

The diversity of microfungi in peatlands originated from the White Sea

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Abstract: The diversity of culturable filamentous microfungi in peat and sediments of four peatlands at the coastal zone of Kandalaksha Bay of the White Sea (Murmansk region, Russia) was studied by culture methods on standard and selective media. Annually 100 samples were collected from the bogs 2007–2010. Based on morphological, molecular markers and cultural features, 211 taxa were identified. Fungal communities observed at the peatlands were influenced mostly by their sea origin. We discovered a large difference between fungal communities from the peat and the sediments of the peatlands. In contrast to the sediments, the fungal community of the peat was found to be consistent throughout sampling sites. Fungi with specific ecophysiology, such as *Sphagnum*-decomposing species (*Oidiodendron griseum*, *O. tenuissimum*, *Penicillium spinulosum*, *P. thomii*, *Talaromyces funiculosus*), psychrotolerant and associated with insects species (*Pseudogymnoascus pannorum*, *Tolyocladium* spp.), typical marine species (*Acremonium* spp.) were found. In addition, different types of sterile mycelia were characteristic for the researched peatlands.

Key words: fungal diversity, fungi decomposing *Sphagnum*, fungi in sediments, molecular identification, psychrotolerants

INTRODUCTION

Peatlands cover about 4% of the world, more than 10% of the territory of Russia and about 70–80% of the White Sea coastal territory (Yurkovskaya 2004). Peatlands accumulate peat, partially decayed plant material, and play a significant role in the global carbon

cycle by virtue of their significant peat deposits that contain 45–50% carbon (Thormann 2006b). The importance of peatlands for the global C cycle is illustrated by the fact that northern peatlands store 180–277 Gt C (1 Gt = 1×10^9 metric tons), which constitutes approximately 10–16% of the total global terrestrial detrital C (Thormann et al. 2001a).

Bogs are a dominant peatland type in the north of Russia. Coupled with spruce forest, raised bogs prevail in the taiga zone in northeastern Europe. Coastal raised bogs predominate along the White Sea coast (Schulze et al. 2002, Yurkovskaya, 2004). Raised bogs and aapa fens (also called aapa mires) are the zonal mire complex types of boreal regions (Laitinen et al. 2005). Raised bogs are ombrotrophic ecosystems that receive water and nutrients solely from atmospheric precipitation. They are commonly dominated by species of *Sphagnum* mosses, *Picea mariana* and members of the *Ericaceae*, including species of *Rhododendron* spp., *Andromeda* spp. and *Vaccinium* spp. (Thormann et al. 1999, Thormann 2006a). Aapa fens are more minerotrophic (i.e. they receive their nutrients both from precipitation and the surrounding land because of their hydrological regime). These peatlands consist of a lake, elongated *Sphagnum*-formed hummocks and water channels (Keränen and Kalpio 2001; Laitinen et al. 2005, 2007). Aapa mire is a Finnish term for a large, complex, cold-climate wetland. This is a mire-system type, the central parts of which are characterized by minerotrophy and near to mire inherent influence. These systems may receive supplementary nutrition to their central parts, in addition to marginal parts and brook sides, through meltwater from the surrounding area. Aapa mires are morphologically variable (Laitinen et al. 2007).

The annual accumulation of peat is caused by relatively slow organic decomposition by microorganisms because of extremely unfavorable conditions: lack of oxygen, low temperatures, high acidity and humidity, the presence of inhibitory complex phenolic compounds from specific vegetation (mostly *Sphagnum* spp.) and an inherent lack of microbial diversity to degrade the most complex polymers of peat (Untiedt and Müller 1984, Tsuneda et al. 2001, Thormann et al. 2002, Rice et al. 2006, Andersen et al. 2010).

In White Sea coastal raised bogs, peat consists of the complex of plant material dominated by *Sphagnum fuscum* (Yurkovskaya 2004). Fungi, together with heterotrophic bacteria, are the main decomposers of the organic matter in peat (Pankratov et al. 2005; Gilbert and Mitchell 2006; Thormann et al. 2001a, b,

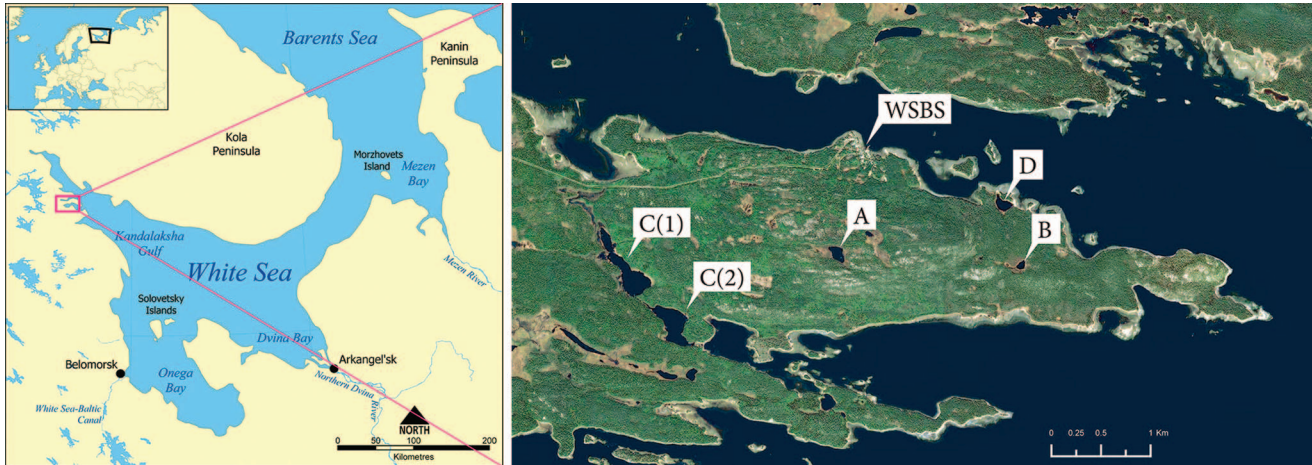


FIG. 1. Map of the Kindo Peninsula with four studied peatlands tagged: A = Verkhnee Peatland, B = Krugloe Peatland, C = Ershovskoe Peatland, C(1) = Ershovskoe Verkhnee Lake, C(2) = Ershovskoe Nizhnee Lake, D = Kislosladkoe Peatland, WSBS = White Sea Biological Station.

2006a, b, 2007; Andersen et al. 2010). In the northern peatlands fungal diversity estimates are 22–55 species per peatland. Those species have a capacity for living and physiological activity in peat (Nilsson and Rülcker 1992, Czeczuga 1993, Thormann et al. 2001b).

The respective role of fungi in litter decomposition and the multiple-factor peat-forming process in peatlands is still poorly studied. Most peatlands are in the northern hemisphere (Thormann et al. 2007), however, little is known about fungal biodiversity of the northern peatlands. Some data is available of peatland fungi from western Siberian and central Russia (Golovchenko et al. 2002, Kachalkin et al. 2005, Grum-Grzhimaylo and Bilanenko 2009, Filippova and Thormann 2014) but almost no data is available for the fungi from the peatlands in northwestern Russia.

The peatlands at the Kandalaksha Bay of the White Sea have a unique origin. They appear as a result of a part of the sea becoming isolated during rapid land uplift (0.5 cm/y), followed by both demineralization and the development of bogs (Shaporenko et al. 2005, Pantyulin and Krasnova 2011). In this process the succession of marine biota by freshwater takes place, which is common for peatlands. Fungi, functioning as decomposers, symbionts, parasites and pathogens, are associated with the evolution of the reservoirs that have a sea origin (their number is evaluated from one to several hundred at Kandalaksha Bay), but the data on mycobiota of these systems are hardly discussed in the literature.

The aim of our research was to investigate fungal diversity in the peatlands around the White Sea Biological Station (WSBS) of Lomonosov Moscow State University in northwestern Russia. The fungi were isolated from the peat and sediment samples taken from

four peatlands at different altitudes above sea level (1.5–87 m) representing different stages of bog formation. Fungi were identified with morphological and cultural features as well as DNA sequence data (ITS rDNA region, along with SSU and LSU rDNA). We characterized the composition, abundance and spatial distribution of species in fungal communities from peatlands in connection with the age of the reservoirs and their contact with the sea.

MATERIALS AND METHODS

Study area.—It is near the Karelian coast of Kandalaksha Bay of the White Sea (FIG. 1) near the WSBS (66°34'N, 33°08'E). Kindo Peninsula, where the station is located, is near the Arctic Circle. The geographic position of lakes determines the climatic conditions under which their hydrological regime is formed. In this case this is a long winter with an average daily temperature of –11 C in Jan and a relatively short humid summer with a maximum precipitation in Aug and a mean temperature of 14 C in Jul (Shaporenko et al. 2005). Annual precipitation is 300–400 mm (Bubnova 2005). Geomorphologically the region lies on the northern margin of Pribelomorskaya Lowland. The maximum elevation of the area is less than 100 m.

Description of the investigated peatlands.—Four investigated peatlands are located, ranging from the lowest to the highest point of the peninsula and represent almost all evolution stages of bogs in this area of the White Sea coast (FIG. 1, TABLE I). Two of them represent raised bog-type peatlands (Verkhnee, Krugloe; FIGS. 2A, 2B), the third is a transition aapa fen (Ershovskoe; FIG. 2C) and the fourth is a brackish lake detaching from the sea (Kislosladkoe; FIG. 2D). Kislosladkoe Lake has both marine and continental features. There is a combination of typical littoral vegetation with bog plants depending of coast parts in this peatland. The characteristics of aapa fen types were described in detail by Laitinen et al. (2007).

TABLE I. Description of the investigated peatlands

Peatland No.	Name	Age (year) (Shilova 2011)	Altitude (m)	Type of peatland	Peat depth (m)	Max depth of sampling (m)	pH of samples	Water level in sampling places (cm)	Dominant vegetation			Latitude/longitude (in centers of lakes)	
									Trees	Shrubs/subshrubs	Herbs		Mosses/lichens
1	Verkhnee	8400 ± 110	87	Raised bog	4.6	2.0	Peat 4.1, sediments 6.0	-20	<i>Pinus sylvestris</i> , <i>Betula nana</i>	<i>Chamaedaphne caryocata</i> , <i>Calluna vulgaris</i> , <i>Rubus chamaemorus</i> , <i>Oxycoccus microcarpus</i> , <i>Ledum palustre</i>	<i>Drosera rotundifolia</i> , <i>D. anglica</i> , <i>Eriophorum latifolium</i> , <i>Menyanthes trifoliata</i>	<i>Planarizium schreberi</i> , <i>Sphagnum fuscum</i> , <i>Sph. capillifolium</i> , <i>Sph. papillosum</i> , <i>Sph. magellanicum</i> , <i>Sph. majus</i> , <i>Cladonia rangiferina</i> , <i>Cl. alpestris</i> , <i>Cl. mitis</i> , <i>Cetraria islandica</i> , <i>Nephroma</i> sp.	66°32'37.0206"/33°5'50.4348"
2	Krugloe	3970 ± 40	27.5	Oligotrophic aapa	2.4	1.4	Peat 4.1, sediments 6.0-6.5	-10	<i>Pinus sylvestris</i> , <i>Betula nana</i>	<i>Calluna vulgaris</i> , <i>Rubus chamaemorus</i> , <i>Oxycoccus microcarpus</i> , <i>Vaccinium</i> sp.	<i>Drosera rotundifolia</i> , <i>D. anglica</i> , <i>Baccharis caespitosum</i>	<i>Planarizium schreberi</i> , <i>Sphagnum papillosum</i> , <i>Sph. fuscum</i> , <i>Sph. balticum</i> , <i>Sph. lindbergii</i> , <i>Sph. subfulvum</i> , <i>Cladonia rangiferina</i> , <i>Cladonia</i> spp.	66°32'32.8416"/33°8'22.4592"
3	Ershovskoe	810 ± 40	3.5	Transition aapa-fen	1.8	1.8	Peat 5.5, sediments 5.5-8.0	-5	<i>Pinus sylvestris</i> , <i>Betula nana</i>	<i>Rubus chamaemorus</i> , <i>Oxycoccus microcarpus</i> , <i>Vaccinium</i> sp.	<i>Eriophorum polytachyon</i> , <i>Carex rostrata</i> , <i>Baccharis caespitosum</i> , <i>Menyanthes trifoliata</i> , <i>Utricularia</i> sp., <i>Comarum palustre</i> , <i>Deschampsia</i> sp., <i>Calamagrostis</i> sp.	<i>Sphagnum papillosum</i> , <i>Sph. subfulvum</i> , <i>Sphagnum</i> spp.	3_166°32'14.3874"/33°3'35.7156"; 3_266°32'27.9198"/33°3'2.9628"
4	Kislosladkoe	—	1.5	Detaching from the sea	0.3	0.3	Peat 5.0-6.0, sediments 5.0-6.0, water 7.5-9.2	-5	<i>Pinus sylvestris</i> , <i>Betula pubescens</i> , <i>Betula pubescens</i> × <i>B. nana</i> , <i>B. nana</i>	<i>Comus suecica</i> , <i>Empetrum hermaphroditum</i> , <i>Vaccinium vitis-idaea</i> , <i>Oxycoccus palustris</i> , <i>Rubus chamaemorus</i> ,	<i>Aster tripolium</i> , <i>Triglochin maritima</i> , <i>Phleum alpinum</i> , <i>Festuca rubra</i> , <i>Juncus antrifuscus</i> , <i>Polygonum viviparum</i> , <i>Blysmus rufus</i> , <i>Eleocharis unguiculata</i> ,	<i>Sphagnum</i> spp.	66°32'52.5186"/33°8'8.865"

