On filamentous fungi in polar regions and boreal peatlands

OLGA A. GRUM-GRZHIMAYLO

Propositions

1. Fungi thrive in polyextreme conditions of polar and peatland habitats.
   (this thesis)

2. Preserve fungal cultures is essential for the progress of science.
   (this thesis)

3. A unified protocol for studying soil microbiota is essential for understanding their ecology.

4. No good science without routine work.

5. The death of men in large-scale wars destroys several generations of society.

6. Don't shoot, just talk.

Propositions belong to the thesis, entitled
"On filamentous fungi in polar regions and boreal peatlands"
Olga Grum-Grzhimaylo
Wageningen, 19 May 2025

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This research was conducted under the auspices of the C. T. de Wit Graduate School for Production Ecology and Resource Conservation

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Thesis

submitted in fulfilment of the requirements for the degree of doctor at Wageningen University by the authority of the Rector Magnificus, Prof. Dr C. Kroeze, in the presence of the Thesis Committee appointed by the Academic Board to be defended in public on Monday 19 May 2025 at 3.30p.m. in the Omnia Auditorium

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On filamentous fungi in polar regions and boreal peatlands
352 pages
PhD thesis, Wageningen University, Wageningen, the Netherlands (2025)
With references, with summary in English

ISBN: 978-94-6510-575-8
DOI: 10.18174/682135

The research described in this thesis was financially supported by The Laboratory of Genetics, Wageningen University & Research
Financial support from Wageningen University for printing this thesis is gratefully acknowledged.

Cover: Denis Landin
Layout: Dennis Hendriks, GWHconcepts.nl
Printing: ProefschriftMaken.nl on FSC-certified paper

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CHAPTER 1

General Introduction

Polar and high-mountain regions are considered extremely harsh places for living organisms, including fungi (Tsuji and Hoshino, 2019). One of the characteristic features of these biotopes is the presence of permafrost, ground that remains frozen for at least two years. The area of permafrost is rapidly decreasing due to global warming (Turetsky et al., 2020, 2019). Peatlands are also extreme habitats for fungi due to high acidity and moisture, lack of oxygen, oligotrophy, and difficult-to-decompose organic matter (Grum-Grzhimaylo et al., 2016). The northern part of boreal peatlands has an underlying permafrost layer, thus accumulating all the aforementioned polyextreme conditions. As the Arctic permafrost melts, a significant part of it transforms into peatlands, expanding their area. There is a general warming and drying of peat, which affects the activity of microorganisms (Altshuler et al., 2017; Jassey et al., 2013; Juan-Ovejero et al., 2020).

There is a limited group of fungi that are active in perennially frozen regions (Altshuler et al., 2017; Ludley and Robinson, 2008; Robinson, 2001). Due to the extreme conditions of peatland, also only a limited group of fungi can function there (Filippova and Thormann, 2014; Grum-Grzhimaylo et al., 2016; Thormann and Rice, 2007). The group of inhabitants of perennially frozen peatlands is limited by the entirety of these extreme conditions (Altshuler et al., 2017). However, similar to the permafrost of polar and high-mountain regions, a huge pool of inactive fungi in the form of spores and DNA fragments is also stored in peat and brought by the wind, birds, and people and other animals from other regions. With climate change, spores can become active and will impact global substance flows, including the release of greenhouse gases.

Currently, there is little data on the species composition and functioning of fungi in the Arctic, Antarctica, and high mountains, as well as in boreal peatlands (Lapteva et al., 2017; Pastukhov et al., 2022; Vinogradova et al., 2023; Wang et al., 2015). There are even fewer comparative characteristics of these fungal communities, as well as predictions of their activity in relation to climate change. To make these predictions, it is necessary to know the species composition of the fungal community and their physiological characteristics. This study compiles existing data on terrestrial mycelial fungi of polar regions and presents the results of research on fungal communities in boreal peatlands, which is an essential contribution to filling the existing knowledge gaps in this area of research and provide information for predicting the response of fungi in these regions to global warming.

Extreme conditions for life and fungi

Alongside "normal" living conditions (such as habitats with temperatures ranging from 4 to 40°C, pH values from 5 to 8.5, and salinity between freshwater and seawater), there are extreme conditions on our planet that hinder the functioning of most organisms (Oarga, 2009). The concept of "extreme conditions" is anthropocentric and subjective, with the only truly necessary factor for life being the presence of water (Coleine et al., 2022; Harrison et al., 2013; Rothschild and Mancinelli, 2001). Typically, extreme conditions include excessively high or low temperatures, pressures, salinity, pH, desiccation, intense radiation, oxygen deficiency or high levels of reactive oxygen species, high concentrations of heavy metals, nutrient deficiency, and several other factors (Oarga, 2009). Examples of extreme habitats include geysers and hot springs, ocean depths, deserts, volcanoes, soda salt flats, hypersaline lakes, deep hypersaline anoxic basins, evaporites, permafrost, snow and ice, and peatlands (Coleine et al., 2022; Grum-Grzhimaylo et al., 2016; Harrison et al., 2013; Rothschild and Mancinelli, 2001). Organisms that survive and function in extreme conditions are called extremotolerant, while narrowly specialized organisms thriving in extreme conditions are called extremophiles (Rekadwad et al., 2023). Extremotolerant and extremophilic organisms often tolerate the impact of multiple adverse factors, and are thus referred to as polyextremotolerant and polyextremophilic, respectively (Coleine et al., 2022; Harrison et al., 2013; Rothschild and Mancinelli, 2001). The study of organisms inhabiting extreme conditions is relevant due to their economic potential in biotechnology, their roles in geochemical processes, addressing environmental issues, such as cleaning polluted soil, and the search for life in the universe (Harrison et al., 2013), as well as understanding the processes of life's origin on Earth and its limits (Coleine et al., 2022).

Fungi are found in almost any habitat and under many conditions, including extreme ones (Oarga, 2009). This is because they are among the most adaptable and resilient organisms to extreme conditions, including extreme water deficit (some can grow even at a_w[1] < 0.7, whereas most organisms require a_w within the range of 0.99 to 0.97 for active life; Coleine et al., 2022). Furthermore, since adapted microorganisms dominate in extreme habitats compared to macroforms, fungi, along with bacteria and other microorganisms, play a crucial role in such ecosystems, performing key functions in carbon, nitrogen, and other nutrient cycles (Coleine et al., 2022). There are known fungi that inhabit conditions of desiccation, extremely low or high pH values, high salinity, low temperature, intense radiation, oligotrophy, and more (Coleine et al., 2022; Grum-Grzhimaylo et al., 2016; Rothschild and Mancinelli, 2001).

