostrata	Submerged decaying wood (stream)	**Thailand**	[5]
Distoseptispora obclavata	Submerged decaying wood (stream)	**Thailand**	[5]
Distoseptispora obpyriformis	Submerged decaying wood (river)	**China**	[1245]
Distoseptispora phangngaensis	Submerged decaying wood (stream)	**Thailand**	[1212]
Distoseptispora rostrata	Submerged decaying wood (river)	**China**	[1245]
Distoseptispora saprophytica	Submerged decaying wood (stream)	**Thailand**	[587]
Distoseptispora songkhlaensis	Submerged decaying wood (stream)	**Thailand**	[587]
Distoseptispora submersa	Submerged decaying wood (river)	**China**	[1245]
Distoseptispora suoluoensis	Submerged decaying wood (river)	**China**	[1212]
Distoseptispora tectonae	Submerged decaying wood (stream)	**Thailand**	[587]
Distoseptispora yunnanensis	Submerged decaying wood (river)	**China**	[1246]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Magnaporthales			
Ceratosphaeriaceae			
Ceratosphaeria aquatica	Submerged decaying wood (river)	**China**	[5]
Ceratosphaeria lampadophora	Submerged decaying wood (water-cooling tower)	Australia	[1247, 1248]
Ceratosphaeria phialidica	Submerged decaying wood (river)	USA	[1249]
Ceratosphaeria pusilla	Submerged decaying wood (swamp)	USA	[706]
Ceratosphaeria lignicola	Submerged decaying wood (stream)	**Thailand**	[5]
Magnaporthaceae			
Aquafiliformis lignicola	Submerged decaying wood (river, stream)	**China**	[5]
Buergenerula biseptata	*Carex rostrata*	Austria	[642]
Clasterosporium flexum	Foam (stream), submerged decaying *Thuja plicata* foliage (pond)	Japan, UK	[523, 731]
Gaeumannomyces graminis	*Carex rostrata*	Australia	[1079]
Ophioceraceae			
Ophioceras aquaticus	Submerged decaying wood (reservoir)	**China**	[498]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Ophioceras arcuatisporum	Submerged *Typha* sp. (lake)	**Canada**, **China**, **USA**	[627, 1250]
Ophioceras commune	Submerged decaying wood (lake, stream, river, waterfall)	**China**, Egypt, Japan, Malaysia, **Panama**, Thailand, **USA**	[78, 521, 627, 656, 660, 807, 1223, 1250, 1251]
Ophioceras dolichostomum	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (lake, river)	Australia, Brunei, China, Japan, Malaysia, Philippines, Seychelles, Thailand, USA	[70, 432, 627, 693, 864, 1223, 1252]
Ophioceras fusiforme	Submerged decorticated woody debris (stream)	**USA**	[1250]
Ophioceras guttulatum	Submerged decaying wood (river, stream)	China	[435, 1253]
Ophioceras hongkongense	Submerged decaying wood (river)	China	[1253]
Ophioceras leptosporum	Submerged plant stalks	**UK**	[1254]
Ophioceras submersum	Submerged decaying wood (waterfall)	**Thailand**	[5]
Ophioceras tenuisporum	Submerged decaying twig (creek)	**Panama**	[1250]
Ophioceras venezuelense	Submerged decaying wood (stream)	Brazil, **Venezuela**	[1250]
Pseudohalonectriaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Pseudohalonectria adversaria	Submerged decaying wood (swamp, stream)	China, Malaysia, South Africa, UK	[583, 627, 688, 696, 1249, 1255]
Pseudohalonectria falcata	Submerged decaying wood (river)	**USA**	[1249]
Pseudohalonectria fuxianii	Submerged decaying wood (lake)	China	[670]
Pseudohalonectria lignicola	Submerged decaying wood and *Acer saccharinum* twig (creek, lake, stream, waterfall)	**China**, Japan, Thailand, **USA**	[521, 627, 670, 1223, 1249, 1255, 1256]
Pseudohalonectria longirostrum	Submerged decaying wood (river)	Panama, Philippines	[432, 1249]
Pseudohalonectria lutea	Submerged decaying *Quercus* wood (stream)	China, Chile, USA	[670, 749, 1249]
Pyriculariaceae			
Neocordana musae	Submerged decaying wood (stream)	China	[583]
Pyricularia fusispora	Submerged decaying leaves (stream)	Brazil	[683]
Pyricularia rabaulensis	Submerged decaying wood (stream)	Brazil	[683]
Myrmecridiales			
Myrmecridiaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Myrmecridium aquaticum	Submerged decaying wood (river, stream)	**China**	[5]
Myrmecridium fluviae	Freshwater	**Korea**	[415]
Myrmecridium montsegurinum	Submerged wood of *Fraxinus excelsior*, *Fagus sylvatica*, *Hedera helix* and *Alnus glutinosa* (stream)	**France**	[1239]
Myrmecridium schulzeri	Water (stream), submerged decaying wood	**China, South Korea**	[1257, 1258]
Ophiostomatales			
Ophiostomataceae			
Subbaromyces aquaticus	Submerged decaying wood	India	[1259]
Parasympodiellales			
Parasympodiellaceae			
Parasympodiella laxa	Submerged decaying leaves (stream)	Brazil	[683]
Phomatosporales			
Phomatosporaceae			
Phomatospora aquatica	Submerged decaying wood (stream)	Australia, Japan	[752, 1256]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Phomatospora berkeleyi	Submerged decaying wood (*Typha latifolia*, *Carex comosa*, *Scirpus brevicaudatus*), wood (lake, river, stream), decaying *Licuala longicalycata* (peat swamp)	Australia, China, Philippines, Thailand, USA	[749, 752]
Phomatospora helvetica	Submerged decaying wood (stream)	Norway	[1260]
Phomatospora luteotingens	Submerged decaying wood (*Alnus glutinosa*, *Fraxinus excelsior*)	France, Spain	[1261]
Phomatospora muskellungensis	Submerged decaying wood and stem of *Typha latifolia* (lake)	USA	[749]
Phomatospora striatigera	Submerged *Carex gracili*	Australia	[1262]
Phomatospora triseptata	Submerged decaying wood (swamp)	USA	[756]
Rhamphoriales			
Rhamphoriaceae			
Rhamphoria pyriformis	Submerged decaying wood (stream)	China	[583]
Rhodoveronaea aquatica	Submerged decaying wood (stream)	**China**	[5]
Sporidesmiales			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Sporidesmiaceae			
Sporidesmium altum	Submerged decaying wood (reservoir)	China	[626]
Sporidesmium appendiculatum	Submerged decaying wood (stream)	**Thailand**	[587]
Sporidesmium aquaticivaginatum	Submerged decaying wood (stream)	Thailand	[310]
Sporidesmium aturbinatum	Submerged decaying wood	**China**	[590]
Sporidesmium brachypus	Submerged decaying wood (river)	**China**	[5]
Sporidesmium cangshanense	Submerged decaying wood (stream)	**China**	[5]
Sporidesmium chiangmaiense	Submerged decaying wood (stream)	**Thailand**	[587]
Sporidesmium dulongense	Submerged decaying wood (river)	**China**	[23]
Sporidesmium ensiforme	Foam (tarn)	UK	[1118]
Sporidesmium fluminicola	Submerged decaying wood (stream)	**China**	[699]
Sporidesmium gyrinomorphum	Submerged decaying wood (stream)	**Thailand**	[1212]
Sporidesmium lageniforme	Submerged decaying wood (river)	**China**	[5]
Sporidesmium lignicola	Submerged decaying wood (river, stream)	**China**	[5]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Sporidesmium macrurum	Submerged decaying wood (stream)	Brunei	[583]
Sporidesmium olivaceoconidium	Submerged decaying wood (stream)	**Thailand**	[310]
Sporidesmium nujiangense	Submerged decaying wood (river)	**China**	[590]
Sporidesmium paludosum	Submerged decaying wood (lake) and bamboo (river)	China, Philippines	[432, 627]
Sporidesmium ponapense	Submerged decaying leaves (stream)	Brazil	[683]
Sporidesmium pyriformatum	Submerged decaying wood (stream)	**Thailand**	[310]
Sporidesmium submersum	Submerged decaying wood (stream)	**China**	[699]
Sporidesmium thailandense	Submerged decaying wood (river)	**Thailand**	[437, 1212, 1263]
Sporidesmium tropicale	Foam (river), submerged decaying wood (stream)	Brazil, **China**, Thailand	[590, 683, 881, 1212]
Tirisporellales			
Tirisporellaceae			
Thailandiomyces bisetulosus	Submerged decaying wood, decaying *Licuala longicalycata* (peat swamp)	Thailand	[585, 1264]
Tirisporella beccariana	Foam (stream)	Malaysia	[1265]
Togniniales			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Togniniaceae			
Erostella minutissima	Submerged decaying wood (stream)	China	[583]
Phaeoacremonium aquaticum	Submerged decaying wood (stream)	**China**	[498]
Phaeoacremonium ovale	Submerged decaying wood (stream)	**China**	[499]
Phaeoacremonium thailandense	Submerged decaying wood (river)	**Thailand**	[386]
Trichosphaeriales			
Trichosphaeriaceae			
Brachysporium obovatum	Submerged decaying wood	USA	[656]
Brachysporium nigrum	Submerged decaying wood	USA	[690]
Koorchaloma bambusae	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Unisetosphaeria penguinoides	Submerged petiole of *Eleiodoxa conferta* (peat swamp)	Thailand	[62, 1266]
Xenospadicoidales			
Xenospadicoidaceae			
Neospadicoides aquatica	Submerged decaying wood (stream)	**China**	[5]
Neospadicoides lignicola	Submerged decaying wood (stream)	**China**	[5]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Neospadicoides thailandica	Submerged decaying wood	**Thailand**	[590]
Neospadicoides yunnanensis	Submerged decaying wood (river)	**China**	[5]
Spadicoides americana	Submerged decaying wood (stream)	China	[1267]
Spadicoides atra	Submerged decaying wood (stream)	China	[437]
Spadicoides bambusicola	Submerged decaying wood (stream)	China	[435]
Spadicoides cordanoides	Submerged decaying wood (stream)	Australia	[1268]
Spadicoides hodgkissa	Submerged decaying wood (stream)	China	[446]
Spadicoides klotzschii	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Spadicoides minuta	Submerged decaying *Phyllostachys bambusoides* (stream)	China	[1269]
Spadicoides obovata	Submerged decaying wood, decaying *Licuala longicalycata* (peat swamp)	China, Thailand	[585, 1270]
Spadicoides stoveri	Decaying *Nenga pumila* (peat swamp)	Thailand	[585]
Spadicoides subsphaerica	Submerged decaying wood (stream)	Brazil	[1140]
Torrentispora aquatica	Submerged decaying wood (stream)	China	[1271]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Torrentispora biatriispora	Submerged decaying wood (river, stream)	Australia, China, Costa Rica, Seychelles	[666, 693, 1218, 1272]
Torrentispora calembola	Submerged decaying wood of *Fagus sylvatica* and *Fraxinus excelsior* (lake)	Czech Republic**, France**	[1273]
Torrentispora crassiparietis	Submerged decaying wood (river, stream)	Brazil, Brunei, Costa Rica	[666, 692, 1274]
Torrentispora fibrosa	Submerged decaying wood (lake, reservoir, stream)	China, **New Zealand**	[1273, 1275]
Torrentispora fusiformis	Submerged decaying wood (river)	Brunei	[1274]
Torrentispora pilosa	Submerged decaying wood (stream)	Costa Rica	[666]
Diaporthomycetidae family *incertae sedis*			
Acrodictyaceae			
Acrodictys aquatica	Submerged decaying wood (stream)	**Thailand**	[5, 312]
Acrodictys fluminicola	Submerged decaying wood (stream)	**China**	[5]
Acrodictys liputii	Submerged decaying wood and bamboo (river)	Philippines, **Thailand**	[431, 432, 590]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Acrodictys porosiseptata	Submerged decaying wood (stream)	**Thailand**	[587]
Acrodictys sacchari	Submerged decaying bamboo (river)	Philippines	[432]
Acrodictys similis	Rainwater from building roofs	Poland	[633]
Junewangiaceae			
Dictyosporella aquatica	Submerged decayed stem of *Phragmites australis* (river)	**Egypt**	[516]
Dictyosporella chiangmaiensis	Submerged decaying wood (stream)	**Thailand**	[587]
Dictyosporella ellipsoidea	Submerged decaying wood (stream)	**China**	[587]
Dictyosporella guizhouensis	Submerged decaying wood (river)	**China**	[868]
Dictyosporella hydei	Submerged decaying wood (stream)	**China**	[1276]
Dictyosporella thailandensis	Submerged decaying wood (river)	**Thailand**	[437]
Jennwenomyces navicularis	Submerged decaying culm of *Miscanthus floridulus* (stream)	**China**	[1277]
Junewangia aquatica	Submerged decaying wood	**China**	[1278]
Junewangia thailandica	Submerged decaying wood (stream)	**Thailand**	[587]
Sporidesmiella aquatica	Submerged decaying wood (stream)	**China**	[5]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Sporidesmiella aspera	Submerged decaying angiosperm twigs (stream)	Malaysia	[1279]
Sporidesmiella ciliaspora	Submerged decaying wood (stream)	Brazil	[683]
Sporidesmiella claviformis	Submerged decaying twigs (stream)	Malaysia	[1279]
Sporidesmiella cornuta	Submerged decaying twigs (stream)	Malaysia	[1279]
Sporidesmiella incrassata	Submerged decaying twigs (stream)	Malaysia	[1279]
Sporidesmiella hyalosperma	Submerged decaying wood (river, stream)	**China**	[5]
Sporidesmiella novae-zelandiae	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks)	**China**, Thailand	[5, 70]
Sporidesmiella obovoidia	Submerged decaying wood (stream)	**Thailand**	[587]
Sporidesmiella oraniopsidis	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Sporidesmiella parvissima	Submerged decaying wood and leaves (stream)	Brazil, Malaysia	[683, 1279]
Sporidesmiella vignalensis	Submerged decaying leaves (stream)	Brazil	[683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Papulosaceae			
Brunneosporella aquatica	Submerged decaying wood (reservoir)	China	[1227]
Fluminicola aquatica	Submerged decaying wood (river)	**Thailand**	[437, 1263]
Fluminicola bipolaris	Submerged decaying wood (river, stream, waterfall)	China, Philippines, Thailand	[77, 432, 521, 627]
Fluminicola saprophytica	Submerged decaying wood (river)	**Thailand**	[437]
Fluminicola striata	Submerged decaying wood (stream)	**Thailand**	[587]
Fluminicola thailandensis	Submerged decaying wood (river)	**Thailand**	[5, 437, 1263]
Wongia aquatica	Submerged decaying wood	China	[5]
Wongia fusiformis	Submerged decaying wood	**Thailand**	[590]
Pseudoproboscisporaceae			
Diluviicola capensis	Submerged decaying wood (stream)	Brunei, **Thailand**	[587, 802]
Neodiluviicola aquatica	Submerged decaying bamboo (river)	**Thailand**	[437]
Pseudoproboscispora aquatica	Submerged decaying wood	Australia, Philippines, Japan	[1223, 1280]
Pseudoproboscispora caudae-suis	Submerged decaying wood (*Acer ruburm*, *Fraxinus excelsior*) (lake)	UK, USA	[59, 749, 1236]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Pseudoproboscispora thailandensis	Submerged decaying bamboo (river)	**Thailand**	[437]
Pseudostanjehughesiaceae			
Pseudostanjehughesia aquitropica	Submerged decaying wood (stream)	Thailand	[450]
Pseudostanjehughesia lignicola	Submerged decaying wood (stream)	China	[5]
Woswasiaceae			
Cyanoannulus petersenii	Submerged decaying wood (stream)	**USA**	[1281]
Diaporthomycetidae genera *incertae sedis*			
Aquaticola hyalomura	Submerged decaying wood (stream)	China	[1240]
Aquaticola longicolla	Submerged decaying wood (creek, river)	Australia, Brunei	[692, 1282]
Aquaticola minutiguttulata	Submerged decaying wood	China	[1282]
Aquaticola triseptata	Submerged decaying wood (river)	China	[1282]
Aquidictyomyces appendiculatus	Submerged decaying wood (stream)	**Thailand**	[587]
Ceratostomella hyalocoronata	Submerged decaying wood (stream)	China	[1283]
Clohiesia corticola	Submerged decaying wood (river)	Australia, Japan	[1223, 1272]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Clohiesia curvispora	Submerged decaying wood (stream)	China	[1284]
Clohiesia lignicola	Submerged decaying wood (river)	China	[1285]
Hyalorostratum brunneisporum	Submerged decaying wood (stream)	**USA**	[1286]
Hypocreomycetidae			
Coronophorales			
Bertiaceae			
Bertia convolutispora	Submerged decaying wood (stream)	Australia	[1287]
Chaetosphaerellaceae			
Chaetosphaerella phaeostroma	Submerged bark	Brazil	[697]
Nitschkiaceae			
Rhagadostoma lichenicola	Lake	USA	[1288]
Coronophorales genera *incertae sedis*			
Papulaspora pulmonaria	Submerged decaying leaves	UK, Netherlands	[840]
Papulaspora sepedonioides	Submerged bamboo culms (stream)	China	[435]
Glomerellales			
Australiascaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Dischloridium gloeosporioides	Submerged leaves	Brazil	[697]
Dischloridium inaequiseptatum	Submerged decaying wood (stream)	Brazil, China	[583, 683]
Glomerellaceae			
Colletotrichum godetiae	Submerged decaying leaves (stream)	**Korea**	[1289]
Plectosphaerellaceae			
Acrostalagmus luteoalbus	Water (pond, stream)	**Korea**	[1290]
Lectera nordwiniana	Freshwater	**Korea**	[984]
Reticulascaceae			
Cylindrotrichum aquaticum	Submerged decaying wood (stream)	**China**	[5, 310]
Cylindrotrichum clavatum	Submerged decaying wood (*Alnus glutinosa*, *Fraxinus* sp., *Platanus* sp.) (river)	China, France	[1291]
Cylindrotrichum gorii	Submerged decaying wood (river)	**China**	[1291]
Cylindrotrichum helisciforme	Foam (stream)	Canada, Slovakia	[588, 1292]
Cylindrotrichum oligospermum	Submerged decaying wood (river)	UK	[688]
Cylindrotrichum submersum	Submerged decaying wood (stream)	**China**	[5]
Kylindria aquatica	Submerged decaying wood (stream)	**China**	[1291]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Kylindria chinensis	Submerged decaying wood (stream)	**China**	[1291]
Hypocreales			
Bionectriaceae			
Acremonium guillematii	Freshwater	**Korea**	[984]
Bionectria byssicola	Submerged decaying wood (stream)	Brunei, China, Malaysia	[583]
Didymostilbe australiensis	Submerged decaying wood (stream)	Australia	[691]
Fusariella sarniensis	Submerged decaying wood	China	[1293]
Ovicuculispora parmeliae	River watershed	Canada	[622]
Hypocreaceae			
Gliocladium cylindrosporum	Submerged decaying wood (stream)	China	[583]
Sibirina orthospora	Submerged decaying wood (stream)	Brunei, China	[583]
Trichoderma glaucum	Submerged decaying wood	China	[1158]
Trichoderma harzianum	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Trichoderma polysporum	Submerged decaying wood (stream)	China	[583]
Myrotheciomycetaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Emericellopsis terricola	Submerged organic debris and freshwater muds of Lake Sengari	Ireland, Japan	[37, 1294]
Nectriaceae			
Aquanectria devians	Submerged decaying leaf (reservoir)	**Singapore**	[1295]
Aquanectria jacinthicolor	Submerged decaying wood (stream)	**China**	[1296]
Aquanectria penicillioides	Submerged decaying wood and leaves of broad-leaved trees, shrubs and angiosperm, foam (lake, spring, stream, river), sediment (dam), stemflow and throughfall of tree canopies and palm species	**China**, Cuba, India, Ireland, Jamaica, **Korea**, New Zealand, South Africa, UK, **USA**	[5, 44, 738, 1057, 1091, 1114, 1158, 1297, 1298, 63, 632, 636, 713, 716, 718, 721, 727]
Aquanectria submersa	Submerged decaying leaves of *Alnus glutinosa* (stream), foam (stream)	Jamaica, Portugal, Venezuela	[519, 1160, 1299]
Aquanectria tenuispora	Submerged decaying leaf (reservoir)	**Singapore**	[1295]
Bacillispora inflata	Water (river)	Poland	[687]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Baipadisphaeria spathulospora	Submerged trunk of *Licuala longicalycata* (peat bog)	**Thailand**	[1210]
Bisifusarium dimerum	Groundwater	**Slovenia**	[648]
Calonectria candelabrum	Submerged leaf	Brazil	[697]
Chaetopsina aquatica	Submerged decaying stem of *Phragmites australis* (river)	**Egypt**	[1300]
Chaetopsina beijingensis	Submerged decaying wood	China	[5]
Chaetopsina fulva	Submerged decaying leaves and petioles (stream), submerged decaying test blocks (*Dipterocarpus alatus* and *Xylia dolabriformis*)	Brazil, Thailand	[683]
Chaetopsina hongkongensis	Submerged decaying wood	China	[446]
Chaetopsina illini	Submerged decayed wood of *Taxodium distichum* (swamp)	USA	[1301]
Chaetopsina penicillata	Submerged decaying *Xylia dolabriformis* test block (stream)	Thailand	[70]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Chaetopsina polyblastia	Submerged decaying *Xylia dolabriformis* test block (stream)	Thailand	[70]
Chaetopsina splendida	Submerged decaying petioles (stream)	Brazil	[683]
Chaetopsinectria chaetopsinae	Submerged decaying *Xylia dolabriformis* test block (stream)	Thailand	[70]
Cosmospora aquatica	Submerged decaying wood (stream)	**China**	[5]
Cosmosporella olivacea	Submerged decaying wood (lake)	**China**	[1296]
Cylindrocarpon aquaticum	Water (river), foam (stream), submerged decaying plant materials (stream)	India, Poland, USA	[687, 722, 1167]
Cylindrocarpon destructans var. *destructans*	Submerged leaves (river)	UK	[714]
Cylindrocladiella infestans	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Cylindrocladiella parva	Submerged leaves	Brazil	[697]
Fusarium solani	Submerged decaying wood and bamboo (river, stream)	Philippines, USA	[432, 1193]
Fusicolla aquaeductuum	Submerged decaying wood (lake), water (river), submerged decaying leaves of angiosperm, foam (river, lake, spring, stream)	Brazil, **China**, Poland, USA	[637, 687, 716, 1296]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Gliocladiopsis aquaticus	Submerged decaying wood (lake)	**Thailand**	[312]
Gliocladiopsis guangdongensis	Submerged decaying wood (stream)	**China**	[1211]
Gliocladiopsis singaporiensis	Submerged decaying leaf (stream)	**Singapore**	[1295]
Gliocladiopsis tenuis	Submerged petioles	India	[697]
Heliscus tentaculus	Submerged decaying leaves of *Platanus occidentalis,* unidentified leaves (stream)	Jamaica, USA	[721, 1187]
Ilyonectria destructans	Foam (stream)	India	[722]
Mariannaea aquaticola	Submerged decaying wood (stream)	**Thailand**	[1302]
Mariannaea catenulata	Submerged decaying wood (stream)	**China, Thailand**	[1303]
Mariannaea chlamydospora	Submerged decaying wood (stream)	**China**	[1304]
Mariannaea cinerea	Submerged decaying wood (reservoir)	**China**	[1304]
Mariannaea elegans	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Mariannaea fusiformis	Submerged decaying wood (stream)	**China**	[1304]
Mariannaea lignicola	Submerged decaying wood (stream)	**China**	[1304]
Mariannaea samuelsii	Submerged decaying wood (stream)	**China**	[5]
Mariannaea submersa	Submerged decaying wood (river)	**China**	[1303]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Mariannaea superimposita	Submerged decaying wood (river)	**China**	[5]
Nectria curta	Submerged wood of *Fraxinus excelsior*	UK	[1305]
Nectriella lacustris	*Carex rostrata*	Austria	[642]
Nectria lugdunensis	Submerged decaying wood (river)	UK	[1142]
Nectria submersa	Water	Japan	[1306]
Neocosmospora haematococca	Submerged decaying wood (river, stream)	China	[78, 663]
Neonectria coccinea	Submerged beech (stream)	Hungary	[817]
Neonectria lugdunensis	Submerged decaying wood (*Acer pseudoplatanus*, *Fraxinus excelsior*), rainwater from building roofs, water (river, stream), foam (stream, rivulet, spring, river, lake), submerged decaying leaves of *Alnus glutinosa* (stream), water (stream)	**Austria**, Canada, **Czech Republic**, France, **Germany**, Ireland, Japan, **Poland**, Portugal, Rhodesia, **Slovakia**, Spain, Sweden, **UK**, USA	[13, 63, 715, 716, 724, 728, 729, 732, 828, 1090, 1092, 1095, 64, 1166, 588, 628, 630, 632, 633, 639, 714]
Ophionectria trichospora	Submerged decaying wood (stream)	Mexico	[1307]
Paracremonium binnewijzendii	Submerged decaying wood (lake)	**China**	[5]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Payosphaeria minuta	Submerged decaying wood (stream)	China	[435]
Thelonectria discophora	Submerged oak twigs (river)	UK	[1142]
Thelonectria lucida	Submerged twigs (stream)	USA	[1193]
Thelonectria discophora	Submerged decaying wood (stream)	UK	[1142]
Varicosporella aquatica	Submerged decaying wood wood (*Populus* sp. *Buxus sempervirens*, *Salix* sp., *Alnus glutinosa*, *Fraxinus* sp.)	**France**	[1308]
Niessliaceae			
Paraniesslia aquatica	Submerged decaying wood (stream)	China	[1284]
Paraniesslia tuberculata	Submerged decaying wood (river)	China	[753]
Stachybotryaceae			
Koorchalomella salmonispora	Submerged decayed stem of *Phragmites australis*	**Egypt**	[514]
Stachybotrys chartarum	Submerged decaying wood (lake, river, stream)	**China**	[5]
Stachybotrys chlorohalonatus	Submerged decaying wood (river)	**China**	[5]
Stachybotrys nephrosporus	Submerged leaf	Brazil	[697]
Stachybotrys sansevieriae	Water (river)	**South Korea**	[1309]
Stachybotrys sphaerosporus	Submerged decaying petioles (stream)	Brazil	[683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Virgatospora echinofibrosa	Submerged decaying leaves (stream)	Brazil	[683]
Sarocladiaceae			
Sarocladium implicatum	Water (river)	**Poland**	[728]
Hypocreales genera *incertae sedis*			
Idriella lunata	Submerged decaying leaves (stream)	**Korea**	[1289]
Illosporiopsis christiansenii	River watershed	Canada	[622]
Illosporium carneum	River watershed	Canada	[622]
Microascales			
Gondwanamycetaceae			
Knoxdaviesia undulatistipes	Submerged decaying petiole of *Eleiodoxa conferta* (peat swamp)	Thailand	[62, 1310]
Halosphaeriaceae			
Aniptodera aquadulcis	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (lake, stream, river, waterfall)	China, Thailand	[521, 627, 1311, 1312]
Aniptodera aquibella	Submerged decaying wood (stream)	**Thailand**	[302]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Aniptodera chesapeakensis	Submerged decaying wood (lake, stream, reservoir)	Australia, Brazil, Brunei, China, India, Iraq, Japan, Mauritius, South Africa, USA	[626, 627, 666, 692, 696, 706, 1255, 1256, 1312–1315]
Aniptodera fusiformis	Submerged decaying cottonwood twigs (*Populus deltoides*)	Iraq, USA	[1255, 1313]
Aniptodera inflatiascigera	Submerged decaying wood (river, stream)	Brunei, China, Philippines	[583, 1312, 1316]
Aniptodera lignicola	Submerged decaying wood (lake, stream) and bamboo (river)	Australia, Brunei, China, India, Malaysia, Philippines	[432, 627, 1312, 1315]
Aniptodera limnetica	Submerged decaying wood (creek)	USA	[1255]
Aniptodera margarition	Submerged decaying wood	UK, USA	[1255]
Aniptodera mauritaniensis	Submerged decaying wood (river, lake)	China, Iraq, Mauritius	[627, 1312, 1313]
Aniptodera megaloascocarpa	Submerged decaying wood (lake)	USA	[756]
Aniptodera megalospora	Submerged decaying wood (stream)	Brunei, China, Malaysia	[1312]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Aniptodera palmicola	Submerged decaying wood (lake), submerged *Raphia australia* rachis	China, Iraq, South Africa	[627, 1312, 1313]
Aniptosporopsis lignatilis	Submerged decaying wood (river, stream, waterfall)	Australia, China, Mauritius Philippines, Seychelles, South Africa	[72, 583, 1312]
Ascosacculus aquaticus	Submerged decaying wood (river)	**Australia**	[1312]
Ascosacculus heteroguttulatus	Submerged decaying wood (creek, river, stream)	Australia, Brunei, China, Mauritius, Philippines, South Africa	[1312]
Ascosacculus fusiformis	Submerged decaying wood (stream)	**Thailand**	[5]
Cirrenalia macrocephala	Submerged decaying wood (stream)	China	[583]
Cucurbitinus constrictus	Submerged decaying wood (lake)	China	[1317]
Cucurbitinus ibericus	Submerged wood	Spain	[474]
Clavatospora filiformis	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (stream), foam (stream), submerged decaying *Eleiodoxa conferta*, *Licuala longicalycata* *Metroxylon sagu* (peat swamp)	Brunei, India, Malaysia, **Thailand**	[62, 70, 450, 521, 577, 722, 827, 847, 890, 1318–1320]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Clavatospora longibrachiata	Foam (stream, rivulet), submerged decaying leaves of *Alnus glutinosa* (stream), water (river, stream), scum (stream)	Austria, Canada, France, Ireland, **Poland**, **Portugal**, South Africa, Sweden, Spain, UK, USA	[13, 588, 728, 729, 732, 783, 828, 1091, 1145, 628, 630–632, 639, 713, 714, 717]
Clavatospora tentacula	Submerged leaves (*Coffea arabica*, *Hevea brasiliensis*, unidentified) (stream), stemflow and throughfall of tree canopies, foam (stream)	Cuba, India, Malaysia, Thailand, USA, Venezuela	[500, 519, 739, 827, 847, 888, 1167, 1186]
Fluviatispora reticulata	Submerged *Livistona* sp. and *Eleiodoxa conferta* (peat swamp)	Papua New Guinea, Thailand	[62, 750]
Fluviatispora tunicata	Submerged *Livistona* sp. (river)	Papua New Guinea	[750]
Haligena elaterophora	Submerged decaying wood (river)	UK	[760]
Halosarpheia viscosa	Submerged decaying wood (stream)	Philippines, South Africa	[1312]
Halosphaeriopsis mediosetigera	Submerged decaying balsa wood (river)	USA	[582]
Luttrellia estuarina	Submerged decorticated wood (river, stream)	Canada, USA	[1321, 1322]
Luttrellia guttulata	Submerged decorticated wood (stream)	Costa Rica, Panama	[1321]
Luttrellia halonata	Submerged decorticated wood (river)	Ecuador	[1321]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Luttrellia parvulospora	Submerged decorticated wood (river)	USA, French Guiana	[1321]
Magnisphaera stevemossago	Submerged decorticated wood (creek, pond, river)	USA	[1323]
Nais aquatica	Submerged decaying wood (river, stream, waterfalls)	Australia, China, South Africa	[1312]
Nais inornata	Submerged decaying wood of *Pinus sylvestris* and *Fagus sylvatica* (water-cooling towers), wood (lake)	China, Japan, USA, UK	[627, 656, 1174, 1256]
Natantispora lotica	Submerged decaying wood	Australia, China, Mauritius, Philippines, South Africa, USA	[1312, 1323]
Natantispora retorquens	Submerged decaying wood (river, reservoir, stream) and wood (river), submerged rachis of *Raphia australia*	Australia, China, Mauritius, Philippines, South Africa, **USA**	[432, 626, 670, 1312, 1323]
Okeanomyces cucullatus	Submerged decaying wood (lake)	China	[627]
Phaeonectriella appendiculata	Submerged decaying wood (stream)	Australia, Philippines	[1312]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Phaeonectriella lignicola	Submerged decaying wood (lake, river, stream, water-cooling towers)	China, Mauritius, UK	[627, 759, 1312]
Sigmoidea aurantiaca	Foam (rivulet), submerged decaying wood (river)	Austria, UK	[631, 1118]
Sigmoidea contorta	Submerged decaying leaves (stream)	Thailand	[884]
Sigmoidea praelonga	Foam (stream)	Austria	[628]
Sigmoidea prolifera	Submerged decaying wood and leaves (stream), foam (lake, stream, river, spring)	USA	[67, 716]
Microascaceae			
Scedosporium cereisporum	Fluid (wastewater treatment plant)	France	[1324]
Scedosporium minutisporum	Sediment (river)	**Spain**	[1325]
Triadelphiaceae			
Triadelphia fusiformis	Submerged decaying wood (stream)	**Thailand**	[1326]
Triadelphia heterospora	Submerged decaying wood (river)	USA	[582]
Triadelphia hexaformispora	Submerged decaying wood	**Thailand**	[1327]
Triadelphia hungarica	Water-filled treeholes	Hungary	[638]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Triadelphia morgoensis	Submerged decaying wood	Hungary	[1328]
Microascales genera *incertae sedis*			
Sporendocladia bactrospora	Submerged decaying wood (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[683, 695]
Torpedosporales			
Juncigenaceae			
Juncigena fruticosae	Submerged decayed stems of *Suaeda fruticosa* (lake)	Egypt	[339]
Vermiculariopsiellales			
Vermiculariopsiellaceae			
Vermiculariopsiella cornuta	Submerged decaying leaves (stream)	Brazil	[683]
Vermiculariopsiella cubensis	Submerged decaying leaves and petioles (stream)	Brazil	[683]
Vermiculariopsiella falcata	Submerged decaying leaves and twigs (stream)	Malaysia	[1329]
Vermiculariopsiella immersa	Submerged decaying leaves and twigs (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, Malaysia	[683, 695, 1329]
Vermiculariopsiella parvula	Submerged decaying twigs (stream)	Malaysia	[1329]
Hypocreomycetidae genera *incertae sedis*			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Campylospora brasiliensis	Submerged decaying leaves (stream, river, waterfall)	**Brazil**	[1330]
Campylospora chaetocladia	Submerged decaying leaves of *Acer* sp., *Coffea arabica*, *Hevea brasiliensis* (stream, river), decaying unidentified leaves (spring), foam, scum (lake, spring, stream, river), stemflow and throughfall of tree canopies	Brazil, Cuba, Ghana, India, Jamaica, Malaysia, Nigeria, Portugal, Thailand, USA, Venezuela	[63, 519, 847, 881, 888, 1331, 577, 636, 716, 720–722, 732, 734]
Campylospora filicladia	Submerged decaying leaves of *Coffea arabica*, and *Hevea brasiliensis* (stream), foam (river, stream)	Brazil, India, Venezuela	[519, 722, 888, 1331]
Campylospora parvula	Foam (water, river, rivulet. stream), stemflow and throughfall of tree canopies	Austria, Brazil, Canada, India, Ireland, Japan, Venezuela	[519, 588, 631, 632, 636, 731, 1331]
Porosphaerellopsis bipolaris	Submerged decaying wood (stream)	China	[1227]
Lulworthiomycetidae			
Pisorisporiales			
Pisorisporiaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Achroceratosphaeria potamia	Submerged wood of *Platanus* species (stream)	**France**	[1332]
Pisorisporium cymbiforme	Submerged decorticated wood of *Alnus glutinosa* and *Fraxinus excelsior* (brook)	**France**	[1333]
Savoryellomycetidae			
Conioscyphales			
Conioscyphaceae			
Conioscypha aquatica	Submerged decaying wood (river)	China	[5]
Conioscypha gracilis	Submerged decaying wood (stream)	Japan, Peru	[1256, 1334]
Conioscypha lignicola	Submerged decaying wood (stream)	Australia, China	[1335, 1336]
Conioscypha nakagirii	Submerged decaying wood (stream)	**Thailand**	[1337]
Conioscypha peruviana	Submerged decaying wood (stream)	**Peru**	[1334]
Conioscypha submersa	Submerged decaying wood (river)	**China**	[5]
Conioscypha tenebrosa	Submerged decaying wood (river)	**China**	[530]
Conioscypha verrucosa	Submerged decaying wood (stream)	**China**	[403]
Vanakripa ellipsoidea	Submerged decaying wood (pond)	China	[1338]
Vanakripa fasciata	Submerged decaying wood (river)	Cuba	[1339]
Vanakripa gigaspora	Submerged decaying wood (river)	Philippines	[432]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Vanakripa menglensis	Submerged decaying wood (stream)	China	[703]
Vanakripa minutiellipsoidea	Submerged dead petiole of *Eleiodoxa conferta* (peat swamp), submerged decaying wood	**Thailand**	[62, 530, 1310]
Fuscosporellales			
Fuscosporellaceae			
Bactrodesmiastrum obovatum	Submerged decaying wood (reservoir)	Spain	[1340]
Fuscosporella aquatica	Submerged decaying wood (stream)	**Thailand**	[529]
Fuscosporella pyriformis	Submerged decaying wood (stream)	**Thailand**	[1341]
Mucispora infundibulata	Submerged decaying wood (stream)	**Thailand**	[23]
Mucispora obscuriseptata	Submerged decaying wood (stream)	**Thailand**	[1341]
Mucispora phangngaensis	Submerged decaying wood (stream)	**Thailand**	[529]
Parafuscosporella aquatica	Submerged decaying wood (river)	**Thailand**	[530]
Parafuscosporella garethii	Submerged decaying wood (stream)	**Thailand**	[1342]
Parafuscosporella moniliformis	Submerged decaying wood (stream)	**Thailand**	[1341]
Parafuscosporella mucosa	Submerged decaying wood (stream)	**Thailand**	[1341]
Parafuscosporella obovata	Submerged decaying wood (waterfall)	**Thailand**	[1343]
Parafuscosporella pyriformis	Submerged decaying wood (river)	**Thailand**	[530]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Plagiascoma frondosum	Submerged decorticated wood of *Fraxinus excelsior* (brook)	**France**	[1344]
Pseudoascotaiwania persoonii Pleurotheciales Pleurotheciaceae	Submerged decaying wood (river)	Canada	[1345]
Coleodictyospora muriformis	Submerged decaying wood (stream)	**Thailand**	[1346]
Neomonodictys muriformis	Submerged decaying wood (stream)	**Thailand**	[403]
Phaeoisaria aguilerae	Submerged decaying twig (river)	Cuba	[1347]
Phaeoisaria annesophieae	Submerged decaying wood	Thailand	[1348]
Phaeoisaria aquatica	Submerged decaying wood	**China**	[1349]
Phaeoisaria clematidis	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (lake, reservoir, river, stream), bamboo (river), submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	Brazil, **China**, Philippines, Thailand	[62, 432, 584, 626, 627, 683, 807, 1349]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Phaeoisaria guttulata	Submerged decaying wood (river)	**China**	[312]
Phaeoisaria filiformis	Submerged decaying wood (waterfall)	**Thailand**	[5]
Phaeoisaria sparsa	Submerged decaying wood (stream)	Brunei, Malaysia	[583, 660]
Pleurotheciella aquatica	Submerged decaying wood (river)	**China**	[1349]
Pleurotheciella centenaria	Submerged decaying wood (lake)	**Canada**	[1350]
Pleurotheciella fusiformis	Submerged decaying wood (lake)	**China**	[1349]
Pleurotheciella guttulata	Submerged decaying wood (river)	**China**	[1349]
Pleurotheciella krabiensis	Submerged decaying wood (stream)	**Thailand**	[312]
Pleurotheciella lunata	Submerged decaying wood (river)	**China**	[1349]
Pleurotheciella nilotica	Submerged decaying wood (river)	**China, Egypt, Thailand**	[1348, 1351]
Pleurotheciella rivularia	Submerged decaying wood of *Hedera helix* (rivulets)	**France**	[1350]
Pleurotheciella saprophytica	Submerged decaying wood (river)	**China**	[1349]
Pleurotheciella submersa	Submerged decaying wood (river)	**China**	[1349]
Pleurotheciella tropica	Submerged decaying wood (stream)	**Thailand**	[312]
Pleurotheciella uniseptata	Submerged decaying wood (river)	**China**	[1349]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Pleurothecium aquaticum	Submerged decaying wood (stream)	**China**	[1349]
Pleurothecium floriforme	Submerged decaying wood (stream)	**Thailand**	[514]
Pleurothecium pulneyense	Submerged decaying wood (river, stream)	**China**, India	[1349, 1352]
Pleurothecium recurvatum	Submerged decaying wood (stream)	**China**	[5]
Pleurothecium semifecundum	Submerged decaying wood of *Sambucus nigra* (brook)	France	[1350]
Saprodesmium dematiosporum	Submerged decaying wood (stream)	**China**	[1346]
Sterigmatobotrys macrocarpus	Submerged decaying wood (river, stream)	Canada, UK	[688, 1353]
Sterigmatobotrys rudis	Submerged decaying wood (water-cooling towers, lake)	China, UK	[627, 701]
Sterigmatobotrys uniseptatus	Submerged decaying wood (stream)	**China**	[5, 1354]
Pseudodactylariales			
Pseudodactylariaceae			
Pseudodactylaria aquatica	Submerged decaying wood (stream)	**Thailand**	[590]
Pseudodactylaria camporesiana	Submerged decaying wood (stream)	**Thailand**	[403]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Pseudodactylaria fusiformis	Submerged decaying wood (stream)	**China**	[1355]
Pseudodactylaria hyalotunicata	Submerged decaying wood (stream, river)	Brazil, China	(Tsui et al. 2000)
Savoryellales			
Savoryellaceae			
Ascotaiwania fusiformis	Submerged decaying wood (stream)	**Thailand**	[1341]
Ascotaiwania hsilio	Submerged decaying wood (stream)	China, USA	[656, 1345, 1356]
Ascotaiwania hughesii	Submerged decaying wood (lake)	USA	[1345]
Ascotaiwania limnetica	Submerged decaying wood (stream)	China, France, India	[1344, 1356–1358]
Ascotaiwania mitriformis	Submerged decaying wood (reservoir)	China	[1359]
Ascotaiwania pallida	Submerged decaying wood (river, stream)	Australia, Brunei, UK	[688, 692, 752]
Ascotaiwania palmicola	Submerged decaying wood (lake, stream)	Australia, China	[627, 691]
Ascotaiwania sawadae	Submerged decaying wood (stream)	China, Thailand	[1356, 1360]
Ascotaiwania wulai	Submerged decaying wood (stream)	China	[1356]
Canalisporium aquaticium	Submerged decaying wood (stream)	**Thailand**	[403]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Canalisporium caribense	Submerged decaying wood (river, stream, waterfall), rainwater from building roofs, decaying *Licuala longicalycata* (peat swamp)	Brazil, Brunei, China, India, North Maharashtra, Malaysia, Panama, Poland, Thailand, USA	[583, 585, 656, 1361–1364]
Canalisporium elegans	Submerged decaying wood (river, stream)	Brunei, **China**, Malaysia, Panama, Thailand	[1361, 1364–1367]
Canalisporium exiguum	Submerged decaying wood (stream)	Australia, Brazil	[683, 1361]
Canalisporium grenadoideum	Submerged wood of *Wrightia tomentosa* (stream)	Thailand	[1368]
Canalisporium jinghongensis	Submerged decaying wood (stream, waterfall)	China, Thailand	[771, 1364]
Canalisporium kenyense	Submerged decaying wood (stream)	Panama, USA	[656, 1365]
Canalisporium macrosporum	Submerged decaying culm of *Miscanthus floridulus* (stream)	**China**	[1366]
Canalisporium nanhuaense	Submerged decaying wood	**China**	[1366]
Canalisporium pallidum	Submerged decaying wood	China	[1361]
Canalisporium panamense	Submerged decaying wood	Panama	[1365]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Canalisporium parvum	Submerged decaying culm of *Miscanthus floridulus* (stream)	**China**	[1366]
Canalisporium paulopallidum	Submerged decaying wood	**China**	[1366]
Canalisporium pulchrum	Submerged decaying wood (reservoir, stream)	Australia, Brunei, China, Malaysia, Panama, **Thailand**	[626, 807, 1361, 1364, 1365, 1367]
Canalisporium taiwanense	Submerged decaying wood	**China**	[1366]
Canalisporium variabile	Submerged decaying wood (lake), submerged decaying *Licuala longicalycata* (peat swamp)	Australia, China, Thailand	[584, 627, 1369]
Canalisporiam waffleum	Submerged decaying culm of *Miscanthus floridulus* (stream)	**China**	[1366]
Dematiosporium aquaticum	Submerged decaying wood (lake)	**China**	[5]
Helicoascotaiwania hughesii	Submerged decaying wood (lake)	USA	[1345]
Savoryella aquatica	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks) (creek, lake, river, stream) and bamboo (river)	Australia, Brunei, China, Malaysia, Philippines, South Africa, Thailand	[432, 626, 627, 685, 1370]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Savoryella curvispora	Submerged decaying wood (lake, river, stream)	China, Malaysia, Mauritius, Philippines, South Africa	[627, 660, 1370]
Savoryella fusiformis	Submerged decaying wood	Brunei	[1370]
Savoryella grandispora	Submerged decaying wood (river)	Australia, Malaysia	[1370]
Savoryella lignicola	Submerged decaying wood (lake, river, stream, waterfall), submerged pine test blocks (water-cooling towers)	Australia, Brunei, China, Japan, Malaysia, South Africa, Thailand, UK	[521, 627, 685, 691, 1223, 1370, 1371]
Savoryella verrucosa	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks)	Australia, Brunei, Japan, Malaysia, Thailand	[70, 1370]
Rhexoacrodictys erecta	Submerged decaying wood (lake, river, stream, waterfall) and leaves (stream)	Brazil, China, Thailand	[521, 627, 683]
Savoryellomycetidae genera *incertae sedis*			
Obliquifusoideum guttulatum	Submerged decaying wood (stream)	**China**	[1346]
Sordariomycetidae			
Chaetosphaeriales			
Chaetosphaeriaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Anacraspedodidymum submersum	Submerged decaying dicotyledonous leaves (stream)	**China**	[1372]
Arcuatospora novae-zelandiae	Submerged decaying wood and leaves (stream)	Brazil	[683]
Bahusutrabeeja dwaya	Submerged decaying wood (river, stream)	China, Malaysia	[700]
Brunneodinemasporium jonesii	Submerged decaying wood (stream)	**China**	[1373]
Catenularia angulospora	Submerged decaying wood (stream)	Brunei, China	[583]
Catenularia catenulata	Submerged decaying wood	**China**	(Luo et al. 2019)
Chaetosphaeria anglica	Submerged decaying wood (stream)	Brunei, Sudan, UK	[583, 1374]
Chaetosphaeria aquatica	Submerged decaying wood (river)	**China**	[5]
Chaetosphaeria cubensis	Submerged decaying wood (river)	**China**	[5]
Chaetosphaeria guttulata	Submerged decaying wood (stream)	**China**	[5]
Chaetosphaeria hiugensis	Decaying *Nenga pumila* (peat swamp)	Thailand	[585]
Chaetosphaeria innumera	Submerged decaying wood (reservoir)	China	[626]
Chaetosphaeria lentomita	Submerged decaying wood (stream)	China	[583]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Chaetosphaeria lignomollis	Submerged decaying twig (stream)	Brazil	[666]
Chaetosphaeria myriocarpa	Submerged decaying wood (river)	**China**	[5]
Chaetosphaeria pulchriseta	Submerged decaying wood and twig (stream)	Brazil, Malaysia	[683, 1375]
Chaetosphaeria rivularis	Submerged wood of *Fagus sylvatica* associated with *Minutisphaera japonica* (brook)	**France**	[516]
Chaetosphaeria submersa	Submerged decaying wood (stream)	**China**	[5]
Chaetosphaeria vermicularioides	Stemflow and throughfall of palm species	India	[727]
Chloridium aquaticum	Submerged decaying wood	**Thailand**	[1376]
Chloridium aseptatum	Submerged decaying wood	**Thailand**	[1376]
Chloridium chloroconium	Submerged decaying wood and leaves (stream)	Brazil, China	[583, 683]
Chloridium cylindrospora	Submerged decaying wood (river)	Philippines	[432]
Chloridium gonytrichii	Submerged decaying wood (stream)	**China**, **Thailand**	[5, 590]
Chloridium lignicola	Submerged decaying wood (stream)	Brunei, China, Malaysia	[446, 583, 660]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Chloridium matsushimae	Submerged decaying wood (stream)	China	[662]
Chloridium obclaviforme	Submerged decaying wood (stream)	Brazil	[683]
Chloridium pachytrachelum	Submerged decaying wood (stream)	China	[446]
Chloridium submersum	Submerged decaying wood (river)	**China**	[23]
Chloridium transvaalense	Submerged leaf	Brazil	[697]
Chloridium virescens	Submerged decaying wood (stream)	Brazil	[683]
Codinaea aquatica	Submerged decaying wood	Brazil	[1377]
Codinaea lunulospora	Submerged decaying twig (stream)	Malaysia	[1375]
Codinaea yunnanensis	Submerged decaying wood (river)	**China**	[5]
Craspedodidymum cubense	Submerged decaying leaves (stream)	Brazil	[683]
Cryptophiale cucullata	Submerged decaying leaves (stream)	Brazil	[1378]
Cryptophiale kakombensis	Submerged decaying leaves (stream)	Brazil	[683]
Cryptophiale manifesta	Submerge decaying *Licuala longicalycata* (peat swamp)	Thailand	[584]
Cryptophiale multiseptata	Submerged decaying wood (river)	Australia	[1379]
Cryptophiale udagawae	Submerged decaying wood (e.g. *Dipterocarpus alatus* test block) and leaves (stream)	Brazil, Thailand	[70, 683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Cryptophialoidea fasciculata	Submerged decaying twigs and petioles (stream)	Brazil, Malaysia	[683, 1380]
Cryptophialoidea secunda	Submerged decaying wood and leaves (stream)	Brazil	[683]
Cryptophialoidea uncispora	Submerged decaying leaves	Malaysia	[1381]
Dictyochaeta aciculata	Submerged petiole	Brazil	[1382]
Dictyochaeta aquatica	Submerged decaying wood	**Thailand**	[1376]
Dictyochaeta assamica	Submerged decaying wood (reservoir, river, stream)	China, Malaysia, UK	[626, 688, 1375]
Dictyochaeta britannica	Submerged decaying petiole (stream)	Brazil	[683]
Dictyochaeta cangshanensis	Submerged decaying wood (stream)	**China**	[5]
Dictyochaeta coffeae	Submerged decaying wood (river)	China	[78]
Dictyochaeta curvispora	Submerged bamboo (river)	Philippines	[432, 433]
Dictyochaeta daphnioides	Submerged decaying angiospermous petioles	Malaysia	[1383]
Dictyochaeta ellipsoidea	Submerged decaying wood	China	[5]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Dictyochaeta fertilis	Submerged decaying leaves of unidentified dicotyledon plant (stream), wood (stream, reservoir), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, China, Malaysia	[88, 683, 1375]
Dictyochaeta gamundiae	Decaying bark (river)	Argentina	[1384]
Dictyochaeta guadalcanalensis	Submerged decaying twig of unidentified angiosperm	Malaysia	[1375]
Dictyochaeta gyrosetula	Submerged decaying wood (e.g., *Xylia dolabriformis* test block) (stream)	Malaysia, Thailand	[70, 1385]
Dictyochaeta heteroderae	Submerged decaying wood (stream), and leaves of *Calophyllum brasiliense* (stream)	Brazil	[88, 683]
Dictyochaeta lignicola	Submerged decaying wood (river)	**China**	[5]
Dictyochaeta longispora	Submerged decaying leaves of unidentified dicotyledon plant (stream)	Malaysia	[1375]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Dictyochaeta lunulospora	Submerged decaying twig of unidentified dicotyledon plant	Malaysia	[1375]
Dictyochaeta malaysiana	Submerged decaying leaves	Malaysia	[1386]
Dictyochaeta microcylindrospora	Submerged decaying wood and leaves (stream)	Brazil	[683]
Dictyochaeta plovercovensis	Submerged decaying wood and bamboo (lake, reservoir)	China, Philippines	[626, 627, 771]
Dictyochaeta pluriguttulata	Submerged decaying wood (stream)	Brazil, Malaysia	[683, 1385]
Dictyochaeta subfuscospora	Submerged decaying wood	Australia, Malaysia	[691, 1385]
Dictyochaeta ramulosetula	Submerged decaying leaves, decaying *Metroxylon sagu* (peat swamp)	Malaysia, Thailand	[585, 1386]
Dictyochaeta sampahia	Submerged decaying leaves	Malaysia	[1385]
Dictyochaeta simplex	Submerged decaying wood and leaves (stream) and leaves (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, Malaysia	[88, 683, 1375]
Dictyochaeta subfuscospora	Submerged decaying wood (stream)	Australia, Malaysia	[691, 1385]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Dictyochaeta siamensis	Submerged decaying wood (stream)	**Thailand**	[1387]
Dictyochaeta submersa	Submerged decaying wood (stream)	**China**	[5]
Dictyochaeta tumidoseta	Submerged decaying culm of *Miscanthus floridulus* (stream)	Taiwan	[1388]
Dictyochaeta vittata	Submerged decaying wood	Malaysia	[1385]
Dictyochaetopsis hamata	Submerged decaying leaves	Malaysia	[1389]
Dictyochaetopsis gonytrichodes	Submerged decaying wood (stream, river) and leaves (stream)	Brazil, Malaysia, USA	[1389] [582, 683]
Dictyochaetopsis pahangensis	Submerged decaying leaves	Malaysia	[1389]
Dictyochaetopsis polysetosa	Submerged decaying leaves and petioles (stream)	Brazil	[683]
Dinemasporium lanatum	Submerged decaying leaves and petiole (stream), decaying *Metroxylon sagu* (peat swamp)	Brazil, Thailand	[585, 683]
Exserticlava aquatica	Submerged decaying wood	Brazil	[1390]
Exserticlava globosa	Submerged decaying wood (river)	China	[1391]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Exserticlava triseptata	Submerged decaying wood (river, stream), Submerged decaying culm of *Miscanthus floridulus* (stream)	Brazil, China, Malaysia, Seychelles	[683, 693, 1388, 1391, 1392]
Exserticlava vasiformis	Submerged decaying wood (river, stream)	China, Malaysia, USA	[898, 1391, 1392]
Exserticlava yunnanensis	Submerged decaying wood (stream)	China	[683, 775]
Gonytrichum macrocladum	Submerged decaying wood (reservoir, stream, waterfall), submerged decaying *Eleiodoxa conferta* (peat swamp)	China, Thailand	[62, 521, 626]
Kionochaeta australiensis	Submerged decaying wood (stream)	Australia	[1393]
Kionochaeta pughii	Submerged decaying leaves	Malaysia	[1394]
Kionochaeta ramifera	Submerged decaying leaves	Malaysia	[1394]
Kionochaeta setosimplicia	Submerged decaying wood (rivulet)	**Thailand**	[1395]
Kionochaeta spissa	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Miyoshiella triseptata	Submerged decaying wood (lake, reservoir, stream) and bamboo (river)	Brazil, China, Philippines	[432, 626, 627, 683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Menisporopsis multisetulata	Submerged decaying wood (river)	China	[1396]
Menisporopsis pirozynskii	Submerged decaying leaves (stream)	Brazil	[683]
Menisporopsis theobromae	Submerged decaying wood	**Thailand**	[1387]
Nawawia oviformis	Submerged leaves of an unidentified dicotyledonous plant (stream)	China	[1397]
Nawawia quadrisetulata	Submerged decaying wood	Malaysia	[1398]
Paliphora multiseptata	Submerged leaf	Brazil	[697]
Paliphora porosa	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Phaeonawawia diplocladielloidea	Submerged decaying wood	**Malaysia**	[1399]
Phialogeniculata africana	Submerged decaying wood (river)	South Africa	[696]
Phialosporostilbe dendroidea	Submerged pieces of stems of *Phragmites*, Submerged decaying culm of *Miscanthus floridulus* (stream)	China, South Africa	[1234, 1388]
Rattania aquatica	Submerged decaying wood (river)	**Thailand**	[386]
Sporoschisma australiense	Submerged decaying wood (stream)	Australia	[1400]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Sporoschisma chiangraiense	Submerged decaying wood	**Thailand**	[590]
Sporoschisma hemipsilum	Submerged decaying wood (e.g., *Dipterocarpus alatus* test block) and herbaceous debris (lake, stream)	Australia, Brazil, Brunei, China, Malaysia, Perú, South Africa, Thailand	[70, 586, 627, 683, 1242, 1400–1402]
Sporoschisma juvenile	Submerged decaying wood (stream, river) and bamboo (river)	Brazil, China, Perú, Philippines, Seychelles	[432, 586, 683, 1242, 1400]
Sporoschisma longicatenatum	Submerged decaying wood (stream)	**Thailand**	[1402]
Sporoschisma mirabile	Submerged decaying wood (river)	**China**	[586]
Sporoschisma nigroseptatum	Submerged decaying wood (river, stream)	China, India	[586, 1224]
Sporoschisma palauense	Submerged decaying wood (stream)	**Thailand**	[1402]
Sporoschisma parcicuneatum	Submerged decaying wood (stream)	Philippines	[1400]
Sporoschisma phaeocentron	Submerged decaying wood	China, Malaysia	[583, 586, 1400]
Sporoschisma taitense	Submerged decaying wood	China	[586]
Sporoschisma uniseptatum	Submerged decaying wood (e.g., *Dipterocarpus alatus* test block) (stream, reservoir)	Brunei, China, India, Malaysia, Perú, Seychelles, Thailand	[70, 583, 626, 1224, 1242]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Tainosphaeria aquatica	Submerged decaying wood (stream)	**Thailand**	[1403]
Tainosphaeria jonesii	Submerged decaying wood (stream)	**China**	[1373]
Tainosphaeria siamensis	Submerged decaying wood	**Thailand**	[1387]
Tainosphaeria lunata	Submerged decaying wood (river)	**China**	[5]
Tainosphaeria obclavata	Submerged decaying wood (stream)	**Thailand**	[5]
Tainosphaeria thailandense	Submerged decaying wood (stream)	**Thailand**	[1403]
Thozetella acerosa	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[695]
Thozetella canadensis	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[695]
Thozetella coronata	Submerged decaying wood (stream)	Brazil	[1404]
Thozetella cristata	Submerged decaying wood and leaves (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[683, 695]
Thozetella cubensis	Submerged decaying wood and leaves (stream)	Brazil	[683]
Thozetella gigantea	Submerged decaying wood and leaves (stream)	Brazil	[683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Thozetella nivea	Submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks), decaying *Eleiodoxa conferta, Licuala longicalycata* (peat swamp)	Thailand	[70, 585]
Thozetella pinicola	Submerged decaying leaves (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[683, 695]
Thozetella queenslandica	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[695]
Thozetella radicata	Submerged decaying *Licuala longicalycata* (peat swamp), submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, Thailand	[584, 695]
Thozetella submersa	Submerged decaying wood (stream)	Brazil	[683, 1405]
Thozetella ypsiloidea	Submerged decaying wood (stream)	Brazil	[1404]
Zanclospora novae-zelandiae	Submerged decaying wood (stream)	Brazil	[683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Helminthosphaeriaceae			
Diplococcium aquaticum	Submerged decaying wood (lake)	Australia	[1406]
Diplococcium asperum	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Endophragmiella boothii	Submerged decaying wood (stream)	Brazil	[683]
Endophragmiella mexicana	Submerged decaying wood (stream)	China	[446]
Endophragmiella occidentalis	Submerged decaying wood (stream)	China	[446]
Endophragmiella profusa	Submerged decaying decaying leaves of *Bucida palustris* (pool)	Cuba	[1407]
Endophragmiella ramificata	Submerged decaying wood (stream)	China	[446]
Endophragmiella rostrata	Submerged decaying twig (stream)	Brazil	[683]
Endophragmiella triseptata	Submerged decaying wood (river)	China	[1408]
Hilberina breviseta	Submerged decaying wood (lake, stream)	Brunei, China	[583, 627]
Linocarpaceae			
Linocarpon apiculatum	Submerged decaying palm petiole (swamp)	Indonesia	[1409]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Linocarpon appendisporum	Submerged decaying *Pandanus* leaves (swamp)	Indonesia	[1409]
Linocarpon bambusicola	Submerged bamboo (river)	Philippines	[433]
Linocarpon elaeidis	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Linocarpon livistonae	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Linocarpon pandani	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Linocarpon pandanicola	Submerged decaying *Pandanus* leaves	Indonesia	[1409]
Neolinocarpon inconspicuum	Submerged decaying leaves (stream)	China	[583]
Coniochaetales			
Coniochaetaceae			
Coniochaeta gigantospora	Submerged decaying wood (river)	**France**	[1410]
Coniochaeta hoffmannii	Polluted water	**UK**	[1411]
Coniochaeta kellermanii	Submerged decaying wood (river)	USA	[706, 773]
Coniochaeta leucoplaca	Submerged decaying wood (pond)	USA	[706]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Coniochaeta ligniaria	Submerged decaying wood (cooling tower)	UK	[761]
Coniochaeta mutabilis	Water (river)	**Germany**	[1412]
Coniochaeta renispora	Submerged decaying wood (river)	USA	[1413]
Coniochaeta velutina	Submerged decaying wood	USA	[706]
Cordanales			
Cordanaceae			
Cordana abramovii	Submerged decaying wood and herbaceous debris, bamboo (river)	Brunei, Perú, Philippines Thailand	[5, 432, 583, 1242]
Cordana aquatica	Submerged decaying wood (river)	**China**	[5]
Cordana lignicola	Submerged decaying wood (river)	**China**	[5]
Cordana terrestris	Submerged decaying wood and bamboo (river, stream)	Brazil, **China**	[5, 775]
Cordana uniseptata	Submerged decaying *Phyllostachys bambusoides* (stream)	China	[1269]
Phyllachorales			
Phyllachoraceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Ascovaginospora stellipala	Submerged dead stems and leaves of *Carex limosa*	USA	[1414]
Phyllachora therophila	*Juncus filiformis*	Austria	[642]
Tamsiniella labiosa	Submerged decaying wood	Australia	[1415]
Phyllachorales genera *incertae sedis*			
Neoxylomyces multiseptatus	Submerged decaying wood (stream)	**Thailand**	[386]
Sordariales			
Chaetomiaceae			
Arcopilus aureus	Submerged decaying wood	USA	[706]
Chaetomium cochliodes	*Phragmites australis*, balsa wood	UK, USA	[789]
Chaetomium elatum	Beech wood	UK	[761]
Chaetomium globosum	Submerged decaying balsa wood, submerged dead stems of *Carex oligosperma* (bog, lake)	China, USA, UK	[5, 749, 761]
Chaetomium trilaterale	Balsa wood	USA	[706]
Corynascella inquinata	sewage sludge	Japan	[1416]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Collariella carteri	Water (pond, stream)	**Korea**	[1290]
Dichotomopilus funicola	Wood	USA	[706]
Collariella carteri	Water (pond, stream)	**Korea**	[1290]
Dichotomopilus funicola	Wood	USA	[706]
Humicola asteroidea	Submerged decaying wood (stream)	USA	[656]
Humicola homopilata	Submerged decaying twig (stream)	Brazil	[683]
Humicola seminuda	Submerged leaf litter	USA	[706]
Staphylotrichum longicolle	Submerged decaying leaves (stream)	Brazil	[683]
Trichocladium englandense	Submerged decaying wood (river)	UK	[688]
Trichocladium lignicola	Submerged decaying wood (lake, river)	China, China	[670, 855]
Trichocladium linderi	Submerged decaying wood (river)	USA	[1417]
Trichocladium lobatum	Submerged decaying wood (swamp)	USA	[1417]
Trichocladium moenitum	Submerged decaying wood (lake, swamp)	USA	[1417]
Lasiosphaeriaceae			
Apiosordaria hamata	Sediment (lake)	China	[1418]
Arnium apiculatum	*Equisetum fluviatile*	USA	[1419]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Bombardia arachnoidea	Balsa wood	USA	[773]
Cercophora appalachianensis	Submerged decaying wood (stream)	China	[583]
Cercophora aquatica	Submerged decaying wood of *Quercus* (stream)	France	[1420]
Cercophora caudata	Submerged decaying wood (river)	**China**	[5]
Cercophora costariensis	Submerged decaying wood (stream)	China	[662]
Cercophora squamulosa	Submerged decaying wood (brook, stream)	**France**	[1324]
Cercophora sulphurella	Submerged decaying wood (lake)	USA	[749]
Cercophora vinosa	Submerged decaying wood (stream)	**France**	[1421]
Cladorrhinum australe	Submerged decaying stem	**Korea**	[841]
Cladorrhinum foecundissimum	Submerged decaying wood (river)	UK	[688]
Cladorrhinum samala	Submerged decaying wood (stream)	Brunei	[583]
Echria gigantospora	Submerged decaying wood (lake)	**USA**	[1422]
Immersiella immersa	Submerged decaying wood (stream)	China	[662]
Zopfiella cephalothecoidea	Submerged dead twig	Iraq	[1423]
Zopfiella latipes	Submerged decaying wood (lake)	China, Egypt	[627, 670, 1251]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Zopfiella leucotricha	Submerged decaying wood (river)	Egypt	[1251]
Zopfiella lundqvistii	Submerged decaying wood (*Ochroma pyramidale*) (swamp)	USA	[1424]
Zopfiella submersa	Submerged dead culms of *Phragmites* sp. (river)	Iraq	[1425]
Podosporaceae			
Triangularia setosa	Submerged beech wood	UK	[760]
Sordariaceae			
Neurospora retispora	Submerged decaying wood (lake)	China	[627]
Sordariales genera *incertae sedis*			
Ascolacicola aquatica	Submerged decaying wood (lake)	China	[1359]
Cuspidatispora xiphiago	Submerged decaying wood (river)	**China**	[5]
Lockerbia striata	Submerged decaying wood (lake, river)	USA	[756]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Lunulospora curvula	Foam (lake, spring, river, stream), submerged decaying leaves *of Alnus glutinosa* and *Salix*, submerged leaves of *Coffea arabica* and *Hevea brasiliensis* (river, stream), rainwater from building roofs, water (river, stream), sediment (dam, stream), stemflow and throughfall of tree canopies	Austria, Brazil, Cuba, France, India, Jamaica, Malaysia, Nigeria, **Poland**, Portugal, Spain, UK, USA, Venezuela	[13, 63, 716, 718, 720–722, 728, 732, 739, 783, 828, 519, 847, 888, 1426, 628, 633, 636, 637, 639, 713, 714]
Lunulospora cymbiformis	Submerged decaying leaves of dicotyledon (river), submerged leaves of *Coffea arabica* and *Hevea brasiliensis* (stream), sediment (dam, stream), foam (stream, river)	**Australia**, Brazil, India, Japan, Malaysia, Thailand	[637, 718, 731, 827, 847, 881, 888, 1066, 1427]
Sordariomycetidae genera *incertae sedis*			
Hanliniomyces hyaloapicalis	Submerged decaying wood	USA	[756]
Hydromelitis pulchella	Submerged decaying wood	Costa Rica	[1243]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Rhexodenticula aquatica	Submerged decaying wood (stream)	**Thailand**	[1428]
Xylariomycetidae			
Amphisphaeriales			
Amphisphaeriaceae			
Amphisphaeria uniseptata	Submerged decaying wood (river)	China	[753]
Capsulospora frondicola	Submerged decaying *Eleiodoxa conferta* and *Metroxylon sagu* (peat swamp)	Thailand	[62, 585]
Lepteutypa aquatica	Submerged decaying wood (stream)	**Thailand**	[5]
Pestalosphaeria austroamericana	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Apiosporaceae			
Arthrinium aquaticum	Submerged decaying wood (river)	**China**	[5]
Arthrinium arundinis	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Arthrinium sinense	Submerged decaying wood (lake)	China	[627]
Beltraniaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Beltrania africana	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88]
Beltrania rhombica	Foam (river, stream), submerged decaying leaves and petioles (stream)	Brazil, India, Thailand, Venezuela	[519, 683, 722, 881]
Beltraniella botryospora	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88]
Beltraniella fertilis	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88]
Beltraniella portoricensis	Submerged decaying leaves (stream), foam/water (stream)	Brazil, Venezuela	[519, 683]
Beltraniopsis aquatica	Submerged decaying leaves (stream)	Cuba	[1429]
Hemibeltrania decorosa	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88]
Hyponectriaceae			
Arecomyces bruneiensis	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Arecomyces epigenus	Submerged decaying *Licuala longicalycata* and *Nenga pumila* (peat swamp)	Thailand	[584]
Arecomyces frondicola	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Atractium holubovae	Submerged decaying wood (e.g., *Xylia dolabriformis* test block) (river, stream)	China, Philippines, South Africa, Thailand	[70, 583, 1430]
Physalospora aquatica	Submerged *Eleocharis palustris* (lake)	UK	[61]
Physalospora limnetica	Submerged herbaceous debris (pond)	USA	[756]
Pseudomassariaceae			
Leiosphaerella leonensis	Submerged twig	Africa	[1374]
Pseudomassaria sepincoliformis	Submerged decaying wood	China	[1293]
Sporocadaceae			
Bartalinia robillardoides	Water (pond, stream)	**Korea**	[1290]
Discosia rubi	Submerged plant litter	**Korea**	[1289]
Discostroma corticola	Scots pine wood	UK	[836]
Hymenopleella lakefuxianensis	Submerged decaying wood (lake)	China	[1431]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Pestalotiopsis submersa	Submerged decaying rotten needles of *Pinus roxburghii*	India	[1432]
Robillarda sessilis	Submerged plant litter	**Korea**	[1289]
Seiridium aquaticum	Submerged decaying wood (stream)	**China**	[5]
Xylariales			
Castanediellaceae			
Castanediella cagnizarii	Submerged decaying leaves (stream)	Brazil, Mexico	[683] [1433]
Castanediella ramosa	Submerged decaying leaves (stream)	Brazil	[683]
Clypeosphaeriaceae			
Apioclypea apiosporioides	Submerged decaying *Eleiodoxa conferta* (peat awamp)	Thailand	[62]
Clypeosphaeria mamillana	Scots pine wood	UK	[760]
Diatrypaceae			
Peroneutypa lignicola	Submerged decaying wood (stream)	**China**	[5]
Hypoxylaceae			
Daldinia kretzschmarioides	Submerged decaying wood (stream)	Brunei	[583]
Hypoxylon lignicola	Submerged decaying wood (river)	**China**	[5]
Microdochiaceae			
Selenodriella fertilis	Submerged decaying leaves (stream)	Brazil	[683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Selenodriella fertilis	Submerged decaying leaves (stream)	Brazil	[683]
Myelospermataceae			
Myelosperma tumidum	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothidaceae			
Oxydothis angustispora	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[584]
Oxydothis atypica	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[584]
Oxydothis frondicola	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[584]
Oxydothis grisea	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis hoehnelii	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis licualae	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis livistonae	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis livistonica	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis oraniopsis	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis licualae	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Oxydothis rattanicola	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Zygosporiaceae			
Vesiculozygosporium echinosporum	Submerged decaying leaves and petiole (stream)	Brazil	[683]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Zygosporium masonii	Submerged decaying wood (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[683, 695]
Zygosporium minus	Submerged decaying wood (stream)	Brazil	[683]
Xylariaceae			
Anthostomella aquatica	Submerged decaying wood of *Dipterocarpus alatus*, *Xylia dolabriformis* and unidentified wood (reservoir, stream)	Australia, China, Thailand	[70, 626, 1434]
Anthostomella palmaria	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Astrocystis eleiodoxae	Submerged decaying petiole of *Eleiodoxa conferta* and *Licuala longicalycata* (peat swamp)	**Thailand**	[585] [1435]
Astrocystis rachidis	Decaying *Licuala longicalycata* and *Metroxylon sagu* (peat swamp)	Thailand	[585]
Rosellinia corticium	Submerged decaying *Licuala longicalycata* (peat swamp)	Thailand	[584]
Vamsapriyaceae			
Vamsapriya aquatica	Submerged decaying bamboo culms	**China**	[590]
Vamsapriya indica	Submerged decaying bamboo culms (river)	**China**	[590]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Xylariales genera *incertae sedis*			
Circinotrichum papakurae	Submerged decaying leaves (stream)	Brazil	[683]
Gyrothrix circinata	Submerged decaying wood (stream)	Brazil	[683]
Gyrothrix magica	Submerged decaying leaves (stream)	Brazil	[683]
Gyrothrix microsperma	Submerged decaying wood and leaves (stream)	Brazil	[683]
Gyrothrix podosperma	Submerged decaying leaves (stream)	Brazil	[683]
Gyrothrix verticiclada	Submerged decaying leaves (stream)	Brazil	[683]
Lanceispora amphibia	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Melanographium citri	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Melanographium palmicola	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Polyancora globosa	Submerged decaying leaves (peat swamp)	Malaysia	[1436]
Roselymyces brasiliensis	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[695]
Stilbohypoxylon elaeidicola	Decaying *Eleiodoxa conferta*, *Licuala longicalycata* (peat swamp)	Thailand	[585]
Stilbohypoxylon moelleri	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]
Xylariomycetidae family *incertae sedis*			
Cainiaceae			