TABLE I. Continued

Peatland No.	Name	Age (year) (Shilova 2011)	Altitude (m)	Type of peatland	Peat depth (m)	Max depth of sampling (m)	pH of samples	Water level in sampling places (cm)	Dominant vegetation			Latitude/longitude (in centers of lakes)
									Trees	Shrubs/subshrubs	Herbs	
									<i>Sorbus aucuparia</i>	<i>Vaccinium uliginosum</i>	<i>Ophioglossum vulgatum</i> , <i>Primula nutans</i> , <i>Salix</i> sp., <i>Carex</i> sect. <i>Tennidis</i> , <i>Trinitatis europaea</i> , <i>Triglochin palustris</i> , <i>Triglochin maritima</i> , <i>Parnassia palustris</i> , <i>Comarum palustre</i> , <i>Listera cordata</i> , <i>Comarum palustre</i> , <i>Dactylorhiza maculata</i> , <i>Eleocharis polystachion</i>	

Sampling.—Peat samples (0.5-2 m deep) were taken every 50 cm with a hand peat drill from each of the peatlands in *Sphagnum*-covered sites (one series of samples from one core of each peatland). Peat samples, 50-10 cm deep, plants (living and dead parts of *Sphagnum* spp.) and soil samples were taken with a knife. The tools were cleansed with water and 96% alcohol after each extraction. Twenty-two samples of peat were taken from the Verkhnee Peatland, 21 from Krugloe, 19 from Verkhnee Ershovskoe and nine from Kislosladkoe. Peatland sediment samples were taken every 0.5 m at different depths by Scuba and free diving, from both surface and from approximately 0.3 m below surface at each sampling site. Six sediment samples were taken from each of the three peatlands, the Verkhnee, Krugloe and Nizhnee Ershovskoe, four samples from the Verkhnee Ershovskoe and seven from the Kislosladkoe. The collected samples were transferred to sterile Petri dishes and transported in a cooler to the laboratory where they were stored at 5 C 1-2 d after sampling. The samples of different species of *Sphagnum* were collected in sterile paper envelopes for identification.

Fungal isolation and identification.—From the peat samples *Sphagnum* spp. plant material and sediment, dilutions were prepared with 1 g in 10 mL sterile distilled water, pounded by a mortar, and further diluted 100-fold. From this final dilution 0.25 mL was pipetted on each of two Petri plates of six media: malt agar (MA, containing 17 g malt extract [Merck] and 20 g agar per liter); water agar (WA, containing 20 g agar per liter); citric-acid buffer agar (CA, pH 4, containing 800 mL citric-acid buffer (McIlvaine, 1921), 17 g malt extract, 30 g agar and 200 mL dH₂O); *Sphagnum* extract agar (SEA, containing 600 mL *Sphagnum*-extract (from 200 g *Sphagnum* spp. in 500 mL bog H₂O), 20 g agar and 400 mL dH₂O); alkaline buffer agar (AA, pH 9, containing 12 g Na₂CO₃, 6 g NaHCO₃, 17 g malt extract and 20 g agar); semi-saltwater agar (SWA, containing 20 g agar per liter unfiltered water from Kislosladkoe Lake). Petri dishes were incubated at room temperature in light until fungal colonies appeared (5-30 d according to growth of fungi); the colonies were subcultured onto MA as soon as they grew from the samples. Our isolation method did not yield yeasts or chytridiomycetous fungi or lower fungi-like organisms, such as *Oomycota*. Naturally our recovery output of fungi from the investigated habitats was affected by isolation and incubation biases, such as media type and incubation conditions. Newly isolated fungi were subcultured for identification according to the morphology and cultural features. The cultures that failed to sporulate after incubation were considered sterile. The major part of the sterile mycelia and other species that were difficult to identify by morphology (*Acremonium*-like, *Cadophora*/*Phialophora*-like, *Phoma*-like isolates) were identified by DNA sequence analysis of the ITS regions, LSU and SSU of nuclear-encoded rDNA. The same analysis was conducted for dominant fungal species to verify identification by morphological features.

Data analysis.—Data on the total number of microscopic fungi were expressed in colony-forming units (CFU) per g dry peat. For this purpose 1 g of every sample was placed in

a drying chamber at 120 C for 24 h to establish the water content of each sample. The spatial frequency (%) of every species was calculated as the number of sites of occurrence times 100 divided by the total number of sites samples. The abundance (%) of fungal divisions was calculated as the CFU of the genus \times 100/the total CFU of all genera from the peatland. Species diversity was determined by enumerating the number of species of the genus in the peatland. Sørensen index was used to compare fungal communities among the peatlands (Zak et al. 2004).

Molecular techniques and sequence analysis.—Genomic DNA was isolated from mycelium of the 152 fungal strains with a chloroform/isopropanol method (Karakousis et al. 2006). Before DNA isolation the fungi were grown on MA with under cellophane membranep 3-5 d at 27 C. The mycelium was harvested, frozen with liquid nitrogen and grinded twice for 10 s with a bead-beater machine (beads 2 mm diam) added to the Eppendorf tube with mycelium. Then 1 mL LETS buffer (0.1 M LiCl, 10 mM EDTA pH = 8.0, 10 mM Tris pH = 8.0, 0.5% SDS) was added, mixed thoroughly (withvortex) and centrifuged 15 min at 13 000 rpm. A total of 700 mL supernatant was transferred into a fresh 2 mL Eppendorf tube. Five milliliters of proteinase K was added and incubated 1 h at 37 C. Subsequently 300 mL phenol and 300 mL SEVAG (isoamylalcohol:chloroform 1:24) were added, mixed thoroughly and centrifuged 15 min at 13 000 rpm. A total of 600 mL of the supernatant was transferred to a clean 1.5 mL Eppendorf tube; 300 mL SEVAG was added, mixed thoroughly and centrifuged 15 min at 13 000 rpm. A total of 500 mL supernatant was transferred to a clean Eppendorf tube, 300 mL (0.6 \times volume) was added, mixed and stored for 15 min at -20 C or overnight at 4 C. Then nucleic acids were centrifuged out of suspension in an Eppendorf centrifuge for 15 min at 13 000 rpm at 4 C. The supernatant was discarded with a micropipette; the pellet was washed with 100 mL ice-cold 70% ethanol and centrifuged 1 min at 13 000 rpm at 4 C. The supernatant was discarded with a micropipette; the pellet was dried under vacuum and dissolved overnight in 50 mL MQ water at 4 C. Subsequently the solution was mixed with a pipette and stored -20 C. The resultant DNA solution was used for subsequent PCR procedure.

The primers ITS1f and ITS4r (White et al. 1990) were used to amplify a portion of the nuclear ribosomal gene (rDNA) including the two internal transcribed spacer regions (ITS1 and ITS2) and the 5.8S rDNA. The primers LR0R, LR7, LR9, NS1, NS4 and NS8 (Vilgalys et al. 1990; <http://www.lutzonilab.net/primers/page244.shtml>) were used for amplification of part of the nuclear large and small subunits (LSU and SSU) of rDNA.

PCR mixes (Promega Corp., Madison, Wisconsin) contained 0.5 mL 25 mM MgCl₂, 5 mL 5 \times PCR GoTag buffer, 1 mL 10 mM dNTP, 1 mL 10 mM of each PCR primer, 0.1 mL GoTag polymerase and 2 mL gDNA in 25 mL. The amplification program included 35 cycles of 94 C for 1 min, 52 C for 1 min and 72 C for 1 min followed by final extension at 72 C for 7 min. PCR products were purified with GenElute™ PCR Clean-Up Kit (Sigma) and sequenced in Eurofins MWG Operon (Ebersberg, Germany). Sequences were compared with data from GenBank with a BLAST similarity

query. If the ITS sequence similarity was more than 85%, we considered the isolate a member of kingdom Fungi.

RESULTS

In total 501 fungal isolates were obtained from the 100 samples of *Sphagnum* moss, peat and sediments that were collected annually in summer (Jun-Jul) 2007–2010. These isolates belong to 211 taxa, representing 65 genera. Of these taxa 113 (54%) were *Ascomycota*, 30 (15%) *Basidiomycota*, seven (3%) *Zygomycota* and 61 were sterile unidentified morphotypes (including *Fungus* sp. strain) (TABLE II). The number of viable fungal propagules were 10²–10⁵ CFU per 1 g dry weight. Taxonomic identification of all 211 taxa was based on morphological characteristics, and 98 of them also were identified by molecular genetics (ITS region, LSU, SSU rDNA), including a major part of the sterile mycelia (93 of 153 isolates), other species difficult to identify by morphology (13 taxa from *Acremonium*-like, *Cadophora/Phialophora*-like and *Phoma*-like groups of fungi) and few frequent species (10 taxa). Newly generated sequences were deposited in the GenBank with accession numbers provided (TABLE III). Due to the lack of the GenBank data sequence identity for the ITS in some cases was higher than for LSU (TABLE III). On the whole 25 taxa were linked with known species and 73 remained undetermined. The number of taxa in the peatlands ranged from 44 (Krugloe Peatland) to 84 (Ershovskoe Peatland). The number of identified taxa in the peat and sediments ranged from 30 (Krugloe Peatland) to 47 (Verkhnee and Kislosladvkoe peatlands) and from 18 (Krugloe) to 42 (Ershovskoe Nizhnee). The overall frequency of fungal taxa was low (20% and lower). The frequency of fungal taxa in the peat and sediments of different bogs was 3.4–32.1% and 3.4–17.9%, respectively (TABLE II).

The dominance of fungi from the *Ascomycota* division was a common characteristic of the mycobiota from all reservoirs investigated due to the anamorphic species (FIG. 3). The prevailing genus was *Penicillium* Link with its *Talaromyces* C.R.Benj. sexual stage (32 species) predominantly from *Monoverticillata* and *Biverticillata-Symmetrica* sections (TABLE II). Only eight species (e.g. *Talaromyces funiculosus*, *P. spinulosum*, *P. thomii*, *Cladosporium cladosporioides*, *C. herbarum*, *Pseudogymnoascus pannorum*, *Beauveria bassiana*, *Tolypocladium inflatum*) were obtained from all peatlands and labeled typical species for the investigated peatlands (TABLE II). The similarity of the fungal communities among the different peatlands ranged from 0.20 (Ershovskoe and Kislosladvkoe) to 0.32 (Verkhnee and Krugloe) (FIG. 4).

Because the fungal communities of the peat and sediments of each of the four peatlands differed substantially, peat and sediments had to be analyzed