Cold polyextreme conditions

Low temperature creates extreme conditions for life, primarily because water freezes at negative temperatures for the Celsius scale. The formation of ice crystals can rupture cell membranes, and the freezing of intracellular water and the cessation of biochemical reactions without water leads to cell death (Rothschild and Mancinelli, 2001). However, some organisms have physiological mechanisms that allow them to actively live at nega-

1 a_w – water activity – the ratio of the water vapor pressure of the sample to the water vapor pressure of pure water under the same conditions (Coleine et al., 2022).

tive temperatures or tolerate them, and some microorganisms are capable of using ice or dry snow as a source of water (Rekadwad et al., 2023).

The Arctic, Antarctic, and high mountain regions are considered extreme cold habitats on Earth (Rekadwad et al., 2023). They are characterized by extensive permafrost areas, low temperatures, short or absent vegetation periods, water deficit, intense UV radiation, and often poor organic substrates. Polar regions also experience the extremity of prolonged polar nights and days (Tsuji and Hoshino, 2019; Tsuji et al., 2022). The dry valleys of Antarctica are considered the coldest and driest places on Earth (Oagra, 2009), including permafrost with a dry soil layer above the icy cement (Canini et al., 2021; Ottoni et al., 2022). The Arctic is a milder region compared to Antarctica, with higher temperatures, humidity, and more organic matter (Tsuji and Hoshino, 2019). In contrast to the Arctic, which is covered with thick peat deposits, Antarctica is predominantly a rocky continent, more than 98% covered in ice, and characterized by unevenly developed soil or its absence (Bockheim, Haus, 2014; Pires et al., 2017). Antarctic permafrost exhibits significant differences between the deep continental and marine parts and is strongly influenced by regional climate, proximity to glaciers, age, vegetation, snow cover, and surface albedo (Ottoni et al., 2022).

Fungi have been found in all the aforementioned cold regions and on all studied substrates (e.g., Tsuji and Hoshino, 2019; Coleine et al., 2022; Tsuji et al., 2022; Wang et al., 2015). Several studies have shown that some fungal species isolated from permafrost not only survive, but also grow consistently at negative temperatures down to -18 °C, and are capable of temporary growth for up to three weeks in the range of -18 to -35 °C (Altshuler et al., 2017).

Northern peatlands as polyextreme environments and their development in the changing World

For some habitats, low acidity is characteristic, for example in geothermal and volcanic areas, acidic lakes, acid rock drainage, and most peatlands (Coleine et al., 2022; Grum-Grzhimaylo et al., 2016). Peatlands occupy vast areas on the Earth's surface. Their total area is estimated at approximately 350 million hectares, which represents about 3-4% of the land surface. Peatlands are a type of land surface that is constantly or long-term moistened and characterized by characteristic soil-forming processes; the presence of peat is usually considered a mandatory feature of peatlands. Peat is an organic massive material containing no more than 50% mineral substances from absolutely dry matter, formed as a result of the death and incomplete decay of peatland plants in conditions of increased humidity and lack of oxygen (Grum-Grzhimaylo and Bilanenko, 2010). Despite the fact that globally, peatlands cover a small portion of the world's surface, they contain up to more than one-third of all soil organic carbon (Grum-Grzhimaylo et al., 2016; Minasny et al., 2019; Tfaily et al., 2013).

Peatlands are divided into three types: lowland (eutrophic), transitional (mesotrophic), and upland (oligotrophic). Lowland peatlands are understood to be peatlands whose surface is moistened by waters rich in mineral salts, and upland peatlands are moistened by waters poor in mineral salts. Transitional peatlands represent an intermediate group. Lowland peatlands are conditionally considered peatlands with an ash content of the upper layer above 6-7%, transitional peatlands - with an ash content from 4 to 6-7%, and upland peatlands - with an ash content of less than 4%. Upland peatlands have high acidity of the feeding aqueous solutions, while lowland peatlands have low acidity. Since all types of peatlands differ in their nutrient richness, the composition of plants here is not the same. The only similarity of peatland flora is that all these plants are to varying degrees moisture-loving (Grum-Grzhimaylo and Bilanenko, 2010). Thus, upland peatlands have the lowest acidity, which is associated with the dominant *Sphagnum* mosses here, which release acids, and poor mineral nutrition, as well as the increased humidity and lack of oxygen characteristic of all types of peatlands.

Due to these extreme conditions, the activity of microorganisms in the decomposition of plant residues in peatlands is greatly hindered; however, it is known that there are about 700 species of fungi characteristic of peatlands (Thormann and Rice, 2007).

Peatlands are predominantly found in the Northern Hemisphere, including Western and Northern Europe, as well as certain parts of Canada and Siberia, covering 70-80% of the Northern land surface and often located in the Arctic region, including the permafrost zone (Filippova and Thormann, 2014; Kim et al., 2012; Minasny et al., 2019; Thormann and Rice, 2007). Oligotrophic upland peatlands dominate among northern bogs, in contrast to transitional and lowland bogs, which are widely spread in mid-latitude regions (Bilanenko and Grum-Grzhimaylo, 2016) . According to various studies, northern peatlands contain 10-50% of the global soil carbon, despite occupying only 3% of the Earth's land surface (Altshuler et al., 2017; Andersen et al., 2010; Asemaninejad et al., 2018; Thormann and Rice, 2007; Tveit et al., 2013; Weedon et al., 2013).

By now, two reasons for the growth of northern peatlands have been identified. Firstly, the origin of northern peatlands is directly linked to the uplift of the Earth's crust resulting from post-glacial movement (Zadareev et al., 2017). When the sea recedes, groundwater drains away and lakes become boggy. As a result, peatlands gradually emerge from brackish coastal lakes and transform into oligotrophic upland bogs (O.A. Grum-Grzhimaylo et al., 2018). Secondly, a large portion of northern peatlands is located on the permafrost land surface, and as it thaws, the area of peatlands expands (Altshuler et al., 2017; Schütte et al., 2019; Sjögersten et al., 2016; Turetsky et al., 2019). Both factors contribute to the expansion of peatland area.

Fungi, along with heterotrophic bacteria, are the primary decomposers of organic matter in peat (Gilbert and Mitchell, 2006). According to the literature, in the initial stages of degradation, fungi play a more significant role due to their enzymatic activity which allows them to break down poorly decomposable plant tissues, such as lignin and cellulose, while bacteria join the process of decomposition with their repertoire of extracellular enzymes and break down simpler substances (Song et al., 2020; Tveit et al., 2013). Being mostly aerobic organisms, fungi predominantly function in the upper aerobic levels of peatlands, while bacteria dominate in the lower layers of peat (Dobrovol'skaya et al., 2012; Tveit et al., 2013). In addition to saprophytic fungi, peatlands are inhabited by entomopathogenic, nematophagous, phytopathogenic, and symbiotic species of fungi (Asemaninejad et al., 2017; Kiheri et al., 2020; Monteux et al., 2018; Safitri et al., 2018; Schütte et al., 2019; Yakushev et al., 2019). Under nitrogen deficiency in the soil, typical for peat, most terrestrial plants form symbioses with fungi (mycorrhizae): mycelia absorb soil nitrogen, transport it to plant roots, and receive plant sugars in exchange (Hobbie and Hobbie, 2006). Saprotrophic fungi in peat can obtain nitrogen from complex phenolic compounds of plant tissues (specifically from tissues of *Sphagnum* moss) as well as from animal tissues, for example, insect larvae and nematodes, due to their enzymes.