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Endocalyx melanoxanthus	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Myelospermataceae			
Myelosperma tumidum	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Sordariomycetes genera *incertae sedis*			
Aquadulciospora rhomboidia	Submerged decomposed stems of *Scirpus validus* (lake)	USA	[749]
Aquasphaeria dimorphospora	Submerged decaying wood	Australia	[1272]
Ascoyunnania aquatica	Submerged bamboo (stream)	China	[434]
Ellisembia acicularia	Submerged decaying culms of *Miscanthus floridulus* (stream)	China	[1388]
Ellisembia bambusicola	Submerged decaying wood (stream)	Brazil, China	[583, 683]
Ellisembia brachypus	Submerged decaying *Dipterocarpus alatus* and *Xylia dolabriformis* test block	Thailand	[70]
Ellisembia flagelliformis	Submerged leaves	Brazil	[697]
Ellisembia opaca	Submerged decaying wood (stream)	China	[583]
Ellisembia plovercovensis	Submerged decaying wood (reservoir)	China	[626]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Ellisembia repentioriunda	Submerged decaying wood (lake, reservoir)	China	[626, 627]
Ellisembia vaginata	Submerged twig	Brazil	[697]
Flammispora bioteca	Submerged dead leaves of *Licuala longicalycata* (peat swamp)	**Thailand**	[584, 1437]
Flammispora pulchra	Submerged decaying wood	USA	[756]
Phialemoniopsis endophytica	Submerged plant litter (stream)	**Korea**	[1289]
Pleurophragmium bitunicatum	Submerged decaying wood (reservoir, river) and bamboo (river)	China, Philippines	[432, 626]
Pleurophragmium malaysianum	Submerged decaying wood (stream)	Brazil	[683]
Potamomyces armatisporus	Submerged decaying wood (river)	Australia, Malaysia	[1272] [660]
Paoayensis lignicola	Submerged decaying wood (lake)	Philippines	[1438]
Plagiosphaera nilotica	Submerged twig	Sudan	[1439]
Rivulicola aquatica	Submerged decaying wood (reservoir)	China	[1237]
Rivulicola cygnea	Submerged decaying wood (lake)	USA	[899]
Rivulicola incrustata	Submerged decaying wood	Australia	[1247]
Saccardoella allequashensis	Submerged decaying wood (lake)	USA	[749]
Saccardoella aquatica	Submerged decaying wood (river)	China, South Africa	[652]

Table 7.9 (continued)

Taxon	Substrate	Country	Reference
Saccardoella horizontalis	Submerged decaying wood (river)	Philippines, USA	[749, 771]
Saccardoella lacustris	Submerged decaying wood (lake)	USA	[749]
Saccardoella minuta	Submerged bamboo and wood (river)	Philippines	[430]
Stanjehughesia clavata	Submerged decaying bark	Brazil	[1440]
Stanjehughesia curviapicis	Submerged decaying wood (stream, river)	Australia, China	[583, 1441]
Stanjehughesia kaohsiungensis	Submerged decaying wood (stream)	**China**	[1442]
Selenosporella aristata	Submerged decaying leaves (stream)	Malaysia	[1443]
Selenosporella curvispora	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[695]
Selenosporella minima	Submerged decaying leaves of *Calophyllum brasiliens*	Brazil	[1444]
Selenosporella perramosa	Submerged decaying leaves (stream)	Brazil	[683]

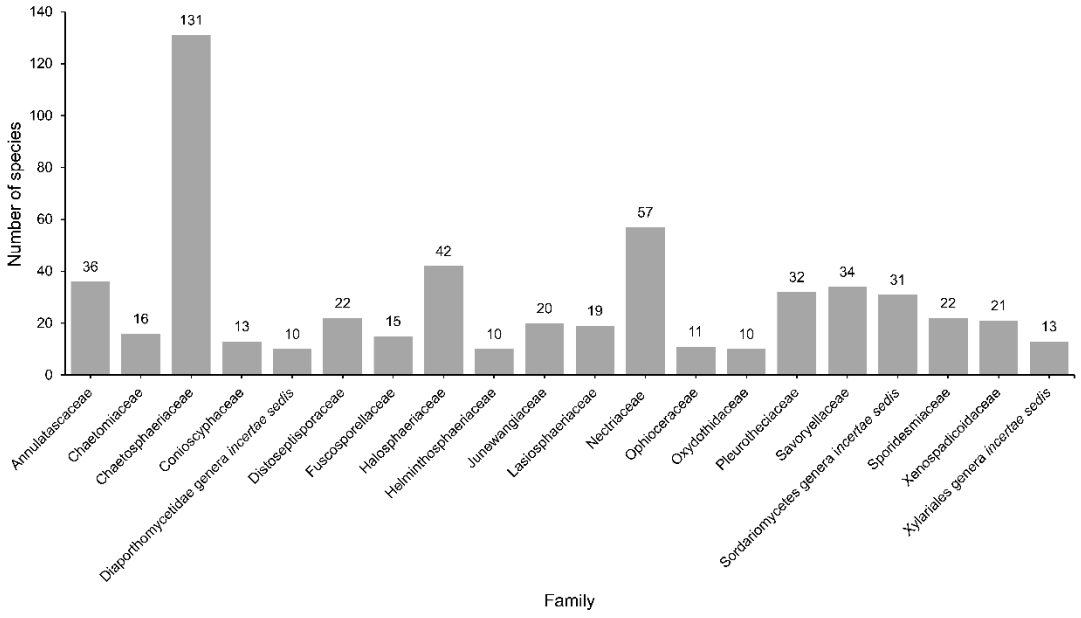


Figure 7.5 Major Families Among Different Orders of Sordariomycetes Taxa from Freshwater

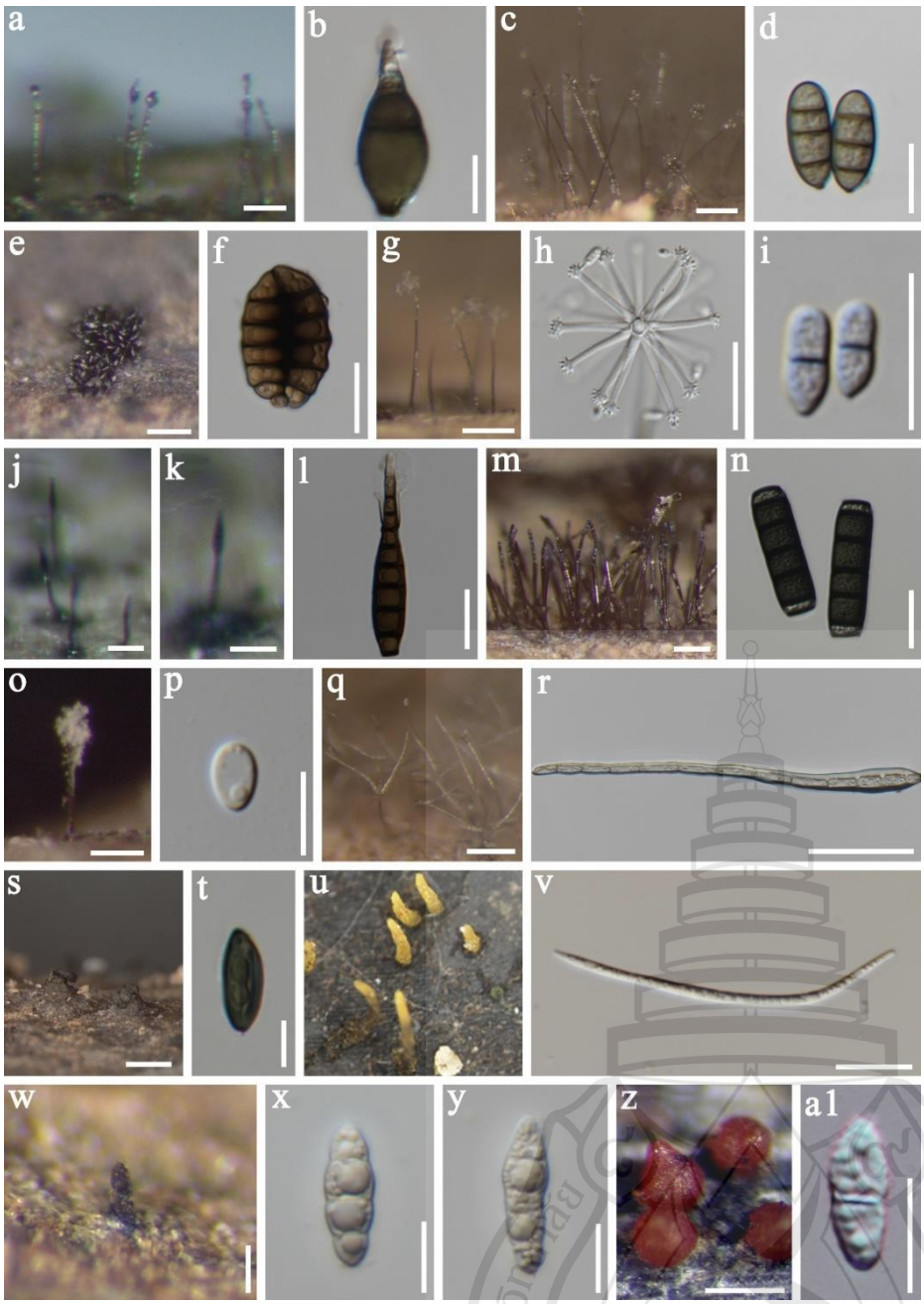


Figure 7.6 Freshwater Sordariomycetes. (a,b) *Sporidesmium* sp.; (c,d) *Aquapteridospora* sp.; (e,f) *Canalisporium* sp.; (g–i) *Cordana* sp.; (j–l) *Sporidesmium* sp.; (m,n) *Sprochisma* sp.; (o,p) *Phaeoisaria* sp.; (q,r) *Distoseptispora* sp. (s,t) *Xylaria* sp.; (u,v) *Ceratosphaeria* sp.; (w–y) *Peroneutypa* sp.; (z,a1) *Cosmospora aquatica*. Scale bar: (a,c,e,g,j,k,m,o,q) 100 μm; (r) 40 μm; (f,l,v) 20 μm; (b,d,h,i,n,p,t,x, y,a1) 10 μm; (s,w,z) 300 μm

7.3.1.10 Freshwater Lichens

Lichens are one of the most successful lifestyles among fungi [1445]. Lichens are recently redefined as “a self-sustaining ecosystem formed by the interaction of an exhabitant fungus and an extracellular arrangement of one or more photosynthetic partners and an indeterminate number of other microscopic organisms” [1446]. The lichen forming fungi are mainly terrestrial but can occur also in aquatic and semiaquatic habitats in both freshwater and marine environments [1447]. Santesson [1448] and [1449] stated that freshwater lichens are amphibious organisms as most of them are submerged for particular period. The mycobiont is ascomycetes in most freshwater lichens while the photobiont can be commonly coccoid green alga or a cyanobacterium [942, 1450, 1451]. Verrucariales and Lichinales are frequently recorded freshwater species from predominantly submerged zone [939]. The species are mostly found in the surface of water since the photobiont needs direct sunlight [1450, 1451]. However, their vertical distribution is highly influenced by transparency of the water as some species found in the deeper lakes and rivers which has high water clarity (e.g., *Hydropunctaria rheithrophila*) [939]. Species have been recorded on rocks, pebbles and wood and provide favorable host surface for many lichenicolous fungi [939, 1452].

Freshwater lichens have worldwide distribution, but this group are poorly studied [935, 951]. The diversity of freshwater lichens is influenced by the duration of submergence, dynamics of stream currents, type and stability of the substrate, light availability, chemical and physical parameters of the water [951]. The type of substrate, such as bedrock and size of the rocks, is the most important factor in determining their distribution. Many aquatic lichens became endangered or rare in some regions of Europe due to high demands in the water clarity and the sensitivity of lichens to pollution [934]. Furthermore, the water current and scouring effect of sediments drifting over the thallus can cause physical stress to lichen [1453].