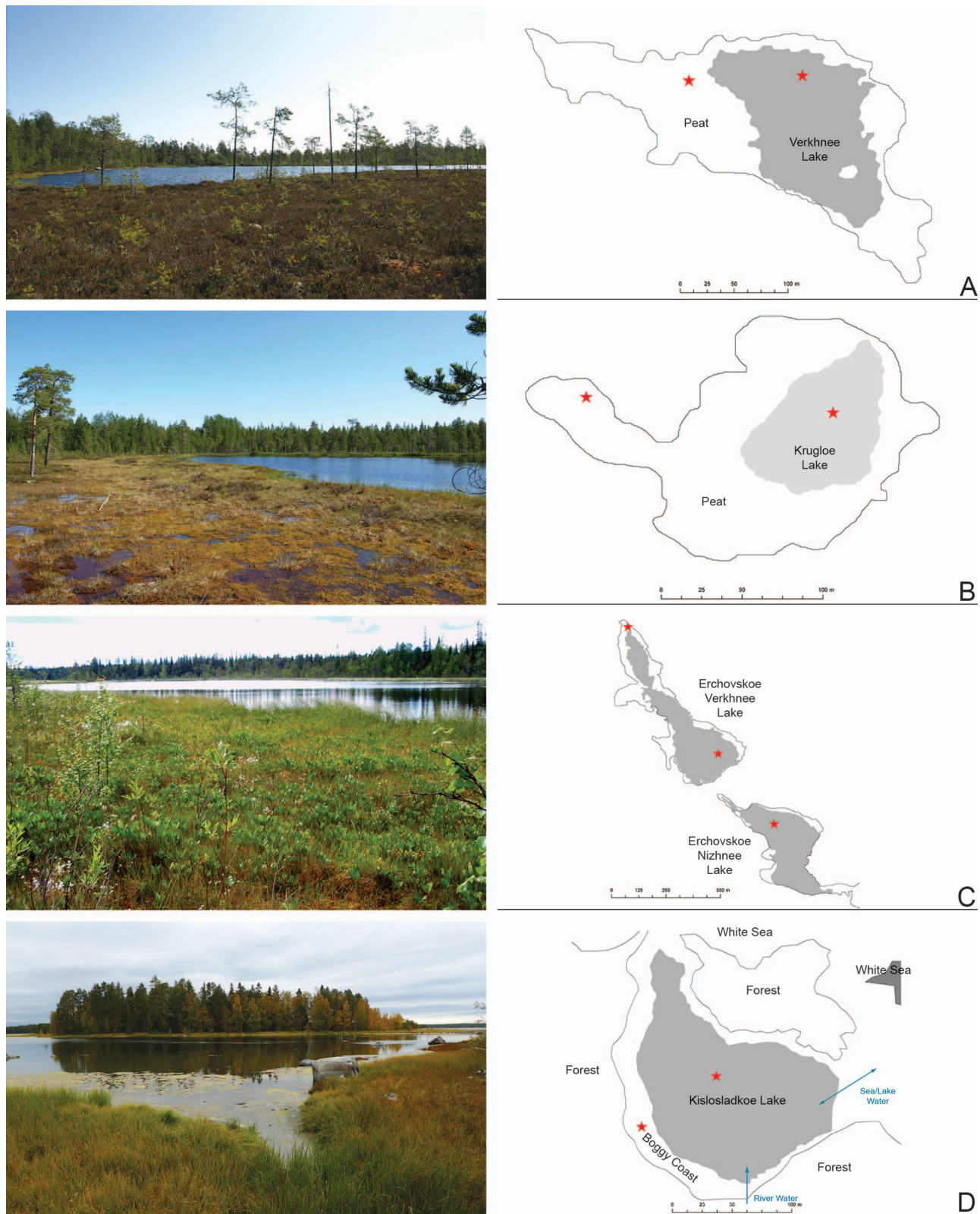


FIG. 2. Pictures and schemes of the investigated peatlands. A. Verkhnee Peatland. B. Krugloe Peatland. C. Ershovskoe Peatland. D. Kislosladkoe Peatland.

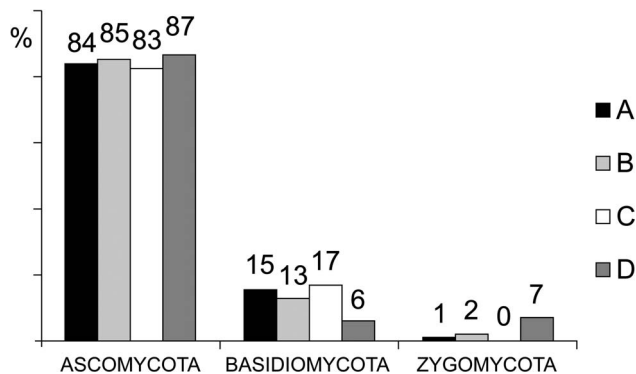


FIG. 3. Abundance (%) of fungal divisions in four peatlands. A. Verkhnee. B. Krugloe. C. Ershovskoe. D. Kislosladkoe.

independently. An average specific abundance of the genus *Penicillium* was 29.5% in peat and 11.5% in sediments. Common species in peat were *Talaromyces funiculosus*, *Penicillium spinulosum*, *P. glabrum*, *P. thomii*, *Cladosporium bruhnei*, *C. cladosporioides*, *C. herbarum*, *Beauveria bassiana*, *Oidiiodendron griseum*, *Tolyptocladium inflatum* and *Trichoderma harzianum*. We found 31 species that have not been observed before in *Sphagnum* peat (TABLE II) (Thormann and Rice 2007). In the bottom sediments sterile mycelia *Tolyptocladium inflatum*, *Trichoderma hamatum*, *T. polysporum*, *Talaromyces funiculosus*, *Penicillium spinulosum*, *Aureobasidium pullulans* and *Sistotrema brinkmannii* were prevalent.

In total, 43 isolates of the *Basidiomycota* division were found; among them were species of genera *Phlebiopsis* Jülich, *Sistotrema* Fr., *Amylostereum* Boidin, *Antrrodia* P. Karst., *Ceriporiopsis* Domański, *Gloeophyllum* P. Karst., *Neolentinus* Redhead & Ginns, *Phellinus* QuéL., *Pholiota* (Fr.) P. Kumm., *Piptoporus* P. Karst., *Peniophora* Cooke, *Polyporus* P. Micheli, *Resinicium* Parmasto, *Stereum*

Hill ex Pers., *Strobilurus* Singer and unidentified *Basidiomycota*.

The observed fungal diversity was affected by the isolation media (TABLE II). Many species were isolated only on one type of media. Some versatile species such as *Penicillium* spp., *Cladosporium* spp., *Trichoderma* spp. and *Sistotrema* spp. appeared on all types of media.

We did not find distinct correlation between the species composition of the fungi and the depth at which the peat samples were taken. The maximum species number of the micromycetes was isolated from the upper and the deepest peat horizons. The number of fungi isolated from the surface sediment was larger than that obtained from the deep layer sediment.

DISCUSSION

The composition of fungal species in the studied peatlands is primarily associated with their origin. Substantial parts of the coastal zone of the White Sea are rising. As the result numerous bays, armlets and coastal straits separate from the sea, which in turn leads to the formation of small lakes (Shaporenko et al. 2005). Geological investigations and diatom analysis of the sediments indicated that all peatlands of the Kindo Peninsula formerly were a part of the sea (Romanenko, 2012). These isolated basins develop into peatland lakes and evolve in different ways depending on depth. Those that are 5-6 m deep remain as meromictic lakes, the shallower ones turn to fresh peatland lakes or slack marshes (Pantulin and Krasnova 2011).

The maximum depth of the peatland lakes explored was 2.0–2.5 m (lakes Verkhnee, Krugloe, Ershovskoe Verkhnee). Based on this fact it can be assumed that these peatlands have a similar way of formation starting from their detachment from the sea and ending with freshening and bogging (Olyunina 2008). The

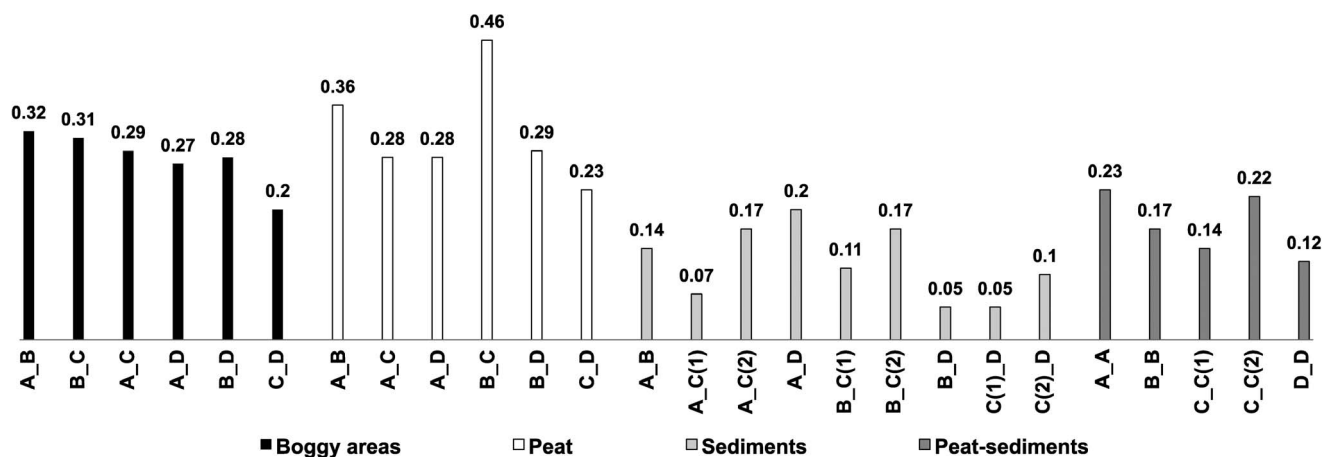


FIG. 4. Similarity of fungal communities of the peatlands (Sørensen index). A. Verkhnee Peatland. B. Krugloe Peatland. C. Ershovskoe Peatland. C(1). Ershovskoe Verkhnee Lake. C(2). Ershovskoe Nizhnee Lake, D. Kislosladkoe Peatland.

TABLE II. The results of the molecular analysis of 152 taxa including accession numbers of DNA sequences and the closest match from the GenBank database

Species	GenBank accession No.			BLAST	
	ITS	LSU	SSU		
<i>Acremonium</i> sp. 1 ^a	JQ780657	JQ768402		<i>Acremonium</i> sp., 499/505, 99% ITS	FJ571421
				<i>Acremonium strictum</i> , 1319/1337, 98% LSU	FJ176879
<i>Acremonium</i> sp. 2	JX535092	JX535093		<i>Acremonium</i> sp., 498/505, 99% ITS	FJ571421
				<i>Sarocladium ochraceum</i> , 800/813, 98% LSU	HQ232070
				<i>Acremonium strictum</i> , 1272/1299, 98% LSU	FJ176879
<i>Acremonium</i> sp. 2	JX507654	JX507655		<i>Acremonium</i> sp., 498/505, 99% ITS	FJ571421
				<i>Sarocladium ochraceum</i> , 800/813, 98% LSU	HQ232070
				<i>Acremonium strictum</i> , 1272/1299, 98% LSU	FJ176879
<i>Acremonium</i> sp. 3	JX535076	JX535077		<i>Acremonium potronii</i> , 443/443, 100% ITS	DQ865091
				<i>Emericellopsis maritima</i> , 1318/1321, 99% LSU	FJ176861
<i>Agaricomycetes</i> sp.	JQ780614	JQ768389		<i>Sistotrema brinkmannii</i> , 560/560, 100% ITS	JQ912675
				<i>Antrodia gossypium</i> , 1010/1016, 99% LSU	EU232298
				<i>Phanerochaete lamprocystidiata</i> , 898/903, 99% LSU	GQ470648
<i>Alternaria</i> sp.	JX507701			<i>Alternaria tenuissima</i> , 503/503, 100% ITS	JX406554
				<i>Alternaria brassicae</i> , 503/503, 100% ITS	JX290140
				<i>Alternaria alternata</i> , 503/503, 100% ITS	JF802121
<i>Alternaria</i> sp.	JX535139			<i>Alternaria tenuissima</i> , 503/503, 100% ITS	JX406554
				<i>Alternaria brassicae</i> , 503/503, 100% ITS	JX290140
				<i>Alternaria alternata</i> , 503/503, 100% ITS	JF802121
<i>Amylostereum areolatum</i>	JX507658			<i>Amylostereum areolatum</i> , 525/525, 100% ITS	JX049992
				<i>Amylostereum areolatum</i> , 525/525, 100% ITS	HQ864715
<i>Antrodia xantha</i>	JX507636	JX507637		<i>Antrodia xantha</i> , 531/531, 100% ITS	EU232210
				<i>Antrodia xantha</i> , 2087/2094, 99% LSU	AJ583430
<i>Antrodia</i> sp. 1	JQ780622	JQ780623	JQ780624	<i>Antrodia serialis</i> , 446/560, 98% ITS	AJ345010
				<i>Antrodia serialis</i> , 1081/1092, 99% LSU	EU232293
				<i>Antrodia variiformis</i> , 1663/1668, 99% SSU	AY336783
<i>Antrodia</i> sp. 2	JX507729	JX507730		<i>Antrodia sinuosa</i> , 587/587, 100% ITS	GU991578
				<i>Antrodia xantha</i> , 2015/2114, 95% LSU	AJ583430
<i>Antrodiella romellii</i>	JQ780621	JQ768396		<i>Antrodiella romellii</i> , 587/587, 100% ITS	AF126902
				<i>Antrodiella romellii</i> , 879/879, 100% LSU	JN710520
<i>Ascomycota</i> sp. 1	JX535148	JX535149		<i>Helotiales</i> sp., 457/464, 98% ITS	FN548161
				<i>Articulospora tetracladia</i> , 1957/2051, 95% LSU	EU998928
<i>Ascomycota</i> sp. 2	JX535116			<i>Ascomycete</i> sp., 432/450, 96% ITS	AY805600
<i>Ascomycota</i> sp. 3	JX507652	JX507653		<i>Ascomycota</i> sp., 488/510, 96% ITS	JN120374
				<i>Setomelanomma holmii</i> , 700/701, 99% LSU	GQ387633
<i>Ascomycota</i> sp. 4	JX507689			<i>Articulospora atra</i> , 459/479, 96% ITS	FJ000402
<i>Ascomycota</i> sp. 5	JX507709			<i>Hirsutella</i> sp., 489/493, 99% ITS	EF029185
				<i>Ascomycete</i> sp., 448/450, 99% ITS	AM084797
<i>Ascomycota</i> sp. 6	JX507650	JX507651		<i>Lecythophora mutabilis</i> , 505/505, 100% ITS	HQ637304
				<i>Hyalodendriella betulae</i> , 757/779, 97% LSU	EU040232
<i>Basidiomycota</i> sp. 1	JQ780626	JQ780627	JQ780628	<i>Basidiomycota</i> sp., 490/492, 99% ITS	GU062230
				<i>Leptosporomyces galzinii</i> , 683/692, 99% LSU	EU118642
				<i>Athelia</i> sp., 994/1005, 99% SSU	GU187619
<i>Basidiomycota</i> sp. 2	JX507638	JX507639		<i>Basidiomycota</i> sp., 642/642, 100% ITS	FR682225
				<i>Antrodia xantha</i> , 1968/2096, 94% LSU	AJ583430