It is known that perennially frozen permafrost is most often overlaid by a seasonally thawed active layer (Altshuler et al., 2017). In peatlands, two functional groups of microorganisms can be expected to exist: 1) slow-growing and constantly active at subzero temperatures; 2) fast-growing and mainly functioning at the upper level during a short summer period. It has already been proven that bacteria can function at negative temperatures (Altshuler et al., 2017). Fungal DNA is present in samples from perennially frozen peatlands, but the functioning of fungi at low temperatures remains a question. Altshuler et al. (2017) described a study in which they discovered three species of fungi capable of growing at low temperatures: *Leucosporidium* spp. and *Geomyces* spp. could grow down to -35 °C, while *Mrakia* sp. down to -12°C. Bellemain et al. (2013) obtained data on the presence of psychrophilic and psychrotolerant fungal taxa in samples from Siberian Pleistocene permafrost using metabarcoding. However, it is unknown whether these fungi are active or whether their DNA is simply stored frozen. Active ascomycete fungi are present in conditions of frozen permafrost, according to RNA data (Altshuler et al., 2017). It is also known that ascomycetes cause "soft rot", which is a dominant type of decay in extreme terrestrial environments such as arid deserts and polar regions. However, the mechanisms of this type of decay have been poorly studied so far (Hibbett et al., 2016). It is evident that fungi actively function in thawing layers during the summer.

Despite the importance of fungi as initiators of peat formation, little is known about fungal biodiversity in northern peatlands, especially in the permafrost zone. Some data on peat fungi from Canada, Northern Europe, Western Siberia, Central and Northern Russia exist (Bilanenko and Grum-Grzhimaylo, 2016; Dobrovol'skaya et al., 2012; Filippova and Thormann, 2014; Golovchenko et al., 2013; Grum-Grzhimaylo et al., 2016, 2018; Thormann and Rice, 2007). There is almost no data on fungi in perennially frozen peatlands, and in tundra soils fungi are primary decomposers (Oechel et al., 1997; Ozerskaya et al., 2009), making plant material accessible to bacteria. It is crucial to determine which fungal species function under what conditions in thawing permafrost peatlands. Currently, there is a growing interest in studying microbial communities in peatlands (Gandhi et al., 2019; Juan-Ovejero et al., 2020). Schütte et al. (2018) showed in their study that the relative abundance of mycorrhizal fungi decreases, while the relative abundance of presumed saprotrophic and fungal pathogens increases with thawing. The authors suggest that changes in fungal composition may mediate the response of the plant community to permafrost thaw and may have a key influence on the consequences of climate change. They also note that very few studies have investigated the impact of permafrost thaw on fungal communities, and overall, only a tenth of fungal diversity has been described (Schütte et al., 2019).

Given that peatlands play a significant role in climate change through the emissions of greenhouse gases resulting from the activity of microbial communities (fungi and bacteria), the most promising direction is the monitoring of fungal communities in northern bog ecosystems as a response to global warming and increasing peatland areas (Altshuler et al., 2017; Jassey et al., 2013; Juan-Ovejero et al., 2020; Lee et al., 2013; Song et al., 2020). Based on published scientific data, some conclusions can be drawn regarding the processes occurring in northern peatlands and the involvement of fungi in them:

1) scientists do not have a complete understanding of the processes occurring in peatlands, including the influence of climate change (Page and Baird, 2016);
2) the study of regions with permafrost thaw is recognized by many researchers as one of the most important scientific directions today (Fedorov, 2022; Philipp et al., 2021; Walvoord and Kurylyk, 2016);
3) the composition and activity of microbial communities affect the intensity of greenhouse gas emissions (AminiTabrizi et al., 2020; Sjögersten et al., 2016; Turetsky et al., 2020);
4) a significant portion of the thawing permafrost area is converted into peatlands (Hugelius et al., 2020);
5) it is known that fungi play a significant role in the early stages of peat formation: they make the plant substrate accessible to bacteria (Juan-Ovejero et al., 2020; Yarwood, 2018);

6) fungal activity affects peat formation processes and greenhouse gas emissions (Juan-Ovejero et al., 2020);
7) data on fungi during permafrost thaw are very limited (Juan-Ovejero et al., 2020);
8) due to the unique species composition of fungi and bacteria in deposits of ponds formed as a result of permafrost thaw, they represent unique ecosystems (Wurzbacher et al., 2017);
9) fungal abundance rapidly increases immediately after permafrost thaw with temperature rising above 0°C, which can lead to a significant acceleration of plant-substrate decomposition in thawing zones (Chen et al., 2016);
10) this supports the assumption that fungi isolated from permafrost habitats function poorly but become activated immediately with changing conditions (Ozerskaya et al., 2009);
11) to study fungal biodiversity, researchers usually use either molecular approaches (Asemaninejad et al., 2017; Christiansen et al., 2017; Kujala et al., 2018; Schütte et al., 2019; Singer et al., 2019; Song et al., 2020; Veselá et al., 2019; Wurzbacher et al., 2017; Zhang et al., 2017), or cultural methods (Dobrovol'skaya et al., 2012; Filippova and Thormann, 2014; Golovchenko et al., 2013; Grum-Grzhimaylo et al., 2016, 2018; Ozerskaya et al., 2009; Singh et al., 2012), both of these methods have their own strengths and weaknesses. I was able to find very few studies that used both groups of methods, although they complement each other very well (Arenz et al., 2006; Edwards et al., 2013; Ferrari et al., 2005; Kochkina et al., 2012; Nikitin and Semenov, 2022; Pudasaini et al., 2017; Selbmann et al., 2021).

Outline of my thesis: the aims of this study and an overview of the contents

This thesis studies and describes the diversity of filamentous fungi from the northern peatlands of several geographical locations and the Polar regions. In this General Introduction (**Chapter 1**) I have presented the background of my research and have identified key knowledge gaps and research questions. I have compiled these knowledge gaps in the form of questions and below display them in a diagram (Fig. 1).