The studies on freshwater lichens started during early lichenological history [934, 951, 1447, 1454–1457]. Studies of freshwater lichens in British Isles has a huge contribution to the taxonomic knowledge of this group [1458]. Thüs et al. [939] estimated a total number of freshwater lichens to be 270 but this is an underestimate, and the number could be higher [1459]. The taxonomic studies of

freshwater lichens are in the urgent need of revision due to lack of molecular support and morphological data [937]. Most of the studies on freshwater lichens were solely based on floristics surveys [646, 936, 1458, 1460, 1461]. Ecological studies have been done also in aquatic lichens: effect of substrates in aquatic lichens [1448]; influence of mineral composition of water to the occurrence of freshwater lichens and their thalli development [936]; pollution indicator of water level fluctuations, water acidity, water quality [646, 939, 953]. Thüs et al. [939] revised the freshwater lichens and lichen-like organisms. The present review provides the updated checklist of lichens and lichenicolous fungi in freshwater habitats (Table 7.10). Lichens and lichenicolous taxa under Arthoniomycetes, Dothideomycetes, Eurotiomycetes, and Sordariomycetes included in this section are already listed for each taxonomic class above.

Table 7.10 Classification of Freshwater Lichens from Different Fungal Classes with Information on the type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa. Number Sign Symbol (#) Indicate Lichenicolous Taxa while Asterisk Sign (*) are Lichens and Lichens-like

Taxon	Substrate	Country	Reference
ASCOMYCOTA			
ARTHONIOMYCETES			
Arthoniales			
Arthoniaceae			
*Arthonia caudata**	River watershed	Canada	[622]
*Arthonia helvola**	River watershed	Canada	[622]
*Arthonia radiata**	River watershed	Canada	[622]
Chrysotrichaceae			
Chrysothrix caesia*	River watershed	Canada	[622]
Chrysothrix granulosa*	River	Canada	[619]
Lecanographaceae			
Alyxoria varia*	River watershed	Canada	[622]
Opegraphaceae			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Cresponea chloroconia**	River watershed	Canada	[622]
Roccellaceae			
Enterographa osagensis #	Creek	Central North America	[620]
Enterographa zonata*	Waterfall	Canada	[619]
Gyrographa gyrocarpa*		North America	[623]
Pseudoschismatomma rufescens*	River watershed	Canada	[622]
Schismatomma cretaceum*	Nature Reserve	Western Ukraine	[621]
CANDELARIOMYCETES			
Candelariales			
Candelariaceae			
Candelaria concolor*	River watershed	Canada	[622]
Candelariella aurella*	River watershed	Canada	[622]
*Candelariella efflorescens**	River watershed	Canada	[622]
Candelariella vitellina*	River watershed	Canada	[622]
CONIOCYBOMYCETES			
Coniocybales			
Coniocybaceae			
Chaenotheca balsamconensis*	River watershed	Canada	[622]
Chaenotheca ferruginea*	River watershed	Canada	[622]
Chaenotheca furfuracea*	River watershed	Canada	[622]
Chaenotheca xyloxena*	River watershed	Canada	[622]
DOTHIDEOMYCETES			
Capnodiales			
Stigmidium rivulorum#	River	Bulgaria	[643]
Collemopsidiales			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Xanthopyreniaceae			
*Collemopsidium japonicum**	Nature reserves	Japan	[645]
*Collemopsidium monense**	Stream	UK	
Zwackhiomyces lacustris#	Stream and lake margin	Europe	[647]
Lichenotheliales			
Lichenotheliaceae			
Endococcus rugulosus#	Stream and lake margin	Europe	[647]
Endococcus verrucosporous#	Stream and lake margin	Europe	[647]
Monoblastiales			
Monoblastiaceae			
*Acrocordia cavata**	Stream and lake margin	Europe	[647]
Pleosporales			
Mycoporaceae			
*Mycoporum antecellens**	Waterfall	Canada	[619]
Phaeosphaeriaceae			
Didymocyrtis pseudeverniae#	Nature Reserve	Western Ukraine, Great Britain	[621]
Trypetheliales			
Polycoccaceae			
Polycoccum microsticticum#	Stream and lake margin	Europe	[647]
Trypetheliaceae			
Arthopyrenia fallaciosa*	Stream and lake margin	Europe	[647]
EUROTIOMYCETES			
Mycocaliciales			
Mycocaliciaceae			
Chaenothecopsis debilis*	River watershed	Canada	[622]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Chaenothecopsis haematopus**	Rainwater from building roofs	Poland	[633]
Chaenothecopsis pusiola*	River watershed	Canada	[622]
Chaenothecopsis savonica*	River watershed	Canada	[622]
Phaeocalicium curtisii*	River watershed	Canada	[622]
*Phaeocalicium polyporaeum**	River watershed	Canada	[622]
Phaeocalicium populneum*	River watershed	Canada	[622]
*Sphinctrina anglica**	River watershed	Canada	[622]
Stenocybe pullatula*	River watershed	Canada	[622]
Verrucariales			
Adelococcaceae			
Sagediopsis lomnitzensis#	Stream and lake margin	Europe	[647]
Verrucariaceae			
Agonimia allobata*	Stream	Lithuania	[935]
Agonimia tristicula*	Stream	UK	[646]
Catapyrenium lachneum*	Stream	UK	[646]
*Catapyrenium squamulosum**	River watershed	Canada	[622]
*Catillaria cf. chalybeia**	Stream	Gwynedd	[936]
Dermatocarpon arnoldianum*	River and Stream	Europe	[643, 646]
Dermatocarpon intestiniforme*	Stream	UK	[646]
*Dermatocarpon leptophyllodes**	Stream	UK	[646]
Dermatocarpon luridum*	Stream	UK, Gwynedd	[646, 936]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Dermatocarpon meiophyllizum*	Stream	UK	[646]
*Dermatocarpon meiophyllum**	Stream	UK	[646]
Dermatocarpon miniatum*	River	Bulgaria	[643]
Dermatocarpon rivulorum*	Stream and River	Bulgaria and UK	[646, 1462]
Endocarpon adscendens*	Stream	UK	[646]
*Endocarpon globosum**	Stream	China	[1463]
*Hydropunctaria orae**	Stream		[938, 939]
Hydropunctaria rheitrophila*	River and Stream	Poland, alpine Australia	[646, 943, 951]
Hydropunctaria scabra*		Bulgaria	[948]
Muellerella pygmaea #	Stream and lake margin	Europe	[647]
Placopyrenium cinereoatratum#	Siliceous rocks (brook, lake, river, stream)	Bulgaria, **Finland**, Norway, Sweden, **UK**	[948]
Placopyrenium formosum#	Rock (river)	**Finland, Iceland, UK**	[941]
*Polyblastia ardesiaca**		Italy	[942]
Psoroglaena stigonemoides*	Waterfall	Canada	[619]
Sporodictyon cruentum*	River and Streams	Alpine Australia, UK, Italy	[646, 942–944]
*Staurothele acarosporoides**	Nature reserves	Northern Vietnam	[946]
*Staurothele arenaria**	Nature reserves	Vietnam	[946]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Staurothele chlorospora**	Nature reserves	Northern Vietnam	[946]
*Staurothele clopimoides**	River	Italy, USA	[942, 947]
*Staurothele fauriei**	Nature reserves	Northern Vietnam	[946]
Staurothele fissa*	Lakes and Streams	Europe	[646, 942, 948, 949]
Staurothele fuscocuprea*		Italy	[942]
*Staurothele honghensis**	Nature reserves	Northern Vietnam	[946]
*Staurothele kwapiensis**	Nature reserves	Northern Vietnam	[946]
*Staurothele muliensis**	Nature reserves	Northern Vietnam	[946]
*Staurothele ochroplaca**	Nature reserves	Northern Vietnam	[946]
*Staurothele pachystroma**	Nature reserves	Northern Vietnam	[946]
*Staurothele paraguayensis**	Nature reserves	Northern Vietnam	[946]
*Staurothele sinensis**	Nature reserves	Northern Vietnam	[946]
*Staurothele succedens**	Stream	UK, Italy	[646, 942]
*Staurothele yunnanica**	Nature reserves	Northern Vietnam	[946]
*Thelidium aquaticum**	Stream	Poland	[951]
*Thelidium carbonaceum**	Nature reserves	Australia	[952]
*Thelidium circumspersellum**	Stream	Poland	[953]
*Thelidium epomphalum**	Creek and River	Europe	[945]
*Thelidium fontigenum**	–	Europe	[945]
*Thelidium klementii**	Stream	Poland	[953]
*Thelidium lahmianum**	-	Europe	[945]
Thelidium methorium*	-	Europe	[945]
Thelidium minutulum*	Stream	UK, Poland	[646, 951]
Thelidium nigricans*	Siliceous rocks (creek's splash	Switzerland	[945]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
	water zone)		
Thelidium papulare*	Stream	UK	[646, 936]
Thelidium pertusatii*		Italy	[942]
Thelidium pluvium*	Stream	UK, Poland	[646, 953]
Thelidium rehmii*	Stream	Poland	[953]
*Thelidium rivulicola**		Europe	[945]
*Thelidium spadanum**		Europe	[945]
*Thelidium sublacteum**		Europe	[945]
Thelidium submethorium*		Europe	[945]
*Thelidium suzaeanum**		Europe	[945]
Thelidium zwackhii*	Stream	Poland	[951]
*Verrucaria aeithiobola**	Stream	Italy and UK	[936, 942]
Verrucaria alpicola*		Bulgaria	[940]
*Verrucaria amnica**	mountain stream	New Zealand	[954]
Verrucaria aquatilis*	Nature reserve, River, Stream	Italy, alpine Australia, UK	[646, 943, 955]
*Verrucaria austroalpina**	Creeks and rivers	Eastern Australia	[956]
*Verrucaria basaltica**	Streams and lakes	Poland	[957]
Verrucaria calkinsian*	River watershed	Canada	[622]
*Verrucaria consociata**	Stream	Great Britain	[959]
Verrucaria conturmatula#	Stream and lake margin	Europe	[647]
*Verrucaria cootapatambensis**	River	Alpine Australia	[943]
Verrucaria devensis*	Stream	Poland	[951, 953]
Verrucaria dolosa*	Stream	UK, Poland	[646, 951]
Verrucaria elaeina	Stream	Poland	[951]
Verrucaria elaeomelaena*	Nature reserve,	Italy, Poland,	[936, 942,

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
	Stream	Gwynedd	951, 955]
Verrucaria funckii*	Stream	France, UK	[646, 1464]
*Verrucaria glaucina**	Stream	UK	[646]
Verrucaria hydrela*	Stream	Gwynedd and UK	[646, 936]
Verrucaria hydrophila*	Stream	Poland, Europe	[938, 951]
*Verrucaria igii**	River	Alpine Australia	[943]
*Verrucaria inconstans**	Creeks and rivers	Eastern Australia	[956]
Verrucaria latebrosa*	Stream	UK, Italy, **Poland**	[646, 942, 951]
*Verrucaria maas-geesterani**			
Verrucaria margacea*	Creeks, rivers, Stream	Eastern Australia, UK	[646, 1465]
*Verrucaria morosa**	River	Alpine Australia	[943]
*Verrucaria mundula**	Creeks, rivers, Stream	Eastern Australia	[1466]
Verrucaria nodosa*	Stream	Europe	[938]
Verrucaria pachyderma*	Stream	Australia, Italy, Europe	[942, 957]
*Verrucaria phaeoderma**	Creeks and rivers, Stream	Eastern Australia, France, Gwynedd	[936, 1464, 1465, 1467]
Verrucaria placida*	Stream	Europe	[938]
Verrucaria praetermissa*	River and Stream	Italy, Europe	[646, 942, 960]
*Verrucaria puncticulata**	Creeks and rivers	Eastern Australia	[943]
Verrucaria rosula*	Stream	UK, Europe	[938, 959]
*Verrucaria ruttneri**	River	Alpine Australia	[943]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Verrucaria submersella*	Stream	Poland	[951]
Verrucaria sublobulata*	Stream	Great Britain	[959]
*Verrucaria tasmanica**	River, creeks, and rivers	Alpine Australia, Eastern Australia	[943, 956]
*Verrucaria tholocarpa**	Creeks and rivers	Eastern Australia	[956]
*Verrucaria unckii**	Stream	Italy	[942]
*Willeya australis**	Nature reserves	Northern Vietnam	[946]
Willeya diffractella*	Nature reserves	Northern Vietnam	[946]
Willeya fusca*	Nature reserves	Northern Vietnam	[946]
*Willeya iwatsukii**	Nature reserves, river	Japan, Northern Vietnam	[946, 950]
*Willeya japonica**	Nature reserves	Northern Vietnam	[946]
Willeya laevigata*	Nature reserves	Northern Vietnam	[946]
*Willeya malayensis**	Nature reserves	Northern Vietnam	[946]
*Willeya microlepis**	Nature reserves	Northern Vietnam	[946]
Willeya pallidipora*	Nature reserves	Northern Vietnam	[946]
Willeya protrudens*	Nature reserves	Northern Vietnam	[946]
*Willeya rimosa**	Nature reserves	Northern Vietnam	[946]
LECANOROMYCETES			
Acarosporales			
Acarosporaceae			
Acarospora fuscata*	River watershed	Canada	[622]
Acarospora schleicheri*	Waterfall	Canada	[619]
Acarospora smaragdula*	Stream	UK	[646]
Sarcogyne regularis*	River watershed	Canada	[622]
Arctomiales			
Arctomiaceae			
Arctomia delicatula*	Lake	Canada	[619]
Baeomycetales			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Baeomycetaceae			
Baeomyces rufus*	Stream	UK	[646]
Caliciales			
Caliciaceae			
Amandinea punctata*	River watershed	Canada	[622]
*Buellia aethale**	Stream	UK	[646]
Cyphelium tigillare*	River watershed	Canada	[622]
*Diplotomma venustum**	River watershed	Canada	[622]
Physciaceae			
Heterodermia albicans*	Stream	USA	[1468]
Hyperphyscia adglutinata*	River watershed	Canada	[622]
Phaeophyscia adiastola*	River watershed	Canada	[622]
Phaeophyscia orbicularis*	Stream	UK	[646]
Phaeophyscia pusilloides*	River watershed	Canada	[622]
Phaeophyscia rubropulchra*	River watershed	Canada	[622]
Phaeophyscia sciastra*	Stream	UK	[646]
Physcia caesia*	Stream	UK	[646]
Physcia dubia*	River watershed	Canada	[622]
Physcia millegrana*	River watershed	Canada	[622]
Physcia stellaris*	River watershed	Canada	[622]
Rinodina fimbriata*	Stream	UK	[646]
Physciella chloantha*	River watershed	Canada	[622]
Physconia detersa*	River watershed	Canada	[622]
Physconia enteroxantha*	River watershed	Canada	[622]
Physconia perisidiosa*	River watershed	Canada	[622]
*Rinodina fimbriata**	Stream	UK	[646]
Rinodina freyi*	River watershed	Canada	[622]
Rinodina teichophila*	Stream	UK	[646]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Rinodina rivularis**	River	China	[961]
Hymeneliales			
Hymeneliaceae			
*Hymenelia cyanocarpa**	Stream	UK	[646]
Ionaspis lacustris*	Stream and river	Gwynedd, alpine Australia, France, UK	[646, 936, 943, 1464]
Ionaspis odora*		Italy	[942]
Ionaspis sp.*	River	Alpine Australia	[943]
Protothelenellaceae			
*Thrombium thelostomum**	Stream	UK	[646]
Trapeliaceae			
Placopsis gelida*	Stream	UK	[646]
*Sarea resinae**	River watershed	Canada	[622]
Trapelia coarctata*	Stream	UK	[646]
Trapelia involuta*	Stream	UK	[646]
Trapelia obtegens*	Stream	UK	[646]
Trapelia placodioides*	Stream	UK	[646]
Xylographaceae			
Xylographa vitiligo*	Nature Reserve	Western Ukraine	[621]
Lecanorales			
Byssolomataceae			
Micarea peliocarpa*	Stream	UK	[646]
Micarea prasina*	River watershed	Canada	[622]
*Micarea viridiatra**	Nature Reserve	Western Ukraine	[621]
Micarea viridileprosa*	Nature Reserve	Western Ukraine	[621]
Catillariaceae			
Catillaria chalybeia*	Stream	UK	[646]
Catillaria nigroclavata*	River watershed	Canada	[622]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Cladoniaceae			
Cladonia cervicornis*	River watershed	Canada	[622]
Cladonia chlorophaea*	River watershed	Canada	[622]
Cladonia fimbriata*	River watershed	Canada	[622]
Cladonia furcata*	River watershed	Canada	[622]
Cladonia macilenta*	River watershed	Canada	[622]
Cladonia ochrochlora*	River watershed	Canada	[622]
Cladonia pocillum*	River watershed	Canada	[622]
*Cladonia pyxidata**	River watershed	Canada	[622]
Cladonia rangiferina*	River watershed	Canada	[622]
Cladonia rei*	River watershed	Canada	[622]
Lepraria lobificans*	River watershed	Canada	[622]
Stereocaulon saxatile*	River watershed	Canada	[622]
Haematommataceae			
Haematomma ochroleucum*	Waterfall	Canada	[619]
Lecanoraceae			
*Claurouxia chalybeioide**	Stream	UK	[646]
Lecanora campestris*	Stream	UK	[646]
*Lecanora epanora**	Stream	UK	[646]
Lecanora gangaleoides*	Stream	UK	[646]
Lecanora hybocarpa*	River watershed	Canada	[622]
Lecanora pulicaris*	River watershed	Canada	[622]
*Lecanora soralifera**	Stream	UK	[646]
*Lecanora symmicta**	River watershed	Canada	[622]
Lecidella carpathica*	Stream	UK	[646]
Lecidella scabra*	Stream	UK	[646]
Lecidella stigmatea*	Stream	UK	[646]
Lepra amara*	River watershed	Canada	[622]
Myriolecis hagenii*	River watershed	Canada	[622]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Lepra amara*	River watershed	Canada	[622]
Myriolecis hagenii*	River watershed	Canada	[622]
*Polyozosia dispersa**	Stream	UK	[646]
*Polyozosia sambuci**	River watershed	Canada	[622]
*Polyozosia semipallida**	River watershed	Canada	[622]
Protoparmeliopsis muralis*	River watershed	Canada	[622]
Verseghya thysanophora*	River watershed	Canada	[622]
Parmeliaceae			
Evernia mesomorpha*	River watershed	Canada	[622]
Flavoparmelia caperata*	River watershed	Canada	[622]
Flavopunctelia flaventior*	River watershed	Canada	[622]
Flavopunctelia soredica*	River watershed	Canada	[622]
Hypogymnia oceanica*	Waterfall	Canada	[619]
Hypogymnia physodes*	River watershed	Canada	[622]
Melanelixia subaurifera*	River watershed	Canada	[622]
Parmelia sulcata*	River watershed	Canada	[622]
Protoparmelia hypotremella*	River watershed	Canada	[622]
Punctelia rudecta*	River watershed	Canada	[622]
Usnea hirta*	River watershed	Canada	[622]
Xanthoparmelia conspersa*	-	Italy	[646]
Xanthoparmelia conspersa*	River watershed	Canada	[622]
Psoraceae			
Protoblastenia rupestris*	River watershed	Canada	[622]
Ramalinacea			
*Bacidia arnoldiana**	Stream	UK	[646]
Bacidia fuscoviridis*	Stream	UK	[646]
*Bacidia inundata**	Stream	UK	[646]
Bacidina delicata*	Stream	Europe	[935]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Bacidina inundata**	Stream	UK	[646]
Bilimbia sabuletorum*	River watershed	Canada	[622]
Lecania croatica*	River watershed	Canada	[622]
Lecania erysibe*	Stream	UK	[646]
Lecania hutchinsiae*	Stream	Lithuania	[935]
Ramalina intermedia*	River watershed	Canada	[622]
Scoliciosporaceae			
Scoliciosporum chlorococcum*	River watershed	Canada	[622]
Scoliciosporum umbrinum*	Stream	UK	[646]
Stereocaulaceae			
Stereocaulon pileatum*	Stream	UK	
Lecideales			
Lecideaceae			
*Bryobilimbia ahlesii**	Stream	Poland	[953]
Koerberiella wimmeriana*		Italy	[942]
Porpidia crustulata*	Stream	UK	[646]
Porpidia hydrophila*	stream	UK, France, Italy	[646, 942, 1464]
Porpidia macrocarpa*	River watershed	Canada	[622]
*Porpidia platycarpoides**	Stream	UK	[646]
Porpidia soredizodes*	Stream	UK, Italy	[646, 942]
Porpidia tuberculosa*	Stream	UK	[646]
Ostropales			
Coenogoniaceae			
Coenogonium pineti*	River watershed	Canada	[622]
Graphidaceae			
*Graphis scripta**	River watershed	Canada	[622]
Gyalectaceae			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Gyalecta jenensis*	Stream	UK	[646]
*Gyalidea roseola**	Stream	UK	[646]
Porinaceae			
*Porina ahlesiana**	Stream	UK	[646]
Porina lectissima*		Italy, UK	[646, 942]
*Porina otagensis**	semi aquatic	New Zealand	[1467]
*Pseudosagedia chlorotica**	Stream	Lithuania, UK	[646, 935]
Pseudosagedia guentheri*	Nature Reserve	Great Britain, Western Ukraine	[621]
*Pseudosagedia interjungens**	Stream	Western Ukraine	[646]
*Porina grandis**	-	-	[939]
*Porina rivalis**	Stream, river	Great Britain	[959]
Pertusariales			
Megasporaceae			
Aspicilia aquatica*	Stream	UK	[646]
Aspicilia caesiocinerea*	Stream	UK	[646]
*Aspicilia inornata**	Stream	UK	[646]
Aspicilia laevata*	Stream	UK	[646]
*Aspicilia laevatoides**	Stream	UK	[646]
Lobothallia melanaspis*		Italy	[942]
Microcaliciaceae			
Microcalicium ahlneri*	River watershed	Canada	[622]
Ochrolechiaceae			
*Ochrolechia arborea**	River watershed	Canada	[622]
Pertusariaceae			
*Loxosporopsis corallifera**	River	Canada	[619]
*Pertusaria macounii**	River watershed	Canada	[622]
Peltigerales			
Collemataceae			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Collema elenkii**	-	-	[939]
Collema flaccidum*	Stream	UK	[646]
*Collema ramenskii**	-	Russia	[1447]
Enchylium bachmanianum*	Stream	UK	[646]
*Enchylium tenax**	Stream	UK	[646]
*Lathagrium dichotomum**	Stream	UK	[646]
Leptogium teretiusculum*	Stream	UK	[646]
*Scytinium gelatinosum**	Stream	UK	[646]
*Scytinium lichenoides**	River watershed	Canada	[622]
*Scytinium massiliense**	Stream	UK	[646]
*Scytinium plicatile**	Stream	UK	[646]
*Scytinium rivale**	River	USA	[1469]
Lobariaceae			
Pseudocyphellaria crocata*	Twig (waterfall)	Canada	[619]
Pseudocyphellaria mallota*	Twig (river)	Canada	[619]
Massalongiaceae			
Massalongia carnosa*	Stream	UK	[646]
Peltigeraceae			
Nephroma occultum*	Bark (lake, river)	Canada	[619]
Peltigera canina*	River watershed	Canada	[622]
Peltigera elisabethae*	River watershed	Canada	[622]
Peltigera evansiana*	River watershed	Canada	[622]
Peltigera horizontalis*	Stream	UK	[646]
Peltigera hydrothyria*	River	USA	[939, 1469]
Peltigera praetextata*	Stream	UK	[646]
Peltigera rufescens*	River watershed	Canada	[622]
Peltigeraceae			
*Loxosporopsis corallifera**	River	Canada	[619]
Nephroma occultum*	Waterfall	Canada	[619]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Placynthiaceae			
Placynthium flabellosum*	Stream	UK, Italy	[646, 942]
Placynthium nigrum*	River watershed	Canada	[622]
Placynthium rosulans*	–	Italy	[942]
Placynthium tantaleum*	Stream	UK	[646]
Rhizocarpales			
Rhizocarpaceae			
Rhizocarpon amphibium*	Stream	UK	[646]
Rhizocarpon lavatum*	Stream	UK	[646, 936]
*Rhizocarpon sublavatum**	Stream	Poland	[953]
Teloschistales			
Teloschistaceae			
Athallia holocarpa*	River watershed	Canada	[622]
Athallia pyracea*	River watershed	Canada	[622]
*Blastenia ferruginea**	River watershed	Canada	[622]
*Caloplaca borreri**	Nature Reserve	Western Ukraine	[621]
Caloplaca flavovirescens*	River	Brazil	[939]
Caloplaca obscurella*	Stream	UK	[646]
Flavoplaca oasis*	Stream	UK	[646]
Ostropomycetidae genera *incertae sedis*			
Dictyocatenulata alba*	River watershed	Canada	[622]
Gyalolechia flavovirescens*	River watershed	Canada	[622]
Polycauliona polycarpa*	River watershed	Canada	[622]
Rufoplaca arenaria*	River watershed	Canada	[622]
Xanthomendoza fallax*	River watershed	Canada	[622]
Xanthoria elegans*	River watershed	Canada	[622]
Xanthoria parietina*	River watershed	Canada	[622]
Umbilicariales			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Ophioparmaceae			
Hypocenomyce scalaris*	River watershed	Canada	[622]
Umbilicariaceae			
Umbilicaria deusta*	Stream	UK	[646]
LICHINOMYCETES			
Lichinomycetidae			
Lichinales			
Lichinaceae			
Ephebe brasiliensis*	Submerged rocks (river, stream)	Brazil, Uruguay	[939, 1470]
*Ephebe lanata**	Submerged rocks (river, stream)	UK	[646, 936, 1471]
*Ephebe ocellata**	Semi-inundated rocks	Australia, South America	[1470, 1472]
Ephebe perspinulosa*	Stream	UK	[646]
*Jenmania goebelii**	Submerged rocks (river, stream)	Central & South America	[939]
*Jenmania osorioi**	Submerged rocks (river, stream)	Uruguay	[939]
*Lempholemma botryosum**	Damp limestone, seepage tracks	UK	[1458]
*Lempholemma cladodes**	Block bellow limestone (waterfalls)	UK	[1458]
Lempholemma polyanthes*	Damp limestone, seepage tracks	UK	[1458, 1473]
*Porocyphus coccodes**	Stream	UK	[646]
Porocyphus kenmorensis*	Stream	UK	[646]

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
*Psorotichia schaereri**	Submerged rocks (limestone river)	UK	[1458]
*Pterygiopsis australiensis**	Submerged stone (river)	Australia	[939]
*Pterygiopsis coracodiza**	Submerged rocks (limestone river)	UK	[1458]
*Pterygiopsis lacustris**	Submerged rocks (limestone river)	UK	[1458]
*Pterygiopsis submersa**	Granite covered by running water (stream)	South Africa	[1474]
Pterygiopsis sp.*	Stream	UK	
Pyrenocarpon cf. *flotowianum**	Submerged rocks (limestone river)	UK	[1458]
*Pyrenopsis furfurea**	-	Italy	[942]
*Pyrenopsis subareolata**	Stream	Italy, UK	[936, 942]
*Thelignya lignyota**	Moist rocks (lakes, river)	USA	[1475]
*Zahlbrucknerella calcarea**	-	Italy	[1458]
Peltulaceae			
Peltula euploca*	Drainage surface with periodical rain	Morocco, South Africa	[939, 1476]
Peltula obscurans*	Drainage surface with periodical rain	Morocco	[1476]
Peltula omphaliza*	Drainage surface with periodical rain	Morocco	[1476]
SORDARIOMYCETES			
Hypocreomycetidae			
Coronophorales			

Table 7.10 (continued)

Taxon	Substrate	Country	Reference
Nitschkiaceae			
Rhagadostoma lichenicola[#]	Lake	USA	[1288]
Hypocreales			
Bionectriaceae			
*Ovicuculispora parmeliae**	River watershed	Canada	[622]
Hypocreales genera *incertae sedis*			
Illosporiopsis christiansenii[#]	River watershed	Canada	[622]
Illosporium carneum*	River watershed	Canada	[622]
Pezizomycotina genera *incertae sedis*			
Psammina stipitata #	Nature Reserve	Western Ukraine, Great Britain	[621]

Note Number sign symbol (#) indicate Lichenicolous taxa while asterisk sign (*) are lichens and lichens-like

7.3.1.11 Ascomycota genera *incertae sedis*

The list of freshwater fungal taxa in the Ascomycota with uncertain taxonomic placements are provided in Table 7.11. A total of 252 species under 141 genera are recorded.

Table 7.11 Classification of Freshwater Ascomycota *Incertae Sedis* with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	Reference
Ascomycota genera *incertae sedis*			
Actinocladium rhodosporum	Submerged decaying twig (stream), water-filled treeholes	Brazil, Hungary	[683] [638]
Actinocladium verruculosum	Submerged decaying twig (stream)	Brazil	[683]
Alatosessilispora bibrachiata	Rainwater from leaves of *Quercus mongolica* var. *grosseserrata*	Japan	[1477]
Angulospora aquatica	Submerged decaying leaves, rainwater from building roofs, foam (stream)	India, Poland, Venezuela	[633, 722, 1478]
Anisospadicoides macroobovata	Submerged bark	Brazil	[697]
Anungitopsis speciosa	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88]
Anungitopsis triseptata	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88]
Arachnophora combuensis	Submerged decaying wood	Brazil	[1479]
Arachnophora longa	Submerged decaying wood	Australia	[1480]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Arborispora dolichovirga	Foam (stream)stemflow and throughfall of tree canopies	Canada, India	[636, 1148]
Arborispora palma	Rainwater: building roofs, draining from leaves of *Quercus*, sediment (dam)	India, Japan, Poland	[633, 718, 1481]
Arborispora paupera	Spume (river), submerged decaying leaves (stream), stemflow and throughfall of tree canopies	Canada, India	[636, 729, 1482]
Ardhachandra aequilatera	Submerged decaying leaves of *Calophyllum Brasiliense* (stream)	Brazil	[88, 1140]
Arthrotaeniolella aquatica	Submerged decaying leaves and twigs (stream)	Brazil	[1214]
Ascomauritiana lignicola	Submerged decaying wood (stream)	Mauritius	[1483]
Biflagellospora gracilis	Submerged decaying wood of *Dipterocarpus alatus* and *Xylia dolabriformis* test block (stream)	Thailand	[1484]
Biflagellospora japonica	Submerged decaying wood of *Xylia dolabriformis* test block (stream)	Thailand	[70, 1484]
Biflagellospora papillata	Submerged decaying wood of *Xylia dolabriformis* test block (stream)	Thailand	[1484]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Biflagellospora siamensis	Submerged decaying wood of *Xylia dolabriformis* test block (stream)	Thailand	[1484]
Blastoheterospora catenata	Submerged decaying wood (river)	Brazil	[1213]
Blodgettia indica	Submerged decaying leaves, foam (stream)	Brazil, India	[722, 1485]
Brachydesmiella anthostomelloidea	Submerged decaying wood (stream) and petiole (stream)	Australia, Brazil	[1486]
Brachydesmiella biseptata	Submerged test block (*Anisoptera oblonga*)	Thailand	[1486]
Brachydesmiella caudata	Submerged decaying wood (*Machilus velutina*) and petiole (stream)	Brazil, China, India, Thailand	[683, 1486]
Brachydesmiella orientalis	Submerged test block (*Anisoptera oblonga*), submerged decaying wood (stream)	China, Thailand	[1336, 1486]
Brachydesmiella verrucosa	Submerged wood	Malaysia, Thailand	[660, 1486]
Brevicatenospora enteroproliferata	Submerged decaying leaves of *Andira inermis* (stream)	Cuba	[1429]
Cacumisporium capitulatum	Water-filled treeholes	Hungary	[638]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Cacumisporium pleuroconidiophorum	Submerged decaying twig and bark (stream)	Brazil	[683]
Cacumisporium rugosum	Submerged decaying wood (river)	China	[700]
Cacumisporium sigmoideum	Submerged decaying twig (stream)	Brazil	[683]
Cacumisporium uniseptatum	Submerged decaying wood (stream)	China	[862]
Calcarispora hiemalis	Foam (stream), submerged decaying leaves of *Fagus sylvatica*	Czechoslovakia, France	[630, 1148]
Camposporidium cristatum	Submerged decaying angiospermous leaves (stream)	Brazil, Malaysia	[683, 1487]
Camposporidium hughesii	Submerged decaying bark (stream)	Cuba	[1488]
Candelabrum clathrosphaeroides	Submerged decaying wood (stream), submerged decaying leaves of *Fagus sylvatica* (peat hole)	Austria, Thailand	[858, 1489]
Candelabrum desmidiaceum	Submerged decaying leaves of *Fagus sylvatica* (peat hole)	Austria	[1489]
Candelabrum macrosporum	Submerged decaying leaves of broad-leaved tree (stream)	Japan	[1136]
Candelosynnema ranunculosporum	Submerged decaying wood (waterfall)	Australia	[1490]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Casaresia sphagnorum	Foam (lake, spring, stream, river), submerged decaying leaves of *Quercus* and angiosperm (lake), water (stream)	Canada, France, Ireland, USA	[66, 588, 639, 716, 719, 828]
Ceuthospora gaeumannii	Submerged decaying wood (stream)		[583]
Chaetendophragmia triangularis	Foam (stream)	India, Malaysia	[577, 722]
Chaetopsis prosbosciophora	Submerged decaying wood (reservoir)	China	[626]
Casaresia sphagnorum	Foam (lake, spring, stream, river), submerged decaying leaves of *Quercus* and angiosperm (lake), water (stream)	Canada, France, Ireland, USA	[66, 588, 639, 716, 719, 828]
Cheiromyces lignicola	Submerged decaying wood (river)	China	[1491]
Cladoconidium articulatum	Foam (stream)	Canada	[1148]
Clavariana aquatica	Foam (stream), rainwater from building roofs. Sediment (stream)	Malaysia, India, Poland	[633, 671, 718]
Colispora cavincola	Submerged leaves, twigs, and cupules of *Fagus sylvatica* in wet tree hollow	Hungary	[638, 1492]
Colispora elongata	Rainwater from building roofs, water (stream), foam (rivulet)	Austria, Poland, Slovakia	[631, 633, 1127]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Colispora curvata	Submerged decaying angiospermic petioles (stream)	Malaysia	[1493]
Condylospora flexuosa	Submerged decaying twig (stream), foam (stream)	Brazil, Malaysia, Venezuela	[519, 1169, 1494]
Condylospora gigantea	Submerged decaying twig and leaves of *Calophyllum brasiliense* (stream), foam (stream),	Brazil, Malaysia	[723, 847, 1494, 1495]
Condylospora spumigena	Foam (stream, river), submerged decaying twigs, throughfall of palm species	Brazil, India, Japan, Malaysia, Thailand	[727, 731, 827, 881, 1169, 1494, 1496]
Conioscyphopsis australiensis	Submerged decaying of angiospermous wood	Australia	[1497]
Corynesporella superioramifera	Rainwater from building roofs	Poland	[633]
Corynesporopsis antillana	Submerged twig, submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88, 697]
Culicidospora aquatica	Foam (lake, spring, stream, rivulet, river), submerged decaying leaves (stream), submerged leaf litter of *Alnus glutinosa* (stream), scum (stream), water (stream)	Austria, Canada, France, Malaysia, USA	[66, 588, 628, 630, 631, 716, 717, 729, 828, 847]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Culicidospora gravida	Foam (river, stream, rivulet), submerged decaying leaves (river, stream), submerged leaf litter of *Alnus glutinosa* (stream)	Austria, Brazil, Canada, France, Japan, USA, Venezuela	[66, 519, 588, 628, 630, 631, 723, 729, 731]
Curucispora ombrogena	Rainwater from leaves of *Phyllostachys bambusoides*	Japan	[1477]
Curucispora ponapensis	Stemflow and throughfall of tree canopies	India	[636]
Delortia palmicola	Submerged decaying *Licuala longicalycata* and *Eleiodoxa conferta* (peat swamp)	Thailand	[62, 584]
Dendrospora erecta	Foam (lake, stream, spring, rivulet, river), submerged decaying leaves of *Alnus glutinosa* (stream), scum (stream), water (stream)	Austria, Brazil, Canada, France, India, Ireland, UK, USA	[65, 588, 717, 827, 828, 628, 630–632, 637, 639, 713, 716]
Dendrospora fastuosa	Foam (river)	Canada, UK	[588, 1498]
Dendrospora fusca	Foam (river), submerged leaf litter of *Alnus glutinosa* (stream)	France, Ireland, UK	[630, 632, 1498]
Dendrospora juncicola	Submerged decaying culms of *Juncus effusus* (river), foam (stream), stemflow	India, UK	[727, 737, 827]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Dendrospora moniliformis	Submerged decaying wood (*Fagus sylvatica, Picea abies*), foam (stream, rivulet), water (stream)	Austria, Canada, UK	[588, 628, 631, 1168]
Dendrospora nana	Spume (river), foam (river), submerged decaying leaves (stream), stemflow	Canada, India, UK	[588, 727, 729, 1498]
Dendrospora polymorpha	Foam (river, stream)	Austria, Spain	[628, 1499]
Dendrospora tenella	Foam (stream, rivulet), submerged decaying twigs (river)	Austria, Canada, **Portugal**, UK	[588, 628, 631, 1066, 1498]
Dendrospora torulosa	Submerged rotting cupules of *Castanea (*river), stemflow	India, UK	[727, 1498]
Dendrospora yessemreddyi	Foam (stream)	India	[1500]
Dendrosporium lobatum	Submerged decaying *Xylia dolabriformis* test block, foam (river, stream), submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, India, Thailand	[70, 88, 722, 723]
Dendryphiosphaera parvula	Submerged decaying twig (stream)	Malaysia	[1501]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Denticularia limoniformis	Submerged decaying wood (stream)	Brunei	[583]
Dictyoaquaphila appendiculata	Submerged decaying wood (river, stream)	Brazil	[1502]
Dictyotrichocladium aquaticum	Submerged decaying leaves of *Calophyllum Brasiliense* (river)	Brazil	[87]
Diplocladiella appendiculata	Foam (river), submerged decaying wood	Malaysia, Thailand	[881, 1503]
Diplocladiella aquatica	Submerged decaying wood	Brunei	[1504]
Diplocladiella scalaroides	Foam (stream, river, rivulet), water-filled treeholes	Austria, Hungary, India, Malaysia, Thailand, Venezuela	[519, 628, 631, 638, 722, 847, 881]
Diplocladiella tricladioides	Submerged decaying wood	Malaysia	[1505]
Drepanospora viridis	Stemflow and throughfall of palm species	India	[727]
Dwayaangam colodena	Foam (stream)	Canada	[1506]
Dwayaangam cornuta	Foam (stream, rivulet), stemflow and throughfall of tree canopies and palm species, water-filled treeholes	Austria, Brazil, Canada, Hungary, India, UK	[588, 628, 631, 636, 638, 727, 1118, 1169]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Dwayaangam dichotoma	Spume (river), stemflow and throughfall of tree canopies	India, Malaysia	[636, 1505]
Elegantimyces sporidesmiopsis	Submerged decaying wood	China	[1507]
Enantioptera bialata	Foam (stream)	Czech Republic	[1171]
Enantioptera tetra-alata	Foam (river, stream)	Ireland, UK	[632, 1168]
Endophragmia boewei	Submerged decaying plant material (swamp)	USA	[1508]
Everhartia aquatica	Submerged decaying wood (stream)	Australia	[1509]
Everhartia tumidiapicis	Submerged decaying wood (stream)	Australia	[1509]
Flabellocladia gigantea	Foam (stream)	Malaysia	[1510]
Flabellospora acuminata	Foam (river), submerged leaf litter of *Alnus glutinosa* (stream)	France, UK, Venezuela	[519, 630, 1118]
Flabellospora amphibia	Dead insects (pond), foam (stream), submerged decaying wood	Portugal, Uzbekistan, UK	[1118, 1160, 1511]
Flabellospora crassa	Submerged decaying leaves of *Phoenix dactylifera*, *Coffea arabica* and *Hevea brasiliensis*, stemflow and throughfall, foam (stream, river)	Brazil, India, Nigeria, Thailand, USA, Venezuela	[519, 636, 637, 722, 727, 827, 881, 888, 1167, 1512]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Flabellospora multiradiata	Foam (river, stream), stemflow and throughfall of tree canopies	India, Malaysia, Thailand	[636, 827, 881, 1513]
Flabellospora tetracladia	Foam (stream)	Brazil, India, Japan, Malaysia, Venezuela	[519, 723, 731, 827, 1510]
Flabellospora verticillata	Submerged decaying leaves of *Coffea arabica* and *Phoenix dactylifera*, stemflow and throughfall of tree canopies and palm species, foam (river, stream)	Brazil, India, Nigeria, Thailand, Venezuela	[519, 636, 723, 727, 827, 881, 888, 1512]
Frigidispora colnensis	Submerged decaying wood (river)	UK	[688]
Fusticeps laevisporus	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Gemmulina botryosa	Foam (stream)	UK	[1118]
Helicoubisia coronata	Submerged decaying angiospermous twig, decaying *Eleiodoxa conferta* (peat swamp)	Malaysia, Thailand	[62, 1392]
Goidanichiella fusiformis	Submerged decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[62]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Heliscella stellata	Foam (stream, rivulet), submerged decaying leaves of *Alnus glutinosa* (stream), stemflow and throughfall of tree canopies and pal species, water (stream)	Austria, France, India, Ireland, Malaysia, Spain, Sweden, UK, USA	[577, 628, 1118, 1145, 1514, 630–632, 636, 639, 727, 783, 828]
Heliscella stellatacula	Foam (rivulet)	Austria, Malaysia	[577, 631]
Heliscina antennata	Decaying leaf litter of *Alnus glutinosa* (stream), foam, (stream), spring, water (stream)	Austria, Czech Republic, France, Spain, USA	[628, 630, 639, 1318, 1515]
Heliscina campanulata	Foam (river, stream), submerged leaf litter of *Alnus glutinosa* (stream), water (stream)	Austria, Canada, France, India, Ireland, USA	[588, 628, 630, 632, 639, 722, 828, 1118]
Henicospora amazonensis	Submerged decaying leaves (stream)	Brazil	[1516]
Henicospora coronata	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[88]
Henicospora longissima	Submerged decaying litter of *Saraca thaipingensis*	Malaysia	[1392]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Hormiactis ontariensis	Water-filled treeholes	Hungary	[638]
Hyalocamposporium acutum	Submerged decaying wood (stream)	Hungary	[1517]
Hyalocamposporium longiflagellatum	Submerged decaying wood (stream)	China, Hungary	[624, 1517]
Hydrometrospora symmetrica	Foam/water (stream), stemflow	India, Venezuela	[519, 727]
Inesiosporium longispirale	Submerged decaying wood and leaves (stream)	Brazil	[683, 1140]
Ityorhoptrum verruculosum	Submerged decaying bamboo (stream, river)	Brazil, Philippines	[432, 683]
Isthmolongispora asymmetrica	Decaying leaves (river)	Argentina	[1384]
Isthmolongispora geniculata	Submerged decaying angiospermic leaves	Malaysia	[1518]
Isthmolongispora lanceata	Water	Netherlands	[1519]
Isthmolongispora minima	Foam (river), water-filled treeholes	Hungary, Ireland	[632, 638]
Isthmolongispora rotundata	Submerged decaying leaves	China	[1520]
Isthmophragmospora laevispora	Submerged decaying leaves (stream)	Brazil	[1516]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Isthmophragmospora verruculosa	Submerged decaying angiospermous twigs (stream)	Malaysia	[1521]
Isthmotricladia britannica	Foam (stream, river rivulet)	Austria, Canada, Ireland, UK	[588, 628, 631, 632, 1118]
Isthmotricladia gombakiensis	Foam (stream, river), stemflow and throughfall	India, Malaysia, Thailand, Venezuela	[519, 727, 827, 881, 1522]
Isthmotricladia laeensis	Stemflow and throughfall of tree canopies and palm species, foam (stream, river)	India, Malaysia, Thailand	[577, 636, 827, 881]
Iyengarina asymmetrica	Submerged decaying angiospermous twigs (stream)	Malaysia	[1521]
Iyengarina furcata	Submerged decaying twig (stream)	Malaysia	[1521]
Jerainum triquetrum	Submerged decaying twig (stream)	Malaysia	[1523]
Kameshwaromyces globosus	Submerged decaying wood (stream)	China	[583]
Kiliophora fusispora	Submerged decaying angiospermous leaves	Malaysia	[1524]
Kiliophora ubiensis	Submerged decaying leaves	Malaysia	[1524]
Kontospora halophila	Submerged leaves of *Populus euphratica* (stream)	Spain	[1525]
Kostermansinda magna	Submerged decaying culm of *Miscanthus floridulus*	China	[1388]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
	(stream)		
Kostermansinda minima	Decaying bark (river)	Argentina	[1384]
Lambdasporium viridense	Spume (river)	Malaysia	[1505]
Lateriramulosa quadriradiata	Foam (stream), stemflow and throughfall of tree canopies	Canada, India	[636, 1148]
Lateriramulosa uniinflata	Foam (stream, river, rivulet), sediment (dam, river), stemflow and throughfall of tree canopies, water (stream)	Austria, Canada, France, India, Ireland, Japan, Malaysia, USA	[588, 631, 632, 636, 639, 718, 731, 828, 847]
Linkosia aquatica	Submerged decaying twig (stream)	Brazil	[1526]
Listeromyces insignis	Submerged decaying wood (stream)	China	[583]
Magdalaenaea monogramma	Foam (stream)	Canada	[588]
Megaloseptoria mirabilis	Submerged decaying wood (stream)	Brunei	[583]
Melanocephala australiensis	Submerged decayingwood (river, stream)	Brazil. China, USA	[582, 583, 683]
Melanocephala triseptata	Submerged decaying wood	USA	[1157]
Mirandina corticola	Rainwater from building roofs, submerged decaying woods (river), water-filled treeholes	Brazil, Hungary, Poland	[633, 638, 683]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Mirandina taiwanensis	Submerged decaying wood	China	[1520]
Mirandina uncinata	Submerged decaying leaves of *Calophyllum brasiliense*	Brazil	[1527]
Neopodoconis ampullacea	Submerged decaying wood (river, stream)	Brunei, Philippines	[432, 583]
Neta angliae	Submerged decaying wood (river)	UK	[688]
Neta lignicola	Submerged decaying wood (river)	USA	[524]
Neta mexicana	Submerged decaying leaves (stream)	Mexico	[1433]
Neta patuxentica	Submerged balsa wood (river), rainwater from building roofs	Poland, USA	[582, 633]
Neta salmonicolor	Submerged decaying balsa wood (river)	USA	[524]
Nidulispora quadrifida	Submerged decaying wood (river)	Brazil, Malaysia	[660, 1140, 1528]
Obeliospora basispira	Submerged decaying twigs (stream)	Malaysia	[1529]
Obeliospora microappendiculata	Submerged decaying twigs (river, stream)	**Brazil**	[1530]
Obeliospora nitida	Submerged decaying angiospermous twigs (stream)	Malaysia	[1319, 1530]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Obeliospora triappendiculata	Submerged decaying wood, foam (stream)	Brazil, Malaysia	[1392]
Obstipispora chewaclensis	Submerged decaying leaves of *Populus deltoides* (stream)	USA	[1531]
Ordus tribrachiatus	Rainwater from building roofs	Poland	[633]
Pachycladina hispanica	Foam (stream)	Spain	[1525]
Pachycladina mutabilis	Foam (stream)	Czech Republic	[1532]
Pachycladina parva	Foam (stream)	Canada	[1182]
Paraceratocladium malaysianum	Submerged decaying wood (river)	Malaysia	[660, 1533]
Paracryptophiale kamaruddinii	Submerged decaying twigs (stream)	Malaysia	[1534]
Paraulocladium fabisporum	Submerged decaying angiospermous wood	Malaysia	[1392]
Phaeomonilia aquatica	Submerged decaying wood (stream)	China	[1535]
Phaeomonilia pleiomorpha	Submerged decaying palm petioles (stream)	Mexico	[1307]
Phaeotrichoconis aquatica	Decaying branch (river)	Argentina	[1384]
Phaeotrichoconis minigelatinosa	Decaying branch (river)	Argentina	[1384]
Pleuropedium macrum	Foam (stream)	Canada	[1182]
Pleuropedium multiseptatum	Submerged decaying *Juncus effusus* (stream)	UK	[1124]
Pleuropedium tricladioides	Submerged rotten culms of *Juncus effusus*, foam (stream,	Austria, Canada,	[588, 631, 639,