TABLE II. Continued

Species	GenBank accession No.			BLAST	
	ITS	LSU	SSU		
<i>Basidiomycota</i> sp. 3	JX507646			<i>Armillaria novae-zelandiae</i> , 536/592, 91% ITS	AF394919
				<i>Coprinus</i> sp., 526/590, 89% ITS	AY254874
<i>Basidiomycota</i> sp. 4	JX507631	JX507632		<i>Armillaria novae-zelandiae</i> , 536/592, 91% ITS	AF394919
				<i>Coprinus</i> sp., 526/590, 89% ITS	AY254874
				<i>Multiclavula mucida</i> , 1983/2059, 96% LSU	EU909345
<i>Botryotinia</i> sp.	JX535121			<i>Botryotinia fuckeliana</i> , 474/474, 100% ITS	KC172064
				<i>Botrytis elliptica</i> , 474/474, 100% ITS	AY684918
				<i>Botrytis</i> sp., 474/474, 100% ITS	FR822791
<i>Cadophora fastigiata</i>	JX535145			<i>Cadophora fastigiata</i> , 521/521, 100% ITS	JN689948
				<i>Cadophora fastigiata</i> , 521/521, 100% ITS	GU212371
<i>Cadophora luteo-olivacea</i>	JX535088			<i>Cadophora luteo-olivacea</i> , 563/564, 99% ITS	JQ796751
				<i>Cadophora luteo-olivacea</i> , 563/564, 99% ITS	FJ486274
<i>Cadophora luteo-olivacea</i>	JX535123			<i>Cadophora luteo-olivacea</i> , 565/565, 100% ITS	GU212374
				<i>Cadophora luteo-olivacea</i> , 565/565, 100% ITS	GU128589
<i>Cadophora luteo-olivacea</i>	JX535125			<i>Cadophora luteo-olivacea</i> , 563/564, 99% ITS	AB725391
				<i>Cadophora luteo-olivacea</i> , 563/564, 99% ITS	GU212374
<i>Cadophora luteo-olivacea</i>	JX535132			<i>Cadophora luteo-olivacea</i> , 560/560, 100% ITS	GU212374
<i>Cadophora luteo-olivacea</i>	JX535171			<i>Cadophora luteo-olivacea</i> , 567/568, 99% ITS	GU212374
<i>Cadophora luteo-olivacea</i>	JX535179			<i>Cadophora luteo-olivacea</i> , 581/581, 100% ITS	FJ430742
<i>Cadophora</i> sp.	JX507647			<i>Cadophora</i> sp., 555/564, 98% ITS	JN859254
<i>Ceriporiopsis subvermispora</i>	JX507705	JX507706		<i>Ceriporiopsis subvermispora</i> , 580/580, 100% ITS	HQ659228
				<i>Ceriporiopsis subvermispora</i> , 840/842, 99% LSU	FJ496707
<i>Cladosporium cladosporioides</i>	JX535079			<i>Cladosporium cladosporioides</i> , 483/483, 100% ITS	JQ768327
<i>Cladosporium cladosporioides</i>	JX535084			<i>Cladosporium cladosporioides</i> , 481/481, 100% ITS	JQ768327
<i>Cladosporium cladosporioides</i>	JX535135			<i>Cladosporium cladosporioides</i> , 491/491, 100% ITS	JQ768327
<i>Cladosporium cladosporioides</i>	JX535166			<i>Cladosporium cladosporioides</i> , 480/480, 100% ITS	JQ768327
<i>Cladosporium cladosporioides</i>	JX535173			<i>Cladosporium cladosporioides</i> , 491/491, 100% ITS	HQ380766
<i>Cladosporium cladosporioides</i>	JQ780660			<i>Cladosporium cladosporioides</i> , 481/481, 100% ITS	JQ768327
<i>Cladosporium herbarum</i>	JX535143			<i>Cladosporium herbarum</i> , 494/494, 100% ITS	AF455517
<i>Cladosporium herbarum</i>	JX535172			<i>Cladosporium herbarum</i> (<i>Davidiella tassiana</i>), 408/408, 100% ITS	KC292373
<i>Cladosporium langeronii</i>	JQ780666			<i>Cladosporium langeronii</i> , 490/490, 100% ITS	DQ780380
<i>Cladosporium langeronii</i>	JQ780667			<i>Cladosporium langeronii</i> , 490/490, 100% ITS	DQ780380
<i>Cladosporium</i> sp. 1	JQ780649			<i>Cladosporium langeronii</i> , 501/502, 99% ITS	DQ780380
				<i>Cladosporium cladosporioides</i> , 486/490, 99% ITS	JN986780
<i>Cladosporium</i> sp. 2	JQ780629			<i>Cladosporium cladosporioides</i> , 487/488, 99% ITS	JN986780
				<i>Cladosporium</i> sp., 490/491, 99% ITS	GU395509
<i>Cladosporium</i> sp. 3	JX535124			<i>Cladosporium langeronii</i> , 463/467, 99% ITS	JQ780667
				<i>Cladosporium cladosporioides</i> , 463/467, 99% ITS	AF455525
<i>Clavulinaceae</i> sp.	JX507640	JX507641		<i>Clavulinaceae</i> sp., 608/609, 99% ITS	FJ475570

TABLE II. Continued

Species	GenBank accession No.			BLAST	
	ITS	LSU	SSU		
<i>Clavulinaceae</i> sp.	JX507727	JX507728		<i>Clavulina</i> sp., 792/829, 96% LSU	AY745694
				<i>Clavulinaceae</i> sp., 610/611, 99% ITS	FJ475570
				<i>Clavulina</i> sp., 812/850, 96% LSU	AY745694
<i>Coniochaeta</i> sp.	JX507629	JX507630		<i>Coniochaeta</i> sp., 489/489, 100% ITS	HM595513
				<i>Coniochaeta</i> sp., 509/509, 100% LSU	HM595603
<i>Crocicreas</i> sp.	JQ780618	JQ768393		<i>Crocicreas</i> sp., 477/478, 99% ITS	FJ005100
<i>Crocicreas</i> sp.	JX507682			<i>Cyathicula microspora</i> , 1323/1339, 99% LSU	EU940088
				<i>Crocicreas</i> sp., 440/442, 99% ITS	FJ005098
				<i>Crocicreas</i> sp., 438/442, 99% ITS	FJ005099
<i>Dothideales</i> sp.	JX535090	JX535091		<i>Dothideales</i> sp., 510/511, 99% ITS	HM240804
				<i>Dothideomyces</i> sp., 503/513, 98% ITS	GQ153228
				<i>Dothideomyces</i> sp., 763/774, 99% LSU	GU323957
				<i>Dothidea insculpta</i> , 764/808, 95% LSU	NG027643
<i>Dothideomyces</i> sp. 1	JX535078			<i>Paraconiothyrium</i> sp., 497/515, 97% ITS	HM999948
<i>Dothideomyces</i> sp. 1	JX507635			<i>Paraphaeosphaeria</i> sp., 496/515, 96% ITS	KC208020
				<i>Paraconiothyrium</i> sp., 494/512, 96% ITS	HM999948
<i>Dothideomyces</i> sp. 2	JX535162			<i>Paraphaeosphaeria</i> sp., 493/512, 96% ITS	KC208020
				<i>Mycosphaerella fragariae</i> , 472/476, 99% ITS	GU214691
<i>Fungus</i> sp.	JX507690			<i>Ramularia grevilleana</i> , 469/475, 99% ITS	GU939181
<i>Gloeophyllum sepiarium</i>	JX507712	JX507713		<i>Hongkongmyces pedis</i> , 252/285, 88% ITS	JQ435790
				<i>Gloeophyllum sepiarium</i> , 569/570, 99% ITS	JQ358803
<i>Gnomoniaceae</i> sp.	JX507716			<i>Gloeophyllum sepiarium</i> , 821/821, 100% LSU	JN649344
				<i>Gnomonia cf. ischnostyla</i> , 475/477, 99% ITS	EU254903
<i>Gnomoniaceae</i> sp.	JX507717			<i>Ophiognomonia</i> sp., 474/477, 99% ITS	JQ414264
				<i>Gnomonia cf. ischnostyla</i> , 475/477, 99% ITS	EU254903
<i>Helotiales</i> sp. 1	JQ780635			<i>Ophiognomonia</i> sp., 474/477, 99% ITS	JQ414264
				<i>Lachnum</i> sp., 416/435, 97% ITS	FJ378861
<i>Helotiales</i> sp. 2	JQ780665			<i>Gremmeniella</i> sp., 450/453, 99% ITS	FR715997
<i>Helotiales</i> sp. 3	JQ780658	JQ780659		<i>Helotiales</i> sp., 421/423, 99% ITS	AY354243
				<i>Godronia</i> sp., 439/453, 98% ITS	EF672237
<i>Helotiales</i> sp. 4	JX535181			<i>Godronia urceulos</i> 1320/1321, 99% LSU	EU754163
				<i>Varicosporium elodeae</i> , 489/492, 99% ITS	GQ152148
<i>Helotiales</i> sp. 5	JX535100	JX535101		<i>Helotiales</i> sp., 480/490, 98% ITS	JN655578
				<i>Mollisia cinerea</i> , 801/811, 99% LSU	DQ470942
<i>Helotiales</i> sp. 6	JX535046	JX535047		<i>Hyaloscyphaceae</i> sp., 479/488, 98% ITS	GU393951
				<i>Hyalodendriella betulae</i> , 727/746, 97% LSU	EU040232
<i>Helotiales</i> sp. 7	JX535102	JX535103		<i>Catenulifera brevicollaris</i> , 479/507, 94% ITS	GU727561
				<i>Catenulifera brachyconia</i> , 784/800, 98% LSU	GU727559
<i>Helotiales</i> sp. 8	JX507674	JX507675		<i>Hymenoscyphus</i> sp., 472/487, 97% ITS	GU479911
				<i>Hyaloscypha fuckelii</i> , 766/780, 98% LSU	EU940154
<i>Helotiales</i> sp. 8	JX507670	JX507671		<i>Hymenoscyphus</i> sp., 471/486, 97% ITS	GU479911
				<i>Hyaloscypha fuckelii</i> , 806/820, 98% LSU	EU940154
<i>Helotiales</i> sp. 9	JX507660	JX507661		<i>Meliniomyces bicolor</i> , 480/480, 100% ITS	HQ157926
				<i>Hyaloscypha hepaticola</i> , 829/838, 99% LSU	EU940118
<i>Helotiales</i> sp. 9	JX507662	JX507663		<i>Meliniomyces</i> sp., 500/503, 99% ITS	JQ711936
				<i>Hyaloscypha hepaticola</i> , 830/839, 99% LSU	EU940118