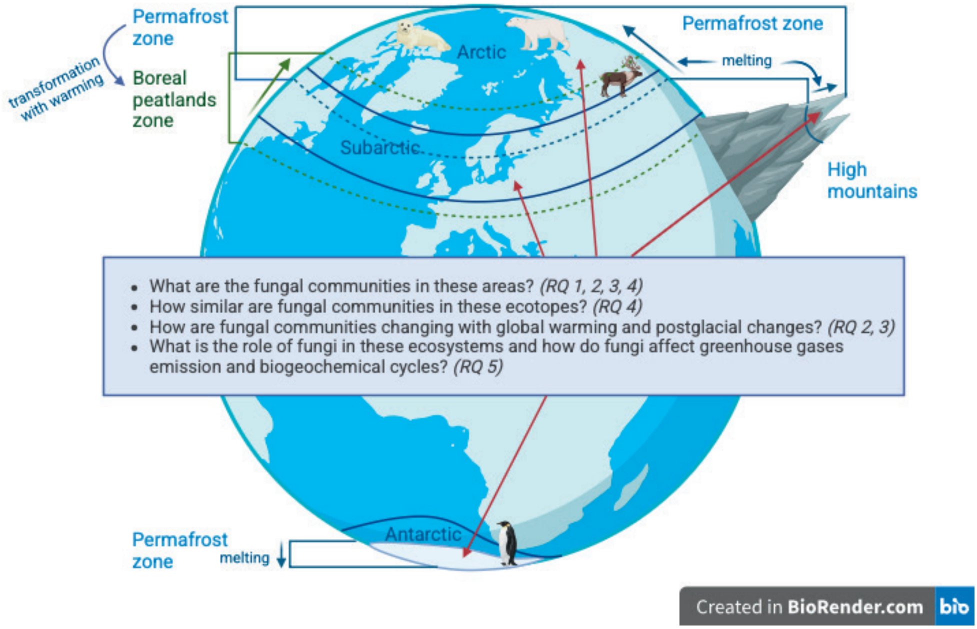

Fig. 1. An overview of the questions that motivated this work and the predicted changes in permafrost and peatland areas in the polar and high mountainous regions under the influence of global warming. RQ – research questions, the corresponding questions that were investigated in this work (see in the text).

In the present study, I have partially addressed these knowledge gaps based on my own research and review of scientific literature, and have attempted to answer several more specific and detailed questions, namely:

RQ1) What are the characteristics of fungal communities in northern *Sphagnum* peatlands located in the taiga zone near the White Sea?
RQ2) Does the origin of these peatlands from the sea influence the fungal communities?
RQ3) Are there differences in fungal communities in *Sphagnum* peatlands between the northern and temperate zones?
RQ4) How similar and unique are the fungal communities of the Arctic and Antarctica?
RQ5) What ecological roles do fungi fulfill in northern peatlands and polar regions?

The results obtained in this study may contribute to finding answers to the global questions presented in Figure 1 in future research.

In **Chapter 2 and 3**, I describe the diversity of culturable fungi in northern peatlands originated at different times from the White Sea due to postglacial Earth rising. It is shown here that the marine origin of these peatlands partly determines the species composition of fungi, and that the fungal communities of peat and bottom sediments of the peatlands differ from each other. I also discuss the ecological role of fungi in northern peatlands in these chapters. In **Chapter 4**, I compare communities of cultivated fungi in oligotrophic *Sphagnum* peatlands in the northern and central latitudes. The similarities and differences between fungal communities, due to a similar substrate (*Sphagnum* mosses), but different climatic zones and the origin of the studied peatlands, are hightlighted. In **Chapter 5**, the diversity and location of filamentous terrestrial fungi in Arctic and Antarctic regions is described based on literature data. Also, I discuss and compare the methods of fungal investigations and uniqueness of fungal communities and their ecological role in the Polar regions. **Chapter 6** is devoted to discovering, identification, and studying the physiology of the fungus *Psychrophilomyces antarcticus* from the Arctic region. Previously, this species was known only from Antarctica and the Tibet Plateau. **Chapter 7** is a discussion of the results obtained during all stages of the work presented in this thesis.

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CHAPTER 2

The diversity of microfungi in peatlands originated from the White Sea

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Published in Mycologia, 108(2), 2016, pp. 233–254. DOI: 10.3852/14-346

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 insect's species (*Pseudogymnoascus pannorum*, *Tolypocladium* 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

Abstract

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 x 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, 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 January and a relatively short humid summer with a maximum precipitation in August and a mean temperature of 14° C in July (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.

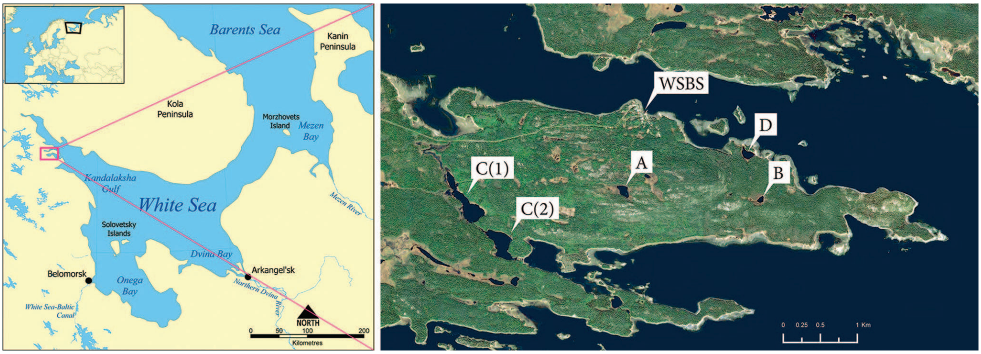

Fig. 1. Map of the Kindo Peninsula with four studied peatlands tagged: A – Verkhnee Peatland; B – Krugloe Peatland; C – Ershovskoe Peatland; C(1) – Ershovskoe Verkhnee Lake; C(2) – Ershovskoe Nizhnee Lake; D – Kislosladkoe Peatland; WSBS – White Sea Biological Station.

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 1). 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 1. Description of the investigated peatlands.