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
	rivulet), water (stream)	UK, USA	1536]
Polycladium equiseti	Submerged dead inter-nodes of *Equisetum fluviatile*	UK	[1537]
Porocladium aquaticum	Foam (river)	UK	[671]
Pseudoanguillospora gracilis	Submerged decaying leaves of *Platanus occidentalis* (stream), foam (stream)	USA	[640]
Pseudoanguillospora prolifera	Submerged decaying leaves of Poaceae and culms of *Juncus effusus*	USA	[1538]
Pseudoanguillospora stricta	Submerged decaying leaves of Poaceae and culms of *Juncus effusus*	USA	[1538]
Pseudoclathrosphaerina evamariae	Submerged decaying wood (stream) and leaves (creek, water-filled channel, lake)	Thailand, USA	[858, 1539]
Pseudoclathrosphaerina spiralis	Submerged decaying wood (stream)	Thailand	[858]
Pseudofuscophialis lignicola	Submerged decaying wood (stream)	China	[775]
Pseudotracylla dentata	Submerged decaying wood and leaves (stream)	Brazil	[683]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Pyramidospora casuarinae	Submerged decaying leaves of *Calophyllum Brasiliense* and branches of *Casuarina*, foam (stream),	Brazil, Cuba, India, USA, Venezuela	[637, 739, 827, 1167, 1495]
Pyramidospora constricta	Submerged decaying leaves of *Dicotyledonae* (stream), foam (stream)	India, Sierra Leone	[827, 1540]
Pyramidospora densa	Submerged decaying leaves (stream) and wood (river)	Nigeria	[720]
Pyramidospora fluminea	Submerged decaying leaves (stream) and wood (river)	Japan, Malaysia	[1541]
Pyramidospora herculiformis	Submerged decaying leaves	Sierra Leona	[1542]
Pyramidospora quadricellularis	Submerged decaying leaves (stream)	Brazil	[1543]
Pyramidospora ramificata	Submerged decaying leaves (stream)	Japan	[1541]
Pyramidospora robusta	Submerged decaying leaves of *Caesalpinia echinata* and *Campomanesia phaea* (lake)	Brazil	[1485]
Pyramidospora stellata	Submerged decaying leaves of *Acer saccharinum*, *Quercus alba*, and *Salix* sp.	USA	[640]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Quadracaea staurocondia	Submerged decaying wood (stream)	Brazil	[683]
Quadricladium aquaticum	Submerged deciduous bark (stream)	Malaysia	[1544]
Ramicephala sphaerospora	Submerged decaying wood (river)	Cuba	[839]
Satchmopsis brasiliensis	Submerged decaying leaves (stream)	Brazil	[683]
Scutisporus brunneus	Foam (river, stream), submerged decaying petioles (stream), submerged decaying wood (e.g., *Dipterocarpus alatus* and *Xylia dolabriformis* test blocks), submerged leaves of *Calophyllum brasiliense* (stream)	Brazil, Malaysia, Thailand, Venezuela	[70, 519, 683, 723, 890, 1495]
Septotrullula bacilligera	Submerged decaying wood (river)	UK	[688]
Sirothecium triseriale	Submerged decaying bamboo culms	China	[1545]
Solheimia costispora	Decaying *Licuala longicalycata* (peat swamp)	Thailand	[585]
Sphaerulomyces coralloides	Parasitic on conidia of *Anguillospora crassa* from foam (brook)	Slovakia	[1546]
Spiropes caaguazuensis	Submerged decaying wood (river)	Philippines	[432]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Spirosphaera beverwijkiana	Submerged decaying leaves of *Quercus pedunculata, Quercus* sp., *Q. coccinea, Fagus sylvatica, Betula verrucosa, Populus tremula* (lake, stagnant water)	Belgium, Ireland, Netherlands	[719, 1547]
Spirosphaera carici-graminis	Submerged decaying leaves and culms of *Calamagrostis epigejos, Juncus effusus* and *Carex brizides* (puddle)s, Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Austria, Brazil	[695, 1548]
Spirosphaera dimorpha	Foam (stream)	Canada	[1549]
Spirosphaera floriformis	Submerged decaying *Betula* leaves, submerged decaying wood (river)	Netherlands, Malaysia	[583, 1122]
Spirosphaera lignicola	Submerged decaying twigs (stream)	Italy	[1550]
Spirosphaera minuta	Submerged decaying leaves of *Betula alba, B. verrucosa, Fagus sylvatica, Populus termula,* and *Corylus avellana, Quercus pedunculata, Quercus* sp.	Belgium, Netherlands	[1547]
Spirosphaera verruculosa	Submerged decaying leaves (pond)	Japan	[1551]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Spondylocladiopsis cupulicola	Water-filled treeholes	Hungary	[638]
Subulispora biappendiculata	Submerged decaying leaves (stream)	Malaysia	[1552]
Subulispora longirostrata	Submerged decaying angiospermous leaves and petiole (stream)	Brazil, Malaysia	[683, 1553]
Subulispora malaysiana	Submerged decaying leaves (stream), foam (stream)	Malaysia	[890, 1554]
Subulispora procurvata	Submerged decaying petioles, foam (stream), Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, India	[683, 695, 722]
Stenocladiella neglecta	Foam (stream, rivulet), submerged decaying leaves of *Alnus glutinosa*, *Alnus* sp. (stream), water (stream)	Austria, France, Slovakia, Spain	[628, 630, 631, 783, 828, 1117, 1118]
Sympodiella goidanichii	Water-filled treeholes	Hungary	[638]
Sympodiocladium frondosum	Foam (stream)	Canada, UK	[1118, 1148]
Synnematophora constricta	Sediment (stream), submerged decaying leaves of *Mangifera indica* (river), stemflow and throughfall of tree canopies	India	[636, 718, 1555]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Synchaetomella aquatica	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[1556]
Tetrabrachium elegans	Submerged decaying leaves (stream), submerged decaying angiosperm submerged (stream)	Canada, Malaysia	[729, 1557]
Tetranacrium gramineum	Submerged decaying wood (river)	USA	[582]
Tetrabrunneospora ellisii	Foam (stream), submerged decaying *Betula* leaves (brook)	Canada, USA	[1098, 1148]
Titaea callispora	Foam (stream)	Malaysia	[577]
Titaea clarkeae	Rainwater from building roofs, stemflow and throughfall of tree canopies	India, Poland	[633, 636]
Triramulispora gracilis	Foam (rivulet)	Austria	[631]
Triramulispora obclavata	Foam (rivulet)	Austria	[631]
Triscelosporium verrucosum	Foam (stream), submerged decaying angiospermic leaves (stream)	Malaysia	[890, 1558]
Tricellula aquatica	Submerged leaves of *Alnus glutinosa, Castanea sativa, Hedera helix* (river), foam (stream), rainwater from building roofs	Austria, Poland, UK	[628, 633, 1118, 1559]
Tricellula inaequalis	Rainwater from building roofs	Poland	[633]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Tricellula ornata	Foam (stream)	Czech Republic	[1171]
Tricladiopsis flagelliformis	Foam (stream), submerged decaying leaves of *Quercus* (river)	Portugal, UK	[1118, 1160]
Tricladiopsis foliosa	Foam (stream)	UK	[1118]
Tricladiospora longissima	Submerged decaying angiospermic leaves (stream)	Malaysia	[1560]
Tricladiospora stricta	Submerged decaying angiospermic leaves (stream)	Malaysia	[1560]
Trifurcospora irregularis	Foam (stream), stemflow and throughfall	Canada, India	[727, 1148]
Triglyphium alabamense	Foam (stream)	Canada	[1148]
Triscelophorus acuminatus	Foam (stream, river), submerged leaves of *Cinnamomum zeylanicum*, *Coffea arabica*, and *Hevea brasiliensis*, unindentified leaves (stream, lake), sediment (dam, stream), stemflow and throughfall of tree canopies and palm species. Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Austria, Brazil, Canada, India, Ireland, **Italy**, Malaysia, **Portugal**, **Spain**, Thailand, Venezuela	[500, 519, 729, 732, 881, 890, 1066, 1118, 1186, 1485, 577, 628, 632, 636, 695, 718, 722, 727]
Triscelophorus curviramifer	Foam/water (stream)	Brazil, Venezuela	[1169] [519]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Triscelophorus konajensis	Submerged rotten leaves of *Ficus benghalensis*, sediment (dam, stream), stemflow and throughfall of tree canopies and palm species, foam (stream), water (stream)	India, USA	[636, 639, 718, 727, 827, 1561]
Triscelophorus magnificus	Submerged leaves (stream), foam (stream)	Canada, USA	[65, 588]
Triscelophorus monosporus	Submerged decaying leaves (river), submerged leaves of *Coffea arabica*, and *Hevea*, water (river), foam, scum (stream, spring, river, lake), sediment (dam, stream), stemflow and throughfall of tree canopies, submerged leaves of *Calophyllum brasiliense* (stream), water (stream)	**Australia**, Brazil, Canada, Cuba, France, Ghana, India, Ireland, Jamaica, Malaysia, Nigeria, Poland, Portugal, UK, USA, Venezuela	[63, 65, 687, 713, 716, 718, 720, 721, 732, 734, 739, 828, 67, 888, 1066, 1426, 1495, 1562, 519, 577, 588, 632, 636, 637, 639]
Triscelophorus ponapensis	Submerged decaying leaves of *Pandanus*	Micronesia, Thailand	[500, 1563]
Triscelophorus septatus	Submerged decaying leaves	USA	[741]

Table 7.11 (continued)

Taxon	Substrate	Country	Reference
Trisulcosporium acerinum	Stemflow and throughfall of tree canopies, foam (river, stream)	Brazil, India, Japan, Malaysia	[636, 723, 731, 847]
Uberispora heteroseptata	Submerged decaying wood (river)	Malaysia	[583, 660]
Umbellidion radulans	Submerged decaying leaves (stream)	Brazil	[683]
Vanbeverwijkia spirospora	Submerged decaying wood (river)	USA	[582]
Veramyces manuensis	Rainwater from building roofs	Poland	[633]
Verticicladus subiculifer	Submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil	[1140, 1556]
Virgariella atra	Submerged decaying wood (stream)	Brazil, Brunei	[583, 683]
Virgariella globigera	Submerged decaying wood (stream)	Brazil	[683]
Xiuguozhangia appendiculata	Submerged decaying wood	Thailand	[500]
Xylohyphopsis aquatica	Submerged decaying wood (stream)	China	[1564]
Yinmingella mitriformis	Submerged decaying wood (river)	China	[1565]
Zelotetraploa aquatica	Submerged decaying wood (river)	Brazil	[1213]

7.3.2 Classification of Freshwater Basidiomycota

When compared to Ascomycota, few Basidiomycota have been recorded from freshwater habitat. Jones and Choeyklin [1566] and Jones, Southworth, et al. [1567] listed freshwater Basidiomycota with 29 and 115 species, respectively. Asexual morphs, with elaborate conidial forms, are mainly reported and they are taxonomically diverse including both yeasts and filamentous fungi. A special section on freshwater yeast discusses both ascomycetous and basidiomycetous yeasts. Freshwater Basidiomycota have been isolated from variety of substrates: submerged decaying wood [447, 858, 1336, 1568–1572], leaf litter [1573–1581], foam [1582–1584], and water [650, 1585–1593]. Most of the taxa of freshwater Basidiomycota in Table 7.12 were observed from plant substates. Fungi from foam records 19 species, eight (*Leptosporomyces crucelliger, Taeniospora nasifera, Fibulotaeniella canadensis, Nodulospora inconstans, Helicogloea angustispora, Anguillomyces acadiensis, A. acadiensis, Arcispora bisagittaria*) of which were reported exclusively from foam. There are notions on fungi observed from foam as spores originating from the neighboring terrestrial environment and just trapped in air bubbles, however studies showed that the vast majority of these spores originated from aquatic habitats [17, 58]. Thus, they are no different from ascomycetous spores that are also recovered from foam samples. Foam serves as a natural trap for conidia and gives a fairly accurate indication of the fungal flora of stream or river. For instance, Nilsson [58] concluded that the foam and scum samples give us an overview of the species from the stream system in the sampling area. In many cases, the host substrate is determined in subsequent studies, e.g., *Mrakia aquatica* was initially isolated from foam samples [43], but later collected on *Equisetum* culms (Webster unpublished).

In this section, we update the list of Jones, Southworth, et al. [1567] with a total of 218 species (in 100 genera) (Tables 7.12 and 7.13). Eleven classes comprise freshwater Basidiomycota and distributed in 26 orders and 43 families.

Table 7.12 Classification of Freshwater Basidiomycota with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	Reference
AGARICOMYCOTINA			
AGARICOMYCETES			
Agaricales			
Agaricales genera *incertae sedis*			
Mycocalia denudata	Decaying *Eleiodoxa conferta* (peat swamp)	Thailand	[585]
Mycocalia reticulata	Submerged wood	Australia	[447]
Limnoperdaceae			
Limnoperdon incarnatum	Soaked hardwood twigs, marsh water	USA	[1594]
Limnoperdon sp.	Submerged wood and date palm rachis (river)	Egypt	[1251]
Niaceae			
Flagelloscypha sp.	Submerged decaying wood (stream)	Japan	[1569]
Peyronelina glomerulata	Submerged decaying *Cyperus* sp. culm, unidentified pod; twig, litter (pond, stream, waterfall)	China, Japan, Thailand	[858, 1336, 1569]
Physalacriaceae			
Gloiocephala aquatica	Decaying culms of *Scirpus californicus* (lakes, eutrophic ponds)	Argentina	[1595]

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Gloiocephala aquatica	Decaying culms of *Scirpus californicus* (lakes, eutrophic ponds)	Argentina	[1595]
Psathyrella aquatica	Submerged wood or sediment	USA	[1571]
Atheliales			
Atheliaceae			
Leptosporomyces crucelliger	Foam (stream)	UK	[1582]
Leptosporomyces galzinii	Foam, submerged decaying *Acer* leaves (stream), water	UK	[1596]
Taeniospora gracilis	Foam (river, rivulet, stream), submerged decaying leaves (stream), water (stream)	Austria, Canada, France, UK, USA	[588, 628, 631, 639, 729, 828, 1582]
Taeniospora gracilis var. *gracilis*	Foam (stream), submerged leaf litter of *Alnus glutinosa* (stream), water	Austria, France, UK	[628, 630, 1582]
Taeniospora nasifera	Foam (river)	Canada	[1583]
Cantharellales			
Ceratobasidiaceae			
Ceratobasidium sp.	Submerged plant root (lake)	Norway	[1572]

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Ceratorhiza sp.	Submerged wood and date palm rachis	Egypt	[1251]
Hydnaceae			
Ingoldiella fibulata	Foam (stream), submerged decaying leaves, throughfall of palm species	India, Malaysia	[577, 727, 1597]
Ingoldiella nutans	Mixed litter of *Pinus contorta* and *Sphagnum (*peat bog)	Canada	[1568]
Rogersiomyces okefenokeensis	Submerged decaying leaves of angiosperms and *Taxodium ascendens* (swamp)	USA	[1598]
Sistotrema hamatum	Submerged decaying petioles of *Hevea brasiliensis*; submerged unidentified leaves (river), submerged leaves (*Calophyllum brasiliense*, *Cinnamomum zeylanicum* and *Hevea brasiliensis*) (stream), sediment (stream), foam (river, stream)	Australia, Brazil, India, Malaysia, Thailand	[88, 683, 718, 827, 881, 890, 1186, 1426, 1599, 1600]
Agaricomycetes genera *incertae sedis*			
Akenomyces costatus	Roots of rotting *Triticum*, submerged leaves of *Cladium muhscus*	France, UK	[1601–1603]
Cruciger lignatilis	Rotting wood	Germany	[1604]

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Dendrosporomyces prolifer	Foam (river), submerged decaying leaves of *Calophyllum brasiliense* (stream)	Brazil, Malaysia	[88, 1605]
Dendrosporomyces splendens	Submerged water leaves (river)	Malaysia	[1606]
Fibulotaeniella canadensis	Foam (river)	Canada	[1583]
Titaeella capnophila	Rainwater on needles of *Pinus densiflora*; foam (stream), stemflow and throughfall of tree canopies	India, Japan, Portugal, Spain	[636, 921, 1160, 1515]
Tricladiomyces geniculatus	Immersed rotten angiospermic leaves (stream)	Malaysia	[1607]
Tricladiomyces malaysianus	Foam and scum (river), stemflow and throughfall of tree canopies	India, Malaysia	[578, 636, 1146]
BARTHELETIOMYCETES			
Polyporales			
Polyporales genera *incertae sedis*			
Bulbillomyces farinosus	Decaying bark of the fallen branch of *Alnus glutinosa*	Ukraine	[1570]
Sebacinales			
Sebacinaceae			

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Chaetospermum camelliae	Submerged decaying *Licuala longicalycata* (peat swamp), foam (river)	Thailand	[584, 881]
Chaetospermum chaetosporum	Foam and scum (stream), submerged decaying leaves	India, USA	[722, 730]
Chaetospermum indicum	Scum (river), submerged stems of *Fimbristylis quinquangularis* (river)	India	[1608]
Trechisporales			
Hydnodontaceae			
Subulicystidium longisporum	Wood (channel)	UK	[688, 1609]
TREMELLOMYCETES			
Tremellales			
Tremellales genera *incertae sedis*			
Xenolachne flagellifera	Hymenium of *Hyaloscypha atomaria* growing on the lower side of damp logs (*Libocedrus decurrens, Pinus Strobus, Pseudotsuga taxifolia*)	USA	[1610]
Agaricomycotina *incertae sedis*			

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Nodulospora inconstans	Foam (river)	Canada	[1611]
PUCCINIOMYCOTINA			
ATRACTIELLOMYCETES			
Atractiellales			
Phleogenaceae			
Helicogloea angustispora	Foam	-	[1584]
CLASSICULOMYCETES			
Classiculales			
Classiculaceae			
Classicula fluitans	*Scirpus microcarpus* leaf litter (bank of roadside drainage channel), foam (stream)	Canada, Germany	[1612, 1613]
Jaculispora submersa	Submerged rotten leaves (stream)	Jamaica	[721]
MICROBOTRYOMYCETES			
Kriegeriales			
Camptobasidiaceae			
Camptobasidium hydrophilum (*Crucella subtilis*)	Submerged decaying leaves (stream), water (stream)	France USA	[828, 1614]

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Microbotryales			
Microbotryales *incertae sedis*			
Reniforma strues	Biological film (waste-water treatment plant)	USA	[1615]
USTILAGINOMYCOTINA			
EXOBASIDIOMYCETES			
Doassansiales			
Doassansiaceae			
Burrillia narasimhanii	Leaves of *Caldesia reniformis* (pond)	India	[1577]
Pseudodermatosorus alismatis-oligococci	Leaves of *Caldesia oligococca*	Sri Lanka	[1578]
Rhamphosporaceae			
Rhamphospora nymphaeae	Leaves of *Nymphaea nouchali, N. lotus, N. rubra, Caldesia reniformis,* (pond)	India	[1573, 1581]
USTILAGINOMYCETES			
Urocystidales			
Doassansiopsidaceae			
Doassansiopsis caldesiae	Leaves of *Caldesia reniformis* in a marsh close to lakeshore	Cameroon	[1580]

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Doassansiopsis deformans	Leaves, petioles, peduncles, pedicels and ovaries of *Sagittaria variabilis*	USA	[1574]
Doassansiopsis euryales	Leaves, petioles and ovaries of *Euryale ferox*	India	[1579]
Doassansiopsis furva	Leaves of *Sagittaria rigida*	USA	[1616, 1617]
Doassansiopsis hydrophila	Leaves of *Potamogeton* spp.	Spain, USA, UK	[1575, 1576, 1618]
Doassansiopsis nymphaeae	Petioles of *Nymphaea stellata*	India	[1619]
Doassansiopsis nymphoides	Leaves of *Nymphoides rautaneni* (lake)	Zambia	[1620]
Doassansiopsis occulta	Ovaries of *Potamogeton natans*	Germany	[1574]
Doassansiopsis ticonis	Leaves of *Nymphaea blanda*	Costa Rica	[1621]
Doassansiopsis tomasii	Leaves of submerged *Nymphaea nouchali* var. *caerulea* in lake margins	Cameroon, Ethiopia, Uganda	[1580]
Basidiomycota genera *incertae sedis*			
Anguillomyces acadiensis	Foam (river)	Canada	[1611]
Arcispora bisagittaria	Foam (stream)	Canada	[1622]
Microstella pluvioriens	Rainwater from leaves of *Metasequoia glyptostroboides*	Japan	[1477]

Table 7.12 (continued)

Taxon	Substrate	Country	Reference
Stauriella aquatica	Submerged test blocks of *Dipterocarpus alatus* (stream)	Thailand	[1623]

7.3.3 Freshwater yeasts

Few freshwater yeasts are known when compared with the extensive number of hyphomycetes and ascomycetes documented in this study. This can be attributed to the lack of studies undertaken [1592, 1624]. Yeasts are eukaryotic microorganisms that belong to the Ascomycota and Basidiomycota and require different techniques to filamentous fungi for their study. Early studies in their identification required not only isolation and morphological observation but also chemical reactions such as utilization and fermentation of different substrates. The development of molecular techniques has revolutionized their study and enabled their higher order classification [1625], with extensive revisions of the classification of Basidiomycota yeasts by Liu, Wang, Göker, et al. [1626], Liu, Wang, Theelen, et al. [1627], Wang et al. [1628], Wang, Groenewald, et al. [1629], and Wang, Yurkov, et al. [1630]. Kurtzman and Fell [1631] estimated there were circa 1500 yeast species, but the figure is nearer to 2000 to 2200.

Freshwater yeasts have been recovered from a variety of environments: drinking water [1632], surface water [1633], bottled and tap water [1632], wastewater and polluted rivers [1634–1637], rivers [1585, 1638, 1639], trapped in foam [43], freshwater estuaries [1592, 1640], glacial melt water [1589, 1624, 1641], fish ponds [1642], artificial lakes [650], and natural lakes [1591, 1643–1645]. Yeasts have also been isolated from freshwater plants (*Mrakia aquatica* from *Equisetum* culms, *Vishniacozyma victoriae* from submerged roots), while a wide range of taxa occur in the water tanks of bromeliads: *Bromelia karatas*, *Encholirium* sp., *Paepalanthus bromelioides* and *Vriesea minarum* [1646]. Others occur on the surfaces of surface and mouth cavity of two Chelonian (turtles) species, *Podocnemis expansa* and *P. unifilis* [1647].

Yeast distribution in lakes has yielded a wide range of taxa [1645] as well as those found in the freshwater zone of the Everglades [1592]. Many of these studies yielded novel species: *Candida aquatica* (current name = *Mrakia aquatica*), *Cryptococcus agrionensis*, *Sporobolomyces patagonicus*, *Rhodotorula himalayensis* (= *Phenoliferia himalayensis*) and *Rhodotorula meli* (= *Sakaguchia meli*). With recent revisions of the basidiomycetous yeasts, many of the early names are now obsolete and, in this paper, we refer to the currently accepted names. Many taxa listed in Table

7.13 were only isolated once in the various studies, for example, the 317 isolates made by Medeiros et al. [1593] from lakes and rivers in Brazil, yielded 21 genera and 48 species but few were isolated from each of the 18 sites. The most numerous genera are *Candida* (31 species) and *Rhodotorula* (9 species), and with fewer species *Papiliotrema* (6) and *Naganishia* (5). Common species included *Cryptococcus luteolous* (= *Hannaella luteola*) and *Rhodotorula glutinis* in the dry season, while *Aureobasidium pullulans* was common in the rainy season. Brandão et al. [1591] noted that *Candia krusei* (= *Teunomyces kruisii*), and *C. guilliermondii* (= *Meyerozyma guilliermondii*) were the most common in three freshwater lakes in Brazil. These are faecal coliforms, probably present in the water samples as the result of contamination by warm-blooded animals [1644]. Other taxa occurred only once and can be regarded as rare.

While most are regular taxa in freshwater environments: *Mrakia aquatica, M. frigida, Kluyveromyces aestuarii*, others have been described also from mangrove habitats (*Kwoniella mangrovensis*) [1648], or from glacial melt water, e.g. *Cryptococcus agrionensis* (= *Goffeauzyma agrionensis*), *Cystofilobasidium lacus-mascardii*, and *Sakaguchia meli* [1587, 1624]. Yeasts such as *Candida albicans, Candida parapsilosis, Candida krusei* (= *Teunomyces kruisii*), *Candida guilliermondii* (= *Meyerozyma guilliermondii*), *Candida glabrata* and *Candida tropicalis*, are opportunistic pathogens often associated with human activity. Fell et al. [1592], however, did not encounter serious human pathogens (such as in water *Candida tropicalis*) in samples from the freshwater zone of the Everglades. A number of factors determine the occurrence of yeasts in freshwater habitats: temperature, exposure/tolerance to UV light, and nutrient availability. Libkind et al. [1649] concluded that in Patagonian freshwater yeasts, there had an apparent relationship between the ability to produce PPCs (photoprotective compounds), their tolerance to UV radiation (UVR) exposure and their success in colonizing habitats highly exposed to UVR. Brandão et al. [1591] opined those yeasts isolated from an oligotrophic lake in Patagonia (Argentina) are metabolically active and could contribute to organic matter recycling even under these harsh conditions. Some 325 yeasts (162 Basidiomycota, 163 Ascomycota) species are listed in Table 13, but this figure is

undoubtedly an underestimate. These yeast taxa are not recorded in the previous taxonomic groups above and we separately listed.

Table 7.13 Classification of Freshwater Yeasts with Information on the Type of Habitats, Substrates, and Geographical Distribution of Fungal Taxa

Taxon	Substrate	Country	References
ASCOMYCOTA			
DOTHIDEOMYCETES			
Dothideomycetidae			
Dothideomycetes *incertae sedis*			
Endosporiaceae			
Endosporium aviarium	Phytotelmata of bromeliad tanks, rock holes	**Brazil**	[1646]
EUROTIOMYCETES			
Chaetothyriomycetidae			
Chaetothyriales			
Herpotrichiellaceae			
Exophiala alcalophila	Phytotelmata of bromeliad tank, tap water	**Brazil**	[648, 1646]
Exophiala placitae	Phytotelmata of bromeliad tank	**Brazil**	[1646]
Nadsoniella nigra	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
LEOTIOMYCETES			

Table 7.13 (continued)

Taxon	Substrate	Country	References
Leotiomycetidae			
Helotiales			
Sclerotiniaceae			
Monilia zeylanica	Freshwater everglades	USA	[1592]
SACCHAROMYCETES			
Saccharomycetidae			
Saccharomycetales			
Debaryomycetaceae			
Babjeviella inositovora	Surfaces of freshwater turtles *Podocnemis unifilis*	**Brazil**	[1646, 1647]
Debaryomyces delbrueckii	Phytotelmata of bromeliad tanks, water (pond)	**Brazil**, Slovakia	[649, 1646]
Debaryomyces hansenii	Surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*, water (lake, pond), tapwater, glacial meltwater (river)	**Argentina,** Bangladesh, **Brazil**, Poland, Slovakia	[1587, 1645, 1647, 1650, 1651]
Debaryomyces maramus	Water (lake)	Poland	[1645]
Debaryomyces nepalensis	Freshwater mud	**Egypt**	[1652]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Debaryomyces occidentalis var. occidentalis	Surfaces of freshwater turtles, *P. unifilis*	**Brazil**	[1647]
Lodderomyces elongisporus	Water (lake)	Poland	[1645]
Meyerozyma caribbica	Phytotelmata of bromeliad tanks, tapwater, mud (river canal), water (lake)	**Brazil, Slovenia, Egypt**	[648, 1644, 1646, 1652]
Meyerozyma carpophila	Freshwater Everglades	USA	[1592]
Meyerozyma guilliermondii	Water (lake, pond, rivers), phytotelmata of bromeliad tanks, surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, tapwater, mud (river canal)	**Brazil**, Egypt, **Poland**, Slovakia, **Slovenia**, South Africa, USA	[648–650, 1585, 1593, 1644–1646, 1652–1654]
Millerozyma farinosa	Water (lake)	Poland	[1645]
Priceomyces carsonii	Water (lake)	Poland	[1645]
Scheffersomyces coipomensis	Water (lake)	**Argentina**	[1589]
Scheffersomyces segobiensis	Water (lake)	Poland	[1645]
Schwanniomyces occidentalis	Water (lake)	Poland	[1645]
Schwanniomyces polymorphus	Water (lake)	Poland	[1645]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Schwanniomyces pseudopolymorphus	Water (lake)	Poland	[1645]
Schwanniomyces vanrijiae	Freshwater Everglades, surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*	**Brazil**, USA	[1592, 1647]
Suhomyces xylopsoci	Water (lake)	**Brazil**	[1644]
Yamadazyma akitaensis	Water (lake)	Poland	[1645]
Yamadazyma tenuis	Surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*	**Brazil**	[1647]
Dipodascaceae			
Dipodascus armillariae	Water (lake)	Poland	[1645]
Dipodascus fermentans	Polluted water (river)	USA	[1635]
Dipodascus geotrichum	River water, freshwater mud (river canal), water (lake, pond), tapwater	Brazil, **Egypt**, Slovakia, **Slovenia**, USA	[648, 650, 690, 1593, 1650, 1652]
Geotrichum europaeum	Mud (river canal)	**Egypt**	[1652]
Magnusiomyces capitatus	Water (lake)	Poland	[1645]
Saprochaete capitata	Polluted water (river)	USA	[1635]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Saprochaete sericea	Polluted water (river)	USA	[1635]
Lipomycetaceae			
Lipomyces lipofer	Water (lake)	Poland	[1645]
Metschnikowiaceae			
Clavispora lusitaniae	Water (lake, river), tapwater	**South Africa, Slovenia**	[648, 1653]
Kodamaea ohmeri	Water (lake)	Brazil	[1654]
Metschnikowia pulcherrima	Water (lake)	Poland, Slovakia, USA	[650, 1585, 1645]
Metschnikowia reukaufii	Water (lake, river)	Poland, Brazil	[1593, 1645]
Phaffomycetaceae			
Barnettozyma wickerhamii	Surfaces of freshwater turtles *Podocnemis expansa*	**Brazil**	[1647]
Cyberlindnera fabianii	Water (lake)	**Brazil**	[1644]
Cyberlindnera jadinii	Water (lake), freshwater mud, polluted water (lake)	**Egypt**, Poland, USA	[1635, 1645, 1652]
Cyberlindnera japonica	Water (lake)	**Brazil**	[1644]
Cyberlindnera rhodanensis	Water (lake)	**Brazil**	[1644]
Cyberlindnera saturnus	Polluted water (river), water, sediment (lake)	**Colombia**, USA	[1635, 1655]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Starmera stellimalicola	Water (lake)	**Brazil**	[1644]
Pichiaceae			
Brettanomyces nanus	Water (lake)	Poland	[1645]
Dekkera bruxellensis	Water (lake), polluted water (river)	**Brazil**, Poland, USA	[1635, 1644, 1645]
Komagataella pastoris	Surfaces of freshwater turtles	**Brazil**	[1647]
Kregervanrija fluxuum	Freshwater Everglades	USA	[1592]
Ogataea polymorpha	Polluted water (river)	USA	[1635]
Pichia fermentans	Water (lake, pond), tapwater	**Brazil**, Slovakia, **Slovenia**	[648, 650, 1644, 1650]
Pichia galeiformis	Water (lake)	**Brazil**	[1644]
Pichia kluyveri	Freshwater Everglades	USA	[1592]
Pichia mandshurica	Water (lake)	**Brazil**	[1644]
Pichia membranifaciens	Water (lake), Surfaces of freshwater turtles *Podocnemis unifilis*	**Brazil**, Poland	[1645, 1647]
Saturnispora diversa	Water, sediment (lake)	**Colombia**	[1655]
Saturnispora silvae	Water (lake, wetland)	Poland, USA	[1592, 1645]
Saccharomycetaceae			
Citeromyces matritensis	Water (lake, river)	South Africa, Poland	[1645, 1653]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Cyniclomyces guttulatus	Water (lake)	Poland	[1645]
Grigorovia transvaalensis	Water (lake)	Poland	[1645]
Hagleromyces aurorensis	Phytotelmata of bromeliad tank	**Brazil**	[1646, 1656]
Issatchenkia orientalis	Tropical freshwater, water (lake, pond), mud (river canal), wetland	**Brazil**, **Egypt**, **Poland**, Slovakia, USA	[650, 1592, 1593, 1644, 1645, 1650, 1652]
Issatchenkia scutulata	Water (river)	Brazil	[1593]
Kazachstania africana	Water (lake)	Poland	[1645]
Kazachstania exigua	Water (lake), polluted water (river)	Poland, USA	[1645]
Kazachstania lodderae	Water (lake)	Poland	[1645]
Kluyveromyces aestuarii	Water (lake, wetland)	Poland, USA	[1592, 1645]
Kluyveromyces lactis	Water (lake)	Poland**,** Slovakia	[650, 1645]
Kluyveromyces marxianus	Water (lake, river)	**Brazil**, Poland,	[1593]
Kluyveromyces wickerhamii	Water (lake), surfaces of freshwater turtles *Podocnemis unifilis*	**Brazil**, Poland	[1645, 1647]
Lachancea cidri	Water (lake)	Poland	[1645]
Lachancea kluyveri	Water (lake)	Slovakia	[650]
Lachancea meyersii	Water (wetland)	USA	[1592]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Lachancea thermotolerans	Water (lake)	Poland	[1645]
Lachancea waltii	Water (lake)	Poland	[1645]
Nakaseomyces bacillisporus	Water (lake)	Poland	[1645]
Naumovozyma castellii	Water (lake)	Bangladesh, Poland	[1645]
Saccharomyces cerevisiae	Water (lake), polluted water (river), mud (river canal), sediment (lake)	**Colombia**, **Egypt**, **Poland,** USA	[1635, 1645, 1651, 1652, 1655]
Tetrapisispora phaffii	Water (lake)	Poland	[1645]
Torulaspora delbrueckii	Water, sediment (lake)	**Colombia**, Poland	[1645, 1655]
Torulaspora globosa	Water (pond)	Slovakia	[1650]
Torulaspora pretoriensis	Freshwater muds, water, sediment (lake)	**Colombia**, **Egypt**	[1652, 1655]
Vanderwaltozyma polyspora	Water (lake)	Poland	[1645]
Vanderwaltozyma yarrowii	Water (lake)	Poland	[1645]
Zygosaccharomyces bailii	Water (lake)	Poland	[1645]
Zygosaccharomyces mellis	Water (lake)	Poland	[1645]
Zygosaccharomyces rouxii	Water (lake)	Poland	[1645]
Saccharomycodaceae			

Table 7.13 (continued)

Taxon	Substrate	Country	References
Hanseniaspora guilliermondii	Water (lake, river)	**Brazil,** Slovakia	[650, 1593]
Hanseniaspora opuntiae	Phytotelmata of bromeliad tank, water (lake)	**Argentina**, **Brazil**	[1589, 1646]
Hanseniaspora osmophila	Water (lake)	Poland	[1645]
Hanseniaspora uvarum	Freshwater Everglades, polluted water (river), water (lake, pond), sediment (lake)	**Colombia**, Poland, Slovakia, **USA**	[649, 650, 1592, 1635, 1645, 1655]
Hanseniaspora vineae	Water (lake)	Poland	[1645]
Saccharomycodes ludwigii	Water (lake)	Poland	[1645]
Saccharomycopsidaceae	Water (lake)		
Saccharomycopsis capsularis	Water (lake)	Poland	[1645]
Saccharomycopsis crataegensis	Water (river)	**Brazil**	[1593]
Saccharomycopsis fermentans	Water (lake)	Poland	[1645]
Saccharomycopsis fibuligera	Water (lake)	Slovakia	[650]
Saccharomycopsis javanensis	Water (lake)	Poland	[1645]
Trichomonascaceae			
Sugiyamaella smithiae	Water (lake)	Poland	[1645]
Trichomonascus ciferrii	Water (lake), polluted water (river)	**Brazil, Poland, USA**, Slovakia	[650, 1635, 1654]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Trichomonascus farinosus	Water (lake)	Poland	[1645]
Wickerhamiella pararugosa	Water (river), tapwater	**Brazil, Slovenia**	[648, 1593]
Zygoascus tannicola	Surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*	**Brazil**	[1647]
Wickerhamomycetaceae			
Wickerhamomyces anomalus	Tropical freshwater, surfaces of freshwater turtles, water (lake, pond), mud (river canal)	**Brazil, Egypt**, **Poland**, Slovakia	[650, 1645, 1647, 1650, 1652]
Wickerhamomyces bisporus	Water (lake)	Poland	[1645]
Wickerhamomyces bovis	Water (lake)	Poland	[1645]
Wickerhamomyces canadensis	Polluted water (river)	USA	[1635]
Wickerhamomyces hampshirensis	Freshwater everglades	USA	[1592]
Wickerhamomyces pijperi	Water (river)	**Brazil**	[1593]
Wickerhamomyces patagonicus	Glacial meltwater (river)	**Argentina**	[651]
Wickerhamomyces rabaulensis	Water (lake)		
Wickerhamomyces subpelliculosus	Polluted water (lake, river)	USA	[1635]
Wickerhamomyces sydowiorum	Surfaces of freshwater turtles *Podocnemis*	**Brazil**, USA	[1592, 1647]