TABLE II. Continued

Species	GenBank accession No.			BLAST
	ITS	LSU	SSU	
<i>Helotiales</i> sp. 10	JX507720	JX507721		<i>Helotiales</i> sp., 488/542, 90% ITS FJ378857 <i>Neobulgaria</i> sp., 484/542, 89% ITS HQ211726 <i>Neobulgaria pura</i> , 752/788, 95% LSU DQ257365
<i>Helotiales</i> sp. 11	JX507672	JX507673		<i>Helotiales</i> sp., 492/497, 99% ITS JX852365 <i>Catenulifera brachyconia</i> , 766/782, 98% LSU GU727559
<i>Helotiales</i> sp. 12	JX507664	JX507665		<i>Acephala</i> sp., 478/483, 99% ITS JN655564 <i>Mollisia</i> sp., 771/797, 97% LSU EU107273
<i>Helotiales</i> sp. 12	JX507666	JX507667		<i>Acephala</i> sp., 479/484, 99% ITS JN655564 <i>Mollisia</i> sp., 737/781, 94% LSU EU107273
<i>Helotiales</i> sp. 13	JX507676	JX507677		<i>Cudoniella acicularis</i> , 435/470, 93% ITS DQ202512 <i>Varicosporium giganteum</i> , 737/747, 99% LSU GQ477344
<i>Helotiales</i> sp. 14	JX507656	JX507657		<i>Acephala</i> sp., 481/489, 98% ITS HQ889709 <i>Mollisia</i> sp., 737/755, 97% LSU EU107273
<i>Helotiales</i> sp. 15	JX507693			<i>Helotiales</i> sp., 531/534, 99% ITS GU934595
<i>Helotiales</i> sp. 16	JX535119	JX535120		<i>Helotiales</i> sp., 424/426, 99% ITS AY354243 <i>Godronia urceolus</i> , 831/831, 100% LSU EU754163
<i>Helotiales</i> sp. 17	JX507731	JX507732		<i>Helotiales</i> sp., 491/545, 90% ITS FJ378857 <i>Neobulgaria</i> sp., 487/545, 89% ITS HQ211726 <i>Neobulgaria pura</i> , 748/783, 96% LSU DQ257365
<i>Helotiales</i> sp. 18	JX507688			<i>Dimorphospora</i> sp., 479/479, 100% ITS JX077075 <i>Ascocoryne</i> sp., 382/382, 100% ITS JX077076
<i>Helotiales</i> sp. 18	JX507714	JX507715		<i>Dimorphospora</i> sp., 479/479, 100% ITS JX077075 <i>Ascocoryne</i> sp., 382/382, 100% ITS JX077076 <i>Neobulgaria lilacina</i> , 794/821, 97% LSU EU940141
<i>Helotiales</i> sp. 19	JX507683			<i>Dimorphospora</i> sp., 479/479, 100% ITS JX077075 <i>Ascocoryne</i> sp., 382/382, 100% ITS JX077076
<i>Leotiomyces</i> sp. 1	JQ780634			<i>Leotiomyces</i> sp., 471/529, 94% ITS HQ212354
<i>Leotiomyces</i> sp. 2	JQ780630	JQ768398		<i>Helotiaceae</i> sp., 463/478, 97% ITS GU997932 <i>Helotiales</i> sp., 463/478, 97% ITS JN655588 <i>Hyaloscypha fuckelii</i> , 1324/1336, 99% LSU EU940154
<i>Leotiomyces</i> sp. 3	JX507735			<i>Dimorphospora</i> sp., 474/479, 99% ITS JX077075 <i>Ascocoryne</i> sp., 377/382, 100% ITS JX077076
<i>Leotiomyces</i> sp. 4	JX507684	JX507685		<i>Leotiomyces</i> sp., 521/531, 98% ITS HQ211767 <i>Hyaloscypha</i> sp., 810/831, 97% LSU EU940092
<i>Leotiomyces</i> sp. 5	JX507687			<i>Dimorphospora</i> sp., 473/478, 99% ITS JX077075 <i>Ascocoryne</i> sp., 370/377, 100% ITS JX077076
<i>Massarinaceae</i> sp.	JQ780631	JQ780632		<i>Saccharicola bicolor</i> , 491/501, 98% ITS AF455415 <i>Neottiosporina paspali</i> , 813/822, 99% LSU EU754172
<i>Mollisia</i> sp. 1	JX507704			<i>Mollisia minutella</i> , 488/493, 99% ITS FR837920
<i>Mollisia</i> sp. 2	JX507644	JX507645		<i>Mollisia minutella</i> , 477/484, 99% ITS FR837920 <i>Mollisia cinerea</i> , 732/746, 98% LSU DQ470942
<i>Mollisia</i> sp. 3	JX507668	JX507669		<i>Mollisia minutella</i> , 483/483, 100% ITS FR837920 <i>Mollisia cinerea</i> , 806/819, 98% LSU DQ470942
<i>Mortierella elongata</i>	JX535038			<i>Mortierella elongata</i> , 468/468, 100% ITS KC018241
<i>Nectriaceae</i> sp.	JX535175			<i>Cylindrocarpon obtusisporum</i> , 475/476, 99% ITS GU726752

TABLE II. Continued

Species	GenBank accession No.			BLAST	
	ITS	LSU	SSU		
<i>Nectriaceae</i> sp.	JX535186			<i>Nectria lugdunensis</i> , 475/477, 99% ITS	FJ000394
				<i>Cylindrocarpon obtusisporum</i> , 480/481, 99% ITS	GU726752
<i>Nectriaceae</i> sp.	JX535187			<i>Nectria lugdunensis</i> , 482/483, 99% ITS	FJ000394
				<i>Cylindrocarpon obtusisporum</i> , 475/477, 99% ITS	GU726752
<i>Neolentinus</i> sp.	JX507691	JX507692		<i>Neolentinus lepideus</i> , 452/455, 99% ITS	AB615456
				<i>Neolentinus lepideus</i> , 849/856, 99% LSU	HM536077
<i>Penicillium spinulosum</i> ^a	JQ780638			<i>Penicillium spinulosum</i> , 506/507, 99% ITS	KC167850
<i>Penicillium spinulosum</i>	JQ780639			<i>Penicillium spinulosum</i> , 510/510, 100% ITS	DQ888735
<i>Peniophora piceae</i>	JX507718	JX507719		<i>Peniophora piceae</i> , 545/545, 100% ITS	AY781264
				<i>Peniophora</i> sp., 1352/1357, 99% LSU	DQ094783
<i>Peniophora</i> sp. 1	JX507724	JX507725		<i>Peniophora pini</i> , 574/576, 99% ITS	EU118651
				<i>Peniophora pini</i> , 1313/1331, 99% LSU	EU118651
				<i>Peniophora cinerea</i> , 1290/1309, 99% LSU	DQ094786
<i>Peniophora</i> sp. 2	JX535110	JX535111		<i>Peniophora pini</i> , 569/572, 99% ITS	EU118651
				<i>Peniophora pini</i> , 1313/1331, 99% LSU	EU118651
				<i>Peniophora cinerea</i> , 1290/1309, 99% LSU	DQ094786
<i>Pezizomycotina</i> sp. 1	JQ780651			<i>Ramularia eucalypti</i> , 451/453, 99% ITS	EF394861
				<i>Glomerella lagenaria</i> , 451/453, 99% ITS	AJ301970
<i>Pezizomycotina</i> sp. 2	JQ780663			<i>Ramularia eucalypti</i> , 462/465, 99% ITS	EF394861
<i>Phellinus</i> sp.	JQ780625	JQ768397		<i>Phellinus cinereus</i> , 554/557, 99% ITS	AY340047
				<i>Phellinus igniarius</i> , 601/604, 99% ITS	AM269797
				<i>Phellinus cinereus</i> , 858/859, 99% LSU	AF311027
<i>Phellinus igniarius</i> , 1838/1850, 99% LSU	AY839834				
<i>Phlebiopsis gigantea</i> ^a	JQ780612			<i>Phlebiopsis gigantea</i> , 626/626, 100% ITS	AF087487
<i>Phlebiopsis gigantea</i> ^a	JQ780617	JQ768392		<i>Phlebiopsis gigantea</i> , 584/584, 100% ITS	AF087487
<i>Phlebiopsis gigantea</i> ^a	JX507707	JX507708		<i>Ceratobasidiaceae</i> sp., 1291/1335, 97% LSU	JF799768
				<i>Phlebiopsis gigantea</i> , 598/598, 100% ITS	AF087487
<i>Pholiota</i> sp.	JX507628			<i>Antrodiaella romellii</i> , 1961/2058, 95% LSU	JQ768396
				<i>Pholiota lenta</i> , 608/608, 100% ITS	AY281022
<i>Phoma poolensis</i>	JQ780633	JQ768399		<i>Pholiota lubrica</i> , 602/602, 100% ITS	JF908578
				<i>Phoma novae-verbascicola</i> , 468/468, 100% ITS	GU237753
<i>Phoma poolensis</i>	JQ780648	JQ768403		<i>Phoma novae-verbascicola</i> , 1323/1323, 100% LSU	GU238135
				<i>Phoma novae-verbascicola</i> , 455/455, 100% ITS	GU237753
<i>Piptoporus betulinus</i>	JX507733	JX507734		<i>Phoma novae-verbascicola</i> , 1319/1319, 100% LSU	GU238135
				<i>Piptoporus betulinus</i> , 600/600, 100% ITS	GU731570
				<i>Piptoporus betulinus</i> , 601/602, 99% LSU	JQ700297
<i>Piptoporus betulinus</i> , 811/843, 96% LSU	JQ700297				
<i>Pochonia bulbillosa</i>	JX535141			<i>Pochonia bulbillosa</i> , 537/539, 99% ITS	AB378551
<i>Pochonia bulbillosa</i>	JQ780661	JQ780662		<i>Pochonia bulbillosa</i> , 534/535, 99% ITS	AB378551
				<i>Pochonia bulbillosa</i> , 838/840, 99% LSU	HQ232164
<i>Pochonia bulbillosa</i>	JX535180			<i>Pochonia bulbillosa</i> , 538/540, 99% ITS	AB378551
<i>Polyporus</i> sp.	JX507702	JX507703		<i>Polyporus lepideus</i> , 592/593% ITS	GU731572
				<i>Polyporus ciliatus</i> , 560/567, 99% ITS	AB070883
<i>Polyporales</i> sp.	JX507648	JX507649		<i>Polyporus arcularius</i> , 831/840, 99% LSU	AF393067
				<i>Oligoporus placentus</i> , 596/597, 99% ITS	AJ416069

TABLE II. Continued

Species	GenBank accession No.			BLAST	
	ITS	LSU	SSU		
<i>Pseudogymnoascus pannorum</i>	JQ768386	JQ768405		<i>Postia placenta</i> , 590/597, 99% ITS	JQ700293
				<i>Antrodia xantha</i> , 2039/2092, 97% LSU	AJ583430
				<i>Pseudogymnoascus pannorum</i> , 487/487, 100% ITS	HQ115661
<i>Pseudogymnoascus pannorum</i>	JQ780644	JQ768404		<i>Pseudogymnoascus pannorum</i> , 575/576, 99% LSU	GU951694
				<i>Pseudogymnoascus pannorum</i> , 487/487, 100% ITS	HQ115661
<i>Resinicium bicolor</i>	JQ780611	JQ768387		<i>Pseudogymnoascus pannorum</i> , 575/576, 99% LSU	GU951694
				<i>Resinicium bicolor</i> , 518/518, 100% ITS	DQ218310
<i>Resinicium bicolor</i>	JQ780619	JQ768394		<i>Resinicium bicolor</i> , 1260/1266, 99% LSU	AY700183
				<i>Resinicium bicolor</i> , 495/495, 100% ITS	DQ218310
<i>Resinicium sp.</i>	JQ780620	JQ768395		<i>Resinicium bicolor</i> , 1221/1226, 99% LSU	AY700183
				<i>Resinicium furfuraceum</i> , 609/617, 99% ITS	DQ873648
<i>Sistotrema brinkmannii</i>	JQ780616	JQ768391		<i>Resinicium furfuraceum</i> , 1357/1364, 99% LSU	DQ873648
				<i>Sistotrema brinkmannii</i> , 605/605, 100% ITS	JQ912675
<i>Sistotrema brinkmannii</i>	JX507642	JX507643		<i>Sistotrema brinkmannii</i> , 1286/1303, 99% LSU	AF506473
				<i>Sistotrema brinkmannii</i> , 577/577, 100% ITS	JQ912675
<i>Sistotrema brinkmannii</i>	JX535082	JX535083		<i>Sistotrema brinkmannii</i> , 1275/1292, 99% LSU	AF506473
				<i>Sistotrema brinkmannii</i> , 570/571, 99% ITS	JQ912675
<i>Sistotrema brinkmannii</i>	JX507686	JX535118		<i>Sistotrema brinkmannii</i> , 1289/1306, 99% LSU	AF506473
				<i>Sistotrema brinkmannii</i> , 563/563, 100% ITS	JQ912675
<i>Sistotrema brinkmannii</i>	JX535117	JX535118		<i>Sistotrema brinkmannii</i> , 568/569, 99% ITS	JQ912675
				<i>Sistotrema brinkmannii</i> , 1288/1305, 99% LSU	AF506473
<i>Sistotrema brinkmannii</i>	JX507710	JX507711		<i>Sistotrema brinkmannii</i> , 570/571, 99% ITS	AY089729
				<i>Sistotrema brinkmannii</i> , 1282/1300, 99% LSU	AF506473
<i>Sistotrema sp.</i>	JQ780613	JQ768388		<i>Sistotrema sp.</i> , 530/530, ITS 100%	AY781271
				<i>Sistotrema brinkmannii</i> , 1282/1301, 99% LSU	AF506473
<i>Sistotrema sp.</i>	JQ780615	JQ768390		<i>Sistotrema coroniferum</i> , 1247/1277, 98% LSU	AM259215
				<i>Sistotrema sp.</i> , 530/530, ITS 100%	AY781271
<i>Sistotrema sp.</i>	JX507633	JX507634		<i>Sistotrema brinkmannii</i> , 1284/1303, 99% LSU	AF506473
				<i>Sistotrema coroniferum</i> , 1248/1278, 98% LSU	AM259215
<i>Sistotrema sp.</i>	JX535108	JX535109		<i>Sistotrema sp.</i> , 522/522, 100% ITS	AY781271
				<i>Sistotrema brinkmannii</i> , 1288/1307, 99% LSU	AF506473
<i>Sistotrema sp.</i>	JX535114	JX535115		<i>Sistotrema coroniferum</i> , 1252/1282, 98% LSU	AM259215
				<i>Sistotrema sp.</i> , 530/530, 100% ITS	AY781271
<i>Stereum sp.</i>	JX535114	JX535115		<i>Sistotrema brinkmannii</i> , 1285/1304, 99% LSU	AF506473
				<i>Sistotrema coroniferum</i> , 1249/1279, 98% LSU	AM259215
<i>Strobilurus tenacellus</i>	JX507722	JX507723		<i>Stereum hirsutum</i> , 470/472, 99% ITS	JX501297
				<i>Stereum annosum</i> , 565/571, 99% ITS	DQ000294
<i>Sydowia polyspora</i>	JQ780656	JQ768401		<i>Stereum sp.</i> , 789/791, 99% LSU	EF600046
				<i>Strobilurus tenacellus</i> , 686/686, 100% ITS	GQ892812
<i>Sydowia polyspora</i>	JX535167	JX535167		<i>Strobilurus tenacellus</i> , 833/833, 100% LSU	AM946470
				<i>Sydowia polyspora</i> , 536/537, 99% ITS	FR822985
<i>Sydowia polyspora</i>	JX535167	JX535167		<i>Sydowia polyspora</i> , 1305/1305, 100% LSU	DQ678058
				<i>Sydowia polyspora</i> , 526/529, 99% ITS	FR822985
				<i>Sydowia polyspora</i> , 526/530, 99% ITS	FR717223