Peatland		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 the centers of the lakes)
№	Name								Trees	Shrubs/ subshrubs	Herbs	Mosses/lichens	
1	Verkhnee	8400±110	87	raised bog	4.6	2.0	peat 4.1, sediments 6.0	-20	*Pinus sylvestris, Betula nana*	*Chamaedaphne calyculata, Calluna vulgaris, Rubus chamaemorus, Oxycoccus microcarpus, Ledum palustre*	*Drosera rotundifolia, D. anglica, Eriophorum latifolium, Menyanthes trifoliata*	*Pleurozium schreberi, Sphagnum fuscum, Sph. capillifolium, Sph. papillosum, Sph. magellanicum, Sph. majus, Cladonia rangiferina, Cl. alpestris, Cl. mitis, Cetraria islandica, Nephroma* 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	*Pinus sylvestris, Betula nana*	*Calluna vulgaris, Rubus chamaemorus, Oxycoccus microcarpus, Vaccínium* sp.	*Drosera rotundifolia, D. anglica, Baeothryon caespitosum*	*Pleurozium schreberi, Sphagnum papillosum, Sph. fuscum, Sph. balticum, Sph. lindbergii, Sph. subfulvum, Cladonia rangiferina, Cladonia* spp.	66°32'32.8416"/ 33°8'22.4592"
3	Ershovs-koe	810±40	3.5	transition aapa-fen	1.8	1.8	peat 5.5, sediments 5.5-8.0	-5	*Pinus sylvestris, Betula nana*	*Rubus chamaemorus, Oxycoccus microcarpus, Vaccínium* sp.	*Eriophorum polystachyon, Carex rostrata, Baeothryon caespitosum, Menyanthes trifoliata, Utricularia* sp., *Comarum palustre, Deschampsia* sp., *Calamagrostis* sp.	*Sphagnum papillosum, Sph. subfulvum, Sphagnum* spp.	**3_1:** 66°32'14.3874"/ 33°3'35.7156"; **3_2:** 66°32'27.9198"/ 33°3'2.9628"
4	Kisloslad-koe	-	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	*Pinus sylvestris, Betula pubescens, Betula pubescens x B. nana, Sorbus aucuparia*	*Cornus suecica, Empetrum hermaphroditum, Vaccinium vitisidaea, Oxycoccus palustris, Rubus chamaemorus, Vaccinium uliginosum*	*Aster tripolium, Triglochin maritima, Phleum alpinum, Festuca rubra, Juncus atrofuscus, Polygonum viviparum, Blysmus rufus, Eleocharis uniglumis, Ophioglossum vulgatum, Primula nutans, Salix* sp., *Carex* sect. *Temnelis, Trientalis europaea, Triglochin palustris, Triglochin maritima, Parnassia palustris, Comarum palustre, Listera cordata, Comarum palustre, Dactylorhiza maculata, Eleocharis polystachion*	*Sphagnum* spp.	66°32'52.5186"/ 33°8'8.865"

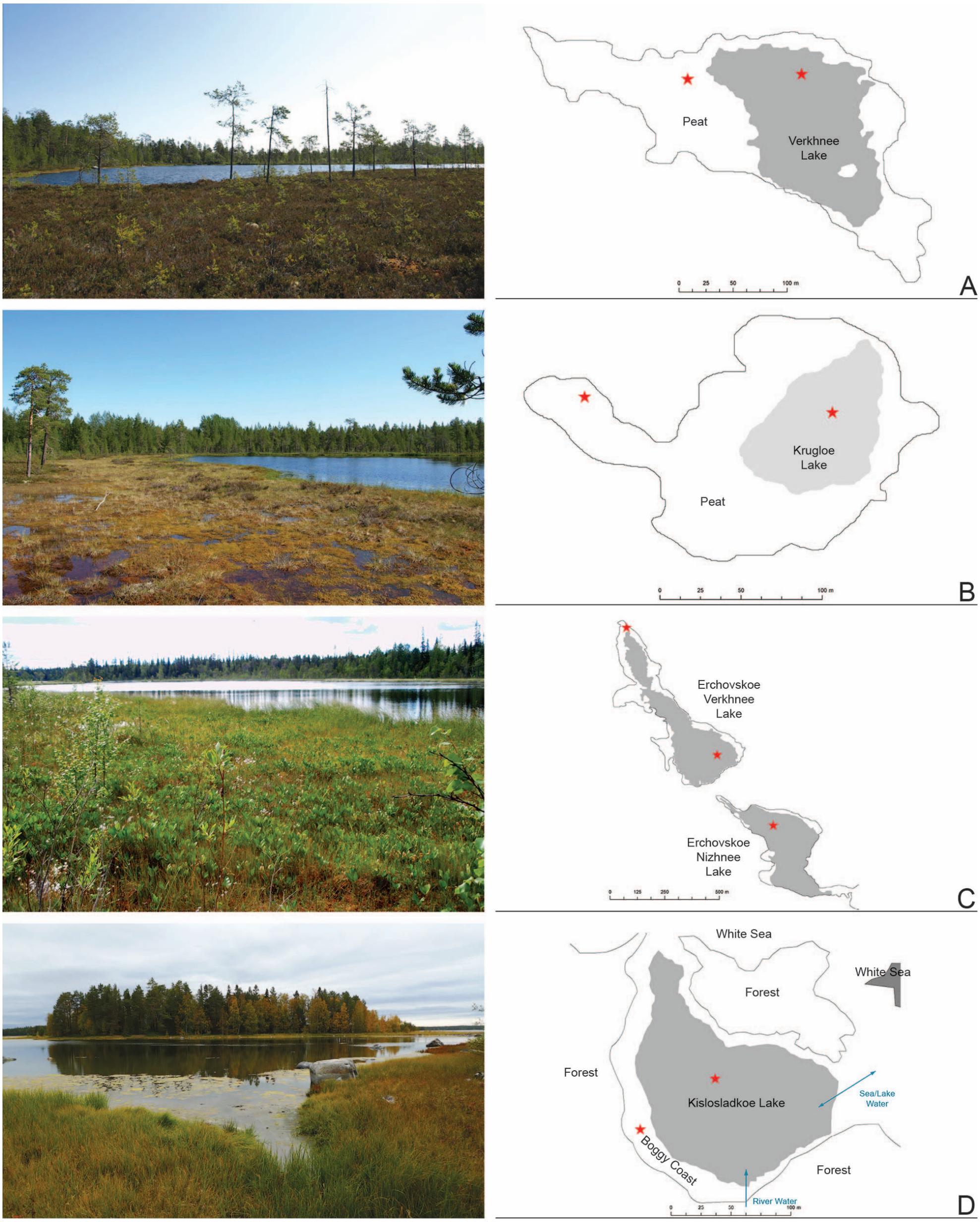

Fig. 2. Pictures and schemes of the investigated peatlands. A – Verchnee Peatland; B – Krugloe Peatland; C – Ershovskoe Peatland; D – Kislosladkoe Peatland.

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 dH_2O); *Sphagnum* extract agar (SEA, containing 600 mL *Sphagnum*-extract (from 200 g *Sphagnum* spp. in 500 mL bog H_2O), 20 g agar and 400 mL dH_2O); alkaline buffer agar (AA, pH 9, containing 12 g Na_2CO_3 6 g $NaHCO_3$, 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 x 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 (with vortex) 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 (0.66 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 at –20° C. The resultant DNA solution was used for subsequent PCR procedure.

The primers ITS-1f 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 µL 25 mM $MgCl_2$, 5 µL 5 x PCR GoTag buffer, 1 µL 10 mM dNTP, 1 µL 10 mM of each PCR primer, 0.1 µL GoTag polymerase and 2 µL gDNA in 25 µL. 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 2). The number of viable fungal propagules were 10^2–10^5 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 3). Due to the lack of the GenBank data sequence identity for the ITS in some cases was higher than for LSU (Table 3). 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 Kislosladkoe 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 2).

Table 2. The list of the isolated species with frequencies (%) of their occurrence and media of isolation.