Table 7.13 (continued)

Taxon	Substrate	Country	References
	expansa, P. unifilis, water (wetland)		
Saccharomycetales genera *incertae sedis*			
Candida albicans	Phytotelmata of bromeliad tanks, polluted water (lake, river), sediment (lake)	**Brazil**, **Colombia**, **Egypt**, **Poland**, USA	[1635, 1644–1646, 1652, 1655]
Candida amphicis	Freshwater Everglades	USA	[1592]
Candida asiatica	Freshwater Everglades	USA	[1592]
Candida atlantica	Water (lake)	**Brazil**	[1644]
Candida atmosphaerica	Polluted water (river)	USA	[1635]
Candida blankii	Water (river)	Brazil	[1593]
Candida boidinii	Surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*, water (pond)	**Brazil**, Slovakia	[1647, 1650]
Candida buenavistaensis	Phytotelmata of bromeliad tanks, rock holes	**Brazil**	[1646]
Candida dendronema	Freshwater Everglades	USA	[1592]
Candida diffluens	Polluted water (river)	USA	[1635]
Candida duobushaemulonis	Phytotelmata of bromeliad tanks, rock holes	**Brazil**	[1646]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Candida ethanolica	Water (lake, river)	Brazil	[1593]
Candida fluviatilis	Aquatic system, glacial water	Argentina	[1624]
Candida glabrata	Phytotelmata of bromeliad tanks, rock holes, polluted water (lake, river), sediment (lake)	**Brazil**, Colombia, **Poland**, USA	[1635, 1644–1646, 1655]
Candida heveicola	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Candida inconspicua	Water (lake, pond), polluted water (river)	**Brazil**, Slovakia, USA	[1644, 1650]
Candida intermedia	Water (lake, pond), Phytotelmata of bromeliad tanks, rock holes, polluted water (river)	**Brazil**, **Poland**, Slovakia, **USA**	[649, 1635, 1645, 1646]
Candida leandrae	Phytotelmata of bromeliad tanks, rock holes	**Brazil**	[1646]
Candida maris	Surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, wetland	**Brazil**, USA	[1592, 1647]
Candida maritima	Glacial meltwater (river)	**Argentina**	[651]
Candida melibiosica	Surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, water (lake, river, wetland)	**Brazil**, Poland, USA	[1592, 1593, 1645]
Candida mesenterica	Polluted water (river), Glacial meltwater (river)	USA**, Argentina**	[1635] [651]
Candida nivariensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Candida oregonensis	Polluted water (river)	USA	[1635]
Candida orthopsilosis	Phytotelmata of bromeliad tanks, rock holes, tapwater	**Brazil, Slovenia**	[1646]
Candida palmioleophila	Surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, water (river)	**Brazil**	[648, 1593, 1646]
Candida parapsilosis	Tropical freshwater, phytotelmata of bromeliad tanks, rock holes, surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, polluted water (lake, river), groundwater, tapwater	**Brazil**, **Slovenia,** USA	[1593, 1635, 1644, 1646, 1647]
Candida pseudointermedia	Phytotelmata of bromeliad tanks, rock holes, tapwater	**Brazil, Slovenia**	[648, 1646]
Candida pseudolambica	Aquatic system, glacial melt water, mud (river canal), water (lake, wetland), sediment (lake)	**Argentina**, **Colombia**, Egypt, USA	[1592, 1624, 1652, 1655]
Candida pinus	Polluted water (lake, river)	USA	[1635]
Candida saitoana	Water (lake), tapwater	**Poland, Slovenia**	[648, 1645]
Candida sake	Acidic water (river)ater (lake), glacial melt water, surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*	**Argentina**, **Brazil**	[1588, 1624, 1645, 1647, 1653]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Candida santamariae	Glacial meltwater (river)	**Italy**	[1590]
Candida sharkensis	Water (wetland)	**USA**	[1592]
Candida silvanorum	Water (wetland)	USA	[1592]
Candida silvicultrix	Surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*	**Brazil**	[1647]
Candida solani	Water (lake), polluted water (river)	Poland, USA	[1635, 1645]
Candida sonorensis	Water (lake)	**Brazil**	[1644]
Candida suecica	Polluted water (river)	Bangladesh, USA	[1635, 1651]
Candida tropicalis	Tropical freshwater, water (lake, pond), mud (river canal)	**Brazil**, **Egypt**, **Poland**, Slovakia, South Africa	[650, 1644, 1645, 1650, 1652, 1653]
Candida ubatubensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Candida zeylanoides	Water (lake)	Poland	[1645]
Diutina catenulata	Water (lake. river), polluted water (river)	South Africa, Poland, USA	[1635, 1645]
Diutina rugosa	Tropical freshwater, water (river), polluted water (river)	Brazil, South Africa, USA	[1593, 1635, 1653]
Hyphopichia burtonii	Water (lake, pond)	**Brazil**, Slovakia	[649, 650, 1644]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Middelhovenomyces tepae	Surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*	**Brazil**	[1647]
Nakazawaea holstii	Polluted water (river)	USA	[1635]
Nakazawaea ernobii	Polluted water (river)	USA	[1635]
Yarrowia galli	Surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*	**Brazil**	[1647]
Yarrowia lipolytica	Water (lake), tapwater	**Colombia**, Poland, Slovenia	[1645, 1655]
BASIDIOMYCOTA			
AGARICOSTILBOMYCETES			
Agaricostilbomycetes *incertae sedis*			
Agaricostilbales			
Agaricostilbaceae			
Sterigmatomyces elviae	Surfaces of freshwater turtles *Podocnemis expansa*	**Brazil**	[1647]
MONILIELLOMYCETES			
Moniliellomycetes *incertae sedis*			
Moniliellales			
Moniliellaceae			

Table 7.13 (continued)

Taxon	Substrate	Country	References
Moniliella spathulata	Water (lake)	**Water (lake)**	[1645]
CYSTOBASIDIOMYCETES			
Cystobasidiomycetes *incertae sedis*			
Cystobasidiales			
Cystobasidiaceae			
Cystobasidium calyptogenae	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Cystobasidium minutum	Freshwater Everglades, polluted water (lake, river), water (lake, pond)	**Argentina**, Slovakia, **USA**	[650, 1589, 1592, 1635, 1650]
Cystobasidium laryngis	Glacial melt water (river), water (lake)	**Argentina**	[1587, 1589]
Cystobasidium pinicola	Water (lake)	**Argentina, Brazil**	[1591, 1641]
Cystobasidium slooffiae	Tapwater, water (lake, wetland)	**Argentina, Brazil, Slovenia**, USA	[648, 1591, 1592, 1641]
Occultifur brasiliensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Occultifur externus	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Erythrobasidiales			
Erythrobasidiaceae			
Erythrobasidium elongatum	Phytotelmata of bromeliad	**Brazil**	[1646]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Erythrobasidium hasegawae	Phytotelmata of bromeliad	**Brazil**	[1646]
Cyrenella elegans	Sand near lake	USA	[1657]
Hasegawazyma lactosa	Phytotelmata of bromeliad tanks, polluted water (river)	**Brazil**, USA	[1635, 1646]
Symmetrospora marina	Phytotelmata of bromeliad tanks, water (wetland)	**Brazil**, USA	[1592, 1646]
Sakaguchia cladiensis	Water (wetland)	**USA**	[1592]
Sakaguchia meli	Glacial melt water	Argentina	[1624]
Exobasidiomycetidae			
Exobasidiales			
Brachybasidiaceae			
Meira geulakonigae	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Georgefischeriales			
Gjaerumiaceae			
Gjaerumia minor	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Tilletiariaceae			
Phragmotaenium oryzicola	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Microstromatales			

Table 7.13 (continued)

Taxon	Substrate	Country	References
Microstromatales genera *incertae sedis*			
Sympodiomycopsis paphiopedili	Water (river)	**Brazil**	[1593]
MICROBOTRYOMYCETES			
Kriegeriales			
Kriegeriaceae			
Phenoliferia himalayensis	Water (lake)	Himalayas	[1658]
Leucosporidiales			
Leucosporidiaceae			
Leucosporidium creatinivorum	Glacial melt water (river), water (lake)	**Argentina**	[1587, 1589]
Leucosporidium fragarium	Glacial melt water (river)	**Argentina**	[1587]
Leucosporidium golubevii	Water (river)		[1659]
Leucosporidium intermedium	Glacial meltwater (river)	**Argentina**	[651]
Leucosporidium muscorum	Water (lake), polluted water (river)	**Argentina**, USA	[1589, 1635]
Leucosporidium scottii	River water, polluted water (lake, river), water (lake, pond)	Slovakia, USA	[649, 650, 1635, 1660]
Microbotryales			
Ustilentylomataceae			

Table 7.13 (continued)

Taxon	Substrate	Country	References
Microbotryozyma collariae	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Microbotryomycetes families *incertae sedis*			
Chrysozymaceae			
Bensingtonia yamatoana	Glacial meltwater (river)	**Argentina**	[651]
Colacogloeaceae			
Colacogloea foliorum	Phytotelmata of bromeliad tanks, polluted water (lake, river)	**Brazil**, USA	[1635, 1646]
Microbotryomycetes genera *incertae sedis*			
Reniforma strues	Wastewater	Poland	[1615]
Sampaiozyma ingeniosa	Water (lake), polluted water (river)	USA	[1635, 1661]
Sampaiozyma vanillica	Freshwater Everglades	USA	[1592]
Slooffia cresolica	Freshwater Everglades	USA	[1592]
Udeniozyma ferulica	Water, glacial lakes and rivers, water (wetland)	**Argentina**, USA	[1592, 1641, 1662, 1663]
Sporidiobolales			
Sporidiobolaceae			
Rhodosporidiobolus colostri	Glacial meltwater (lakes, river), acidic water (river)	**Argentina**	[1587, 1588]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Rhodosporidiobolus lusitaniae	Water (lake)	Poland	[1645]
Rhodosporidiobolus ruineniae	Freshwater Everglades, phytotelmata of bromeliad tanks	**Brazil**, USA	[1592, 1646]
Rhodotorula alborubescens	Water (pond)	Slovakia	[649]
Rhodotorula babjevae	Water (lake), acidic water (river)	**Argentina**	[1588, 1641]
Rhodotorula diobovata	Freshwater Everglades, water (lake)	**Argentina**, USA	[1589, 1592]
Rhodotorula evergladensis	Water (wetland)	**USA**	[1592]
Rhodotorula glutinis	Water (lake), polluted water (lake, river)	Bangladesh, **South Africa**, Slovakia, USA	[650, 1585, 1635, 1651, 1653]
Rhodotorula graminis	Polluted water (lake, river)	USA	[1635]
Rhodotorula kratochvilovae	Glacial melt water (river)	**Argentina**	[1587, 1641]
Rhodotorula mucilaginosa	Glacial meltwater (lake, river), tropical freshwaters, phytotelmata of bromeliad tanks, rock holes, surfaces of freshwater turtles *Podocnemis expansa*, groundwater, mud (river canal), water (lake, wetland, river), acidic water (lake, river), sediment (lake)	**Argentina**, Bangladesh, **Brazil**, **Colombia**, **Egypt**, **Poland**, Slovakia, **Slovenia,** USA,	[648, 650, 1652–1655, 1661, 728, 1585, 1587, 1589, 1592, 1646, 1647, 1651]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Rhodotorula paludigena	Phytotelmata of bromeliad tanks, water (wetland)	**Brazil**, USA	[1592, 1646]
Rhodotorula sphaerocarpa	Water	Portugal	[1661]
Rhodotorula taiwanensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Rhodotorula toruloides	Water (lake), acidic water (river), phytotelmata of bromeliad tanks	**Argentina, Brazil,** Poland	[1588, 1645, 1646]
Sporobolomyces beijingensis	Freshwater Everglades, Water (lake)	USA	[1592]
Sporobolomyces blumeae	Water (wetland)	USA	[1592]
Sporobolomyces carnicolor	Water (wetland)	USA	[1592]
Sporobolomyces japonicus	Water (wetland)	USA	[1592]
Sporobolomyces longiusculus	Water (lake)	**Argentina**	[1589, 1664]
Sporobolomyces marcillae	Water (lake)	**Argentina**	[1589]
Sporobolomyces patagonicus	Water (lake)	**Argentina**	[1664]
Sporobolomyces roseus	Freshwater Everglades, glacial waters and rivers, water (pond)	Argentina, USA, Slovakia	[1592, 1650, 1664]
Sporobolomyces ruberrimus	Freshwater Everglades, glacial meltwater (river)	**USA, Argentina**	[651, 1589, 1592]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Sporobolomyces salmonicolor	Water (lake)	**Argentina**, Slovakia	[650, 1664]
Sporobolomyces shibatanus	Water (wetland)	USA	[1592]
Sporidiobolus salmonicolor	Groundwater	Slovenia	[648]
TREMELLOMYCETES			
Tremellomycetes *incertae sedis*			
Filobasidiales			
Filobasidiaceae			
Filobasidium floriforme	Freshwater Everglades, surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*	USA, **Brazil**	[1592, 1646, 1647]
Filobasidium magnum	Water (lake, river, wetland)	**Brazil**, Slovakia, USA	[650, 1591–1593]
Filobasidium oeirens	Glacial meltwater (river)	**Italy**	[1590]
Filobasidium stepposum	Water (lake), glacial meltwater (river)	**Brazil, Italy**	[1590, 1591]
Filobasidium wieringae	Water (lake), glacial meltwater (river)	**Argentina, Brazil, Italy**	[651, 1590, 1591]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Goffeauzyma agrionensis	Glacial lakes and rivers	**Argentina**	[1587]
Goffeauzyma gastrica	Glacial meltwater (river), water (lake)	**Argentina**, **Italy**, USA,	[1585, 1589, 1590]
Goffeauzyma gilvescens	Glacial melt water	Argentina	[1665]
Naganishia adeliensis	Glacial melt water (river)	**Argentina, Italy**	[1587, 1590]
Naganishia albida	Water (lake, pond), rock pools, surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, polluted water (river)	**Argentina**, **Brazil**, Slovakia, USA	[1585, 1589, 1635, 1647, 1650]
Naganishia albidosimilis	Water (pond), glacial meltwater (river), acidic water (river)	**Argentina**, **Italy**, **Portugal**	[1586, 1588, 1590]
Naganishia antarctica	Water (lake), acidic water (lake)	**Argentina**	[1588, 1589]
Naganishia bhutanensis	Acidic water (lake)	**Argentina**	[1588]
Naganishia diffluens	Freshwater Everglades, polluted water (lake, river), water (lake)	USA	[1585, 1592, 1635]
Naganishia liquefaciens	Water (wetland)	USA	[1592]
Piskurozymaceae			
Piskurozyma cylindrica	Glacial melt water (river)	**Argentina**	[1587]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Solicoccozyma aeria	Polluted water (river), water (lake), glacial meltwater (river)	**Italy**, Slovakia, USA	[650, 1590, 1635]
Solicoccozyma terrea	Freshwater Everglades	USA	[1592]
Solicoccozyma terricola	Polluted water (river), glacial meltwater (river)	**Argentina**, USA	[651, 1635]
Holtermanniales			
Holtermanniaceae			
Holtermanniella festucosa	Glacial meltwater (river)	**Argentina**	[1587, 1624, 1666]
Tremellales			
Bulleraceae			
Bullera alba	Rock holes, water (lake, pond)	**Brazil**, Slovakia	[650, 1593, 1650]
Bulleribasidiaceae			
Dioszegia butyracea	Glacial meltwater (river)	**Argentina**	[651]
Dioszegia crocea	Glacial melt water (river)	**Argentina**	[1587]
Dioszegia fristingensis	Glacial melt water (river), water (lake)	**Argentina**	[1587, 1589]
Dioszegia hungarica	Glacial melt water (river), water (lake)	**Argentina**	[1587, 1589]
Dioszegia zsoltii	Freshwater Everglades	USA	[1592]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Hannaella luteola	River water, phytotelmata of bromeliad tanks, rock pools, polluted water (lake)	**Brazil**, USA	[1593, 1635, 1646]
Hannaella pagnoccae	Phytotelmata of bromeliad tanks, rock pools	**Brazil**	[1646]
Hannaella sinensis	Freshwater Everglades	USA	[1592]
Hannaella zeae	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Vishniacozyma carnescens	Water (lake)	**Brazil**	[1591]
Vishniacozyma dimennae	Glacial meltwater (river)	**Italy**	[1590]
Vishniacozyma victoriae	Water (lake), submerged roots, tapwater, glacial meltwater (river), acidic water (lake, river)	**Argentina**, **Brazil**, **Norway**, **Slovenia**	[651, 1572, 1588, 1591, 1667]
Cryptococcaceae			
Cryptococcus festucosus	Glacial meltwater (river), acidic water (river)	**Argentina, Italy**	[1587, 1588, 1590]
Cryptococcus heveanensis	Water (lake)	**Brazil**	[1591]
Cryptococcus hungaricus	Water (river)	Brazil	[1593]
Cryptococcus macerans	Glacial meltwater (river)	**Argentina, Italy**	[1587, 1590]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Cryptococcus saitoi	Water (lake), glacial meltwater (river)	**Argentina Brazil, Italy**	[1589–1591, 1624]
Cryptococcus tephrensis	Water (lake), glacial meltwater (river)	**Brazil, Italy**	[1590, 1591]
Cryptococcus watticus	Glacial meltwater (river)	**Italy**	[1590]
Gelidatrema spencermartinsiae	Glacial meltwater (river)	**Argentina**	[1668]
Kwoniella dendrophila	Water (lake), phytotelmata of bromeliad tanks	**Brazil**	[1591, 1646]
Kwoniella heveanensis	Phytotelmata of bromeliad tanks, rock pools	**Brazil**	[1646]
Kwoniella mangrovensis	Phytotelmata of bromeliad tanks, rock pools	**Brazil**	[1646]
Naemateliaceae			
Dimennazyma cisti-albidi	Stagnant water		[1669]
Rhynchogastremaceae			
Papiliotrema flavescens	Phytotelmata of bromeliad tanks, water (wetland)	**Brazil**, USA	[1592, 1646]
Papiliotrema laurentii	Tropical freshwaters, phytotelmata of bromeliad tanks, rock holes, surfaces of freshwater turtles *Podocnemis expansa, P. unifilis*, polluted water (lake, river), water (lake, pond, river, wetland), acidic water (lake), sediment (lake)	**Argentina**, **Brazil**, **Colombia**, South Africa, Slovakia, USA,	[650, 1585, 1655, 1588, 1592, 1635, 1646, 1647, 1650, 1653, 1654]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Papiliotrema nemorosa	Phytotelmata of bromeliad tanks *(Very common species on this subsrate)*	**Brazil**	[1646]
Papiliotrema pseudoalba	Water (wetland)	USA	[1592]
Papiliotrema rajasthanensis	Phytotelmata of bromeliad tanks, water, sediment (lake)	**Brazil**, **Colombia**	[1646, 1655]
Papiliotrema taeanensis	Freshwater Everglades	USA	[1592]
Papiliotrema terrestris	Phytotelmata of bromeliad tanks, rock hole	**Brazil**	[1646]
Rhynchogastrema complexa	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Tremellaceae			
Tremella globispora	Phytotelmata of bromeliad tanks, rock holes	**Brazil**	[1646]
Trimorphomycetaceae			
Saitozyma flava	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Saitozyma podzolica	Phytotelmata of bromeliad tanks, surfaces of freshwater turtles *Podocnemis expansa*, *P. unifilis*, water, sediment (lake)	**Brazil**, **Colombia**	[1646, 1647, 1655]
Trichosporonales			
Trichosporonaceae			
Apiotrichum laibachii	Water (lake, river), sediment (lake)	Brazil, **Colombia**	[1593, 1655]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Apiotrichum montevideense	Water (river), tapwater	**Brazil, Slovenia**	[648, 1593]
Apiotrichum scarabaeorum	Water (river), mud (river canal)	**Brazil, Egypt**	[1593, 1652]
Cutaneotrichosporon cutaneum	Water (lake, pond, river)	Poland, Slovakia, USA	[687, 1585, 1650]
Cutaneotrichosporon jirovecii	Water, sediment (lake)	**Colombia**	[1655]
Cutaneotrichosporon moniliiforme	Water (lake)	Antarctica	[1670]
Cutaneotrichosporon mucoides	Water (river)	**Poland**	[728]
Trichosporon aculeatum	Freshwater	Japan	[1671]
Trichosporon asahii	Mud (river canal), surfaces of freshwater turtles *Podocnemis unifilis*, polluted water (river)	**Brazil**, USA, **Egypt**	[1635, 1646, 1647, 1652]
Trichosporon coremiiforme	Water (lake), groundwater	**Brazil, Slovenia**	[648, 1591]
Tremellomycetidae			
Cystofilobasidiales			
Cystofilobasidiaceae			
Cystofilobasidium bisporidii	Water (wetland)	USA	[1592]
Cystofilobasidium capitatum	Water (lake), glacial meltwater (river), acidic water (river)	**Argentina Brazil**, **Slovenia**	[1588, 1590, 1591, 1624]
Cystofilobasidium infirmominiatum	Water (lake)	**Argentina**, **Brazil**	[1591, 1641]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Cystofilobasidium lacus-mascardii	Water (lake)	**Argentina**	[1589]
Cystofilobasidium macerans	Glacial melt water (river), water (lake), acidic water (lake, river)	**Argentina**	[1587–1589, 1624]
Mrakiaceae			
Itersonilia pannonica	Glacial melt water (river)	**Argentina**	[1587]
Krasilnikovozyma huempii	Water (river)	Brazil	[1593]
Mrakia aquatica	Water (lake), *Equisetum* culms, foam (river, rivulet), submerged decaying leaves (stream), stemflow and throughfall of tree canopies, glacial meltwater (river)	**Argentina**, Austria, Canada, India, Ireland, Poland, UK	[43, 588, 631, 632, 636, 651]
Mrakia cryoconiti	Alpine glacier cryoconite	**Austria**	[1672]
Mrakia frigida	Glacial meltwater (river)	**Argentina**	[1587]
Mrakia robertii	Glacial meltwater (river)	**Argentina**	[651]
Tausonia pullulans	Water (lake), polluted water (river), glacial meltwater (river)	**Argentina**¸ USA	[651, 1591, 1635]
Udeniomyces megalosporus	Glacial meltwater (river)	**Argentina**	[651]
Udeniomyces pyricola	Freshwater Everglades, glacial meltwater (river), water (pond)	**Argentina**, Slovakia, USA	[649, 651, 1592]

Table 7.13 (continued)

Taxon	Substrate	Country	References
USTILAGINOMYCETES			
Ustilaginomycetidae			
Ustilaginales			
Anthracoideaceae			
Gymnocintractia samanensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Ustilaginaceae			
Anthracocystis elionuri	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Anthracocystis everhartii	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Macalpinomyces spermophorus	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Moesziomyces aphidis	Phytotelmata of bromeliad tanks, surfaces of freshwater turtles *Podocnemis expansa*, water (wetland)	**Brazil**, USA	[1592, 1646, 1647]
Moesziomyces parantarcticus	Freshwater Everglades	USA	[1592]
Pseudozyma crassa	Tapwater	**Slovenia**	[648]
Moesziomyces rugulosus	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Pseudozyma flocculosa	Freshwater Everglades	USA	[1592]
Pseudozyma hubeiensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Pseudozyma prolifica	Surfaces of freshwater turtles *Podocnemis expansa*	**Brazil**	[1647]

Table 7.13 (continued)

Taxon	Substrate	Country	References
Sporisorium andropogonis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Sporisorium graminicola	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Sporisorium trachypogonis-plumosi	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Ustilago sparsa	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Ustilaginales genera *incertae sedis*			
Anomalomyces panici	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Anomalomyces yakirrae	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Kalmanozyma brasiliensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Kalmanozyma vetiveriae	Phytotelmata of bromeliad tanks	**Brazil**	[1646]
Langdonia jejuensis	Phytotelmata of bromeliad tanks	**Brazil**	[1646]

7.3.4 Ingoldian fungi

Ingoldian fungi, also known as “aquatic (Ingoldian) hyphomycetes”, were named after Prof. Cecil Terence Ingold (1905–2010) who was the first pioneer of this fungal group and for his recognition as one of the most British distinguished mycologists of the twentieth century [1673]. Ingoldian fungi are an ecologically heterogeneous group of freshwater asexual morphs of Ascomycota or Basidiomycota. Uniquely, they produce relatively modified conidia (i.e., hyaline, filiform, tetraradiate, multiradiate, scolecoid, sigmoid or branched as shown in Figure 7.7) for decomposition on submerged plants and for their reproduction in aquatic ecosystems [17, 559, 580, 1674]. Ingoldian fungi are often found in fast flowing water, well-aerated forest streams and humid environments with ubiquitous distribution, but mostly in temperate zones of the earth [1, 54, 176]. Currently, there are over 95 genera with approximately 330 species discovered, and ca 28 genera are monotypic [89, 580, 1065, 1166, 1495, 1674]. In Table 7.14, most of which are in Ascomycota i.e., Helotiales and Leotiales (Leotiomycetes), some of them are phylogenetically related to Jahnulales and Pleosporales (Dothideomycetes), Orbiliales (Orbiliomycetes), Hypocreales, Sordariales and Microascales (Sordariomycetes), while rarely few taxa are Basidiomycota i.e., Cantharellales and Atheliales [580].

Table 7.14 Taxonomic Outline of Ingoldian Fungi Recorded from Freshwater Habitats

Order	Family	Genus	Species
ASCOMYCOTA			
Dothideomycetes			
Capnodiales	Neodevriesiaceae	*Tripospermum*	*T. myrti*
Jahnulales	Aliquandostipitacea	*Brachiosphaera*	*B. jamaicensis*
	e		*B. tropicalis*
Pleosporales	Amniculicolaceae	*Anguillospora*	*A. crassa*
			A. filiformis
			A. furtiva
			A. gigantea
			A. mediocris
			A. pseudolongissima
			A. pulchella
			A. rosea
			A. rubescens
			A. virginiana
		Amniculicola	*A. aquatica*
			A. guttulata
			A. immersa
			A. lignicola
			A. longissima
			A. parva
	Dothidotthiaceae	*Mycocentrospora*	*M. acerina*
			M. angulata
			M. aquatica
			M. clavata
			M. varians

Table 7.14 (continued)

Order	Family	Genus	Species
	Melanommataceae	*Tumularia*	*T. aquatica*
			T. tuberculata
	Tetraplosphaeriaceae	*Tetraploa*	*T. abortiva*
			T. aquatica
			T. aristata
			T. ellisii
			T. puzheheiensis
			T. scheueri
			T. thailandica
			T. yunnanensis
Tubeufiales	Tubeufiaceae	*Helicomyces*	*H. ambiguus*
			H. bellus
			H. chiayiensis
			H. colligatus
			H. geniculatus
			H. hyalosporus
			H. macrofilamentosus
			H. roseus
			H. scandens
			H. torquatus
		Helicosporium	*H. aquaticum*
			H. flavidum
			H. flavisporum
			H. flavum
			H. gracile
			H. lumbricopsis
			H. murinum
			H. panachaeum

Table 7.14 (continued)

Order	Family	Genus	Species
			H. setiferum
			H. thailandense
			H. vesicarium
	Wiesneriomycetace -ae	*Speiropsis*	*S. hyalospora*
			S. pedatospora
			S. scopiformis
		Wiesneriomyces	*W. conjunctosporus*
			W. laurinus
Dothideomycetes genera *incertae sedis*		*Clavariopsis*	*C. aquatica*
			C. azlanii
			C. brachycladia
			C. bulbosa
Leotimycetes Helotiales	Discinellaceae	*Cladochasiella*	*C. divergens*
		Fontanospora	*F. alternibrachiata*
			F. eccentrica
			F. fusiramosa
		Gyoerffyella	*G. craginiformis*
			G. entomobryoides
			G. gemellipara
			G. rotula
			G. speciosa
			G. tatrica
			G. tricapillata
			G. myrmecophagiformis

Table 7.14 (continued)

Order	Family	Genus	Species
		Lemonniera	*L. alabamensis*
			L. aquatica
			L. centrosphaera
			L. cornuta
			L. filiformis
			L. pseudofloscula
			L. terrestris
			L. yulongensis
		Margaritispora	*M. aquatica*
			M. monticola
		Tetrachaetum	*T. elegans*
		Varicosporium	*V. aquaticum*
			V. delicatum
			V. elodeae
			V. giganteum
			V. helicosporum
			V. macrosporum
			V. scoparium
			V. tricladiiforme
			V. trimosum
	Helotiaceae	*Articulospora*	*A. atra*
			A. moniliformis
			A. proliferata
			A. tetracladia
		Dimorphospora	*D. foliicola*
		Geniculospora	*G. grandis*
			G. inflata
	Hyaloscyphaceae	*Arbusculina*	*A. fragmentans*

Table 7.14 (continued)

Order	Family	Genus	Species
			A. irregularis
	Ploettnerulaceae	*Volucrispora*	*V. aurantiaca*
			V. graminea
	Tricladiaceae	*Mycofalcella*	*M. calcarata*
			M. iqbalii
		Tricladium	*T. aciculum*
			T. alaskense
			T. angulatum
			T. anomalum
			T. attenuatum
			T. biappendiculatum
			T. brunneum
			T. castaneicola
			T. caudatum
			T. chaetocladium
			T. curvisporum
			T. fallax
			T. fuscum
			T. gracile
			T. indicum
			T. intermedium
			T. kelleri
			T. marylandicum
			T. minutum
			T. obesum
			T. patulum
			T. procerum
			T. robustum
			T. splendens

Table 7.14 (continued)

Order	Family	Genus	Species
			T. terrestre
			T. varicosporioides
			T. varium
	Vibrisseaceae	*Vibrissea*	*V. decolorans*
			V. dura
			V. filisporia
			V. flavovirens
			V. guernisacii
			V. leptospora
			V. norvegica
			V. sporogyra
			V. truncorum
			V. vibrisseoides
	Helotiales genera *incertae sedis*	*Filosporella*	*F. annelidica*
			F. aquatica
			F. exilis
			F. fistucella
			F. pinquis
			F. versimorpha
		Tetracladium	*T. apiense*
			T. breve
			T. furcatum
			T. globosum
			T. maxilliforme
			T. nainitalense
			T. palmatum
			T. setigerum
			T. marchalianum

Table 7.14 (continued)

Order	Family	Genus	Species
Leotiales	Leotiales genera *incertae sedis*	*Alatospora*	*A. acuminata*
			A. constricta
			A. crassipes
			A. flagellata
			A. pulchella
		Flagellospora	*F. curvula*
			F. fusarioides
			F. leucorhynchos
			F. minuta
			F. saccata
			F. stricta
Leotiomycetes genera *incertae sedis*		*Gorgomyces*	*G. honrubiae*
Orbiliomycetes			
Orbiliales	Orbiliaceae	*Dactylella*	*T. microaquatica*
			T. submersa
			T. yunnanensis
		Dicranidion	*D. fragile*
			D. gracile
		Trinacrium	*T. incurvum*
			T. indicum
			T. robustum
			T. subtile
Sordariomycetes			
Chaetosphaeriales	Chaetosphaeriales genera *incertae sedis*	*Nawawia*	*N. filiformis*
			N. oviformis
			N. quadrisetulata

Table 7.14 (continued)

Order	Family	Genus	Species
Glomerellales	Reticulascaceae	*Cylindrotrichum*	*C. aquaticum*
			C. clavatum
			C. gorii
			C. helisciforme
			C. oligospermum
			C. submersum
			C. zignoellae
Hypocreales	Nectriaceae	*Aquanectria*	*A. devians*
			A. jacinthicolor
			A. penicillioides
			A. submersa
			A. tenuispora
		Heliscus	*H. tentaculus*
		Neonectria	*N. coccinea*
			N. lugdunensis
Microascales	Halosphaeriacea e	*Clavatospora*	*C. filiformis*
			C. longibrachiata
			C. tentacula
		Sigmoidea	*S. aurantiaca*
			S. contorta
			S. praelonga
			S. prolifera
Sordariales	Sordariales genera *incertae sedis*	*Lunulospora*	*L. curvula*
			L. cymbiformis
Hypocreomycetidae genera *incertae sedis*		*Campylospora*	*C. brasiliensis*
			C. chaetocladia
			C. filicladia

Table 7.14 (continued)

Order	Family	Genus	Species
			C. parvula
Ascomycota *incertae sedis*		*Alatosessilispora*	*A. bibrachiata*
		Arborispora	*A. dolichovirga*
			A. palma
			A. paupera
		Blodgettia	*B. indica*
		Calcarispora	*C. hiemalis*
		Casaresia	*C. sphagnorum*
		Cladoconidium	*C. articulatum*
		Clavariana	*C. aquatica*
		Condylospora	*C. flexuosa*
			C. gigantea
			C. spumigena
		Culicidospora	*C. aquatica*
			C. gravida
		Curucispora	*C. ombrogena*
			C. ponapensis
		Colispora	*C. cavincola*
			C. curvata
			C. elongata
		Dendrospora	*D. erecta*
			D. fastuosa
			D. fusca
			D. juncicola
			D. moniliformis
			D. nana
			D. polymorpha

Table 7.14 (continued)

Order	Family	Genus	Species
			D. tenella
			D. torulosa
			D. yessemreddyi
		Dendrosporium	*D. lobatum*
		Diplocladiella	*D. appendiculata*
			D. aquatica
			D. scalaroides
			D. tricladioides
		Dwayaangam	*D. colodena*
			D. cornuta
			D. dichotoma
		Flabellocladia	*F. gigantea*
		Flabellospora	*F. acuminata*
			F. amphibia
			F. crassa
			F. multiradiata
			F. tetracladia
			F. verticillata
		Gemmulina	*G. botryosa*
		Heliscella	*H. stellata*
			H. stellatacula
		Isthmolongispora	*I. asymmetrica*
			I. geniculata
			I. lanceata
			I. minima
			I. rotundata
		Isthmotricladia	*I. britannica*
			I. gombakiensis
			I. laeensis

Table 7.14 (continued)

Order	Family	Genus	Species
		Lateriramulosa	*L. quadriradiata*
			L. uniinflata
		Mirandina	*M. corticola*
			M. taiwanensis
			M. uncinata
		Polycladium	*P. equiseti*
		Pseudoanguillospo	*P. gracilis*
		ra	*P. prolifera*
			P. stricta
		Pyramidospora	*P. casuarinae*
			P. constricta
			P. densa
			P. fluminea
			P. herculiformis
			P. quadricellularis
			P. ramificata
			P. robusta
			P. stellata
		Scutisporus	*S. brunneus*
		Subulispora	*S. biappendiculata*
			S. longirostrata
			S. malaysiana
			S. procurvata
		Sympodiocladium	*S. frondosum*
		Tetrabrachium	*T. elegans*
		Tetrabrunneospor	*T. ellisii*
		a	
		Titaea	*T. callispora*
			T. clarkeae

Table 7.14 (continued)

Order	Family	Genus	Species
		Tricladiopsis	*T. flagelliformis*
			T. foliosa
		Tricellula	*T. aquatica*
			T. inaequalis
			T. ornata
		Trifurcospora	*T. irregularis*
		Triglyphium	*T. alabamense*
		Triramulispora	*T. gracilis*
			T. obclavata
		Triscelophorus	*T. acuminatus*
			T. curviramifer
			T. konajensis
			T. magnificus
			T. monosporus
			T. ponapensis
			T. septatus
		Trisulcosporium	*T. acerinum*
BASIDIOMYCOTA			
Agaricomycetes			
Atheliales	Atheliaceae	*Taeniospora*	*T. gracilis*
			T. gracilis var. gracilis
			T. nasifera
Cantharellales	Hydnaceae	*Ingoldiella*	*I. fibulata*
			I. nutans
Agaricomycetes genera *incertae sedis*		*Dendrosporomyces*	*D. prolifer*
			D. splendens
		Titaeella	*T. capnophila*

Table 7.14 (continued)

Order	Family	Genus	Species
		Tricladiomyces	*T. geniculatus*
			T. malaysianus
Classiculomycetes			
Classiculales	Classiculaceae	*Classicula*	*C. fluitans*
		Jaculispora	*J. submersa*
Microbotryomycetes			
Kriegeriales	Camptobasidiaceae	*Crucella*	*C. subtilis*
Ustilaginomycetes			
Ustilaginales	Ustilaginaceae	*Pseudozyma*	*P. crassa*
			P. flocculosa
			P. hubeiensis
Basidiomycota genera *incertae sedis*		*Arcispora*	*A. bisagittaria*

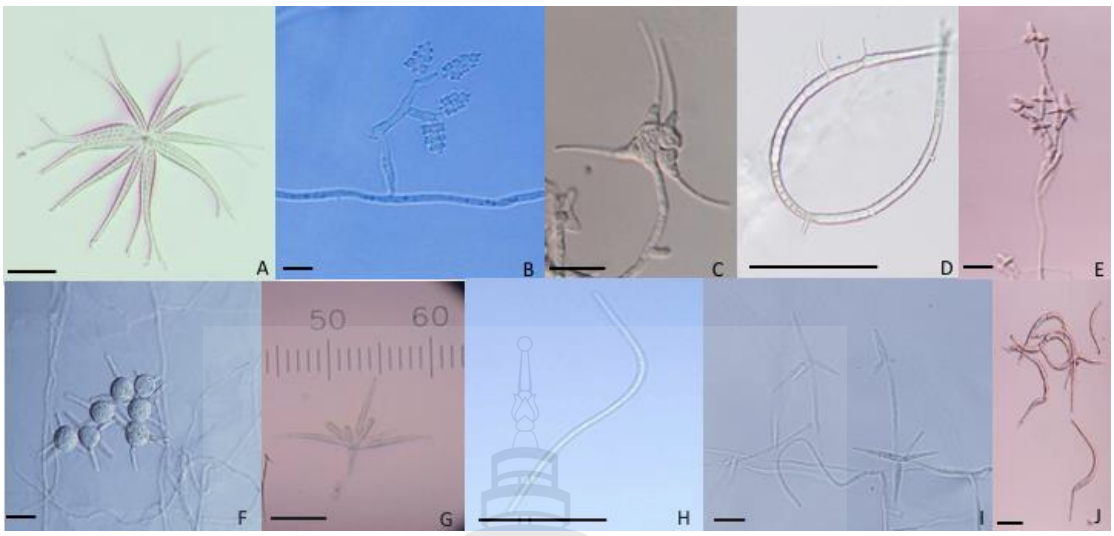


Figure 7.7 Conidia of Some Ingoldian Species Collected from Freshwater Habitats in Thailand. (A) *Flabellospora multiradiata*; (B) *Dendrosporium lobatum*; (C) *Campylospora chaetocladia*; (D) *Anguillospora longissima*; (E) *Lemonniera* sp.; (F) *Brachiosphaera tropicalis*; (G) *Tetracladium setigerum*; (H) *Sigmoidea* sp.; (I) *Triscelophorus acuminatus*; (J) *Mycocentrospora* sp. Scale bars: (A,B,E,F) 10 μm; (C,I) 20 μm; (D) 30 μm; (G) 25 μm; (H) 50 μm; (J) 30 μm.

7.3.5 Classification of freshwater fungal basal clades

Early diverging lineages of the fungal tree of life consist of zoosporic and zygomycetous (zygosporic) fungi [614, 1675]. They comprise saprobic and parasitic fungi isolated from various niches, such as soil and freshwater habitats [1676]. Among basal fungi, the most common in freshwater habitats are the zoosporic ones, such as Chytridiomycota, Blastocladiomycota, Monoblepharomycota, Rozellomycota and Aphelidiomycota [449, 614]. Zoosporic fungal parasites control the numbers of numerous phytoplankton species such as diatoms, green algae, cyanobacteria and dinoflagellates [1676–1678]. Estimation of fungal numbers has always been a debated research topic. Recent estimates of fungal species range from 2.2 to 3.8 million, of which only 100,000 to 143,273 have been described [445, 539]. Most of the described fungal species are from terrestrial habitats, while the discovery and description of aquatic fungi are significantly lower, and even smaller for basal fungi. The diversity

and abundance of basal fungi in aquatic niches have recently started to gain the spotlight in mycological research. For instance, studies have shown that the abundance of Chytridiomycota and Rozellomycota is higher than that of Dikarya in some aquatic habitats [1679]. The results are mostly derived from next generation sequencing, but the isolation and proper description of these fungi remains to be done. Some of the basal lineages, such as Chytridiomycota have mostly been isolated from freshwater habitats, such as ponds and lakes [1680]. The ecological roles of some of these fungi have been studied but for many, their roles are still unclear [580, 1679]. Hence, comprehensive studies keeping track the number of taxa isolated from various niches are important to understand their biology and ecology. Through the years, ecological research on zoosporic fungi has been conducted mostly in moist and cool freshwater ecosystems such as Douglas Lake in the USA, and Lake Windemere in the English Lake District. Other hotspots include countries such South Americas, Australia, Central Europe, and Japan [1680, 1681]. These fungi are thought to be ubiquitous in ecosystems which are rich in organic matter but have also been periodically found in extreme conditions [1681]. Hence, it is important to know the ecological factors that affect the distribution and abundance of these fungi. Waterborne oxygen content, one the abiotic factors that influence the distribution and development of zoosporic fungi, regulates the abundance of these taxa in varying water depths. Temperature also influences the amount of dissolved oxygen in water, hence, affecting the growth, reproduction, and distribution of aquatic fungi [1682]. The morphological description of basal fungi has been well documented, but many taxa lack molecular data, which limits knowledge of their evolutionary relationship. Many previously described species either do not have a valid type specimen or the specimen is unusable. It is also difficult to know the exact number of species with the ranks currently circumscribed. These problems can be seen in genera such as *Rhizophydium* and *Synchytrium* wherein the number of species present within that genera has been specified in some studies but acquiring additional information on these taxa is difficult [204]. This section provides a resource of information of freshwater basal fungi, their substrate, country of isolation and status on DNA-based sequence data. The list, though not exhaustive, provides an idea on the number of basal fungi isolated from freshwater habitats. In this paper, we list 684 species of

basal fungi under 11 phyla, 29 orders, 85 families, and 243 genera (Table 7.15). Chytridiomycota has the largest number with 333 species (in 97 genera), followed by Rozellomycota (221 species, 105 genera), Blastocladiomycota (47 species, 10 genera), Monoblepharomycota (29 species, 6 genera), Mucoromycota (19 species, 10 genera), and Aphelidiomycota (15 species, 3 genera). Other phyla have fewer than 10 species and include Entomophthoromycota (6 species, 4 genera), Mortierellomycota (5 species, 3 genera), Olpidiomycota (4 species, 1 genus), Zoopagomycota (3 species, 2 genera), and Sanchytriomycota (2 species, 2 genera).