TABLE II. Continued

Species	GenBank accession No.			BLAST	
	ITS	LSU	SSU		
<i>Talaromyces funiculosus</i>	JX507726			<i>Penicillium funiculosus</i> , 516/516, 100% ITS	JX045839
<i>Teberdinia hygrophila</i> ^a	JQ780641	JQ780642	JQ780643	<i>Teberdinia hygrophila</i> , 446/447, 99% ITS	AY129291
				<i>Pseudoeurotium zonatum</i> , 1311/1319, 99% LSU	DQ470988
				<i>Pseudoeurotium sp.</i> , 785/791, 99% LSU	AB470594
				<i>Teberdinia hygrophila</i> , 733/734, 99% SSU	AY129282
<i>Teberdinia hygrophila</i> ^a	JQ780645	JQ780646	JQ780647	<i>Teberdinia hygrophila</i> , 447/447, 100% ITS	AY129291
				<i>Teberdinia hygrophila</i> , 1053/1055, 99% SSU	AY129282
				<i>Pseudoeurotium zonatum</i> , 819/822, 99% LSU	AF096198
<i>Teberdinia hygrophila</i> ^a	JQ780653	JQ780654	JQ780655	<i>Teberdinia hygrophila</i> , 448/449, 99% ITS	AY129291
				<i>Pseudoeurotium zonatum</i> , 1307/1315, 99% LSU	DQ470988
				<i>Pseudoeurotium sp.</i> , 785/791, 99% LSU	AB470594
				<i>Teberdinia hygrophila</i> , 1045/1047, 99% SSU	AY129282
<i>Tobypocladium cylindrosporum</i>	JX535129			<i>Tobypocladium cylindrosporum</i> , 497/497, 100% ITS	FJ025179
<i>Tobypocladium cylindrosporum</i>	JX507699			<i>Tobypocladium cylindrosporum</i> , 499/499, 100% ITS	FJ025179
<i>Tobypocladium geodes</i> ^a	JX507694			<i>Tobypocladium geodes</i> , 467/470, 99% ITS	FJ973059
<i>Tobypocladium inflatum</i> ^a	JQ780640			<i>Tobypocladium inflatum</i> , 493/494, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JX507695			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JX507696			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JX507697			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JX507698			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JQ780650			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JQ780652			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Tobypocladium inflatum</i> ^a	JQ780664			<i>Tobypocladium inflatum</i> , 494/495, 99% ITS	JX488470
<i>Trichoderma polysporum</i> ^a	JQ780637			<i>Hypocrea pachybasioides</i> , 555/557, 99% ITS	FJ860796
				<i>Trichoderma polysporum</i> , 532/537, 99% ITS	DQ093710
<i>Trichoderma polysporum</i> ^a	JQ780636	JQ768400		<i>Hypocrea parapilulifera</i> , 539/540, 99% ITS	FJ860799
				<i>Trichoderma sp.</i> , 1018/1018, 100% LSU	AY283550
<i>Volutella sp.</i>	JX507700			<i>Volutella sp.</i> , 517/521, 99% ITS	FR822789
				<i>Volutella ciliata</i> , 517/521, 99% ITS	GU479901

^a Species names identified by morphology.

depth of the other two lakes (Ershovskoe Nizhnee and Kislosladkoe) is less than 5 m, and they evolve presumably in the same way. The evolution of all the lakes explored is followed by the uniform processes of change such as succession of plants, change of organic sediments and physical-chemical properties of the lakes. All these factors influence species composition of fungi in the boggy lakes.

Whereas the fungal communities from the peatlands studied have similarities at higher taxonomic levels, the species composition at lower taxonomic levels change depending on the distance of the lakes from the sea and differences in the age of the peatlands (TABLE I, FIG. 3). However, despite the mentioned similarities, the fungal communities

of the studied peatlands are different (FIG. 4). Consistently pairs Verkhnee-Krugloe and Krugloe-Ershovskoe have the highest similarity. The established Ershovskoe Peatland and the newly forming Kislosladkoe Peatland have the lowest similarity, which can be attributed to the unique species composition of the sediments of Lake Ershovskoe Verkhnee.

Fungal communities from the Verkhnee, Krugloe and Ershovskoe peatlands are similar in spite of the differences in the altitude and age. This stability could be explained primarily by the chemical constitution of *Sphagnum* moss, because it consists of complex phenolic compounds that can be decomposed by a specific group of fungi. Taxa such as *Oidiodendron griseum*, *O.*

TABLE III. Isolated species with frequencies (%) of their occurrence and media of isolation

Species	Sampling site									Total F ^c /No. of isolates	Medium
	Peat				Sediments						
	A ^a	B ^b	C ^c	D ^d	A ^a	B ^b	C (1) ^c	C (2) ^c	D ^d		
<i>Acremonium</i> sp. 1 ^h	3.6	—	—	—	—	—	—	—	—	1	MA
<i>Acremonium</i> sp. 2 ^h	—	—	—	18.8	—	—	—	3.4	—	4	AA
<i>Acremonium</i> sp. 3 ^h	—	—	—	—	3.6	—	—	—	6.3	2	SWA
<i>Acrodontium crateriforme</i> (J.F.H. Beyma) de Hoog	3.6	—	3.4	—	7.1	—	—	—	—	4	MA, CA, WA
<i>Acrodontium simplex</i> (F. Mangenot) de Hoog	—	—	3.4	—	—	—	—	—	—	1	WA
<i>Agaricomycetes</i> sp. ^h	—	3.7	—	—	—	—	—	—	—	1	CA
<i>Alternaria alternata</i> (Fr.) Keissl.	3.6	—	—	6.3	—	—	—	—	—	2	SEA
<i>Alternaria</i> sp. ^h	—	—	—	6.3	—	—	—	3.4	—	2	MA, CA
<i>Amylostereum areolatum</i> (Chaillet ex Fr.) Boidin ^h	—	—	—	—	—	—	—	3.4	—	1	SWA
<i>Antrodia xantha</i> (Fr.) Ryvarden ^h	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Antrodia</i> sp. 1 ^h	—	—	3.4	—	—	—	—	—	—	1	CA
<i>Antrodia</i> sp. 2 ^h	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Antrodiella romellii</i> (Donk) Niemelä^h	—	—	3.4	—	—	—	—	—	—	1	MA
<i>Ascomycota</i> sp. 1 ^h	—	—	—	6.3	—	—	—	—	—	1	CA
<i>Ascomycota</i> sp. 2 ^h	—	—	—	—	—	—	—	—	6.3	1	WA
<i>Ascomycota</i> sp. 3 ^h	—	—	—	—	—	—	—	3.4	—	1	AA
<i>Ascomycota</i> sp. 4 ^h	—	—	—	—	—	—	3.4	—	—	1	SWA
<i>Ascomycota</i> sp. 5 ^h	—	—	—	—	—	—	—	3.4	—	1	MA
<i>Ascomycota</i> sp. 6 ^h	—	—	—	—	—	—	—	3.4	—	1	SWA
<i>Aspergillus repens</i> (Corda) Sacc.	—	—	—	—	3.6	—	—	—	—	1	CA
<i>Aspergillus tubingenis</i> Mosseray	—	—	—	—	—	—	—	—	6.3	1	MA
<i>Aspergillus ustus</i> (Bainier) Thom et Church	3.6	—	—	—	3.6	—	—	—	—	2	MA, SEA
<i>Aspergillus versicolor</i> (Vuill.) Tirab.	—	—	—	6.3	—	—	—	—	—	1	CA
<i>Aureobasidium pullulans</i> (de Bary) G. Arnaud	—	7.4	10.3	—	3.6	—	6.9	6.9	—	10	MA, WA, SEA, SWA
<i>Basidiomycota</i> sp. 1 ^h	—	—	3.4	—	—	—	—	—	—	1	CA
<i>Basidiomycota</i> sp. 2 ^h	—	—	—	—	—	—	—	3.4	—	1	MA
<i>Basidiomycota</i> sp. 3 ^h	—	—	—	—	—	—	3.4	—	—	1	CA
<i>Basidiomycota</i> sp. 4 ^h	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Beauveria bassiana</i> (Bals.-Criv.) Vuill.	10.7	14.8	6.9	6.3	—	—	—	—	—	10	MA, CA, SEA
<i>Beauveria brongniartii</i> (Sacc.) Petch	—	—	—	6.3	—	—	—	—	—	1	MA
<i>Botryotinia</i> sp. ^h	—	—	—	6.3	—	—	—	—	—	1	WA
<i>Botrytis cinerea</i> Pers.	3.6	—	—	6.3	—	—	—	—	—	2	MA, CA
<i>Cadophora fastigiata</i> Lagerb. et Melin ^h	—	—	—	6.3	—	—	—	3.4	—	2	CA, SWA
<i>Cadophora luteo-olivacea</i> (J.F.H. Beyma) T.C. Harr. et McNew^h	—	—	—	12.5	—	—	—	6.9	6.3	5	MA, CA, WA, SEA, SWA
<i>Cadophora</i> sp. ^h	—	—	—	—	—	—	—	3.4	—	1	CA
<i>Cadophora</i> sp.	—	—	—	6.3	—	—	—	—	—	1	SEA
<i>Ceriporiopsis subvermispora</i> (Pilát) Gilb. et Ryvarden ^h	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Chrysosporium</i> sp.	—	—	—	—	—	—	3.4	—	—	1	WA
<i>Cladophialophora humicola</i> Crous et U. Braun	3.6	—	—	—	—	—	—	—	—	1	SEA
<i>Cladosporium antarcticum</i> K. Schub., Crous et U. Braun	—	—	—	18.8	—	—	—	—	—	3	AA
<i>Cladosporium bruhnei</i> Linder	—	3.7	6.9	18.8	—	3.7	—	—	—	7	MA, CA, AA, WA, SWA
<i>Cladosporium cladosporioides</i> (Fresen.) G.A. de Vries ^h	10.7	3.7	6.9	12.5	—	—	3.4	—	12.5	11	MA, CA, WA, SEA, SWA