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]		
Acremonium sp. 1	3.6	—	—	—	—	—	—	—	—	1	MA
Acremonium sp. 2	—	—	—	18.8	—	—	—	3.4	—	4	AA
Acremonium sp. 3	—	—	—	—	3.6	—	—	—	6.3	2	SWA
***Acrodontium crateriforme* (J.F.H. Beyma) de Hoog**	3.6	—	3.4	—	7.1	—	—	—	—	4	MA, CA, WA
***Acrodontium simplex* (F. Mangenot) de Hoog**	—	—	3.4	—	—	—	—	—	—	1	WA
Agaricomycetes sp.	—	3.7	—	—	—	—	—	—	—	1	CA
Alternaria alternata (Fr.) Keissl.	3.6	—	—	6.3	—	—	—	—	—	2	SEA
Alternaria sp.	—	—	—	6.3	—	—	—	3.4	—	2	MA, CA
Amylostereum areolatum (Chaillet ex Fr.) Boidin	—	—	—	—	—	—	—	3.4	—	1	SWA
Antrodia xantha (Fr.) Ryvarden	—	—	—	—	3.6	—	—	—	—	1	MA
Antrodia sp. 1	—	—	3.4	—	—	—	—	—	—	1	CA
Antrodia sp. 2	—	—	—	—	3.6	—	—	—	—	1	MA
***Antrodiella romellii* (Donk) Niemelä**	—	—	3.4	—	—	—	—	—	—	1	MA
Ascomycota sp. 1	—	—	—	6.3	—	—	—	—	—	1	CA
Ascomycota sp. 2	—	—	—	—	—	—	—	—	6.3	1	WA
Ascomycota sp. 3	—	—	—	—	—	—	—	3.4	—	1	AA
Ascomycota sp. 4	—	—	—	—	—	—	3.4	—	—	1	SWA
Ascomycota sp. 5	—	—	—	—	—	—	—	3.4	—	1	MA
Ascomycota sp. 6	—	—	—	—	—	—	—	3.4	—	1	SWA
Aspergillus repens (Corda) Sacc.	—	—	—	—	3.6	—	—	—	—	1	CA
Aspergillus tubingensis Mosseray	—	—	—	—	—	—	—	—	6.3	1	MA
***Aspergillus ustus* (Bainier) Thom et Church**	3.6	—	—	—	3.6	—	—	—	—	2	MA, SEA
Aspergillus versicolor (Vuill.) Tirab.	—	—	—	6.3	—	—	—	—	—	1	CA
Aureobasidium pullulans (de Bary) G. Arnaud	—	7.4	10.3	—	3.6	—	6.9	6.9	—	10	MA, WA, SEA, SWA
Basidiomycota sp. 1	—	—	3.4	—	—	—	—	—	—	1	CA
Basidiomycota sp. 2	—	—	—	—	—	—	—	3.4	—	1	MA
Basidiomycota sp. 3	—	—	—	—	—	—	3.4	—	—	1	CA
Basidiomycota sp. 4	—	—	—	—	3.6	—	—	—	—	1	MA
Beauveria bassiana (Bals.-Criv.) Vuill.	10.7	14.8	6.9	6.3	—	—	—	—	—	10	MA, CA, SEA
Beauveria brongniartii (Sacc.) Petch	—	—	—	6.3	—	—	—	—	—	1	MA
Botryotinia sp.	—	—	—	6.3	—	—	—	—	—	1	WA
Botrytis cinerea Pers.	3.6	—	—	6.3	—	—	—	—	—	2	MA, CA
Cadophora fastigiata Lagerb. et Melin	—	—	—	6.3	—	—	—	3.4	—	2	CA, SWA
***Cadophora luteo-olivacea* (J.F.H. Beyma) T.C. Harr. et McNew**	—	—	—	12.5	—	—	—	6.9	6.3	5	MA, CA, WA, SEA, SWA
Cadophora sp.	—	—	—	—	—	—	—	3.4	—	1	CA
Cadophora sp.	—	—	—	6.3	—	—	—	—	—	1	SEA
Ceriporiopsis subvermispora (Pilát) Gilb. et Ryvarden	—	—	—	—	3.6	—	—	—	—	1	MA
Chrysosporium sp.	—	—	—	—	—	—	3.4	—	—	1	WA

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]		
***Cladophialophora humicola* Crous et U. Braun**	3.6	—	—	—	—	—	—	—	—	1	SEA
***Cladosporium antarcticum* K. Schub., Crous et U. Braun**	—	—	—	18.8	—	—	—	—	—	3	AA
***Cladosporium bruhnei* Linder**	—	3.7	6.9	18.8	—	3.7	—	—	—	7	MA, CA, AA, WA, SWA
Cladosporium cladosporioides (Fresen.) G.A. de Vries	10.7	3.7	6.9	12.5	—	—	3.4	—	12.5	11	MA, CA, WA, SEA, SWA
Cladosporium herbarum (Pers.) Link	3.6	7.4	3.4	18.8	—	—	—	—	—	7	MA, WA, SEA, SWA
***Cladosporium langeronii* (Fonseca, Leão et Nogueira) Vuill.**	7.1	—	—	—	—	—	—	—	—	1	SEA
Cladosporium sphaerospermum Penz.	32.1	11.1	—	—	3.6	—	—	—	—	13	MA, CA, WA, SEA, SWA
Cladosporium sp. 1	3.6	—	—	—	—	—	—	—	—	1	SEA
Cladosporium sp. 2	—	3.7	—	—	—	—	—	—	—	1	MA
Cladosporium sp. 3	—	—	—	6.3	—	—	—	—	—	1	SEA
Clavulinaceae sp.	—	—	—	—	—	3.7	—	3.4	—	2	MA
Coniochaeta sp.	—	—	—	—	3.6	—	—	—	—	1	CA
Crocicreas sp.	—	—	3.4	—	—	—	—	3.4	—	2	CA, SEA
Dothideales sp.	—	—	—	6.3	—	—	—	—	—	1	MA
Dothideomycetes sp. 1	—	—	—	—	—	—	—	3.4	6.3	1	MA, SEA
Dothideomycetes sp. 2	—	—	—	6.3	—	—	—	—	—	1	MA
Elaphocordyceps subsessilis (Petch) G.H. Sung, J.M. Sung et Spatafora	21.4	—	3.4	12.5	17.9	7.4	—	—	6.3	17	all
Emericellopsis minima Stolk	—	—	—	—	—	—	—	6.9	—	2	WA
Emericellopsis sp.	—	—	—	—	—	—	3.4	—	—	1	SWA
***Engyodontium album* (Limber) de Hoog**	—	3.7	—	6.3	—	3.7	—	—	—	3	MA, CA, SEA
Fungal sp.	—	—	—	—	—	—	—	3.4	—	1	WA
Fusarium sp.	—	—	—	—	3.6	—	—	—	—	1	MA
Geomyces pannorum (Link) Sigler et J.W. Carmich.	7.1	3.7	3.4	6.3	—	—	—	6.9	—	7	MA, CA, WA, SEA
Geotrichum candidum Link	3.6	—	—	—	3.6	—	—	6.9	—	4	MA, CA, SEA
***Gibellulopsis nigrescens* (Pethybr.) Zare, W. Gams et Summerb.**	3.6	—	—	—	—	—	—	3.4	—	2	MA, SWA
Gloeophyllum sepiarium (Wulfen) P. Karst.	—	—	—	—	—	—	3.4	—	—	1	MA
Gnomoniaceae sp.	—	—	—	—	3.6	—	—	3.4	—	2	MA, SEA
Hansfordia sp.	—	—	—	—	—	—	3.4	—	—	1	SWA
Helotiales sp. 1	—	—	3.4	—	—	—	—	—	—	1	WA
Helotiales sp. 2	3.6	—	—	—	—	—	—	—	—	1	SEA
Helotiales sp. 3	3.6	—	—	—	—	—	—	—	—	1	MA
Helotiales sp. 4	—	—	—	6.3	—	—	—	—	—	1	MA
Helotiales sp. 5	—	—	—	—	—	—	—	—	6.3	1	SEA
Helotiales sp. 6	—	—	—	6.3	—	—	—	—	—	1	CA
Helotiales sp. 7	—	—	—	—	—	—	—	—	6.3	1	CA
Helotiales sp. 8	—	—	—	—	7.1	3.7	—	—	—	3	MA, CA, SEA