Table 7.15 Classification of Fungal Basal Clades Recorded from Freshwater Environment Including Information on Habitats, Substrates/Hosts, and Geographical Distribution

Taxon	Substrate	Country	Reference
APHELIDIOMYCOTA			
APHELIDIOMYCETES			
Aphelidiales			
Aphelidiaceae			
Amoeboaphelidium achnanthis	Parasitoid of *Achnanthes lanceolata*	Hungary	[1683]
Amoeboaphelidium chlorellavorum	Parasitoid of *Chlorella*	Russia	[1683]
Amoeboaphelidium occidentale	*Scenedesmus dimorphus* (pond)	**USA**	[1684]
Amoeboaphelidium protococcarum	Ponds	**USA**	[1685]
Amoeboaphelidium radiatum	Parasitoid of *Kirchniriella* and *Ankistrodesmus*	Russia	[1683]
Aphelidium arduennense	Roadside ditch	**Belgium**	[1686]
Aphelidium chaetophorae	Parasitoid of *Chaetophora elegans*	Hungary	[1683]
Aphelidium chlorococcorum	Parasite of representatives of various genera of chlorococcus algae	-	[1687]
Aphelidium chlorococcorum f. chlorococcorum	Parasite of representatives of various genera of chlorococcus algae	-	[1683, 1688]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Aphelidium chlorococcorum f. majus	Parasitoid of *Kirchneriella obesa*		[1683]
Aphelidium collabens	Parasitoid of *Coccomyxa* sp. (pond)	**Japan**	[1689]
Aphelidium desmodesmi	Parasitoid of green alga *Desmodesmus armatus*	**USA**	[1690]
Aphelidium deformans	Parasitoid of Coleochaeta	Germany	[1691]
Aphelidium melosirae	Parasitoid of *Melosira varians:* diatom alga *Melosira varians* Ag.	Hungary	[1683]
Aphelidium tribonematis	Parasitoid of *Tribonema*	Hungary	[1683]
Paraphelidium tribonemae	Roadside ditches	**Russia**	[1692]
Paraphelidium letcheri	Dried stream	**Russia**	[1693]
BLASTOCLADIOMYCOTA			
BLASTOCLADIOMYCETES			
Blastocladiales			
Blastocladiaceae			
Allomyces anomalus	*Rozella allomycis* isolated from roadside ditch	Hattiesburg	[1694]
Allomyces arbusculus	Water on dead *Diptera*	India	[1695]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Allomyces catenoides	Tropical fish aquarium	USA	[1696]
Allomyces javanicus	Water, mud from lake	Indonesia, Egypt	[1697, 1698]
Allomyces neomoniliformis	Lake	India	[1699]
Allomyces macrogynus	Mud	Egypt	[1698]
Allomyces moniliformis	Mud	Egypt	[1698]
Blastocladia arborata	Styles of submerged flowers of *Caryopteris* and myrtaceous fruit	India, Egypt	[1700, 1701]
Blastocladia angusta	Weeping white birch twigs, rose hips; lake	Denmark, Egypt	[1701]
Blastocladia aspergilloides	Lake	Australia	[1702]
Blastocladia bonaerensis	Eutrophic water litter	Argentina	[1703]
Blastocladia caduca	Stamens of submerged flowers of *Crateva religiosa*	India	[1700]
Blastocladia coronata	Submerged fruit of *Eugenia jambolana*	India	[1700]
Blastocladia didyma	Submerged fruit of *Physalis peruviana*	India	[1700]
Blastocladia elegans	Submerged fruit of *Mangifera indica*	India	[1700]
Blastocladia excelsa	Ripe guava fruit bait; Tanks	India	[1700]
Blastocladia filamentosa	*Eugenia jambolana* fruit	India	[1700]
Blastocladia fruticosa	Submerged fruits of *Eugenia jambolana*	India	[1700]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Blastocladia fusiformis	Submerged stamens and pistils of flower of *Crateva religiosa*	India	[1700]
Blastocladia globosa	Pond water	India	[1704]
Blastocladia glomerata	Sunken twigs of *Aesculus*	Great Britain	[1705]
Blastocladia gracilis	River, lake, pond, pool	Denmark, UK	[1706]
Blastocladia heterosporangia	Submerged fruit of *Vitis vinifera*	India	[1700]
Blastocladia incrassata	Water	Japan, USA	[1707]
Blastocladia mammillata	Submerged fruit of *Pyrus*	India	[1700]
Blastocladia pileota	Submerged fruit of *Pyrus*	India	[1700]
Blastocladia pringsheimii	Water on rotten fruits of *Malus*, tomato skin (river)	Germany, USA, UK	[1706–1708]
Blastocladia pusilla	Submerged fruit of *Mangifera indica*	India	[1700]
Blastocladia ramosa	Submerged twigs, water (river)	Poland, USA, UK	[687, 1706, 1708]
Blastocladia rostrata	Lake	USA	[1707]
Blastocladia sessilis	Various submerged fruits	India	[1700]
Blastocladia sparrowii	–	USA	[1707]
Blastocladia spiciformis	*Psidium*	India	[1700]
Blastocladia strangulata	*Aphidoidea*	USA	[1709]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Blastocladia truncata	Submerged fruit of *Malus*, submerged plant (river)	North America, UK	[1706, 1710]
Blastocladiopsis parva	Water reservoir, lake, water (stream)	**Poland,** USA	[687, 1707, 1711]
Catenariaceae			
Catenophlyctis peltata	Snake skin in water	Cuba	[1712]
Catenophlyctis variabilis	Water and sediment (reservoir), lake	Brazil, Egypt, **Poland**, UK	
Nematoceromyces ramosus	Parasitic in eggs of *Dicrotendipes modestus* (Stream)	USA	[1713]
Paraphysodermataceae			
Paraphysoderma sedebokerense	*Haematococcus pluvialis*	**Israel**	[1714]
Catenomycetales			
Catenomycetaceae			
Catenomyces persicinus	Grasses in water samples	USA	[1715]
Coelomomycetaceae			
Coelomomyces quadrangulatus	*Anopheles quadrimaculatus* larvae; Lake	**USA**	[1716]
Coelomomyces punctatus	*Anopheles quadrimaculatus* larvae; Lake	**USA**	[1716]
Coelomomyces lativittatus	*Anopheles* spp. Larvae; Pond	**USA**	[1716]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Coelomycidium ephemerae	*Cloeon rufulum* larvae	Former Czechoslovakia	[1717]
Coelomycidium simulii	*Simulium* larvae; stream	France	[1718]
Blastocladiomycetes genus *incertae sedis*			
Microallomyces dendroideus	Pond sediment	Costa Rica	[1719]
CHYTRIDIOMYCOTA			
CHYTRIDIOMYCETES			
Chytridiales			
Asterophlyctaceae			
Asterophlyctis michiganensis	Lake	**USA**	[1720]
Asterophlyctis sarcoptoides	Pond	**USA**	[1720]
Wheelerophlyctis interior	Aquatic sample	**USA**	[1720]
Wheelerophlyctis interiexterior	Pond	**USA**	[1720]
Chytridiaceae			
Chytridium acuminatum	Lake (on cellophane, baby hairs, pine pollen, *Ulothrix* sp.), oogonia of *Oedogonium rothii*, possibly also on *O. echinospermum*, zygospores of *Mougeotia* sp.	USA, Germany, Russia	[1708, 1721, 1722]
Chytridium adpressum	Ditch	India	[1723]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Chytridium aggregatum	Saprophytic on *Spirogyra crassa*, *Oedogonium* sp., and *Cladophora* sp.	USA	[1724]
Chytridium apophysatum	Ditch	India	[1723]
Chytridium amphoroideum	*Hydrodictyon*	UK	[1725]
Chytridium closterii	Water	India	[1723]
Chytridium cocconeidis	Living cells of *Cocconeis pediculus*, epiphytic on *Cladophora* (lake)	UK	[1726]
Chytridium coleochaetes	Parasitic on oogonia of *Coleochaete pulvinata* (tarn)	Germany, UK	[1727, 1728]
Chytridium corniculatum	Pine pollen; freshwater sand	Greenland	[1725]
Chytridium cornutum	Heterocysts of *Aphanizomenon flos-aquae* (pond)	Czechoslovakia	[1729]
Chytridium cresentum	Ditch	India	[1730]
Chytridium deltanum	Parasitic; *Oocystis* spp.; phytoplankton; lake	Canada	[1731]
Chytridium hyperparasiticum	Parasitic; sporangium of *Rhizophlyctis rosea*; soil in water	Greenland	[1732]
Chytridium isthmiophilum	Parasitic on *Staurodesmus curoatus* (lake)	UK	[1733]
Chytridium lagenula	Parasitic on *Tribonema* sp. (pool)	UK	[1734]
Chytridium lecythi	Parasitic on rhizopod *Lecythium Byalinum* (stream)	UK	[1735]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Chytridium marylandicum	Saprobic; matrix of *Botryococcus*; Blue Pon	USA	[1736]
Chytridium neopapillatum	Saprobic; pine pollen; sand in water	Greenland, USA	[1736]
Chytridium oedogonii	*Oedogonium* (lake)	UK, USA	[1737] [1738]
Chytridium olla	*Oedogonium*	Germany	[1739]
Chytridium oocystidis	*Oocystis lacustris*	Switzerland	[1740]
Chytridium ottariense	Saprobic; *Volvox*, chitin, snake skin; impoundment	USA	[1741]
Chytridium rhizophydii	Chitin and pollen baits (pond)	USA	[1742]
Chytridium reniforme	Water; *Spirogyra*; ditch	India	[1700]
Chytridium schenkii	Water		[1730]
Chytridium sparrowii	Water		[1700]
Chytridium telmatoskenae	Parasitic; *Telmatoskene mucosa*; pond; Volary, central	Bohemia	[1743]
Chytridium versatile	*Nitzschia sigmoidea* (lake)	UK	[1726]
Chytridium xylophilum	Water (river)	Poland	[687]
Dendrochytridium crassum	Tree-canopy detritus flooded with water	**Australia**	[1744]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Dinochytrium kinnereticum	Lake, freshwater springs, standing water pools	**Israel, Oman**	[1745, 1746]
Irineochytrium annulatum	Water (lake)	USA	[1747]
Polyphlyctis willoughbyi	Permanently submerged river mud	**Australia**	[1720]
Polyphlyctis unispina	Lake, bog	USA	[1720]
Zopfochytrium polystomum	Submerged shoreline vegetation, mud, and water; Lake	**USA**	[1748]
Chytriomycetaceae			
Avachytrium platense	Lake	**Argentina**	[1749]
Chytriomyces appendiculatus	Saprophytic on chitinous substrata in freshwater and muck soil, water column and sediment (reservoir), mud (lake)	Brazil, UK, **USA**	[1750–1753]
Chytriomyces aureus	Unidentified insects in fresh water, mud (lake)	Brazil, UK, USA	[1753, 1754]
Chytriomyces closterii	Weakly parasitic on *Closterium rostratum*; ditch	USA	[1750]
Chytriomyces confervae	Parasitic on *Tribonema*	Sweden, Hungary, USA, Germany, UK, Canada, Poland	[1750]
Chytriomyces cosmaridis	Water	Poland	[1750]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Chytriomyces fructicosus	Saprophytic in cellulosic substrata in soil and water	USA	[1750]
Chytriomyces heliozoicola	Lake plankton, parasitic on helizoan *Raphidiocystis lemani*; Esthwaite Water and windermere	UK	[1750]
Chytriomyces hyalinus	Water, saprobes on chitin, pollen;	**USA**, UK, Brazil, Taiwan	[1750, 1752]
Chytriomyces laevis	soil-water culture; parasitic on *Pythium* sp, growing on snake skin	Panama	[1750]
Chytriomyces lucidus	Saprophytic in cellulosic substrata in soil and water	USA	[1750]
Chytriomyces nagatoroensis	Weakly parasitic on *Spirogyra* sp.	Japan	[1750]
Chytriomyces rotoruaensis	Watered mud samples, saprophytic on chitin.	New Zealand	[1750]
Chytriomyces stellatus	Saprophytic on chitinous substrata in freshwater and muck soil,	USA, Brazil	[1750]
Chytriomyces tabellariae	Water and mud; parasitic on *Tabellaria* species.	Switzerland, UK	[1750]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Entophlyctis apiculata	Agricultural pond; parasitized cells of Chlamydomonas sp.	Korea	[1755]
Entophlyctis aurea	Saprobic on various Poaceae, *Triticum aestivum*, *Avena sativa*, and *Zea mays* leaves, regenerated cellulose film, filter paper, and lens paper submerged in water	Ontario and Great Britain	[1756]
Entophlyctis bulbigera	Ditch, cells of *Spirogyra* filaments (pool)	India, UK	[1723, 1757]
Entophlyctis caudiformis	Closterium; tank	India	[1723]
Entophlyctis confervae-glomeratae	Aquatic, cells of filaments of *Oedogonium* and *Spirogyra* (pond)	Germany, UK	[1757, 1758]
Entophlyctis crenata	On *Vallisneria*: North-freshwater	New Zealand	[1759]
Entophlyctis lobata	Shrimp chitin bait; littoral of Derwentwater	UK	[1760]
Entophlyctis luteolus	Onion skin and *Utricularia*; bogs and acid lake; mud pond	**USA**	[1761]
Entophlyctis mammilliformis	Oospores of *Spirogyra*; pond	India	[1723]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Entophlyctis molesta	*Stylosphaeridium stipitatum*; phytoplankton; English lakes	Great Britain	[1762]
Entophlyctis reticulospora	*Closterium moniliferum*; swampy area	USA	[1763]
Entophlyctis sphaerioides	Reproductive body of *Spirogyra*; ditch	India	[1723]
Entophlyctis texana	Moribund cells of the aquatic plant *Eriocaulon*	USA	[1764]
Fayochytriomyces spinosus	Onion skin placed in a muck sample taken from a temporary pond	**USA**	[1765]
Obelidium hamatum	Chironomidae larvae; Pond	USA	[1766]
Obelidium megarhizum	From submerged mud: river.	Great Britain, USA	[1766]
Obelidium mucronatum	On the empty skin of a mosquito larva; pond, strips of purified shrimp chitin (water on outdoor tub)	**USA**, New Zealand	[1766, 1767]
Odontochytrium milleri	Pollen and chitin baits (pond); bog	**Argentina,** USA	[1749, 1752]
Pendulichytrium sphaericum	*Aulacoseira granulata*; Lake	**Japan**	[1768]
Physocladia obscura	Growing on onion skin bait placed in water from Bryant's Bog.	**USA**	[1752]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Podochytrium chitinophilum	From submerged mud, Wastewater	Great Britain	[1760]
Podochytrium clavatum	Parasitic on diatoms	Poland	[1769]
Podochytrium cornutum	Planktonic diatom *Stephanadiscus niagarae*; Lake	USA	[1770, 1771]
Podochytrium dentatum	Saprobic on chitin; lake, Pond	USA	[1772]
Podochytrium ellerbeckense	Waterlily leaf stalks; garden pond,	Great Britain	[1772]
Podochytrium emmanuelense	On *Melosira varians* and on *Nitzschia*	Great Britain	[1773]
Podochytrium lanceolatum	On *Melosira varians*:	Great Britain	[1774]
Rhizidium brasiliense	Insect remnants and exuviae in water (stream)	Brazil	[1775]
Rhizidium elongatum	Pond water; chitinous substrata (river)	India, USA	[1776, 1777]
Rhizidium variabile	*Spirogyra* (pond)	UK	[1726]
Rhizidium varians	Pond water; chitinous material in water (river)	India, USA	[1776, 1777]
Rhizidium verrucosum	Bits of insects and exuviae, pieces of onion skin and grass leaves in a water sample	Brazil	[1775]
Rhizoclosmatium aurantiacum	Saprotrophic in water on insect exuviae, chitin, cellulose, and pollen.	Denmark, USA	[1778, 1779]
Rhizoclosmatium globosum	Saprotrophic on insect exuviae, chitin, cellulose, pollen, keratin, and depleted filaments of *Aphanomyces*; purified shrimp chitin	**Denmark**, New Zealand, **USA**	[1752, 1767, 1778]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
	from a rainwater culture in an outdoor tub with *Nitella*		
Rhizoclosmatium hyalinum	Saprotrophic on insect exuviae and chitin; water in outdoor tub with *Elodea*	New Zealand	[1767, 1778]
Rhizoclosmatium sparsum	Saprotrophic on chitin and pollen; spring water, river	**USA**	[1778]
Rhizoclosmatium umbonatum	Saprotrophic on chitin and pollen, water edge	**USA**	[1778]
Rhizoclosmatium persicum	Saprotrophic on chitin and pollen; dam spillway, lake		[1778]
Rhizoclosmatium pessaminum	Saprotrophic on chitin and pollen; edge of lake, pond	**USA**	[1778]
Siphonaria petersenii	Saprophytic inside the exuviae of mayflies and other insects; lake, Salmon Pond	**USA**, Brazil	[1780, 1781]
Siphonaria sparrowii	Mud (pond); purified shrimp chitin in water (lake)	**USA**, New Zealand	[1767, 1781]
Siphonaria variabilis	Purified shrimp chitin in water (lake)	New Zealand	[1767]
Phlyctochytriaceae			
Phlyctochytrium aequale	*Melosira* sp. from a roadside pool	Iceland	[1782]
Phlyctochytrium aureliae	Bog	USA	[1752, 1783]
Phlyctochytrium apophysatum	*Phlyctochytrium dissolutum*; Closterium; tank, garden	India	[1723]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Phlyctochytrium bullatum	Pond, on Cladophora	**USA,** Iceland	[1782]
Phlyctochytrium circulidentatum	Saprobic on pollen and moribund *Closterium*; bottom debris; Lake	Germany	[1784]
Phlyctochytrium dentiferum	Dead *Cladophora*; lake	USA	[1785]
Phlyctochytrium dissolutum	*Closterium*; tank, garden	India	[1723]
Phlyctochytrium furcatum	Test of a testate amoeba in water collected from Bryant's Bog	USA	[1752, 1786]
Phlyctochytrium incrustans	Bog	USA	[1787]
Phlyctochytrium irregulare	Mud (lake)	UK	[1753]
Phlyctochytrium lippsii	Parasites of *Ascobolus, Ascophanus, Lasiobolus* and *Sordaria*; reservoir	USA	[1788]
Phlyctochytrium longicollum	Parasites of *Euglena* spp; bog	USA	[1789]
Phlyctochytrium macrosporum	Lake	USA	[1790]
Phlyctochytrium multidentatum	Saprobic on pollen; water	USA	[1784]
Phlyctochytrium mucronatum	Parasitic on *Closterium pritchardianum*; Bog, pollen bait (pond)	UK, USA	[1742, 1791]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Phlyctochytrium parasitans	Parasites of eggs of *Achlya flagellate*; Damp soil	Hispaniola (Republic of Haiti and the Dominican Republic)	[1792]
Phlyctochytrium planicorne	Growing on a filamentous conjugating green alga; bog, Pond, mud (lake)	UK, **USA**	[1753, 1793]
Phlyctochytrium powhatanense	Impoundment	USA	[1794]
Phlyctochytrium proliferum	Parasitic on *Chlamydomonas* (pond)	UK	[1735]
Phlyctochytrium urceolare	Dead *Cladophora*; lake		[1795]
Phlyctorhizaceae			
Phlyctorhiza endogena	Remains of mosquitoes, mayflies, dragonflies and gnats found on streams, Peep Pond	**USA**	[1796]
Pseudorhizidiaceae			
Pseudorhizidium endosporangiatum	Pine pollen in water (bog)	USA	[1752]
Scherffeliomycetaceae			
Scherffeliomyces parasitans	Freshwater	Great Britain	[1797]
Zygorhizidiales			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Zygorhizidiaceae			
Zygorhizidium cystogenum	*Dinobryon divergens* and *Uroglena americana* cysts (lake)	UK	[1798]
Zygorhizidium parallelosede	Parasitic on *Elakatothrix gelatinosa* and *Ankistrodesmus* sp. (lake)	UK	[1799, 1800]
Zygorhizidium planktonicum	*Asterionella formosa* and *Synedra ascus* var. *angustissima*	UK	[1801, 1802]
Zygorhizidium willei	*Cylindrocystis brebissoni*; surface of a moist rock, lake	**Japan**	[1803]
Zygophlyctidales			
Zygophlyctidaceae			
Zygophlyctis asterionellae	*Asterionella formosa*; lake	**Japan**	[1803]
Zygophlyctis melosirae	*Aulacoseira subarctica*, lake, parasitic on *Melosira italica* subsp. *subarctica*	**UK**	[1801, 1803]
Zygophlyctis planktonica	*Ulnaria* sp; lake	**Germany**	[1803]
Polyphagales			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Polyphagaceae			
Polyphagus arnaudovii	Hyponeustonic	Bulgaria	[1804]
Polyphagus asymmetricus	Hyponeustonic, on *Botrydiopsis*	Bulgaria	[1804]
Polyphagus elegans	Parasitizing *Ulothrix mucosum*	Great Britain	[1798]
Polyphagus euglenae	Ponds	Germany	[1805]
Polyphagus laevis	Cysts of *Euglena viridis* and of *Chlamydomonas*	Northern hemisphere	[1806]
Polyphagus ramosus	*Sphaerocystis schroeteri*	Switzerland	[1805]
Polyphagus serpentinus	Lakes: parasitizing *Spondylosium planum*	United Kingdom	[1798]
Polyphagus starrii	Parasitic; *Eudorina*, *Pandorina*; pond	USA	[1805]
Polyphagus sinicus	*Draparnaldia*	China	[1804]
Chytridiomycetes family *incertae sedis*			
Sparrowiaceae			
Sparrowia subcruciformis	Sporangia of *Rhizophydium coronum*, *Chytriomyces poculatus*, *Chytriomyces annularus* and *Rhizophlyctis rosea*; Lake	USA	[1807]
Chytridiomycetes genera *incertae sedis*			
Bertramia marionensis	Parasite of Chironomidae (Diptera) larvae; lake	Canada	[1808]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Blyttiomyces conicus	Stream	Norway	[1809]
Blyttiomyces helicus	Lake, bog	USA	[1752, 1810]
Blyttiomyces laevis	Parasitic on filaments of *Zygnema* sp.; bog	USA	[1789]
Blyttiomyces lenis	Parasitic on zygospore of *Spirogyra*; ditch	India	[1723]
Blyttiomyces spinosus	*Spirogyra*; aquatic habitat	India	[1723]
Blyttiomyces spinulosus	Zygospores of *Sirogonium*; ditch	China, Japan, the Philippines, Cuba, USA, Argentina	[1811]
Canteria apophysata	Clay pond, on *Mougeotia*	Great Britain	[1812]
Dangeardia echinulata	*Vitreochlamys aulata*; pool	Poland	[1813]
Dangeardia laevis	Lake		
Dangeardia mamillata	Parasite on *P. morum*; small pond, on *Yamagishiella unicocca*; oligo-mesotrophic lake;	Poland, **Germany**, UK	[1814, 1815]
Dangeardia ovata	Parasitic in *Sphaerocystis schroeteri* Chod; lake	USA	[1773]
Dangeardia sporapiculata	*Chlamydomonas*; Lake	Austria	[1816]
Dangeardiana eudorinae	Parasitic on oospores of *Eudorina elegans*; water	Bulgaria	[1817]
Dangeardiana leptorrhiza	*Zygnema*; swampy pool	USA	[1818]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Dictyomorpha dioica	Parasitic of Oomycetes; lake	USA	[1819]
Dictyomorpha pythiensis	Parasitic on *Pythium aphanidermatu*; pond	India	[1820]
Ichthyochytrium vulgare	Parasite of freshwater fishes *Cyprinus*	Germany	[1821]
Loborhiza metzneri	River	USA	[1822]
Macrochytrium botrydioides	Debris and skeletonized leaves found in a stream	USA	[1823]
Mitochytridium ramosum	Bog, swampy ground	France	[1824]
Mitochytridium regale	Pond	Poland	[1825]
Mucophilus cyprini	*Cyprinus*: freshwater fish	Germany	[1826]
Perolpidium utriculiforme	Parasitic on *Closterium lunula, C. costatum, C. dianeae*	UK	[1827]
Pseudopileum unum	Parasitizing cysts of *Mallomonas*; Lake	Great Britain	[1798]
Rhizosiphon akinetovorax	Parasitic on *Anabaena affinis* var. *intermedia*	Great Britain	[1828]
Rhizosiphon akinetum	Parasitic on *Anabaena affinis* var. *intermedia*	Great Britain	[1828]
Rhizosiphon anabaenae	Parasitic on *Anabaena affinis* var. *intermedia*	Sweden	[1828]
Rhizosiphon crassum	Parasitic on Cyanophyceae, parasitic on *Anabaena solitaria* (tarn)	Hungary, UK	[1799, 1828]
Rhopalophlyctis sarcoptoides	Insect skeletons from freshwater	**Brazil, USA**	[1752, 1754]
Saccomyces dangeardii	Small water bodies	Ukraine	[1829]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Septosperma anomalum	Parasites of freshwater chytrids; swamp soils, parasitic on *Asterionella* (tarn)	USA, UK, Hungary	[1802, 1830]
Septosperma rhizophidii	Parasites of freshwater chytrids; swamp soils	USA, Great Britain, New Zealand	[1830]
Septosperma irregulare	Water	New Zealand	[1831]
Septosperma multiforme	Parasites of freshwater chytrids; swamp soils, quiescent cells and immature cysts of *Amphichrysis compressa* (pool), immature cysts of *Mallomonas* sp. (lake)	USA, Great Britain, New Zealand	[1798, 1830]
Sorokinocystis mirabilis	Submerged decaying wood	Italy	[1832]
Sporophlyctidium africanum	Parasitic on *Protoderma* sp; from water cultures of vegetable matter	Morocco	[1833]
Sporophlyctidium neustonicum	Lake water	USA	[1790]
Sporophlyctis chinensis	*Draparnaldia*	China	[1834]
Sporophlyctis rostrata	*Draparnaldia* and *Chaetophora*	Russia	[1835]
Truittella setifera	Soil and water cultures	USA	[1836]
Volvorax ingoldii	Coenobium of *Eudorina*; reservoir	Germany, **UK**	[1814, 1837]
Zygochytrium aurantiacum	Dead insect; water bodies	Poland	[1838]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
CLADOCHYTRIOMYCETES			
Cladochytriales			
Catenochytridiaceae			
Catenochytridium carolinianum	Mud (lake)	UK	[1753]
Catenochytridium hemicysti	Moribund desmid	West Virginia	[1839]
Cladochytriaceae			
Cladochytrium aneurae	Spring	Poland	[527]
Cladochytrium aureum	Pond	Poland	[527]
Cladochytrium aurantiacum	Pond, fragments of leaves, stems and roots of *Avena* and *Triticum* (canal)	Poland, UK	[527]
Cladochytrium cornutum	Submerged plants	France	[1840]
Cladochytrium crassum	Decaying vegetation; lake	USA	[1841]
Cladochytrium granulatum	Decaying vegetation	Brazil	[1842]
Cladochytrium hyalinum	Dead grass; stream	USA	[1843]
Cladochytrium irregulare	Submerged plants	France	[46]
Cladochytrium menyanthis	Parasitic on leaves of *Menyanthes trifoliata* (bog, ditch)	USA, UK	[1734, 1789]
Cladochytrium taianum	Spring	Poland	[527]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Cladochytrium replicatum	Pond, lake, spring, water column and sediment (reservoir), mud (lake), plant debris (lake)	**Brazil**, Egypt, UK, USA	[1751, 1753, 1757, 1844]
Cladochytrium salsuginosum	Blackish water	Poland	[1845]
Cladochytrium setigerum	Sediment (reservoir)	Brazil	[1751]
Cladochytrium tenue	*Acorus calamus* and *Iris pseudacorus*; water	**Brazil;** Poland	[1846, 1847]
Endochytriaceae			
Diplophlyctis amazonensis	Submerged decaying plant debris, mud (lake)	Brazil, UK	[1753, 1848]
Diplophlyctis asteroidea	Mud-acid bogs	USA	[1849]
Diplophlyctis buttermerensis	Submerged mud, ditch	Great Britain, USA	[1850]
Diplophlyctis chitinophila	Submerged mud	Great Britain	[1851]
Diplophlyctis complicata	Submerged mud lakes		[1807]
Diplophlyctis intestina	Fresh-blackish water *Characea*, cortical cells of *Chara* sp. (lake), sediment (reservoir), moribund and dead internodal cells of *Nitella* sp. (bog)	Brazil, Germany, India, USA	[1751, 1789, 1852]
Diplophlyctis laevis	*Cladophora* from Crooked Lake, dead internodal cells of *Nitella* (bog)	USA	[1789, 1853]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Diplophlyctis nephrochytrioides	Saprophytic or weakly parasitic in moribund internodes of *Nitella* sp; Lake	New Zealand	[1759]
Diplophlyctis sarcoptoides	Insects' substrate in aquatic, *Nitella* and *Chara* (lake) water (bog), pond, water column and sediment (reservoir)	Brazil, New Zealand, UK, USA	[1720, 1734, 1767, 1807]
Diplophlyctis sexualis	Submerged decaying plant debris	UK, Canada, USA	[1854]
Diplophlyctis verrucosa	*Chara fragilis* cells; moor and ponds	Japan	[527]
Diplophlyctis versiformis	Bog water	USA	[1807]
Endochytrium digitatum	saprophytic in internodes of *Chara coronata*, *Nitella flexilis*, and other algae, mud (lake)	UK, USA	[1724, 1753]
Endochytrium multiguttulatum	Bogs	USA	[1850]
Endochytrium pseudodistomum	Parasite in *Stigeoclonium tenue*; lake	USA	[1764]
Endochytrium oophilum	Parasitic on rotifers eggs	USA	[1855]
Endochytrium ramosum	*Cladophora* sp.	USA	[1855]
Nowakowskiellaceae			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Nowakowskiella crenulata	Sediment surface	**Brazil**	[1856]
Nowakowskiella delica	Mud (lake)	UK	[1753]
Nowakowskiella elegans	Grass leaf blade and mud (lake)	UK, USA	[1753, 1779]
Nowakowskiella hemisphaerospora	Sediment surface, water (reservoir), mud (lake)	**Brazil,** UK, USA	[1753, 1856, 1857]
Nowakowskiella macrospora	Water (river)	Poland	[687]
Nowakowskiella multispora	Water (stream)	**Brazil**	[1856]
Nowakowskiella ramosa	Water column (reservoir)	**Brazil**	[1856]
Nowakowskiella crassa	Debris in water	USA	[1858]
Nowakowskiella methistemichroma	Onion-skin bait from stagnant water	Poland	[1859]
Nowakowskiella moubasherana	*Sphagnum* bog water	Poland	[1860]
Septochytriaceae			
Septochytrium macrosporum	Water	USA	[1861]
Septochytrium plurilobulum	Water in decaying leaves of *Acer pensylvanicum*	USA	[1862]
Nephrochytrium appendiculatum	Pond	Poland	[527]
Nephrochytrium aurantium	Mud (lake)	UK, USA	[1753, 1863]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Nephrochytrium bipes	Pond	Poland	[1864]
Nephrochytrium stellatum	Pond	Poland	[527]
LOBULOMYCETES			
Lobulomycetales			
Lobulomycetaceae			
Algomyces stechlinensis	*Eudorina elegans* (lake)	**Germany**	[1814]
Clydaea vesicula	Creek bank mud	**USA**	[1865]
Lobulomyces angularis	Sphagnum from acidic lake, mud pond, pollen bait (pond)	**USA**	[1742, 1865]
MESOCHYTRIOMYCETES			
Gromochytriales			
Gromochytriaceae			
Gromochytrium mamkaevae	Parasite of *Tribonema gayanum*; ditch	**Russia**	[1866]
Mesochytriales			
Mesochytriaceae			
Mesochytrium penetrans	Lake, pond	**Russia**	[1867, 1868]
POLYCHYTRIOMYCETES			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Polychytriales			
Arkayaceae			
Arkaya lepida	River	**USA**	[1869]
Polychytriaceae			
Karlingiomyces asterocystis	Shrimp exoskeleton: water and soil.	USA	[1870]
Karlingiomyces curvispinosus	River	USA	[1870]
Karlingiomyces dubius	River	USA	[1870]
Karlingiomyces marylandicus	Water (ditch), mud (lake)	UK, USA	[1753, 1870]
Lacustromyces hiemalis	Lake and pond	USA	[1871]
Neokarlingia chitinophila	Chitinous substrata; water and soil	**USA**	[1869]
Polychytrium aggregatum	Decaying plant material in bog:	USA	[1783]
RHIZOPHYDIOMYCETES			
Rhizophydiales			
Alphamycetaceae			
Alphamyces chaetifer	Stream, pollen bait (pond), *Cosmarium contractum var. ellipsoideum, Staurastrum cingulum, S. planktonicum, S. lunatum, S. anatinum, S. pseudopelagicum, Xanthidium subhastiferum,*	**Argentina,** USA, UK	[1742, 1872, 1873]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
	Asterococcus sp., *Spirogyra, Spondylosium planum*		
Betamyces americae-meridionalis	Roadside pond onto pollen	**Argentina**	[1874]
Angulomycetaceae			
Angulomyces argentinensis	Isolated on pollen from stream	**Argentina**	[1872]
Aquamycetaceae			
Aquamyces chlorogonii	Semi-permanent roadside pond	**Argentina**	[1872]
Collimycetaceae			
Collimyces mutans	*Microglena coccifera*; pond	**Japan**	[1768]
Coralloidiomycetaceae			
Coralloidiomyces digitatus	Submersed mud in lake: Chubut	**Argentina**	[1875]
Globomycetaceae			
Globomyces pollinis-pini	Lake, pine pollen (bog)	**Argentina**, USA	[1789, 1872]
Urceomyces sphaerocarpum	Lake	**Argentina**	[1872]
Gorgonomycetaceae			
Gorgonomyces haynaldii	Stream	**Argentina**	[1872]
Halomycetaceae			
Halomyces littoreus	River	**USA**	[1876]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Paranamyces uniporus	Pond	**USA**	[1876]
Ulkenomyces aestuarii	River, submersed estuary mud.	**Germany**	[1876]
Kappamycetaceae			
Kappamyces laurelensis	Water cultures of moss-covered soil from along a stream	**USA**	[1877]
Pateramycetaceae			
Pateramyces corrientinensis	Small lake	**Argentina**	[1872]
Protrudomycetaceae			
Protrudomyces laterale	Small lake	**Argentina**	[1872]
Rhizophydiaceae			
Rhizophydium algavorum	Parasitic; *Chlorococum minutum*; pond	Russia	[1878]
Rhizophydium androdioctes	Parasitic on *Dictyosphaerium pulchellum*; Loch Leven	Scotland	[1879]
Rhizophydium apiculatum	Pond water	India	[1777]
Rhizophydium blastocladianum	Parasitic on *Blastocladia* on apple; tank sediment	India	[1723]
Rhizophydium blyttiomycerum	Parasitic on *Blyttiomyces spinosus* and zygospore of Spirogyra; ditch	India	[1723]
Rhizophydium clavatum	Parasitic on *Closterium*; tank	India	[1723]
Rhizophydium columnare	Parasitic on *Spirotaenia condensate* (pond)	UK	[1880]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Rhizophydium conchiforme	Ditch	India	[1723]
Rhizophydium constantineanui	Dead cells of *Oedogonium* sp., and *Cosmarium* sp (pool)	UK	[1757]
Rhizophydium contractophilum	Parasitic on *Eudorina elegans* and *Eudorina* sp; Lake	UK	[1881]
Rhizophydium coronum	Organic debris in water (bog), cellulose bait (pond)	USA	[1752] [1742]
Rhizophydium difficile	Parasitic on *Staurastrum jaculiferum* (lake)	UK	[1800]
Rhizophydium dubium	Saprobic on decaying leaves of *Eichornia*; pond	India	[46]
Rhizophydium echinocystoides	Saprobic on pine pollen; bog	USA	[1732]
Rhizophydium elyense	Sediment (reservoir), mud (lake)	Brazil, UK	[1751, 1753]
Rhizophydium fugax	Parasitic on *Cryptomonas* sp.; plankton of lakes	UK	[1799]
Rhizophydium fusus	Parasitic on *Melosira granulata*	UK	[1802]
Rhizophydium gibbosum	*Staurastrum anatinum, S. pseudopelagicum, Staurodesmus curvatus, Staurodesmus* sp.	UK	[1873]
Rhizophydium gonapodyanum	Parasitic on sporangium of *Gonapodya polymorpha*; tank sediment	India	[1723]
Rhizophydium granulosporum	Parasitic on *Tribonema* sp. (ditch)	UK	[1734]
Rhizophydium jobii	Benthic detritus	**Oman**	[1746]
Rhizophydium keratinophilum	Human hair bait, algae debris (bog)	USA	[1789]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Rhizophydium koreanum	Pond	**South Korea**	[511]
Rhizophydium lagenaria	Parasitic on sporangium of *Blastocladia* on fruit bait; tank sediment	India	[1723]
Rhizophydium lenelangeae	Saprobic on pine pollen bait; riverbank soil	Guatemala	[1787]
Rhizophydium mammillatum	Weak parasite or saprophyte on cells of *Cladophora* (ditch)	UK	[1757]
Rhizophydium manoense	Parasitic on diatom (Cocconeis); stream	USA	[1907]
Rhizophydium mougeotiae	Parasitic on *Mougeotia gracillima*; Lake	Switzerland	[1732]
Rhizophydium nobile	Parasitic on the resting spores of *Ceratium hirundinella*; lakes	UK	[1882]
Rhizophydium oblongum	Parasitic on *Dinobryon* spp. (Lake)	UK	[1800]
Rhizophydium obpyriformis	Parasitic on chytrids (pond)	USA	[1742]
Rhizophydium planktonicum	Parasitic on *Asterionella formosa*; lakes	UK	[1883]
Rhizophydium poculiforme	Parasitic on *Closterium*; tank	India	[1723]
Rhizophydium porosum	Bog	USA	[1787]
Rhizophydium punctatum	Lake	Russia	[1732]
Rhizophydium reflexum	Parasitic on the sorangium of *Blastocladia* on *Pyrus* fruit; tank sediment	India	[1723]
Rhizophydium rhizinum	Parasitic on the sorangium of *Blastocladia* on *Pyrus* fruit; tank sediment	India	[1723]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Rhizophydium rotundum	Parasitic on *Closterium*, *Oedogonium*, and *Zygnema*; tank	India	[1723]
Rhizophydium sphaerotheca	Pool and bog	UK	[1734]
Rhizophydium sparrowii	"Saproparasitic" on *Ulothrix* sp.; ditch	India	[1723]
Rhizophydium spinosum	Parasitic on *Blastocladia* on fruit bait; tank sediment	India	[1723]
Rhizophydium squamosum	Lake	Russia	[1732]
Rhizophydium stellatum	Parasitic on the sporangium of *Gonapodya polymorpha*; tank sediment	India	[1723]
Rhizophydium stipitatum	Sediment (reservoir)	Brazil	[1751]
Rhizophydium tetragenum	Parasitic on *Asterionella formosa*; Lake	Switzerland	[1732]
Rhizophydium tubulatum	Parasitic on *Closterium*	India	[1723]
Rhizophydium ubiquetum	Saprobic on *Cosmarium* and other desmids; plankton of lakes	UK	[1873]
Rhizophydium uniguttulum	Parasitic on *Gemellicystis neglecta* (lake)	UK	[1800]
Rhizophydium undatum	Bog, lake	Russia, USA	[1732, 1787]
Rhizophydium urceolatum	Parasitic on *Blastocladia* on fruit bait; tank sediment	India	[1723]
Rhizophydium venustum	Parasitic on *Uroglena americana*; lakes	UK	[1798]
Staurastromycetaceae			
Staurastromyces oculus	Lake	**Germany**	[1884]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Homolaphlyctis polyrhiza	Acidic oligotrophic lake	**USA**	[1885]
Terramycetaceae			
Boothiomyces angulosus	Sediment (reservoir)	**Brazil**	[1751]
Boothiomyces macroporosus	Pollen bait (pond)	**USA**	[1886]
RHIZOPHLYCTIDOMYCETES			
Rhizophlyctidales			
Borealophlyctidaceae			
Borealophlyctis nickersoniae	Pond	**USA**	[1886]
Rhizophlyctidaceae			
Karlingia polonica	Water (pond, river)	Poland	[687, 1864]
Rhizophlyctis columellae	Zygospore of *Spirogyra*	India	[1887]
Rhizophlyctis petersenii	Cellophane "bait," in water culture with soil	USA	[1789]
Rhizophlyctis rosea	Mud (lake)	UK	[1753]
SPIZELLOMYCETES			
Spizellomycetales			
Spizellomycetaceae			
Spizellomyces palustris	Peat bog ditch	**Germany**	[1888]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
SYNCHYTRIOMYCETES			
Synchytriales			
Synchytriaceae			
Endodesmidium formosum	Bog, Parasitic in *Netrium oblongum*, *Cylindrocystis crassa* and *Cylindrocystis brebissonii*	Great Britain	[1889]
Synchytrium laeve	*Mougeotia* sp. (pond)	UK	[1889]
Synchytrium microbalum	Mud Pond, acidic lake	**USA**	[1890]
Synchytrium petersenii	*Mougeotia* sp. (bog)	UK	[1889]
Synchytriales genus *incertae sedis*			
Micromyces intermedius	*Zygnema* (bog)	UK	[1889]
Micromyces mirabilis	Growing in *Closterium* cells; Bog	USA	[1752]
Micromyces oedogonii	*Oedogonium* (lake)	UK	[1891]
Micromyces zygogonii	Growing in *Mougeotia filaments* (pond), pasitic in vegetative filaments of *Mougeotia genuflexa* (bog), *Spirogyra* (pond)	UK, USA	[1752, 1789, 1889]
Chytridiomycota genus *incertae sedis*			
Achlyella flahaultii	River	Poland	[1892]
Achlyogeton entophytum	River	Poland	[1893]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Achlyogeton rostratus	Water	France	[1894]
ENTOMOPHTHOROMYCOTA			
Entomophthoromycetes			
Entomophthorales			
Ancylistes closterii	*Closterium* sp. (bog)	USA	[1752]
Ancylistaceae			
Ancylistes closterii	*Closterium* sp. (bog)	USA	[1752]
Conidiobolus villosus	Saprophytic on cast skin of snake used as "bait" in water culture of soil and rotten wood (bog)	USA	[1789]
Entomophthoraceae			
Erynia aquatica	*Aedes* pupal cadaver (woodland pool)	USA	[631, 827, 1895]
Erynia rhizospora	Foam (stream, rivulet, water)	Austria, India, Poland	[631, 827, 1752]
Erynia conica	Foam (stream, rivulet), *Simulium verecundum* complex (lake)	Austria, Canada, India	[985]
MONOBLEPHAROMYCOTA			
HYALORAPHIDIOMYCETES			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Hyaloraphidiales			
Hyaloraphidiaceae			
Hyaloraphidium curvatum	Freshwater	**South Africa**	[1896]
MONOBLEPHARIDOMYCETES			
Monoblepharidales			
Gonapodyaceae			
Gonapodya bohemica	Forest pools	Czech Republic	[1897]
Gonapodya polymorpha	Submerged twigs	USA	[1898]
Gonapodya prolifera	Decaying apples in water, tomato bait (river)	USA, UK	[1706, 1898]
Gonapodya siliquiformis	Decaying apples in water	USA	[1898]
Harpochytriaceae			
Harpochytrium adpressum	Parasitic on freshwater algae	Hungary	[1899]
Harpochytrium apiculatum	Freshwater algae	USA	[1899]
Harpochytrium botryococci	freshwater	UK	[1900]
Harpochytrium hedenii	Freshwater algae	USA, France, Germany, Russia, UK	[1900]
Harpochytrium hyalothecae	freshwater	USA, Germany, UK	[1900]
Harpochytrium intermedium	freshwater		[1900]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Harpochytrium monae	*Zygogonium ericetorum* in a temporary pool	UK	[1900]
Harpochytrium natrophilum	*Trisetum cernuum*; freshwater	USA	[1900]
Harpochytrium ornithocephalum	freshwater	Switzerland	[1900]
Harpochytrium tenuissimum	Tubs in the ground; freshwater	UK	[1901]
Harpochytrium vermiforme	In cells of freshwater algae	Germany	[1900]
Harpochytrium viride	Parasitic on freshwater algae	Hungary	[1902]
Monoblepharidaceae			
Monoblepharis bullata	Submerged twigs of *Quercus robur* and of *Fraxinus excelsior*	**UK**	[1903]
Monoblepharis fasciculata	Submerged sticks	USA	[1904]
Monoblepharis hypogyna	Submerged twigs of *Quercus robur*, water (river)	Poland, **UK**	[687, 1903]
Monoblepharis insignis	Submerged sticks; pool and ditch	USA	[1904]
Monoblepharis laevis	Fruit of *Rosa*, immersed in water	USA	[1834]
Monoblepharis macrandra	Submerged plants (ponds, stream)	Sweden, USA	[1789, 1905]
Monoblepharis polymorpha	Saprobic on *Quercus robur L.* and *Fraxinus excelsior L*	France?	[1906]
Monoblepharis micrandra	Submerged twigs, swamps	USA	[1907]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Monoblepharis ovigera	Submerged fallen branches of *Abies picea*	Sweden	[1905]
Monoblepharis sphaerica	Submerged twigs of *Quercus robur* L	France	[1722]
Monoblepharis regignens	Submerged fallen branches of *Pinus sylvestris*	Sweden	[1905]
Oedogoniomycetaceae			
Oedogoniomyces lymnaeae	shells of living *Limnaea ollula* and *Linaea reticulata*	Japan	[1908]
Telasphaerulaceae			
Telasphaerula gracilis	Lake water, associated with Chara	**USA**	[1909]
SANCHYTRIOMYCOTA			
SANCHYTRIOMYCETES			
Sanchytriales			
Sanchytriaceae			
Amoeboradix gromovi	Parasitic on *Tribonema gayanum*, *Tribonema vulgare* and *Ulothrix tenerrima*; water of a sand-pit	**Russia**	[1910]
Sanchytrium tribonematis	Pond	**Russia**	[1909]
MORTIERELLOMYCOTA			
MORTIERELLOMYCETES			
Mortierellales			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Mortierellaceae			
Aquamortierella elegans	Midge larvae in a freshwater stream	New Zealand, Japan	[1911]
Gryganskiella fimbricystis	Moss cushion in a very wet bog	**Argentina**	[1911]
Mortierella elongata	Water (river)	**South Korea**	[1912]
Mortierella fluviae	Water (river)	**South Korea**	[310]
Mortierella minutissima	Water (river)	**South Korea**	[1913]
MUCOROMYCOTA			
ENDOGONOMYCETES			
Endogonales			
Endogonaceae			
Endogone pisiformis	*Sphagnum* (bog)	USA	[1789]
MUCOROMYCETES			
Mucorales			
Choanephoraceae			
Gilbertella persicaria	Water (river)	**South Korea**	[1914]
Cunninghamellaceae			
Absidia glauca	Mud (river canal)	Egypt	[1652]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Cunninghamella bertholletiae	Water (river)	**South Korea**	[1915]
Gongronella namwonensis	Freshwater	**South Korea**	[1916]
Lichtheimiaceae			
Rhizomucor pusillus	***Rhizomucor pusillus***	Water (tank)	**USA**
Mucoraceae			
Actinomucor elegans	Water (river)	**South Korea**	[1917]
Mucor abundans	Water (stream)	**South Korea**	[1918]
Mucor aligarensis	Water (stream)	**South Korea**	[1918]
Mucor amphibiorum	Pathogenic to *Ornithorhynchus anatinus* (creek, river)	Australia	[1919]
Mucor fluvius	Freshwater	**South Korea**	[571]
Mucor heterogamus	Freshwater, sediment	**South Korea**	[1918]
Mucor hiemalis	Pathogens of *Cyprinis carpio communis* and *Oncorhynchus mykiss* (cultured farm)	**India**	[1920]
Mucor moelleri	Water, Sediment (stream)	**South Korea**	[1918]
Mucor ramosissimus	Freshwater	**South Korea**	[1921]
Mucor racemosus	Polluted water (canal)	Egypt	[1922]
Rhizopodaceae			