TABLE III. Continued

Species	Sampling site									Total F ^c /No. of isolates	Medium
	Peat				Sediments						
	A ^a	B ^b	C ^c	D ^d	A ^a	B ^b	C (1) ^c	C (2) ^c	D ^d		
<i>Cladosporium herbarum</i> (Pers.) Link ^h	3.6	7.4	3.4	18.8	—	—	—	—	—	7	MA, WA, SEA, SWA
<i>Cladosporium langeronii</i> (Fonseca, Leão et Nogueira) Vuill.^h	7.1	—	—	—	—	—	—	—	—	1	SEA
<i>Cladosporium sphaerospermum</i> Penz.	32.1	11.1	—	—	3.6	—	—	—	—	13	MA, CA, WA, SEA, SWA
<i>Cladosporium</i> sp. 1 ^h	3.6	—	—	—	—	—	—	—	—	1	SEA
<i>Cladosporium</i> sp. 2 ^h	—	3.7	—	—	—	—	—	—	—	1	MA
<i>Cladosporium</i> sp. 3 ^h	—	—	—	6.3	—	—	—	—	—	1	SEA
<i>Clavulinaceae</i> sp. ^h	—	—	—	—	—	3.7	—	3.4	—	2	MA
<i>Coniochaeta</i> sp. ^h	—	—	—	—	3.6	—	—	—	—	1	CA
<i>Crocicreas</i> sp. ^h	—	—	3.4	—	—	—	—	3.4	—	2	CA, SEA
<i>Dothideales</i> sp. ^h	—	—	—	6.3	—	—	—	—	—	1	MA
<i>Dothideomycetes</i> sp. 1 ^h	—	—	—	—	—	—	—	3.4	6.3	1	MA, SEA
<i>Dothideomycetes</i> sp. 2 ^h	—	—	—	6.3	—	—	—	—	—	1	MA
<i>Elaphocordyceps subsessilis</i> (Petch) G.H. Sung, J.M. Sung et Spatafora ^h	21.4	—	3.4	12.5	17.9	7.4	—	—	6.3	17	All
<i>Emericellopsis minima</i> Stolck	—	—	—	—	—	—	—	6.9	—	2	WA
<i>Emericellopsis</i> sp.	—	—	—	—	—	—	3.4	—	—	1	SWA
<i>Engyodontium album</i> (Limber) de Hoog	—	3.7	—	6.3	—	3.7	—	—	—	3	MA, CA, SEA
<i>Fungal</i> sp. ^h	—	—	—	—	—	—	—	3.4	—	1	WA
<i>Fusarium</i> sp.	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Geomyces pannorum</i> (Link) Sigler et J.W. Carmich. ^h	7.1	3.7	3.4	6.3	—	—	—	6.9	—	7	MA, CA, WA, SEA
<i>Geotrichum candidum</i> Link	3.6	—	—	—	3.6	—	—	6.9	—	4	MA, CA, SEA
<i>Gibellulopsis nigrescens</i> (Pethybr.) Zare, W. Gams et Summerb.	3.6	—	—	—	—	—	—	3.4	—	2	MA, SWA
<i>Gloeophyllum sepiarium</i> (Wulfen) P. Karst. ^h	—	—	—	—	—	—	3.4	—	—	1	MA
<i>Gnomoniaceae</i> sp. ^h	—	—	—	—	3.6	—	—	3.4	—	2	MA, SEA
<i>Hansfordia</i> sp.	—	—	—	—	—	—	3.4	—	—	1	SWA
<i>Helotiales</i> sp. 1 ^h	—	—	3.4	—	—	—	—	—	—	1	WA
<i>Helotiales</i> sp. 2 ^h	3.6	—	—	—	—	—	—	—	—	1	SEA
<i>Helotiales</i> sp. 3 ^h	3.6	—	—	—	—	—	—	—	—	1	MA
<i>Helotiales</i> sp. 4 ^h	—	—	—	6.3	—	—	—	—	—	1	MA
<i>Helotiales</i> sp. 5 ^h	—	—	—	—	—	—	—	—	6.3	1	SEA
<i>Helotiales</i> sp. 6 ^h	—	—	—	6.3	—	—	—	—	—	1	CA
<i>Helotiales</i> sp. 7 ^h	—	—	—	—	—	—	—	—	6.3	1	CA
<i>Helotiales</i> sp. 8 ^h	—	—	—	—	7.1	3.7	—	—	—	3	MA, CA, SEA
<i>Helotiales</i> sp. 9 ^h	—	—	—	—	—	—	—	3.4	—	2	WA
<i>Helotiales</i> sp. 10 ^h	—	—	—	—	—	—	—	3.4	—	1	MA
<i>Helotiales</i> sp. 11 ^h	—	—	—	—	—	—	3.4	—	—	1	CA
<i>Helotiales</i> sp. 12 ^h	—	—	—	—	3.6	—	—	—	—	2	MA
<i>Helotiales</i> sp. 13 ^h	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Helotiales</i> sp. 14 ^h	—	—	—	—	—	3.7	—	—	—	1	SWA
<i>Helotiales</i> sp. 15 ^h	—	—	—	—	3.6	—	—	—	—	1	SWA
<i>Helotiales</i> sp. 16 ^h	—	—	—	6.3	—	—	—	—	—	1	WA
<i>Helotiales</i> sp. 17 ^h	—	—	—	—	—	—	—	3.4	—	1	MA
<i>Helotiales</i> sp. 18 ^h	—	—	—	—	—	—	—	3.4	—	2	CA, SWA

TABLE III. Continued

Species	Sampling site									Total F ^e /No. of isolates	Medium
	Peat				Sediments						
	A ^a	B ^b	C ^c	D ^d	A ^a	B ^b	C (1) ^c	C (2) ^c	D ^d		
<i>Helotiales</i> sp. 19 ^h	—	—	—	—	—	—	3.4	—	—	1	MA
<i>Humicola fuscoatra</i> Traaen	—	—	—	—	3.6	—	—	—	—	1	CA
<i>Humicola</i> sp.	—	—	—	—	—	—	3.4	—	—	1	SWA
<i>Lecanicillium evansii</i> Zare et W. Gams	—	—	3.4	—	—	—	—	—	—	1	MA
<i>Lecanicillium muscarium</i> (Petch) Zare et W. Gams	—	—	—	—	—	3.7	—	—	—	1	AA
<i>Leotiomyces</i> sp. 1 ^h	—	3.7	—	—	—	—	—	—	—	1	WA
<i>Leotiomyces</i> sp. 2 ^h	3.6	—	—	—	—	—	—	—	—	1	CA
<i>Leotiomyces</i> sp. 3 ^h	—	—	—	—	3.6	—	—	—	—	1	MA
<i>Leotiomyces</i> sp. 4 ^h	—	—	—	—	—	3.7	—	—	—	1	WA
<i>Leotiomyces</i> sp. 5 ^h	—	—	—	—	—	—	3.4	—	—	1	MA
<i>Massarinaceae</i> sp. ^h	—	—	—	6.3	—	—	—	—	—	1	CA
<i>Mollisia</i> sp. 1 ^h	—	—	—	—	3.6	—	—	—	—	1	CA
<i>Mollisia</i> sp. 2 ^h	—	—	—	—	—	3.7	—	—	—	1	MA
<i>Mollisia</i> sp. 3 ^h	—	—	—	—	—	—	—	3.4	—	1	WA
<i>Mortierella elongata</i> Linnem. ^h	—	—	—	—	—	—	—	—	6.3	1	MA
<i>Mortierella lignicola</i> (G.W. Martin) W. Gams et R. Moreau	—	—	—	—	—	3.7	—	—	—	1	WA
<i>Mortierella longicollis</i> Dixon-Stew.	—	—	—	—	3.6	—	—	—	—	1	SWA
<i>Nectriaceae</i> sp. ^h	—	—	—	12.5	—	—	—	—	—	2	MA
<i>Neolentinus</i> sp. ^h	—	—	—	—	—	3.7	—	—	—	1	CA
<i>Neoscytalidium dimidiatum</i> (Penz.) Crous et Slippers	—	—	3.4	—	—	—	—	—	—	1	WA
<i>Oidiodendron ambiguum</i> Peyronel et Malan	—	—	—	6.3	—	—	—	—	—	1	MA
<i>Oidiodendron echinulatum</i> G.L. Barron	—	—	—	—	—	—	3.4	3.4	—	2	SWA
<i>Oidiodendron griseum</i> Robak	17.9	3.7	—	6.3	3.6	—	—	—	—	8	MA, CA, WA
<i>Oidiodendron maius</i> var. <i>citrinum</i> (Barron) Rice a. Currah	3.6	—	—	—	—	—	—	—	—	1	MA
<i>Oidiodendron periconioides</i> Morrall	—	3.7	—	—	—	—	—	—	—	1	CA
<i>Oidiodendron</i> sp.	—	—	—	—	—	3.7	—	—	—	1	SEA
<i>Penicillium aculeatum</i> Raper et Fennell	—	—	—	—	—	—	—	—	6.3	1	MA
<i>Penicillium aurantiogriseum</i> Dierckx	3.6	3.7	3.4	—	—	—	—	—	—	3	WA, CA
<i>Penicillium brevicompactum</i> Dierckx	3.6	11.1	—	—	—	—	—	—	—	4	MA, WA, SEA
<i>Penicillium chermesinum</i> Biourge	—	—	—	—	—	—	—	3.4	—	1	CA
<i>Penicillium citreonigrum</i> Dierckx	3.6	3.7	3.4	—	—	—	—	—	—	3	MA, CA
<i>Penicillium citrinum</i> Thom	—	—	—	—	—	—	—	3.4	—	1	SEA
<i>Penicillium corylophilum</i> Dierckx	—	—	3.4	—	—	—	—	—	—	1	CA
<i>Penicillium dierckxii</i> Biourge	—	—	—	6.3	—	—	—	—	—	1	WA
<i>Penicillium expansum</i> Link	3.6	—	—	—	—	—	—	—	—	1	CA
<i>Penicillium glabrum</i> (Wehmer) Westling	3.6	18.5	—	6.3	—	—	—	—	—	7	MA, CA, WA, SEA, SWA
<i>Penicillium griseofulvum</i> Dierckx	—	—	—	6.3	—	—	—	—	—	1	CA
<i>Penicillium implicatum</i> Biourge	—	—	3.4	—	—	—	—	—	—	1	MA
<i>Penicillium janczewskii</i> K.M. Zalesky	—	—	3.4	—	—	—	—	—	—	1	CA
<i>Penicillium multicolor</i> Grig.-Man. et Porad.	—	—	—	—	—	—	—	—	6.3	1	WA
<i>Penicillium nalgioense</i> Laxa	—	3.7	—	—	—	—	—	—	—	1	WA
<i>Penicillium purpurascens</i> (Sopp) Biourge	—	—	—	—	3.6	—	—	—	—	1	SWA

TABLE III. Continued

Species	Sampling site										Total F ^c /No. of isolates	Medium
	Peat				Sediments							
	A ^a	B ^b	C ^c	D ^d	A ^a	B ^b	C (1) ^c	C (2) ^c	D ^d			
<i>Penicillium restrictum</i> J.C. Gilman et E.V. Abbott	3.6	—	—	—	—	—	—	—	—	—	1	CA
<i>Penicillium rolfsii</i> Thom	—	3.7	—	—	—	—	—	—	—	—	1	MA
<i>Penicillium roseopurpureum</i> Dierckx	3.6	—	—	—	7.1	—	—	—	6.3	—	3	CA, WA, SEA
<i>Penicillium sclerotiorum</i> J.F.H. Beyma	—	—	—	—	—	—	—	3.4	—	—	1	CA
<i>Penicillium solitum</i> var. <i>solitum</i> Westling	—	—	—	—	3.6	—	—	—	—	—	1	SEA
<i>Penicillium spinulosum</i> Thom ^h	14.3	18.5	10.3	25	3.6	7.4	—	3.4	—	—	20	MA, CA, WA, SEA, SWA
<i>Penicillium thomii</i> Maire	3.6	3.7	17.2	—	—	—	—	—	6.3	—	8	MA, CA, WA
<i>Penicillium verrucosum</i> Dierckx	—	—	3.4	—	—	—	—	—	—	—	1	MA
<i>Penicillium vinaceum</i> J.C. Gilman et E.V. Abbott	3.6	—	3.4	—	—	—	—	—	—	—	2	SEA
<i>Penicillium waksmanii</i> K.M. Zalessky	—	—	—	6.3	—	—	—	—	—	—	1	MA
<i>Peniophora piceae</i> (Pers.) J. Erikss. ^h	—	—	—	—	3.6	—	—	—	—	—	1	MA
<i>Peniophora</i> sp. 1 ^h	—	—	—	—	—	—	—	3.4	—	—	1	CA
<i>Peniophora</i> sp. 2 ^h	—	—	—	—	—	—	—	—	6.3	—	1	WA
<i>Pezizomycotina</i> sp. 1 ^h	3.6	—	—	—	—	—	—	—	—	—	1	MA
<i>Pezizomycotina</i> sp. 2 ^h	3.6	—	—	—	—	—	—	—	—	—	1	SEA
<i>Phaeosphaeria</i> sp.	—	—	—	—	—	—	—	3.4	—	—	1	WA
<i>Phellinus</i> sp. ^h	3.6	—	—	—	—	—	—	—	—	—	1	SEA
<i>Phialophora europaea</i> de Hoog, Mayser et Haase	3.6	—	—	—	—	—	—	—	—	—	1	CA
<i>Phialophora lagerbergii</i> (Melin et Nannf.) Conant	—	—	—	—	—	—	—	3.4	—	—	1	MA
<i>Phialophora verrucosa</i> Medlar	—	—	3.4	6.3	—	—	—	—	—	—	2	CA, WA
<i>Phlebiopsis gigantea</i> (Fr.) Jülich^h	3.6	—	6.9	—	—	—	—	3.4	—	—	4	MA, CA, WA
<i>Pholiota</i> sp. ^h	—	—	—	—	3.6	—	—	—	—	—	1	MA
<i>Phoma poolensis</i> (Ellis et Kellerm.) Aa et Boerema^h	—	—	6.9	—	—	—	—	—	—	—	2	MA, CA
<i>Piptoporus betulinus</i> (Bull.) P. Karst. ^h	—	—	—	—	—	—	—	3.4	—	—	1	MA
<i>Pochonia bulbilosa</i> (W. Gams et Malla) Zare et W. Gams ^h	3.6	—	—	12.5	—	—	—	—	—	—	3	MA, CA
<i>Polyporus</i> sp. ^h	—	—	—	—	—	3.7	—	—	—	—	1	MA
<i>Polyporales</i> sp. ^h	—	—	—	—	3.6	—	—	—	—	—	1	CA
<i>Polyscytalum fecundissimum</i> Riess	3.6	—	—	—	—	—	—	—	—	—	1	WA
<i>Resinicium bicolor</i> (Alb. et Schwein.) Parmasto^h	—	3.7	3.4	—	—	—	—	—	—	—	2	MA
<i>Resinicium</i> sp. ^h	—	—	3.4	—	—	—	—	—	—	—	1	SEA
<i>Sclerotinia</i> sp.	3.6	—	—	—	—	—	—	—	—	—	1	MA
<i>Scopulariopsis brumptii</i> Salv.-Duval	—	—	—	—	—	—	—	6.9	—	—	2	SWA
<i>Sistotrema brinkmannii</i> (Bres.) J. Erikss. ^h	—	—	3.4	—	7.1	—	—	3.4	12.5	—	6	MA, CA, AA, WA, SWA
<i>Sistotrema</i> sp. ^h	3.6	3.7	—	—	3.6	—	—	—	6.3	—	4	MA, CA, SEA, SWA
<i>Stachybotrys chartarum</i> (Ehrenb.) S. Hughes	3.6	—	—	—	—	—	—	—	—	—	1	SEA
<i>Stachybotrys dichroa</i> Grove	—	—	—	6.3	—	—	—	—	—	—	1	SEA
<i>Stephanosporium atrum</i> Dal Vesco	—	—	—	—	—	—	—	3.4	—	—	1	WA, SEA
<i>Stereum</i> sp. ^h	—	—	—	—	—	—	—	—	6.3	—	1	AA, SEA
<i>Strobilurus tenacellus</i> (Pers.) Singer ^h	—	—	—	—	—	—	—	3.4	—	—	1	MA
<i>Sydowia polyspora</i> (Bref. et Tavel) E. Müll.^h	3.6	—	—	6.3	—	—	—	—	—	—	2	CA, SEA
<i>Talaromyces diversus</i> (Raper et Fennell) Samson, Yilmaz et Frisvad	—	3.7	—	—	—	—	—	—	—	—	1	MA
<i>Talaromyces duclauxii</i> (Delacr.) Samson, Yilmaz, Frisvad et Seifert	—	—	—	—	—	—	—	3.4	—	—	1	MA