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]		
Helotiales sp. 9	—	—	—	—	—	—	—	3.4	—	2	WA
Helotiales sp. 10	—	—	—	—	—	—	—	3.4	—	1	MA
Helotiales sp. 11	—	—	—	—	—	—	3.4	—	—	1	CA
Helotiales sp. 12	—	—	—	—	3.6	—	—	—	—	2	MA
Helotiales sp. 13	—	—	—	—	3.6	—	—	—	—	1	MA
Helotiales sp. 14	—	—	—	—	—	3.7	—	—	—	1	SWA
Helotiales sp. 15	—	—	—	—	3.6	—	—	—	—	1	SWA
Helotiales sp. 16	—	—	—	6.3	—	—	—	—	—	1	WA
Helotiales sp. 17	—	—	—	—	—	—	—	3.4	—	1	MA
Helotiales sp. 18	—	—	—	—	—	—	—	3.4	—	2	CA, SWA
Helotiales sp. 19	—	—	—	—	—	—	3.4	—	—	1	MA
Humicola fuscoatra Traaen	—	—	—	—	3.6	—	—	—	—	1	CA
Humicola sp.	—	—	—	—	—	—	3.4	—	—	1	SWA
***Lecanicillium evansii* Zare etW. Gams**	—	—	3.4	—	—	—	—	—	—	1	MA
Lecanicillium muscarium (Petch) Zare et W. Gams	—	—	—	—	—	3.7	—	—	—	1	AA
Leotiomycetes sp. 1	—	3.7	—	—	—	—	—	—	—	1	WA
Leotiomycetes sp. 2	3.6	—	—	—	—	—	—	—	—	1	CA
Leotiomycetes sp. 3	—	—	—	—	3.6	—	—	—	—	1	MA
Leotiomycetes sp. 4	—	—	—	—	—	3.7	—	—	—	1	WA
Leotiomycetes sp. 5	—	—	—	—	—	—	3.4	—	—	1	MA
Massarinaceae sp.	—	—	—	6.3	—	—	—	—	—	1	CA
Mollisia sp. 1	—	—	—	—	3.6	—	—	—	—	1	CA
Mollisia sp. 2	—	—	—	—	—	3.7	—	—	—	1	MA
Mollisia sp. 3	—	—	—	—	—	—	—	3.4	—	1	WA
Mortierella elongata Linnem.	—	—	—	—	—	—	—	—	6.3	1	MA
Mortierella lignicola (G.W. Martin) W. Gams et R. Moreau	—	—	—	—	—	3.7	—	—	—	1	WA
Mortierella longicollis Dixon-Stew.	—	—	—	—	3.6	—	—	—	—	1	SWA
Nectriaceae sp.	—	—	—	12.5	—	—	—	—	—	2	MA
Neolentinus sp.	—	—	—	—	—	3.7	—	—	—	1	CA
***Neoscytalidium dimidiatum* (Penz.) Crous et Slippers**	—	—	3.4	—	—	—	—	—	—	1	WA
***Oidiodendron ambiguum* Peyronel et Malan**	—	—	—	6.3	—	—	—	—	—	1	MA
Oidiodendron echinulatum G.L. Barron	—	—	—	—	—	—	3.4	3.4	—	2	SWA
Oidiodendron griseum Robak	17.9	3.7	—	6.3	3.6	—	—	—	—	8	MA, CA, WA
Oidiodendron maius var. *citrinum* (Barron) Rice a. Currah	3.6	—	—	—	—	—	—	—	—	1	MA
Oidiodendron periconioides Morrall	—	3.7	—	—	—	—	—	—	—	1	CA
Oidiodendron sp.	—	—	—	—	—	3.7	—	—	—	1	SEA
Penicillium aculeatum Raper et Fennell	—	—	—	—	—	—	—	—	6.3	1	MA
Penicillium aurantiogriseum Dierckx	3.6	3.7	3.4	—	—	—	—	—	—	3	WA, CA
Penicillium brevicompactum Dierckx	3.6	11.1	—	—	—	—	—	—	—	4	MA, WA, SEA
Penicillium chermesinum Biourge	—	—	—	—	—	—	—	3.4	—	1	CA