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Rhizopus oryzae	Polluted water (canal)	Egypt	[1922]
Rhizopus stolonifer	Tap water	Portugal	[1923]
Syncephalastraceae			
Syncephalastrum racemosum	Polluted water (canal)	Egypt	[1922]
OLPIDIOMYCOTA			
OLPIDIOMYCETES			
Olpidiales			
Olpidiaceae			
Olpidium gregarium	Freshwater (river), rotifer eggs (pools)	Poland, UK	[687, 1734]
Olpidium hyalothecae	Water	UK	(Canter 1949)
Olpidium pendulum	Pine pollen (lake)	USA	[1789]
Olpidium rotiferum	Freshwater (river)	Poland	[687]
ZOOPAGOMYCOTA			
ZOOPAGOMYCETES			
Zoopagales			
Zoopagaceae			
Acaulopage dichotoma	Freshwater (river), rotifer eggs (pools)	Poland, UK	[631]

Table 7.15 (continued)

Taxon	Substrate	Country	Reference
Zoophagus cornus	Water	UK	[1924, 1925]
Zoophagus insidians	Pine pollen (lake)	USA	[1734, 1752, 1926]

7.3.6 Microsporidia

The number microsporidia from all environments ranges from 118 genera [1927], 144 in Sprague and Becnel [1928] to 200 listed in Becnel et al. [1929], and 217 in Wijayawardene et al. [204]. Species numbers may exceed 1,500 and this may be a conservative estimate. The website www.marinefungi.org lists 62 genera with 138 species of marine microsporidia [36]. Data on freshwater microsporidia is spread widely in the literature with no definitive list of actual species and their hosts. Table 7.16 lists 105 genera of freshwater microsporidia with 221 species in 4 orders and 24 families, but this undoubtedly is an underestimate as new taxa are continuously being introduced.

Microsporidia, now classified as fungi, are obligate, intracellular, spore-forming parasites of a variety of hosts, including insects, birds, fish, mollusks, platyhelminths, while 17 species are known to infect human [1930]. Microsporidia are rarely lethal, generally causing chronic debilitating diseases, resulting in reduced longevity, fertility, weight, and general vigour of their hosts. Microsporidians may also be hyperparasites of other microsporidia [1931]. Microsporidia evolutionary have lost many of their mitochondrial and Golgi genes, with reduced ribosomal RNAs size and genomes 2.5 to 11.6 Mb in size, encoding 1,848 to 3,266 proteins [1932]. Microsporidial classification remains embryonic but currently determined by sequence data [26, 1933–1935]. Species identification is based on spore morphology, their ultrastructure (especially their unique resistant spore) and sequence data. The life cycle commences with a polar filament injecting its spore contents into a host cell [1936]. Fish microsporidia can be broadly classified into two groups: those associated with xenoma (cyst-like) formation (e.g., *Glugea*) and those associated with non-xenoma forming microsporidia (e.g., *Nucleospora*) [1937, 1938]. Microsporidia are transmitted both horizontally and vertically.

The life cycle of a microsporidian is initiated by a spore which on detecting a host cell swell resulting in the breakdown of the sporoplasmic membrane and the rupture of the anchoring disk followed by the release of the polar tube and the transfer of the sporoplasm into the host cell. Inside the host cell more spores are produced and released into the environment.

Hosts for freshwater microsporidia include bryozoans, arthropods, and fish, with nine genera and approximately 50 species described from copepods [1939–1941]. The small planktonic crustacean *Daphnia* is the host of some 17 microsporidia (Table 7.16). Unusual hosts for microsporidia include *Alloglugea bufonis* on metamorphosing tadpoles of the toad *Bufo marinus* and *Amblyospora camposi* on *Culex renatoi*, a bromeliad-inhabiting mosquito [1942, 1943]. Hosts may harbour more than one microsporidian e.g., the freshwater amphipod *Gammarus roeseli* was infected by three species [1931]. Fish are common hosts for microsporidians, especially those reared under high stocking densities with many recorded from salmon species.

Table 7.16 Classification of Microsporidia and Rozellomycota Genera *Incertae Sedis* Recorded from Freshwater Environment Including Information on Habitats, Substrates/Hosts, and Geographical Distribution

Species	Animal host	Distribution	Reference
AMBLYOSPORIDA			
Amblyosporidae			
Amblyospora bakcharia	*Ochlerotatus excrucians* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora baritia	*Ochlerotatus excrucians* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora bogashova	*Ochlerotatus excrucians* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora bracteata	*Simulium damnosum* larva (river); *S. venustum, S. verecundum, and S. vittatum* (pond, river)	Canada, Nigeria	[1945, 1946]
Amblyospora burlaki	*Culex pipiens* larva (floodplain water body)	Russia	[1947]
Amblyospora camposi	*Culex renatoi*, a bromeliad-inhabiting mosquito	Argentina	[1943]
Amblyospora canadensis	*Aedes canadensis, A. cinereus* larva (bog swamp)	USA	[1948]
Amblyospora caspius	*Aedes caspius, A. communis* larva (reservoir from melted snow)	Russia	[1947]
Amblyospora chulymia	*Ochlerotatus caspius* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora dyxenoides	*Culex annulirostris* adult and larvae and *Mesocyclops albicans*	Australia	[1949]
Amblyospora flavescens	*Ochlerotatus dianaetus, Aedes flavescens* larva (sphagnum bog)	**Russia**	[1944, 1950]
Amblyospora hristinia	*Ochlerotatus communis* larva (temporary vernal pool)	**Russia**	[1944]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Amblyospora jurginia	*Ochlerotatus excrucians* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora kazankia	*Ochlerotatus dianaetus* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora khaliulini	*Aedes communis* and *Acanthocyclops vernalis* (vernal pool)	**USA**	[1951, 1952]
Amblyospora kolarovi	*Ochlerotatus punctor*, *Aedes communis* (sphagnum bog)	**Russia (microsporidium), USA (host)**	[1944, 1950]
Amblyospora mavlukevia	*Aedes cinereus* larva (riverside pond)	**Russia**	[1944]
Amblyospora mocrushinia	*Ochlerotatus punctor* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora modestium	*Aedes cinereus* larva (pond)	**Russia**	[1944]
Amblyospora orbiculata	*Aedes diantaeus* larva (sphagnum bog)	Russia	[1950]
Amblyospora rugosa	*Ochlerotatus cataphylla*, *O. cantans*, *Aedes euedes* (temporary reservoirs after snow melting)	**Russia**	[1944, 1950, 1953]
Amblyospora salairia	*Culex modestus* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora severinia	*Ochlerotatus excrucians* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora shegaria	*Aedes cinereus* larva (temporary vernal pool)	**Russia**	[1944]
Amblyospora timirasia	*Aedes cinereus* larva (temporary vernal pool)	**Russia**	[1944]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Amblyospora undata	*Culex pipiens* larva (continental reservoir)	Russia	[1950]
Amblyospora urski	*Aedes communis* larva (temporary reservoirs after snow melting)	Russia	[1950]
Amblyospora weiseri	*Aedes cantans* larvae (pool)	Bohemia	[1954]
Andreanna caspii	*Ochlerotatus caspius* instar (temporary vernal pool)	**Russia**	[1955]
Becnelia sigarae	Testes of the water boatmen, *Sigara lateralis*	Czech Republic	[1956]
Crepidulospora beklemishevi	*Anopheles beklemishevi* larva (water body river floodplain)	Russia	[1957, 1958]
Culicospora damnosi	*Simulium damnosum* larva (river)	Nigeria	[1945]
Culicospora magna	*Culex restuans* larvae (river)	USA	[1959]
Culicosporella lunata	*Culex pilosus* larvae (ditch)	USA	[1960]
Dimeiospora palustris	*Aedes punctor* larvae (sphagnum swamp)	Russia	[1957]
Hyalinocysta chapmani	*Culiseta melanura* larva, *Orthocyclops modestus* (sphagnum bog)	**USA**	[1961]
Hyalinocysta expilatoria	Bogfly *Odagmia ornate* larva (stream)	Sweden	[1962]
Intrapredatorus barri	mosquito *Culex fuscanus* larva (artificial tank)	China	[1963]
Intrapredatorus trinus	*Culex halifaxi* larvae(stream)	Australia	[1964]
Novothelohania ovalae	*Ochlerotatus caspius* larva (temporary vernal pool)	**Russia**	[1944]
Parathelohania anopheles	*Anopheles quadrimaculatus* larva, *Microcyclops varicans* (wading pool)	USA	[1965]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Parathelohania divulgata	*Anopheles messeae, Anopheles beklemishevi* larva (reservoir of river floodplain)	Kazakhstan**, Russia**	[1944, 1966]
Parathelohania formosa	*Anopheles messeae* larva (reservoir of river floodplain)	Russia	[1966]
Parathelohania iranica	*Anopheles superpictus* larva (leakage pool)	**Iran**	[1967]
Parathelohania sibirika	*Anopheles messeae* larva (reservoir of river floodplain)	Russia	[1966]
Parathelohania teguldeti	*Anopheles beklemishevi* larva (water body of river floodplain)	Russia	[1966]
Parathelohania tomski	*Anopheles messeae* (reservoir of river floodplain)	**Russia**	[1944, 1966]
Trichoctosporea pygopellita	*Acanthocyclops reductus, Ochlerotatus cyprius, C. excrucians*	**Russia**	[1944, 1953]
Tricornia muhezae Caudosporidae	Mosquito *Mansonia Africana* larva (pond)	Tanzania	[1968]
Binucleospora elongata	Ostracod *Candona* (temporary water bodies on a meadow_	Sweden	[1969]
Caudospora simulii	Blackfly *Prosimulium mixtum* larva (stream)	Canada	[1946]
Flabelliforma ostracodae	Ostracods (*Candona* sp.), collected on flooded meadows	Sweden	[1940]
Neoflabelliforma aurantiae	Sludge work *Tubifex tubifex* (pond)	**UK**	[1970]
Scipionospora tetraspora Gurleyidae	Midge (*Tanytarsus, Endochironomus*) larva (pond, river)	France, Sweden	[1971]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Agglomerata cladocera	*Daphnia magna* (lake)	**Russia**	[1972]
Agglomerata daphniae	*Daphnia magna*	China	[1973]
Agglomerata volgensae	*Daphnia magna* (pond)	Russia	[1974]
Binucleata daphniae	*Daphnia magna* (pond)	**Belgium**	[1975]
Conglomerata obtusa	*Daphnia* species	**Czech Republic**, Poland	[1976]
Episeptum anaboliae	*Anabolia furcate* larva (pond)	**Czech Republic**	[1977]
Episeptum circumscriptum	Caddisfly *Hydropsyche siltalai, H. incognita* (river)	**Czech Republic,** Sweden	[1977, 1978]
Episeptum invadens	*Limnephilus fuscicornis* larva (small river)	Sweden	[1978]
Episeptum inversum	Caddis fly *Holocentropus picicornis* larvae (pond)	Sweden	[1977]
Episeptum pseudoinversum	*Sericostoma personatum* larva (stream)	**Czech Republic**	[1977]
Episeptum trichoinvadens	*Potamophylax cingulatus* larva (stream)	**Czech Republic**	[1977]
Gurleya daphniae	*Daphnia pulex* in ponds	Austria	[1979]
Gurleya vavrai	*Daphnia pulex* and *D. Longispina* (sewage lagoon)	UK	[1980]
Lanatospora costata	Copepod *Megacyclops viridis* (woodland pool)	**Czech Republic**	[1981]
Lanatospora macrocyclopis	Copepod *Macrocyclops albidus* (lake)	Russia	[1982]
Larssonia obtusa	*Daphnia pulex* in pond	Lithuania	[1983]
Marssoniella elegans	Copepod *Cyclops vicinus*	Czech Republic	[1941]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Norlevinea daphniae	*Daphnia longispina* in carp pond	China, Czechoslovakia	[1984]
Paraepiseptum hydropsycheae	*Hydropsyche siltalai* larva (river)	UK	[1985]
Paraepiseptum plectrocnemiae	Caddis flies *Plectrocnemia conspersa* larva (stream)	**Czech Republic**	[1977]
Paraepiseptum polycentropi	Caddis flies *Polycentropus flavomaculatus, Hydropsyche fulvipes* (stream)	**Czech Republic**	[1977]
Pseudoberwaldia daphniae	*Daphnia longispina* complex (drinking water reservoir)	**Central Europe**	[1986]
Senoma globulifera	Mosquito *Anopheles messeae* (floodplain pond)	Russia	[1987]
Zelenkaia trichopterae	*Halesus digitatus* (stream) and *Micropterna sequax* (pond), *aquatic caddis flies*	**Bulgaria**	[1988]
Amblyosporida genera *incertae sedis*			
Alfvenia sibirica	Cyclopid *Cyclops* sp. (lake)	**Russia**	[1972]
Takaokaspora nipponicus	Mosquito *Ochlerotatus japonicus japonicus, O. hatorii* (riverside rock pools)	**Japan**	[1989]
Trichotuzetia guttata	*Cyclops vicinus* (pond)	**Czech Republic**	[1990]
GLUGEIDA			
Glugeidae			

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Alloglugea bufonis	*Bufo marinus* tadpoles and metamorphosing toads (lake)	Brazil	[1942]
Amazonspora hassar	Teleost fish *Hassar orestis*	Brazil	[1991]
Cambaraspora floridanus	Floridian crayfish, *Procambarus paeninsulanus*	**USA**	[1992]
Glugea anomala	Fish *Gasterosteus aculeatus*, *G. Pungitius* and *Gobius minutus* (ditches, stream)	France, UK, Russia, Germany, Belgium,	[1993, 1994]
Glugea hertwigi	Rainbow Smelt *Osmerus mordax* (lake)	Canada	[1995–1999]
Glugea mesocotti	Fish *Mesocottus haitej* (river)	Russia	[2000]
Glugea plecoglossi	Ayu *Plecoglossus altivelis altivelis*	**China**	[2001]
Glugea stephani	Fish	France, UK, United States and Russia	[2002]
Loma myrophi	Fish *Myrophis platyrhynchus* (river)	Brazil	[2003]
Loma psittaca	Fish *Colomesus psittacus* (river)	**Brazil**	[2004]
Loma salmonae	Fish *Oncorhynchus* sp. (rearing tanks)	Canada	[2005]
Pseudoloma neurophilia	Zebrafish *Danio rerio* (laboratroy colony)	**USA**	[2006, 2007]
Spragueidae			
Apotaspora heleios	Grass shrimp *Palaemonetes paludosus* (wetland)	**USA**	[2008]
Microgemma hepaticus	Grey mullet, *Chelon labrosus*	–	[2009]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Microgemma hepaticus	Grey mullet, *Chelon labrosus*	–	[2009]
Potaspora aequidens	Fish *Aequidens plagiozonatus* (river)	**Brazil**	[2010]
Potaspora macrobrachium	Prawn *Macrobrachium nipponense* (pond)	**China**	[2011]
Potaspora morhaphis	Teleostean fish, *Potamorhaphis guianensis* (river)	**Brazil**	[2012]
Pseudokabatana alburnus	Topmouth culter (*Culter alburnus*) (lake)	**China**	[2013]
Thelohaniidae			
Cucumispora dikerogammari	Amphipod *Dikerogammarus villosus* (reservoir, river)	**France, Poland,** Ukraine	[2014]
Cucumispora ornata	Amphipod *Dikerogammarus haemobaphes* (river)	**UK**	[2015]
Cucumispora roeselii	Amphipod *Gammarus roeseli* (stream)	**Poland**	[2016]
Napamichum aequifilum	Aquatic mite *Limnochares aquatica*	Sweden	[2017]
Napamichum cellatum	Midge *Endochironomus* sp. larva (pond)	Sweden	[2018]
Nudispora biformis	Dragonfly *Coenagrion hastulaturn* (bog)	Sweden	[2019]
Thelohania contejeani	Crayfish *Paranephrops planifrons*, white-clawed crayfish *Austropotamobius pallipes*	New Zealand, **Italy**	[2020, 2021]
Thelohania fibrata	*Simulium damnosum* larva (river), *Simulium venustum/verecundum* complex larva (cove)	Canada, Nigeria	[1945, 1946]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Thelohania montirivulorum	Crayfish, *Cherax destructor*	Australia	[2022, 2023]
Thelohania varians	Blackfly *Simulium tuberosum* (pond) and *S. venustum* (river) larva	Canada	[1946]
Unikaryonidae			
Dictyocoela diporeiae	Amphipod *Diporeia* sp. (lake)	**USA**	[2024]
Dictyocoela muelleri	Amphipod *Gammarus duebeni celticus, G. roeseli* (lake)	**Ireland**	[2025]
Unikaryon moniezi	*Eucyclops macrurus* (lake)	Russia	[2026, 2027]
Unikaryon piriformis	Trematode larvae from aquatic snails	Malaysia	[2028]
Unikaryon pfeifferi	*Acanthocyclops viridis* (lake)	Russia	[2026, 2029]
Unikaryon vrevi	*Macrocyclops distinctus* (lake)	Russia	[2026, 2029]
Glugeida genus *incertae sedis*			
Triwangia caridinae	Shrimp, *Caridina formosae*	**China**	[2030]
NEOPEREZIIDA			
Berwaldiidae			
Berwaldia schaefernai	*Daphnia* sp. Drinking water	Czech Republic	[2031]
Berwaldia daphniae	*Daphnia magna* from inland pool	Siberia	[2032]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Triwangia caridinae	Shrimp, *Caridina formosae*	**China**	[2030]
Berwaldia singularis	*Daphnia pulex* (pool)	Sweden	[2033]
Fibrillanosema crangonycis	Amphipod *Crangonyx pseudogracilis* (pond)	**UK**	[2034]
Neopereziidae			
Bacillidium strictum	Oligochaete *Limnodrilus hoffmeisteri* (stream)	Sweden	[2035]
Bacillidium vesiculoformis	Oligochaete *Nais simplex* (aquarium)	**Scotland**	[2036]
Bryonosema plumatellae	*Plumatella nitens*, freshwater bryozoan	**USA**	[2037]
Bryonosema tuftyi	*Plumatella* sp., freshwater bryozoans (lake)	**UK**	[2037]
Neoperezia chironomi	*Chironomus plumosus* (lake)	**Russia**	[2038]
Neoperezia semenovaiae	*Chironomus plumosus* (lake)	**Russia**	[2038, 2039]
Pseudonosema cristatellae	*Cristatella mucedo*, a freshwater bryozoan (lake)	**UK**	[2037]
Schroedera airthreyi	Bryozoan *Plumatella* sp.	**UK**	[2040]
Schroedera plumatellae	Bryozoan *Plumatella fungosa*	**Scotland**	[2041]
Trichonosema algonquinensis	Bryozoan *Pectinatella magnific* (lake)	**Canada**	[2042]
Trichonosema pectinatellae	Freshwater bryozoan, *Pectinatella magnifica* (lake)	**USA**	[2037]
Janacekia tainanus	*Kiefferulus tainanus*	China	[2043]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Neopereziida genera *incertae sedis*			
Janacekia adipophila	Midge *Ptychoptera paludosa* (river)	Sweden	[2044]
Janacekia tainanus	Midge *Kiefferulus tainanus* (pond)	**China**	[2043]
Systenostrema alba	Dragonfly *Aeshna grandis* larva (pond), *A. viridis* (reservoir)	**Russia**, Sweden	[2045, 2046]
Systenostrema candida	Dragonfly *Libellula quadrimaculata* larva (pond)	Sweden	[2045]
NOSEMATIDA			
Enterocytozoonidae			
Paranucleospora theridion	Salmon Louse *Lepeophtheirus salmonis*, Atlantic Salmon *(Salmo salar)* (farm)	**Norway**	[2047]
Mrazekiidae			
Helmichia aggregata	Midge *Endochironomus* sp. larva (lake)	Russia	[2048]
Helmichia anomala	Midge larva *Microtendipes pedellus* (polluted pond)	Poland	[2049]
Helmichia glandulicola	Midge *Chironomus anthracinus* larva (lake)	Norway	[2050]
Helmichia lacustris	Midge *Chironomus plumosus* larva (lake)	**Russia**	[2048, 2051]
Jirovecia sinensis	Oligochaete, *Branchiura sowerbyi*	China	[2052]
Mrazekia cyclopis	Copepod *Acantho cyclop s americanus* (pond)	Czechoslovakia	[2053, 2054]
Nosematidae			

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Nosema eurytremae	*Echinoparyphium dunni, Echinostoma hystricosum* and *Echinostoma malayanum, trematode* larvae of -water snails	Malaysia	[2055]
Nosema granulosis	Amphipod *Gammarus duebeni celticus, G. roeseli* (lake)	**Ireland**	[2025]
Nosema pimephales	Fish *Pimephales promelas* (lake)	Canada	[1999]
Nosema vasicola	*Echinoparyphium dunni* and *Echinostoma audyi*, trematode larvae snails	Malaysia	[2028]
Vairimorpha austropotamobii	*Austropotamobius pallipes* complex, subspecies *Austropotamobius italicus carsicus* (stream)	**Italy**	[2021]
Vairimorpha cheracis	Freshwater crayfish, *Cherax destructor*	**Australia**	[2056]
Vairimorpha austropotamobii	White-clawed crayfish, *Austropotamobius pallipes*	Italy	[2021]
Ordosporidae			
Ordospora colligata	*Daphnia magna* (pond)	Germany, UK	[2057]
Nosematida genera *incertae sedis*			
Anisofilariata chironomid	Midge *Chironomus plumosus* larva (lake)	**Russia**	[2058]
Crispospora chironomid	Midge *Chironomus plumosus* larva (lake)	**Russia**	[2059]
Enterocytospora artemiae	Shrimp *Palaemonetes sinensis* (paddy field)	**China**	[2060]
Glugoides intestinalis	*Daphnia magna* and *Daphnia pulex*	Czech Republic, UK	[2061]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
MICROSPORIDEA families *incertae sedis*			
Cougourdellidae			
Cougourdella coryniformis	Copepod *Macrocyclops albidus* (lake)	Russia	[2062, 2063]
Cougourdella polycentropi	*Hydropsyche saxonica* larva (stream)	Sweden	[2064]
Duboscqiidae			
Duboscqia sidae	*Holopedium gibberum* (lake)	Ontario, Canada	[2065]
Tardivesicula duplicata	Caddis fly *Limnephilus centralis* (temporary pool)	Sweden	[2066]
Trichoduboscqia epeori	*Rhithrogena iridina* nymph (stream bed)	Germany	[2067]
Fibrillasporidae			
Fibrillaspora daphniae	*Daphnia magna* (inland pool)	**Russia**	[2032]
Golbergiidae			
Krishtalia pipiens	Mosquito *Culex pipiens pipiens*, *Cx. pipiens* form *molestus*, *Cx. Theileri* larva (artificial container with heavily polluted water)	Ukraine	[2068]
Microfilidae			
Microfilum brevirostris	Teleostean fish *Brachyhypopomus brevirostris*	Brazil	[2069]
Microfilum lutjani	Golden African snapper *Lutjanus fulgens* (river)	Senegal	[2070]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Neonosemoidiidae			
Neonosemoides tilapie	Cichlid fish *Sarotherodon melanotheron, Tilapia guineensis and T. Zillii*	Benin, Senegal	[2070, 2071]
Pleistophoridae			
Heterosporis sutherlandae	Fish *Perca flavescens, Sander vitreus)* (lake)	**USA**	[2072, 2073]
Ovipleistophora diplostomuri	Fish and trematodes, crayfish *Procambarus bivittatus*, sunfish *Lepomis macrochirus* (lake)	**USA**	[2074, 2075]
Ovipleistophora ovariae	Golden Shiner *Notemigonus crysoleucas*, Ruffe *Gymnocephalus cernuus* (lake)	**Finland**	[2076, 2077]
Pleistophora beebei	Fish *Brachyhypopomus beebei* (river)	**Brazil**	[2078]
Pleistophora gigantea	Fish *Crenilabrus melops*	–	[2079]
Pleistophora hyphessobryconis	Neon tetra disease of aquarium fishes (Characidae, Cyprinidae, Cyprinodontidae, Poecilidae, Cichlidae), including *Danio rerio* and *D. Nigrofasciatus*	Cosmopolitan	[1937]
Pleistophora mirandellae	Cyprinid fish (river)	France	[2080]
Pleistophora muelleri	Amphipod *Gammarus duebeni celticus*	**Ireland**	[2025, 2081, 2082]
Vavraia multispora	*Simulium damnosum* larva (river)	Nigeria	[1945]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Toxoglugeidae			
Toxospora volgae	Midge *Corynoneura* (reservoir)	Russia	[2083]
Tuzetiidae			
Pankovaia semitubulata	Mayfly *Cloeon dipterum* nymph (floodplain pond)	Russia	[2084]
Paratuzetia kupermani	Procercoid of *Khawia armeniaca* found in oligochaetes *Potamothrix hammonensis* (lake)	Armenia	[2085]
Tuzetia boeckella	Copepod *Boeckella triarticulata* (artificial lake)	Australia	[2086]
Tuzetia ceriodaphniae	*Ceriodaphnia affinis, C. reticulata* (lake)	Russia	[2062]
Tuzetia diaphanosomae	*Diaphanosoma brachyurum* (lake)	Russia	[2062]
Tuzetia dualis	Mayfly *Cloeon dipterum* nymp (floodplain pond)	Russia	[2087]
Tuzetia tschernischovae	*Daphnia cucullata* larva (lake)	Russia	[2062]
MICROSPORIDEA genera *incertae sedis*			
Baculea daphniae	*Daphnia pulex*	France	[2088]
Caullerya mesnili	*Daphnia galeata x hyalina*	Switzerland	[2089]
Evlachovaia chironomi	Midge *Chironomus plumosus* larvae (lake)	Russia	[2039]
Globulispora mitoportans	*Daphnia* spp.	Czech Republic	[2090]
Gurleyides biformis	*Ceriodaphnia reticulata, C. affinis* (lake)	Russia	[2062]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Hamiltosporidium magnivora	*Daphnia* spp. (ponds)	UK, Belgium, Russia	[2091]
Hamiltosporidium tvaerminnensis	Parasite of *Daphnia magna* (pools)	Finland, Sweden, Skerry Islands of the Baltic Sea	[2091]
Haplosporidium companulatum	Snails *Physella parkeri, Lymnaea stagnalis*	USA	[2092, 2093]
Haplosporidium diporeiae	*Diporeia* sp. (Amphipoda, Gammaridea)	USA	[2094]
Haplosporidium limnodrili	oligochaetes *Limnodrilus udekemianu*	–	[2095]
Haplosporidium pickfordi	Snails *Physella parkeri, Lymnaea stagnalis*	USA	[2092, 2093]
Haplosporidium raabei	Zebra mussels *Dreissena polymorpha*, Meuse River	France	[2096]
Holobispora thermocyclopis	*Thermocyclops oithonoides, T. leuckarti* (lake)	Russia	[2062]
Kabataia rondoni	Teleost *Gymnorhamphichthys rondoni,*	Brazil	[2097]
Kabatana takedai	Freshwater fish, *Pangasius sutchi*	Asia	[2098]
Microsporidium brevirostris	Teleostean *Brachyhypopomus brevirostris*	Amazon, Brazil	[2069]
Microsporidium chironomid	Midge *Chironomus dorsalis* larva (water basin)	Russia	[2026, 2099]
Microsporidium epithelialis	Tubificid worms *Tubifex* sp. (commercial aquarium)	Germany	[2100]
Microsporidium fluviatilis	Copepod *Eucyclops serrulatus* (river)	Russia	[2101]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Microsporidium jiroveci	*Cyclops vicinus* (lake)	Russia	[2029, 2062]
Myosporidium ladogensis	Burbot *Lota lota* from Lake Haukivesi	Finland	[2102]
Microsporidium lamproglenae	Freshwater copepod *Lamproglena pulchella* and cyprinid fish, *Leuciscus leuciscus*	Europe	[2102]
Microsporidium luciopercae	Freshwater pike-perch *Sander lucioperca*	Finland	[2103]
Microsporidium spraguei	Freshwater pike-perch *Sander lucioperca*	Finland	[2103]
Stempellia diaptomi	Copepod *Diaptomus gracilis* (lake)	Russia	[2104]
Rozellomycota genera *incertae sedis*			
Mitosporidium daphniae	Parasite of the water flea *Daphnia magna*	**UK**	[2105]
Paramicrosporidium saccamoebae	Parasite of *Saccamoeba* sp; freshwater pond	**Germany**	[2106]
Rozella achlyae	*Achlya flagellata*	USA	[2107]
Rozella allomycetis	*Allomyces arbusculus*	Germany, USA	[2107]
Rozella apodyae	*Apodachlya brachynema*	France	[2107]
Rozella blastocladiae	*Blastocladia pringsheimii, B. gracilis*	USA, Denmark, Germany	[2107]
Rozella canterae	*Chytridium oedognii*	UK	[2107]

Table 7.16 (continued)

Species	Animal host	Distribution	Reference
Rozella chytriomycetis	*Chytriomyces*	UK	[2108]
Rozella cladochytrii	*Nowakowskiella profusum*, *N. elegans*, *N. ramosum*, *Cladochytrium replicatum*, *C. crassum*, and *C. hyalinum*	USA	[2107]
Rozella coleochaetes	Parasitic on Coleochaete sp.; bog		[2107]
Rozella diplophlyctidis	*Diplophlyctis intestina*		[2107]
Rozella endochytrii	Sporangia of *Endochytrium operculatum*; swamp	Brazil, USA	[1764, 2109]
Rozella monoblepharidis	*Monoblepharis polymorpha*, and *M. macrandra*	Germany, France	[2107]
Rozella multimorpha	Parasitic on *Pythium* sp.; Pond	USA	[2107]
Rozella parva	Parasitic on *Zygorhizidium affluens*; lakes	UK	[1770]
Rozella polyphagi	*Polyphagus laevis*	UK	[2107]
Rozella rhipidii	*Araiospora*	France	[2107]
Rozella rhizoclosmatii	Parasitic on *Rhizoclosmatium*; Pond	USA	[2107]
Rozella rhizophydii	*Rhizophydium globosum*	Brazil	[1848]
Rozella septigena	*Achyla*, *Saprolegnia*	France	[2107]

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CHAPTER 8

CONCLUSION

8.1 Overall Conclusion

This thesis has explored several facets concerning the taxonomy, phylogeny, classification, and online database of aquatic fungi. The aim of this chapter is to summarize all the data gathered from the previous chapters and the generated information that contributed to the current understanding of aquatic fungal research.

The exploration of freshwater habitats in Thailand resulted in discoveries of novel fungi from Dothideomycetes (six species under Pleosporales) [*Halobyssothecium bambusicola* (Lentitheciaceae), *Camposporium dulciaquae* (Melanommataceae), *Brunneofusispora hyalina* (Occultibambusaceae), *Wicklowia phuketensis* (Wicklowiaceae)], Sordariomycetes (one genus *Neoxylomyces*, three species) [*Rattania aquatica* (Chaetosphaeriaceae), *Neoxylomyces multiseptatus* (Phyllachorales genera *incertae sedis*), *Phaeoacremonium thailandense* (Togniniaceae), and Ascomycota genera *incertae sedis* (1 species *Mycoenterolobium aquadictyosporium*). These novel taxa show that Thailand has high undiscovered diversity of fungi in lotic habitats. In fact, based on the published work that we reviewed from 2015–2020, 40 novel pleosporolean taxa and 40 new species of Sordariomycetes were discovered from freshwater habitats in Thailand (Figure A2). In the present study, we also provided the phylogenetic placement of *Mycoenterolobium* within Pleosporomycetidae.

The collection of plant substates from aquatic habitats resulted in the isolation of novel Lentitheciaceae species wherein two genera, *Halobyssothecium* and *Lentithecium*, were assessed and revised. Three novel species of *Halobyssothecium* were introduced (*H. bambusicola*, *H. phragmitis*, *H. versicolor*), and five species of *Lentithecium* were transferred to *Halobyssothecium* (*L. cangshanense*, *L. carbonneanum*, *L. kunmingense*, *L. unicellulare*, and *L. voraginesporum*). Asexual morph of *Lentithecium lineare* was collected and phylogenetic analysis confirmed its

taxonomic placement in *Keissleriella*. In the present taxonomic revision, *Halobysso-thecium* has brown and versicolored ascospores without sheath and hyaline conidia, while *Lentithecium* species possess hyaline ascospores with mucilaginous sheaths. We provided notes based on multi-locus phylogenetic analysis to members of Lentitheciaceae. The continuous exploration of different aquatic habitats and the introduction of new fungal species have significantly contributed to the taxonomic revision of fungal taxa. Protein genes are very helpful also in the accurate delineation of taxa and assessment of their genetic relatedness.

As more taxa were isolated with detailed morphological descriptions supported by molecular data, the emergence of a more natural classification of the fungi starts to develop and progress. This can be shown from the recent taxonomic outline of fungi and fungus-like taxa [204, 2110], which includes a more stable classification of fungal taxa [4, 5, 7, 21–23, 29, 36]. In the present work, the taxonomic outline of salt marsh fungi is provided with 486 taxa listed in this ecosystem. A total of 463 taxa (95.27%) of Ascomycota were recorded from salt marsh ecosystems followed by Basidiomycota (19 taxa), and Mucoromycota (four taxa). The most extensively studied halophyte is *Juncus roemerianus*, with 162 documented taxa, followed by *Phragmites australis* (137 taxa) and *Spartina alterniflora* (79 taxa). Atlantic Ocean countries have the highest number of salt marsh fungi recorded, with the USA having the highest number of species recorded (232 taxa), while China (165 taxa) and India (16 taxa) had the highest number of salt marsh fungi in the Pacific Ocean and the Indian Ocean, respectively.

The classification of basal and higher freshwater fungi has been updated and numbers were provided based on the scattered taxonomic papers and biodiversity studies. Freshwater fungal taxa listed in this study total to 3,870 species with representatives from 13 phyla: Ascomycota (2,968 species, 1,018 genera), Chytridio-mycota (333 species, 97 genera), Rozellomycota (221 species, 105 genera), Basidiomycota (218 species, 100 genera), Blastocladiomycota (47 species, ten genera), Monoblepharomycota (29 species, six genera), Mucoromycota (19 species, ten genera), Aphelidiomycota (15 species, three genera), Entomophthoromycota (six species, four genera), Mortierellomycota (five species, three genera), Olpidiomycota (four species, one genus), Zoopagomycota (three species, two genera), and Sanchytriomycota (two

species, two genera). The freshwater fungal numbers listed, 3,870 species, are within the estimated range suggested by Jones et al. [174], around 3,069-4,145.

The scattered taxonomic information of fungi from freshwater habitats are presently collated on the website www.freshwaterfungi.org. The list of taxa generated from the review in Chapter 7 was uploaded to the *Outline* tab of the website. Each taxon in the outline is linked to *Archive*, wherein description, photographic plate (if available), and notes were provided, including references linked to the original article.

8.2 Research Advantages

The present research work adds to the increasing number of novel aquatic fungal taxa from Thailand, the UK, and Sweden. Detailed morphological illustrations, descriptions, and notes were provided for the novel and extant taxa. Updated phylogenetic trees for Chaetosphaeriaceae, Melanommataceae, Occultibambusaceae, Togniniaceae, Wicklowiaceae, and related taxa were provided also. The sequence data for *Mycoenterolobium* was obtained and their closed affinity with Testudinaceae was elucidated. Since morphology of *Mycoenterolobium* and taxa under Testudinaceae are vastly different, we placed the latter in Pleosporales *incertae sedis* until further taxon sampling is undertaken. We also compared *Mycoenterolobium* to their morphologically similar taxa *Cancellidium*. Our collections of aquatic fungi enable us to delineate the closely related genera, *Halobyssothecium* and *Lentithecium*, and provided an updated backbone tree of Lentitheciaceae.