TABLE III. Continued

Species	Sampling site										Total F ^e /No. of isolates	Medium
	Peat				Sediments							
	A ^a	B ^b	C ^c	D ^d	A ^a	B ^b	C (1) ^c	C (2) ^c	D ^d			
<i>Talaromyces funiculosus</i> (Thom) Samson, Yilmaz, Frisvad et Seifert ^h	3.6	14.8	20.7	6.3	10.7	3.7	—	6.9	—	—	18	MA, CA, WA, SEA, SWA
<i>Talaromyces rugulosus</i> (Thom) Samson, Yilmaz, Frisvad et Seifert	—	—	3.4	—	—	—	—	—	—	—	1	MA
<i>Talaromyces variabilis</i> (Sopp) Samson, Yilmaz, Frisvad et Seifert	—	7.4	3.4	—	—	—	—	—	6.3	—	4	MA, CA, SEA
<i>Talaromyces verruculosus</i> (Peyronel) Samson, Yilmaz, Frisvad et Seifert	3.6	—	—	—	—	—	—	—	6.3	—	2	WA, SEA
<i>Teberdina hygrophila</i> Sogonov, W. Gams, Summerb. et Schroers ^h	—	7.4	3.4	—	—	—	—	—	—	—	3	WA
<i>Tolyposcladium cylindrosporium</i> W. Gams ^h	—	—	—	18.8	3.6	—	—	—	6.3	—	5	MA, AA, SWA
<i>Tolyposcladium geodes</i> W. Gams ^h	—	11.1	—	—	3.6	—	—	3.4	—	—	5	WA, AA, SEA
<i>Tolyposcladium nubicola</i> Bissett	—	—	—	6.3	—	—	—	—	—	—	1	WA
<i>Tolyposcladium tundrense</i> Bissett	—	—	—	—	3.6	—	—	—	—	—	1	AA
<i>Trichoderma asperellum</i> Samuels, Lieckf. et Nirenberg	—	—	—	—	3.6	—	—	—	—	—	1	WA, SEA
<i>Trichoderma hamatum</i> (Bonord.) Bainier	—	—	—	—	—	3.7	6.9	6.9	—	—	5	MA, CA, WA, SEA, SWA
<i>Trichoderma harzianum</i> Rifai	—	3.7	6.9	6.3	—	—	—	3.4	—	—	5	CA, WA, SEA, SWA
<i>Trichoderma koningii</i> Oudem.	—	—	—	6.3	—	—	—	—	—	—	1	CA
<i>Trichoderma piluliferum</i> J. Webster et Rifai	—	—	3.4	—	—	—	—	—	—	—	1	WA
<i>Trichoderma polysporum</i> (Link) Rifai ^h	3.6	—	3.4	—	—	7.4	6.9	3.4	—	—	7	MA, CA, WA, SEA, SWA
<i>Trichoderma viride</i> Pers.	—	7.4	6.9	—	7.1	—	3.4	—	—	—	7	WA, SEA, SWA
<i>Trichosporon lignicola</i> (Diddens) Fell et Scorretti	3.6	—	—	—	—	—	—	—	—	—	1	CA
<i>Umbelopsis isabellina</i> (Oudem.) W. Gams	—	—	—	6.3	—	—	—	—	—	—	1	CA
<i>Umbelopsis ramanniana</i> (Möller) W. Gams	—	—	—	6.3	—	—	—	—	—	—	1	MA
<i>Umbelopsis vinacea</i> (Dixon-Stew.) Arx	—	—	—	6.3	—	—	—	—	—	—	1	CA
<i>Umbelopsis</i> sp.	—	—	—	6.3	—	—	—	—	—	—	1	SWA
<i>Volutella</i> sp. ^h	—	—	—	—	—	7.4	—	—	—	—	2	AA
<i>Zythiostroma pinastri</i> (P. Karst.) Höhn.	7.1	—	—	—	—	—	—	—	—	—	2	MA, CA
<i>Cladosporium</i> spp. ^f (3 morphotypes)	3.6	—	—	6.3	—	—	—	3.4	—	—	3	MA, WA, SEA
<i>Lecanicillium</i> spp. ^f (4 morphotypes)	—	3.7	—	12.5	3.6	—	—	—	—	—	4	MA, AA, SEA, SWA
<i>Penicillium</i> spp. ^f (6 morphotypes)	—	3.7	—	—	10.7	3.7	—	3.4	—	—	6	MA, CA, SWA
<i>Phaeoacremonium</i> spp. ^f (4 morphotypes)	—	—	3.4	6.3	—	3.7	—	6.9	—	—	5	MA, WA, SEA
<i>Trichoderma</i> spp. ^f (3 morphotypes)	—	—	—	—	—	—	3.4	6.9	—	—	3	SEA, SWA
Sterile isolates ^g (60 morphotypes)	14.3	18.5	6.9	18.8	46.4	25.9	20.7	27.6	75.0	—	60	All

^a Frequency was calculated as percentage of 28 samples collected from peatland A.

^b Frequency was calculated as percentage of 27 samples collected from peatland B.

^c Frequency was calculated as percentage of 29 samples collected from peatland C.

^d Frequency was calculated as percentage of 16 samples collected from peatland D.

^e Frequency was calculated as percentage of 100 samples collected during the overall investigation.

^f Morphotypes were not determined to species.

TABLE III. Continued

^g Sterile morphotypes were not determined to division.

^h Species identified by morphological and molecular approach. Species not found in sphagnum peat before this research in boldface.

Abbreviations: MA = malt-extract agar, CA = citric agar, AA = alkaline agar, WA = water agar, SEA = sphagnum-extract agar, SWA = seawater agar.

A = Verchnee Peatland. B = Krugloe Peatland. C = Ershovskoe Peatland. C(1) = Ershovskoe Verchnee Lake. C(2) = Ershovskoe Nizhnee Lake. D = Kislosladkoe Peatland.

maius, *O. periconioides*, *Talaromyces funiculosus*, *Penicillium spinulosum*, *P. thomii*, *Pochonia bulbilosa* were found; they are known as decomposers of *Sphagnum* mosses (Thormann et al. 2002, 2003; Rice et al. 2006; Thormann 2006). The community of the Kislosladkoe Peatland appears to be fundamentally different from the others. The *Sphagnum* peat of the Kislosladkoe Peatland contains a higher frequency and quantity of species of genera *Cadophora* Lagerb. & Melin, *Alternaria* Nees, *Tolyposcladium* W. Gams, *Cladosporium* and *Acremonium* Link when compared to the peat of the other peatlands (TABLE II). Presumably it could be explained by the sea proximity and the youth of the peat deposit. These factors influence physical-chemical features and organic composition.

Sediments present a more dynamic system due to some differences in organic input as well as physical-chemical and hydrological exposures. In the upper lake of the Ershovskoe Peatland large numbers of invertebrate animals were found, such as leeches and freshwater shrimp. Apart from that, numerous plants and plant roots were discovered. These facts could indicate the existence of a different fungal community in this lake (TABLE II). The results of the diatom research confirm the difference between the Ershovskoe Peatland and other peatlands of the Kindo Peninsula (Shilova 2011). Taxa such as *Emericellopsis minima* and *Acremonium* spp. were found in the sediments, which are characteristic for marine habitats (Jones et al. 2009, Pivkin 2010).

The abundance of sterile isolates is typical for peat (Golovchenko et al. 2002, Thormann 2006a). Significant amounts of sterile mycelium were found both in the peat and in the sediments of all the peatlands. The identification of a part of the sterile isolates by molecular approaches revealed the abundance of *Ascomycota*; isolates belonging to the *Helotiales* were most abundant, especially in the sediments examined (TABLE II). The fungi of this group can fulfill different functions: members of the *Helotiales* have been described as plant pathogens, endophytes, nematode-trapping fungi, mycorrhiza-forming (including ectomycorrhizae and ericoid mycorrhizae), ectomycorrhizal parasites, fungal parasites, terrestrial

saprobies, aquatic saprobies, root symbionts and wood-rot fungi (Wang et al. 2006).

One of the important results of using molecular approaches for the identification of sterile isolates was the detection of species of the *Basidiomycota*. Thormann (2006a) considers five groups of fungi, which decompose different types of organic substance in peat. One of these includes species that are known as recalcitrant polymer degraders. This group mostly consists of the basidiomycetes species, which are capable of utilizing complex polymers, including lignin, tannins and other polyphenolics typical for peat. Due to slow growth and difficulties related with identification of these fungi, they are difficult to find and study. In our work a significant number of the basidiomycetes isolates was identified, which can be used for future research.

Apart from that fungi that are known as psychrotolerant species were isolated. The examples of these fungi are *Pseudogymnoascus pannorum* and *Tolyposcladium inflatum* (Bisset 1982, Bubnova 2005, Kochkina et al. 2007). Both species were found in almost all studied samples; moreover *T. inflatum* was successfully grown on all media (TABLE II). These facts indicate the adaptation of the species to a wide spectrum of environmental conditions. In addition to *T. inflatum* other anamorphs of the *Cordycipitaceae* and *Ophiocordycipitaceae* were isolated; these include *Tolyposcladium cylindrosporium*, *T. geodes*, *T. nubicola*, *T. tundrense*, *Beauveria bassiana*, *B. brongniartii* and *Engyodontium album*.

Also, fungi that are known as typical soil saprobies for northern regions and species associated with insects such as *Tolyposcladium inflatum*, *Tolyposcladium cylindrosporium*, *T. geodes*, *Engyodontium album* were found at high frequency (Lam et al. 1988, Hodge et al. 1996, Bubnova 2005). The high incidence of entomopathogenic species is remarkable. The abundance of insects and larvae in the peatlands may present a protein source in this N-limited environment and may reflect adaptations similar to that of some carnivorous plants found in the peatlands, such as *Drosera* spp. (TABLE I) (Limpens et al. 2011).

Our investigations revealed high fungal biodiversity and density in all components of the studied peatlands on the Kindo Peninsula at Kandalaksha Bay of the

White Sea. The isolated fungi predominantly belong to saprobiotic ascomycetous species. In addition to the data available on the biological diversity of the fungi from the peatland ecosystems of the northern region we present molecular data on a large group of fungi of undetermined taxonomy and sterile mycelia, among which are a significant percentage of basidiomycetes as well as newly revealed taxa of ascomycetes. The investigations carried out in this study suggest a specificity of the fungal community in aqueous-peatland system of the coastal area of Kandalaksha Bay. It is related to the characteristic properties of the complex communities of the isolated fungi in each of the reservoirs and in particular in a high percentage of entomopathogenic species, as well as in the occurrence of psychrotolerant species. Our research revealed that fungal communities in peat can be characterized by higher stability than those in sediments.

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