The list of Calado and Barata [260] was updated in the present study and outlined the taxa based on the recent classification of fungi by Wijayawardene et al. [204]. We also included additional 27 genera (11 families) of halophytes. The comprehensive review of fungal associations in salt marsh plants gave the present numbers of salt marsh fungi, including the host plant associations, host part where the fungus was observed, life mode, and distribution.

The present work also gave us a comprehensive account of fungal classification from freshwater habitats. We provided the fungal numbers and outline the taxa based on the recent classification of fungi by Wijayawardene et al. [204, 2110]. Though the list is not exhaustive and does not reflect the overall diversity of freshwater fungi, the

provided number gives an idea of the species composition, distribution, and habitat type of freshwater fungal taxa to better understand their biology, biodiversity, and ecology.

8.3 Future Work

The present work gave us an overview of how diverse fungi in aquatic habitats are. Saprobic aquatic fungi from an unidentified submerged decaying wood are mostly studied substrates for taxonomic studies. For example, most of the studies on freshwater Ascomycota focus on the observation of unidentified submerged decaying plant substrates with few reports on fungal associates on a plant host. There are also less studied host plants and their associated fungi, and this holds true to salt marsh plants wherein most studies of fungi on halophytes are from *Spartina*, *Juncus*, and *Phragmites,* probably due to the huge biomass generated by these taxa. The mycota of less bulky halophytes (e.g., *Limonium, Triglochin, Uniola*) and litter from the surrounding seagrass beds washed off to marsh areas (e.g., *Zostera japonica, Z. marina*, *Z. noltii*) are also less represented, or these hosts are yet to be explored. There are few reports and documentations also on ascomycetous and basidiomycetous yeasts, Basidiomycota, and basal fungal lineages on aquatic habitats. Lignicolous aquatic fungi are mostly reported and to expand the information on the ecological roles and lifestyles of these fungi, research on the diversity of endophytes and pathogens and their interaction in the aquatic habitats is of foremost importance. Ecological studies are lacking in the aquatic habitats of Thailand and other countries or regions (e.g., Africa, South America, Australasia, some Asian countries) wherein most of the work was undertaken a decade(s) ago. Most of these biodiversity studies also did not employ molecular identification of fungal taxa and since latest works on freshwater fungi and marine fungi taught us that there could be a number of additional new species within a certain genus and its diversity could be much higher than anticipated.

In the aquatic fungal classification, there are a huge number of taxa that still have uncertain placements brought upon by the lack of living cultures and unavailability of the sequence data of the type species. Recollections of these specimens in the area where they were previously identified and obtaining their sequence data, either by direct sequencing of the fruiting bodies or mycelial extraction, can provide a

better understanding of their phylogenetic placements and evolutionary relationships. In addition, a comprehensive sample collection for fungal observation exploring underexplored and unexploited aquatic habitats in different geographical regions, on various substrates, including aquatic plants, and obtaining their sequence data will lead to a more natural classification system of this ecological group. In addition to the fungal molecular information, genome sequencing, a comprehensive method for analyzing entire genomes of an organism, has become an ultimate source of phylogenetically informative characters that is affordable and efficient. The availability of genome sequences provides a wealth of data on metabolic diversity within the fungal kingdom, including but not limited to the mapping of the phenotypic trait onto the phylogeny and comparison to the evolution of individual genes, evolutionary rates of gene sequences, gene family origins, gene presence/absence and gene duplication and loss patterns. Few aquatic fungi have their genome sequenced and could be the next focus and trend for aquatic mycologists.

Future works on aquatic fungi should also focus on various ecological studies and it include but not limited to: (1) interaction of marine fungi with wood-boring animals; (2) pre-colonization for fungal competition studies; (3) vertical and horizontal distribution of aquatic fungi; (4) wood-decay fungi and the utilization of substrates; (5) world distribution of aquatic fungi in response to climate change. Studies on interaction of aquatic fungi with their biotic and abiotic surroundings, including cellular responses to environmental stress needs further exploration also. Biochemical studies are needed also to further assess the contribution of aquatic fungi to aquatic microbial biomass and organic matter reservoirs, and the cycling of carbon and nutrients.

8.4 Publication

First author publications

Calabon, M. S., Hyde, K. D., Gentekaki, E., Jones, E. B. G., Phookamsak, R., Doilom, M., Boonmee, S., & Promputtha, I. (2020). *Wicklowia phuketensis* (Wicklowiaceae, Pleosporales), a novel freshwater taxon from Thailand. *Phytotaxa*, *452*(1), 55–64. https://doi.org/10.11646/phytotaxa.452.1.5

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APPENDICES

APPENDIX A

PUBLICATIONS

Journal of *Fungi*

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Review

Fungal Biodiversity in Salt Marsh Ecosystems

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Abstract: This review brings together the research efforts on salt marsh fungi, including their geographical distribution and host association. A total of 486 taxa associated with different hosts in salt marsh ecosystems are listed in this review. The taxa belong to three phyla wherein Ascomycota dominates the taxa from salt marsh ecosystems accounting for 95.27% (463 taxa). The Basidiomycota and Mucoromycota constitute 19 taxa and four taxa, respectively. Dothideomycetes has the highest number of taxa, which comprises 47.12% (229 taxa), followed by Sordariomycetes with 167 taxa (34.36%). Pleosporales is the largest order with 178 taxa recorded. Twenty-seven genera under 11 families of halophytes were reviewed for its fungal associates. *Juncus roemerianus* has been extensively studied for its associates with 162 documented taxa followed by *Phragmites australis* (137 taxa) and *Spartina alterniflora* (79 taxa). The highest number of salt marsh fungi have been recorded from Atlantic Ocean countries wherein the USA had the highest number of species recorded (232 taxa) followed by the UK (101 taxa), the Netherlands (74 taxa), and Argentina (51 taxa). China had the highest number of salt marsh fungi in the Pacific Ocean with 165 taxa reported, while in the Indian Ocean, India reported the highest taxa (16 taxa). Many salt marsh areas remain unexplored, especially those habitats in the Indian and Pacific Oceans areas that are hotspots of biodiversity and novel fungal taxa based on the exploration of various habitats.

Keywords: halophytes; marine fungi; marine mycology; salt marsh fungi; worldwide distribution

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1. Introduction

Salt marsh ecosystems are known for their high productivity, exceeding primary production estimates of species rich ecosystems (e.g., tropical rainforests, coral reefs) [1]. The flora in salt marsh ecosystems is mainly composed of grasses, herbs, and shrubs and these are terrestrial organisms variously adapted to, or tolerant of, a semi-marine environment. Halophytes are a diverse group of plants that have a worldwide distribution, and grow in different climatic regions, wherein soils have high salinity levels [2]. Halophytes are common in temperate and Mediterranean climates, and fewer both in the tropics and at high latitudes [3–6]. The vegetation in these ecosystems shows the vertical zonation of different communities as tidal submergence decreases with increasing elevation, and species tolerance to changing gradient conditions. Salt marsh vegetation generally increases the attenuation of both tidal currents and waves as they pass over the vegetated area and immobilize elements with their sediments. Furthermore, halophytes serve as a natural buffer, protecting other shoreline ecosystems from human impacts and disturbances. The

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ORIGINAL ARTICLE

Phylogenetic assessment and taxonomic revision of *Halobyssothecium* and *Lentithecium* (Lentitheciaceae, Pleosporales)

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Abstract
Our studies on lignicolous aquatic fungi in Thailand, Sweden, and the UK resulted in the collection of three new *Halobyssothecium* species (*H. bambusicola*, *H. phragmitis*, *H. versicolor*) assigned to Lentitheciaceae (Pleosporales, Dothideomycetes). Multi-loci phylogenetic analyses of the combined large subunit, small subunit, internal transcribed spacers of ribosomal DNA, and the translation elongation factor 1-alpha sequence data enabled a revision of the taxa assigned to *Lentithecium* and the transfer of *L. cangshanense*, *L. carbonneanum*, *L. kunmingense*, *L. unicellulare*, and *L. voraginesporum* to *Halobyssothecium*. Collection of an asexual morph of *L. lineare* and phylogenetic analysis confirmed its taxonomic placement in *Keissleriella*. Detailed descriptions and illustrations of *H. bambusicola*, *H. phragmitis*, and *H. versicolor* are provided.

Keywords 3 new taxa · Dothideomycetes · Freshwater fungi · Marine fungi · Multi-locus phylogeny

Introduction

Pleosporales, typified by *Pleospora herbarum* (Pers.) Rabenh. (Pleosporaceae), was formally established by Luttrell and Barr (in Barr 1987) and characterized by perithecioid ascomata, usually with a papillate apex, ostiolate, cellular pseudoparaphyses, and bitunicate asci. Phylogenetic studies of Pleosporales have been provided by Schoch et al. (2009), Zhang et al. (2009a, 2012), Hyde et al. (2013), Liu et al. (2017), and Hongsanan et al. (2020). Lumbsch and Huhndorf (2010) included 28 families and 175 genera in Pleosporales, with 12 genera listed under Pleosporales, genera *incertae sedis*. Hyde et al. (2013) accepted 88 families in Pleosporales. Wijayawardene et al. (2020) and Hongsanan

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Journal of *Fungi*

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Article

Five Novel Freshwater Ascomycetes Indicate High Undiscovered Diversity in Lotic Habitats in Thailand

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Abstract: An investigation of freshwater fungi in Thailand resulted in the collection of one new monotypic genus, *Neoxylomyces*, and a novel species each in *Camposporium*, *Brunneofusispora*, *Rattania*, *Neoxylomyces*, and *Phaeoacremonium*. *Camposporium dulciaquae* resembles *C. septatum* in conidial morphology and number of septa but differs in conidial sizes. *Brunneofusispora hyalina* is similar to *B. sinensis* in conidiogenesis and conidial shape but differs in the sizes of conidiomata and conidiogenous cells. *Rattania aquatica* is the second species in *Rattania*, while *Phaeoacremonium thailandense* is the third species recorded from freshwater habitats. A new genus, *Neoxylomyces*, typified by *N. multiseptatus*, is similar to *Xylomyces giganteus*, but differs in the number of septa, chlamydospore measurements, and absence of a mucilaginous coating around the chlamydospores. These novel taxa form an independent lineage distinct from other species based on multi-loci phylogenetic analyses. Descriptions, illustrations, and notes are provided for each taxon. These new freshwater ascomycetes add to the increasing number of fungi known from Thailand and it is now evident that there are numerous novel taxa awaiting to be described as new freshwater habitats are explored. An update of newly discovered taxa in the widely studied freshwater habitats of Thailand over the last five years is also provided.

Keywords: 6 new taxa; aquatic fungi; Dothideomycetes; freshwater fungi; multi-loci phylogenetic analyses; *Neoxylomyces*; Sordariomycetes; tropical mycology

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1. Introduction

Freshwater fungi are a diverse and heterogenous taxonomic group occurring on a wide variety of substrates and with a global distribution [1–4]. Jones et al. [2] estimated the number of freshwater fungi to be between 3069–4145, which is lower as compared to marine fungi with an estimated 12,500 species [5,6]. There are 1898 species under 767 genera of marine fungi listed in www.marinefungi.org (accessed on 13 January 2021) [6], but there are no recent published reports of freshwater fungal numbers [2,7]. An online platform on freshwater fungi, www.freshwarterfungi.org (accessed on 13 January 2021). is presently being compiled. This comprehensive database presently includes 451 species of freshwater

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ORIGINAL ARTICLE

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Mycoenterolobium aquadictyosporium sp. nov. (Pleosporomycetidae, Dothideomycetes) from a freshwater habitat in Thailand

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Abstract
A study of freshwater fungi in Thailand led to the discovery of *Mycoenterolobium aquadictyosporium* sp. nov. Evidence for the novelty and placement in *Mycoenterolobium* is based on comparison of morphological data. The new species differs from the type species, *M. platysporum*, in having shorter and wider conidia, and from *M. flabelliforme* in having much longer and wider conidia. The hyphomycetous genus *Mycoenterolobium* is similar to *Cancellidium* but differs in the arrangement of conidial rows of cells at the attachment point to the conidiophores. The conidia of the former are made up of rows of cells, radiating in a linear pattern from a single cell attached to the conidiophore, while in *Cancellidium*, adherent rows of septate branches radiate from the conidiophore. *Cancellidium* conidia also contain branched chains of blastic monilioid cells arising from the conidia, while these are lacking in *Mycoenterolobium*. At maturity in *Mycoenterolobium*, the two conidial lobes unite and are closely appressed. Phylogenetic analyses based on a combined LSU, SSU, ITS, *TEF1*-α, and *RPB2* loci sequence data support the placement of *Mycoenterolobium aquadictyosporium* close to the family Testudinaceae within Pleosporomycetidae, Dothideomycetes. The novel species *Mycoenterolobium aquadictyosporium* is described and illustrated and is compared with other morphologically similar taxa.

Keywords 1 new taxon · Freshwater hyphomycete · Asian mycology · Multi-locus analysis · Thailand

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Introduction

The incorporation of molecular data in phylogenetic and evolutionary studies has revolutionized the current knowledge of fungal systematics (Tanabe et al. 2005; Shenoy et al. 2006; Taylor and Berbee 2006; Choi and Kim 2017; Liu et al. 2017; Tedersoo et al. 2018; Naranjo-Ortiz and Gabaldón 2019; Samarakoon et al. 2019). Natural taxonomic placements of taxa and development of backbone trees based on molecular phylogeny have been possible (Ebersberger et al. 2012; He et al. 2019; Luo et al. 2019; Hongsanan et al. 2020; Hyde et al. 2020a; Wijayawardene et al. 2020). The knowledge of fungal taxonomy and classification are however limited as only approximately 8% (120,000 described taxa) of the 2.2 to 3.8 million estimated global fungal species are described (Hawksworth and Lücking 2017) and even fewer have been sequenced. Several authors have suggested areas as to where to find the "missing fungi," such as understudied countries and hosts, particularly in tropical regions and biodiversity hot spots, little explored habitats or niches, and cryptic species

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Wicklowia phuketensis (Wicklowiaceae, Pleosporales), a novel freshwater taxon from Thailand

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Abstract

An investigation of aquatic fungi in Thailand resulted in the collection and isolation of a new species of *Wicklowia* (Wicklowiaceae) from submerged wood. *Wicklowia phuketensis* sp. nov. differs from known species in morphology and multigene phylogenetic analyses. Both *W. submersa* and *W. phuketensis* lack appendages at both ends, while *W. aquatica* has basal appendages. *Wicklowia phuketensis* differs from other species in the dimensions of the ascomata, asci and ascospores. The combined LSU and SSU sequence data placed the new species within Wicklowiaceae.

Keywords: 1 new species, aquatic fungi, Dothideomycetes, multi-gene analysis, taxonomy, tropical mycology

Introduction

Freshwater fungi are broadly defined as any species, which rely on freshwater for the entirety or part of their life cycle (Thomas 1996). The number of freshwater fungal species has been estimated between 3,069–4,145 (Jones *et al.* 2014), which is lower when compared to marine fungi with an estimated 12,500 species (Jones 2011, Jones *et al.* 2019). Freshwater fungi are likely to be more numerous than marine fungi as many habitats and substrates are not well-explored. Furthermore, underrepresentation of some taxa and cryptic species may further underestimate diversity of freshwater taxa (Jones *et al.* 2014). In Thailand, 173 species belonging to 112 genera have been recorded from freshwater habitats as of 2010 (Zhang *et al.* 2011). Since then many additional novel taxa have been described bringing the number even higher (see Liu *et al.* 2018, Bao *et al.* 2019, Boonmee *et al.* 2019, Lin *et al.* 2019, Luo *et al.* 2019, Yang *et al.* 2019).

Recently, a species from the genus *Wicklowia*, *W. submersa* Boonmee, Sorvongxay & K.D. Hyde, was discovered in Thailand (Boonmee *et al.* 2019). This genus was introduced by Raja *et al.* (2010) to accommodate *Wicklowia aquatica* Raja, A. Ferrer & Shearer collected from submerged wood in freshwater habitats. Based on the LSU sequence data along with supporting morphological characteristics, Raja *et al.* (2010) placed the genus under *Pleosporales*

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REVIEW

Freshwater fungal numbers

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Abstract
A comprehensive account of fungal classification from freshwater habitats is outlined and discussed in the present review based on literature of biodiversity studies and recent morpho-phylogenetic analyses. A total of 3,870 freshwater fungal species are listed with additional details on the isolation source, habitat, geographical distribution, and molecular data. The Ascomycota (2,968 species, 1,018 genera) dominated the freshwater fungal taxa wherein Sordariomycetes (823 species, 298 genera) had the largest number, followed by Dothideomycetes (677 species, 229 genera), Eurotiomycetes (276 species, 49 genera), and Leotiomycetes (260 species, 83 genera). Other phyla included in the updated classification of freshwater fungi are: Chytridiomycota (333 species, 97 genera), Rozellomycota (221 species, 105 genera), Basidiomycota (218 species, 100 genera), Blastocladiomycota (47 species, 10 genera), Monoblepharomycota (29 species, 6 genera), Mucoromycota (19 species, 10 genera), Aphelidiomycota (15 species, 3 genera), Entomophthoromycota (6 species, 4 genera), Mortierellomycota (5 species, 3 genera), Olpidiomycota (4 species, 1 genus), Zoopagomycota (3 species, 2 genera), and Sanchytriomycota (2 species, 2 genera). The freshwater fungi belong to 1,361 genera, 386 families and 145 orders. The Pleosporales and Laboulbeniaceae are the largest freshwater fungal order and family comprised of 391 and 185 species, respectively. The most speciose genera are *Chitonomyces* (87, Laboulbeniomycetes), *Verrucaria* (50, Eurotiomycetes), *Rhizophydium* (52, Rhizophydiomycetes), *Penicillium* (47, Eurotiomycetes), and *Candida* (42, Saccharomycetes).

Keywords Fungal classification · Fungal taxonomy · Freshwater fungi · Higher fungi · Molecular taxonomy · Basal clades

Introduction

It has been over 140 years since Saccardo (1880) described the first freshwater hyphomycetes, *Heliscus lugdunensis* (≡ *Neonectria lugdunensis*). This was followed by the discovery of four novel taxa [*Tetracladium marchalianum*, *Clavariopsis aquatica*, *Lemonniera aquatica*, *Anguillospora longissima* (≡ *Amniculicola longissima*)] by de Wildeman (1893, 1894, 1895) from different freshwater habitats and on different substrates. Ingold's (1942) documentation of 16 freshwater hyphomycetous species, of which 10 are novel species, and identification of the typical habitat of freshwater fungi served as an impetus for further studies on the occurrence of fungal taxa, both sexual and asexual, in freshwater habitats (Ranzoni 1953; Tubaki 1957; Petersen 1962, 1963a, b; Nilsson 1964; Ingold 1975; Webster and Descals 1981; Tubaki et al. 1983; Dudka 1985; Nawawi 1985a; Goh and Hyde 1996c; Goh 1997; Sivichai et al. 2002; Shearer et al. 2004, 2007; Lu et al. 2018c; Luo et al. 2019; Dong et al. 2020b).

The classical methods used to document freshwater fungal composition have been significantly improved by recent developments in fungal identification using molecular techniques. In the classification of freshwater fungi, incorporation of molecular data in the analysis of extant and novel species provides a better understanding of the phylogenetic relationships of freshwater taxa (e.g., generic boundaries delimitation of polyphyletic taxa, resolving species complexes, linking asexual-sexual morphs, or synasexual morphs). Furthermore, continuous exploration of freshwater habitats led to introduction of many novel taxa (Lu et al. 2018c; Bao et al. 2020; Dong et al. 2020a; Hsieh et al.

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APPENDIX B

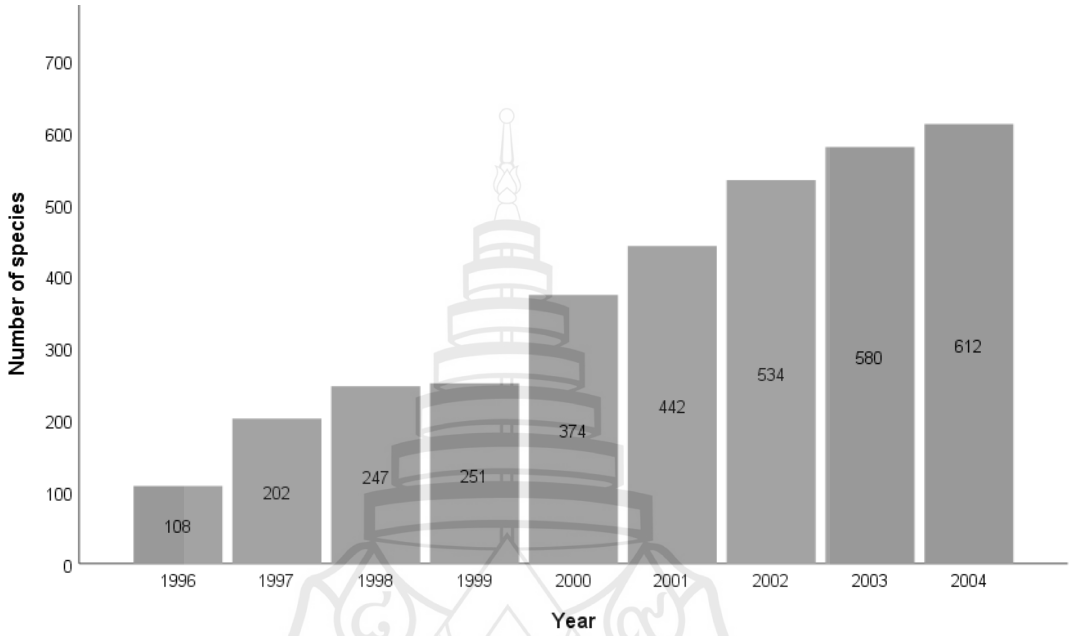


Figure B1 Annual cumulative number of freshwater fungi recorded for Thailand from 1996-2004. (Adapted from Sivichai and Boonyene [500])

APPENDIX C

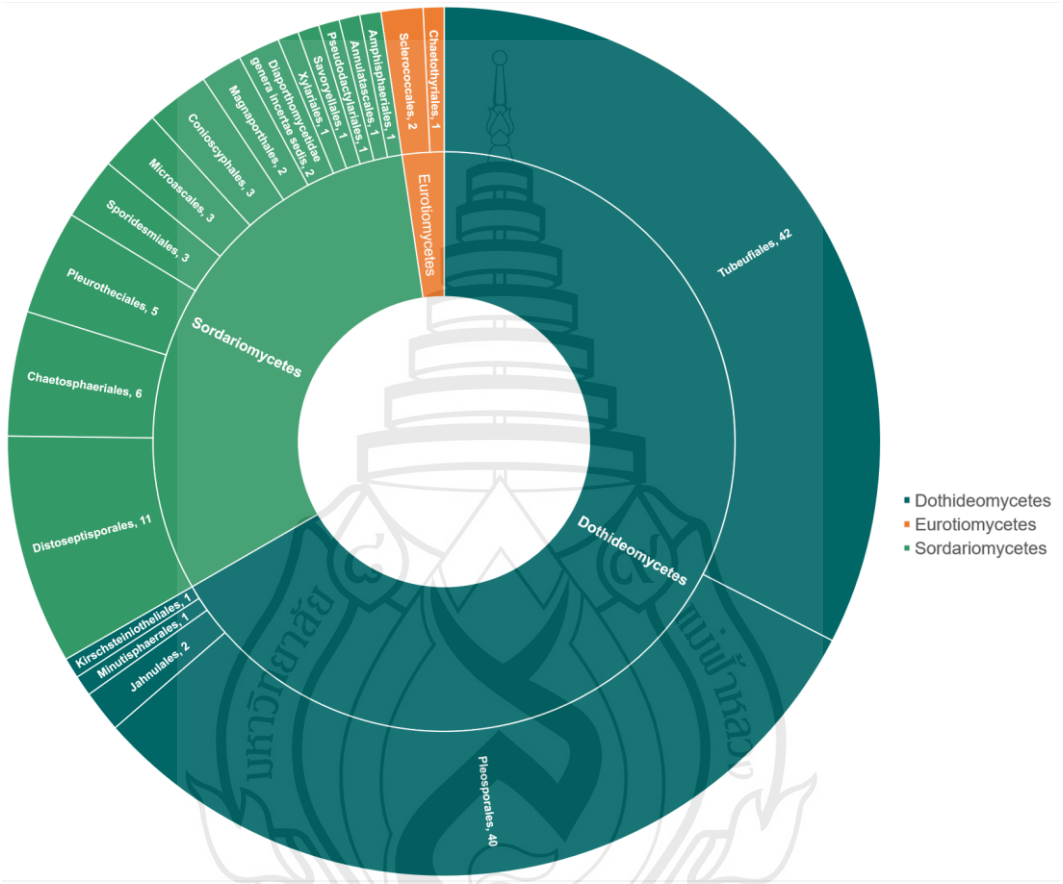


Figure C1 Classification of novel freshwater fungi discovered from Thailand from 2015–2020

APPENDIX D

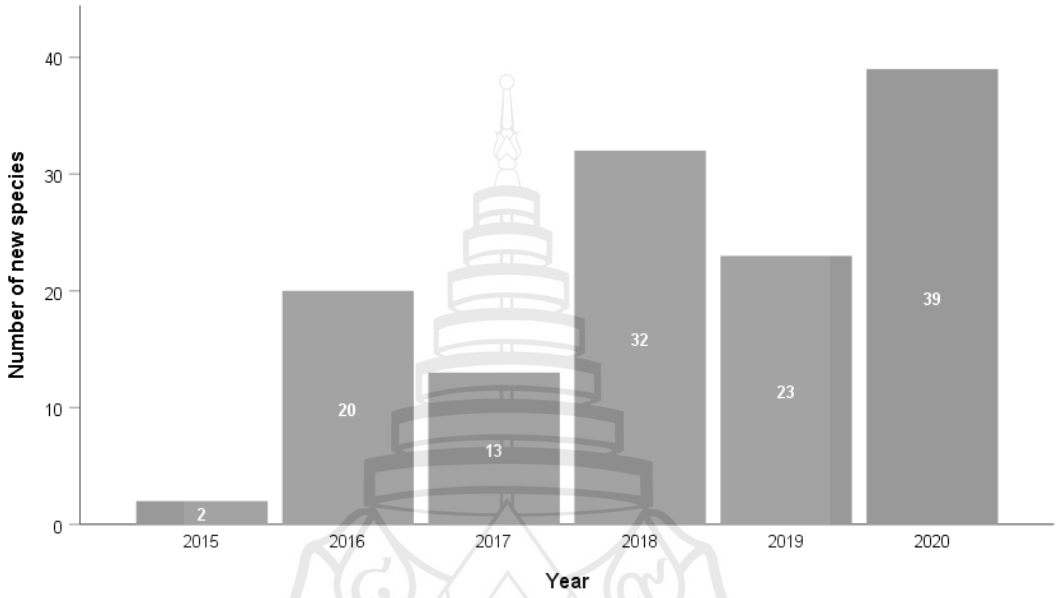


Figure D1 Total number of novel freshwater fungi discovered from Thailand from 2015–2020

APPENDIX E

Table E1 Freshwater fungi discovered from 2015–2020 in Thailand

Species	Habitat	Year	Life mode	Morph	References
DOTHIDEOMYCETES					
JAHNULALES					
Aliquandostipitaceae					
Ascagilis submersa	Stream	2020	Saprobic	Sexual	[7]
Ascagilis thailandensis	Stream	2020	Saprobic	Sexual	[7]
KIRSCHSTEINIOTHELIALES					
Kirschsteiniotheliaceae					
Kirschsteiniothelia rostrata	Stream	2017	Saprobic	Asexual[+]	[514]
MINUTISPHAERALES					
Acrogenosporaceae					
Acrogenospora thailandica	Stream	2019	Saprobic	Asexual[+]	[511]
PLEOSPORALES					
Aigialaceae					
Neoastrosphaeriella aquatica	-	2019	Saprobic	Sexual	[508]
Anteagloniaceae					
Purpureofaciens aquatica	Stream	2020	Saprobic	Sexual	[7]
Astrosphaeriellaceae					
Aquatospora cylindrica	Stream	2020	Saprobic	Sexual	[7]
Caryospora submersa	Stream	2020	Saprobic	Sexual	[7]
Dictyosporiaceae					
Dictyocheirospora rotunda	Stream	2016	Saprobic	Asexual[+]	[510]
Dictyocheirospora thailandica	Stream	2020	Saprobic	Asexual[+]	[7]
Dictyocheirospora vinaya	Stream	2016	Saprobic	Asexual[+]	[510]
Dictyosporium thailandicum	Stream	2015	Saprobic	Asexual[+]	[345]
Dictyosporium tratense	Stream	2018	Saprobic	Asexual[+]	[82]
Dictyosporium tubulatum	Stream	2018	Saprobic	Asexual[+]	[82]
Digitodesmium chiangmaiense	Stream	2019	Saprobic	Asexual[+]	[511]
Latoruaceae					
Pseudoasteromassaria aquatica	Stream	2020	Saprobic	Asexual[*]	[7]
Pseudoasteromassaria spadicea		2017	Saprobic	Asexual[*]	[415]

Table E1 (continued)

Species	Habitat	Year	Life mode	Morph	References
Lentitheciaceae					
Halobyssothecium bambusicola	Stream	2020	Saprobic	Asexual*	[20]
Poaceascoma aquaticum	Stream	2016	Saprobic	Sexual	[512]
Tingoldiago clavata	-	2020	Saprobic	Sexual	[513]
Tingoldiago hydei	-	2020	Saprobic	Sexual	[513]
Ligninsphaeriaceae					
Ligninsphaeriopsis thailandica	Stream	2020	Saprobic	Sexual	[22]
Lindgomycetaceae					
Hongkongmyces aquaticus	Stream	2020	Saprobic	Asexual*	[7]
Hongkongmyces thailandica	River	2017	Saprobic	Sexual	[514]
Lindgomyces aquaticus	Stream	2020	Saprobic	Sexual	[7]
Longipedicellataceae					
Longipedicellata aquatica	Stream	2020	Saprobic	Sexual	[7]
Pseudoxylomyces aquaticus	Stream	2020	Saprobic	Asexual+	[7]
Submersispora variabilis	Stream	2020	Saprobic	Asexual+	[7]
Lophiostomataceae					
Lentistoma aquaticum	Stream	2020	Saprobic	sexual	[7]
Melanommataceae					
Camposporium septatum	Stream	2020	Saprobic	Asexual+	[403]
Morosphaeriaceae					
Aquihelicascus songkhlaensis	Stream	2020	Saprobic	Sexual	[7]
Helicascus chiangraiensis	Pond	2016	Saprobic	Sexual	[515]
Helicascus uniseptatus	Stream	2016	Saprobic	Sexual	[515]
Nigrogranaceae					
Nigrograna aquatica	Stream	2020	Saprobic	Asexual+	[7]
Occultibambusaceae					
Occultibambusa aquatica	Waterfall	2016	Saprobic	Sexual	[310]
Parabambusicolaceae					
Parabambusicola aquatica	Stream	2020	Saprobic	Sexual	[7]
Phaeosphaeriaceae					
Ophiosphaerella aquaticus	Stream	2015	Saprobic	Sexual	[516]
Pleosporales genera *insertae sedis*					
Mycoenterolobium aquadictyosporium	Sream	2020	Saprobic	Asexual+	[451]
Fusiformiseptata crocea	Stream	2020	Saprobic	Sexual	[7]
Pseudoastrosphaeriellaceae					
Pseudoastrosphaeriella aquatica	Stream	2020	Saprobic	Sexual	[7]

Table E1 (continued)

Species	Habitat	Year	Life mode	Morph	References
Tetraplosphaeriaceae					
Shrungabeeja aquatica	Stream	2020	Saprobic	Asexual[+]	[7]
Trematosphaeriaceae					
Falciformispora aquatica	Waterfall	2019	Saprobic	Sexual	[511]
Wicklowiaceae					
Wicklowia phuketensis	Stream	2020	Saprobic	Sexual	[19]
Wicklowia submersa	Stream	2019	Saprobic	Sexual	[24]
TUBEUFIALES					
Tubeufiaceae					
Berkleasmium longisporum	Stream	2018	Saprobic	Asexual[+]	[457]
Chlamydotubeufia aquatica		2017	Saprobic	Sexual/ Asexual[+]	[867]
Chlamydotubeufia cylindrica	Stream	2018	Saprobic	Sexual/ Asexual[+]	[457]
Chlamydotubeufia krabiensis	Stream	2017	Saprobic	Sexual/ Asexual[+]	[514]
Dictyospora thailandica		2017	Saprobic	Sexual/ Asexual[+]	[867]
Helicoarctatus aquaticus	Stream	2018	Saprobic	Asexual[+]	[457]
Helicoarctatus thailandicus	Stream	2020	Saprobic	Asexual[+]	[868]
Helicodochium aquaticum	Stream	2018	Saprobic	Asexual[+]	[457]
Helicohyalinum infundibulum	Stream	2018	Saprobic	Asexual[+]	[457]
Helicoma brunneisporum	Stream	2018	Saprobic	Asexual[+]	[457]
Helicoma longisporum	Stream	2018	Saprobic	Asexual[+]	[457]
Helicoma septoconstrictum	Stream	2018	Saprobic	Asexual[+]	[457]
Helicosporium aquaticum	Stream	2018	Saprobic	Asexual[+]	[457]
Helicosporium flavisporum	Stream	2018	Saprobic	Asexual[+]	[457]

Table E1 (continued)

Species	Habitat	Year	Life mode	Morph	References
Helicosporium flavum		2017	Saprobic	Sexual/ Asexual +	[867]
Helicosporium setiferum	Stream	2018	Saprobic	Asexual +	[457]
Helicosporium thailandense	Stream	2020	Saprobic	Asexual +	[7]
Helicosporium vesicarium	Stream	2018	Saprobic	Asexual +	[457]
Helicotubeufia hydei	Stream	2019	Saprobic	Sexual	[568]
Neoacanthostigma brunneisporum	Stream	2017	Saprobic	Sexual/ Asexual +	[861]
Neoacanthostigma latisporum	Stream	2017	Saprobic	Asexual +	[861]
Neochlamydotubeufia fusiformis	Stream	2018	Saprobic	Sexual/ Asexual +	[457]
Neohelicomyces hyalosporus	Stream	2018	Saprobic	Sexual/ Asexual +	[457]
Neohelicomyces thailandicus	Stream	2020	Saprobic	Asexual +	[7]
Neohelicosporium acrogenisporum	Stream	2018	Saprobic	Asexual +	[457]
Neohelicosporium astrictum	Stream	2018	Saprobic	Asexual +	[457]
Neohelicosporium ellipsoideum	Stream	2018	Saprobic	Sexual/ Asexual +	[457]
Neohelicosporium krabiense	Stream	2018	Saprobic	Asexual +	[457]
Neohelicosporium submersum	Stream	2020	Saprobic	Asexual +	[7]
Neohelicosporium thailandicum	Stream	2017	Saprobic	Asexual +	[873]
Pseudohelicomyces aquaticus	Stream	2018	Saprobic	Asexual +	[457]
Tubeufia abundata	Stream	2018	Saprobic	Asexual +	[457]
Tubeufia brevis	Stream	2018	Saprobic	Asexual +	[457]
Tubeufia brunnea	Stream	2018	Saprobic	Asexual +	[457]

Table E1 (continued)

Species	Habitat	Year	Life mode	Morph	References
Tubeufia chlamydospora	Stream	2018	Saprobic	Asexual^{+}	[457]
Tubeufia filiformis	Stream	2016	Saprobic	Sexual/ Asexual^{+}	[878]
Tubeufia inaequalis	Stream	2018	Saprobic	Asexual^{+}	[457]
Tubeufia krabiensis	Stream	2018	Saprobic	Asexual^{+}	[457]
Tubeufia latispora	Stream	2016	Saprobic	Sexual	[878]
Tubeufia laxispora	Stream	2016	Saprobic	Asexual^{+}	[878]
Tubeufia mackenziei	Stream	2016	Saprobic	Asexual^{+}	[878]
Tubeufia tratensis	Stream	2018	Saprobic	Asexual^{+}	[457]
EUROTIOMYCETES					
SCLEROCOCCALES					
Dactylosporaceae					
Cylindroconidiis aquaticus	Stream	2018	Saprobic	Asexual^{+}	[2110]
Pseudobactrodesmium chiangmaiensis	Stream	2020	Saprobic	Asexual^{+}	[26]
CHAETOTHYRIALES					
Herpotrichiellaceae					
Thysanorea uniseptata	Stream	2019	Saprobic	Asexual^{+}	[511]
SORDARIOMYCETES					
AMPHISPHAERIALES					
Sporocadaceae					
Lepteutypa aquatica	Stream	2019	Saprobic	Sexual	[5]
ANNULATASCALES					
Annulatascaceae					
Annulatascus thailandensis	Stream	2020	Saprobic	Sexual	[23]
CHAETOSPHAERIALES					
Chaetosphaeriaceae					
Dictyochaeta siamensis	Stream	2016	Saprobic	Asexual^{+}	[1386]
Sporoschisma chiangraiense	Stream	2019	Saprobic	Asexual^{+}	[511]
Sporoschisma palauense	Stream	2016	Saprobic	Asexual^{+}	[1401]

Table E1 (continued)

Species	Habitat	Year	Life mode	Morph	References
Sporoschisma longicatenatum	Stream	2016	Saprobic	Asexual +	[1401]
Tainosphaeria obclavata	Stream	2019	Saprobic	Asexual +	[5]
Tainosphaeria siamensis	Stream	2016	Saprobic	Asexual +	[1386]
CONIOSCYPHALES					
Conioscyphaceae					
Conioscypha nakagirii	Stream	2016	Saprobic	Asexual +	[1336]
Barbatosphaeriaceae					
Barbatosphaeria aquatica	Stream	2018	Saprobic	Asexual +	[312]
Diaporthomycetidae genera *incertae sedis*					
Aquimonospora tratensis	Stream	2019	Saprobic	Asexual +	[528]
Proliferophorum thailandicum	Stream	2019	Saprobic	Asexual +	[476]
DISTOSEPTISPORALES					
Distoseptisporaceae					
Distoseptispora appendiculata	Stream	2019	Saprobic	Asexual +	[5]
Distoseptispora lignicola	Waterfall	2019	Saprobic	Asexual +	[5]
Distoseptispora multiseptata	Stream	2016	Saprobic	Asexual +	[310]
Distoseptispora neorostrata	Stream	2019	Saprobic	Asexual +	[5]
Distoseptispora obclavata	Stream	2019	Saprobic	Asexual +	[5]
Distoseptispora rayongensis	Stream	2020	Saprobic	Asexual +	[23]
Fuscosporellaceae					
Fuscosporella aquatica	Stream	2017	Saprobic	Asexual +	[529]
Mucispora infundibulata	Stream	2020	Saprobic	Asexual +	[23]
Mucispora phangngaensis	Stream	2017	Saprobic	Asexual +	[529]
Parafuscosporella aquatica	River	2020	Saprobic	Asexual +	[530]
Parafuscosporella pyriformis	River	2020	Saprobic	Asexual +	[530]
MAGNAPORTHALES					
Ceratosphaeriaceae					

Table E1 (continued)

Species	Habitat	Year	Life mode	Morph	References
Ceratosphaeria lignicola	Stream	2019	Saprobic	Sexual	[5]
Ophioceraceae					
Ophioceras submersum	Waterfall	2019	Saprobic	Sexual	[10]
MICROASCALES					
Halosphaeriaceae					
Aniptodera aquibella	Stream	2016	Saprobic	Sexual	[302]
Ascosacculus fusiformis	Stream	2019	Saprobic	Sexual	[5]
Triadelphialaceae					
Triadelphia hexaformispora	Stream	2019	Saprobic	Asexual+	[1326]
PLEUROTHECIALES					
Pleurotheciaceae					
Neomonodictys muriformis	Stream	2020	Saprobic	Asexual+	[403]
Phaeoisaria filiformis	Waterfall	2019	Saprobic	Sexual	[5]
Pleurotheciella krabiensis	Stream	2018	Saprobic	Asexual+	[312]
Pleurotheciella tropica	Stream	2018	Saprobic	Asexual+	[312]
Pleurothecium floriforme	Stream	2017	Saprobic	Asexual+	[514]
PSEUDODACTYLARIALES					
Pseudodactylariaceae					
Pseudodactylaria camporesiana	Stream	2020	Saprobic	Asexual+	[403]
SAVORYELLALES					
Savoryellaceae					
Canalisporium aquaticium	Stream	2020	Saprobic	Asexual+	[403]
SPORIDESMIALES					
Sporidesmiaceae					
Sporidesmium aquaticivaginatum	Stream	2016	Saprobic	Asexual+	[310]
Sporidesmium olivaceoconidium	Stream	2016	Saprobic	Asexual+	[310]
Sporidesmium pyriformatum	Stream	2016	Saprobic	Asexual+	[310]
XYLARIALES					
Diatrypaceae					
Peroneutypa lignicola	Stream	2019	Saprobic	Sexual	[5]

Note + = Hyphomycete; * = Coelomycete

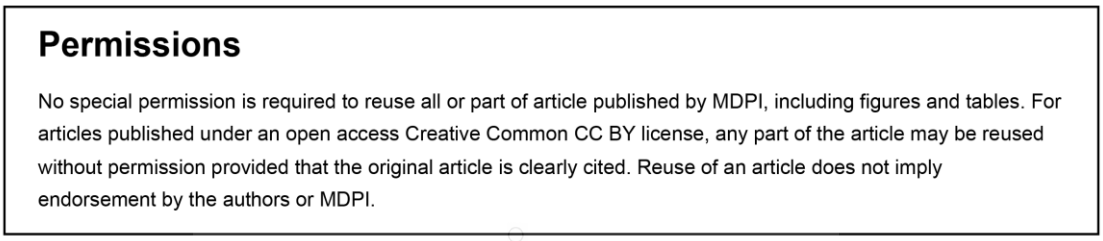
APPENDIX F

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(1) Calabon, M. S., Jones, E. B. G., Promputtha, I., & Hyde, K. D. (2021). Fungal biodiversity in salt marsh ecosystems. *Journal of Fungi*, *7*(8), 648. https://doi.org/10.3390/jof7080648

(2) Calabon, M. S., Jones, E. B. G., Boonmee, S., Doilom, M., Lumyong, S., & Hyde, K. D. (2021). Five novel freshwater ascomycetes indicate high undiscovered diversity in lotic habitats in Thailand. *Journal of Fungi*, *7*(2), 1–27. https://doi.org/10.3390/jof7020117

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