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]		
Penicillium citreonigrum Dierckx	3.6	3.7	3.4	—	—	—	—	—	—	3	MA, CA
Penicillium citrinum Thom	—	—	—	—	—	—	—	3.4	—	1	SEA
Penicillium corylophilum Dierckx	—	—	3.4	—	—	—	—	—	—	1	CA
Penicillium dierckxii Biourge	—	—	—	6.3	—	—	—	—	—	1	WA
Penicillium expansum Link	3.6	—	—	—	—	—	—	—	—	1	CA
Penicillium glabrum (Wehmer) Westling	3.6	18.5	—	6.3	—	—	—	—	—	7	MA, CA, WA, SEA, SWA
***Penicillium griseofulvum* Dierckx**	—	—	—	6.3	—	—	—	—	—	1	CA
Penicillium implicatum Biourge	—	—	3.4	—	—	—	—	—	—	1	MA
Penicillium janczewskii K.M. Zalessky	—	—	3.4	—	—	—	—	—	—	1	CA
Penicillium multicolor Grig.-Man. et Porad.	—	—	—	—	—	—	—	—	6.3	1	WA
***Penicillium nalgiovense* Laxa**	—	3.7	—	—	—	—	—	—	—	1	WA
Penicillium purpurascens (Sopp) Biourge	—	—	—	—	3.6	—	—	—	—	1	SWA
Penicillium restrictum J.C. Gilman et E.V. Abbott	3.6	—	—	—	—	—	—	—	—	1	CA
Penicillium rolfsii Thom	—	3.7	—	—	—	—	—	—	—	1	MA
Penicillium roseopurpureum Dierckx	3.6	—	—	—	7.1	—	—	—	6.3	3	CA, WA, SEA
Penicillium sclerotiorum J.F.H. Beyma	—	—	—	—	—	—	—	3.4	—	1	CA
Penicillium solitum var *solitum* Westling	—	—	—	—	3.6	—	—	—	—	1	SEA
Penicillium spinulosum Thom	14,3	18.5	10.3	25	3.6	7.4	—	3.4	—	20	MA, CA, WA, SEA, SWA
Penicillium thomii Maire	3.6	3.7	17.2	—	—	—	—	—	6.3	8	MA, CA, WA
***Penicillium verrucosum* Dierckx**	—	—	3.4	—	—	—	—	—	—	1	MA
Penicillium vinaceum J.C. Gilman et E.V. Abbott	3.6	—	3.4	—	—	—	—	—	—	2	SEA
Penicillium waksmanii K.M. Zalessky	—	—	—	6.3	—	—	—	—	—	1	MA
Peniophora piceae (Pers.) J. Erikss.	—	—	—	—	3.6	—	—	—	—	1	MA
Peniophora sp. 1	—	—	—	—	—	—	—	3.4	—	1	CA
Peniophora sp. 2	—	—	—	—	—	—	—	—	6.3	1	WA
Pezizomycotina sp. 1	3.6	—	—	—	—	—	—	—	—	1	MA
Pezizomycotina sp. 2	3.6	—	—	—	—	—	—	—	—	1	SEA
Phaeosphaeria sp.	—	—	—	—	—	—	—	3.4	—	1	WA
Phellinus sp.	3.6	—	—	—	—	—	—	—	—	1	SEA
***Phialophora europaea* de Hoog, Mayser et Haase**	3.6	—	—	—	—	—	—	—	—	1	CA
Phialophora lagerbergii (Melin et Nannf.) Conant	—	—	—	—	—	—	—	3.4	—	1	MA
***Phialophora verrucosa* Medlar**	—	—	3.4	6.3	—	—	—	—	—	2	CA, WA
***Phlebiopsis gigantea* (Fr.) Jülich**	3.6	—	6.9	—	—	—	—	3.4	—	4	MA, CA, WA
Pholiota sp.	—	—	—	—	3.6	—	—	—	—	1	MA
***Phoma poolensis* (Ellis et Kellerm.) Aa et Boerema**	—	—	6.9	—	—	—	—	—	—	2	MA, CA
Piptoporus betulinus (Bull.) P. Karst.	—	—	—	—	—	—	3.4	—	—	1	MA
Pochonia bulbillosa (W. Gams et Malla) Zare et W. Gams	3.6	—	—	12.5	—	—	—	—	—	3	MA, CA
Polyporus sp.	—	—	—	—	—	3.7	—	—	—	1	MA
Polyporales sp.	—	—	—	—	3.6	—	—	—	—	1	CA

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]		
***Polyscytalum fecundissimum* Riess**	3.6	—	—	—	—	—	—	—	—	1	WA
***Resinicium bicolor* (Alb. et Schwein.) Parmasto**	—	3.7	3.4	—	—	—	—	—	—	2	MA
Resinicium sp.	—	—	3.4	—	—	—	—	—	—	1	SEA
Sclerotinia sp.	3.6	—	—	—	—	—	—	—	—	1	MA
Scopulariopsis brumptii Salv.-Duval	—	—	—	—	—	—	6.9	—	—	2	SWA
Sistotrema brinkmannii (Bres.) J. Erikss.	—	—	3.4	—	7.1	—	—	3.4	12.5	6	MA, CA, AA, WA, SWA
Sistotrema sp.	3.6	3.7	—	—	3.6	—	—	—	6.3	4	MA, CA, SEA, SWA
Stachybotrys chartarum (Ehrenb.) S. Hughes	3.6	—	—		—	—	—	—	—	1	SEA
***Stachybotrys dichroa* Grove**	—	—	—	6.3	—	—	—	—	—	1	SEA
Stephanosporium atrum Dal Vesco	—	—	—	—	—	—	3.4	—	—	1	WA, SEA
Stereum sp.	—	—	—	—	—	—	—	—	6.3	1	AA, SEA
Strobilurus tenacellus (Pers.) Singer	—	—	—	—	—	—	—	3.4	—	1	MA
***Sydowia polyspora* (Bref. et Tavel) E. Müll.**	3.6	—	—	6.3	—	—	—	—	—	2	CA, SEA
Talaromyces diversus (Raper et Fennell) Samson, Yilmaz et Frisvad	—	3.7	—	—	—	—	—	—	—	1	MA
Talaromyces duclauxii (Delacr.) Samson, Yilmaz, Frisvad et Seifert	—	—	—	—	—	—	—	3.4	—	1	MA
Talaromyces funiculosus (Thom) Samson, Yilmaz, Frisvad et Seifert	3.6	14.8	20.7	6.3	10.7	3.7	—	6.9	—	18	MA, CA, WA, SEA, SWA
Talaromyces rugulosus (Thom) Samson, Yilmaz, Frisvad et Seifert	—	—	3.4	—	—	—	—	—	—	1	MA
Talaromyces variabilis (Sopp) Samson, Yilmaz, Frisvad et Seifert	—	7.4	3.4	—	—	—	—	—	6.3	4	MA, CA, SEA
Talaromyces verruculosus (Peyronel) Samson, Yilmaz, Frisvad et Seifert	3.6	—	—	—	—	—	—	—	6.3	2	WA, SEA
***Teberdinia hygrophila* Sogonov, W. Gams, Summerb. et Schroers**	—	7.4	3.4		—	—	—	—	—	3	WA
***Tolypocladium cylindrosporum* W. Gams**	—	—	—	18.8	3.6	—	—	—	6.3	5	MA, AA, SWA
Tolypocladium geodes W. Gams	—	11.1	—	—	3.6	—	—	3.4	—	5	WA, AA, SEA
***Tolypocladium nubicola* Bissett**	—	—	—	6.3	—	—	—	—	—	1	WA
Tolypocladium tundrense Bissett	—	—	—	—	3.6	—	—	—	—	1	AA
Trichoderma asperellum Samuels, Lieckf. et Nirenberg	—	—	—	—	3.6	—	—	—	—	1	WA, SEA
Trichoderma hamatum (Bonord.) Bainier	—	—	—	—	—	3.7	6.9	6.9	—	5	MA, CA, WA, SEA, SWA
Trichoderma harzianum Rifai	—	3.7	6.9	6.3	—	—	—	3.4	—	5	CA, WA, SEA, SWA
Trichoderma koningii Oudem.	—	—	—	6.3	—	—	—	—	—	1	CA
Trichoderma piluliferum J. Webster et Rifai	—	—	3.4	—	—	—	—	—	—	1	WA
Trichoderma polysporum (Link) Rifai	3.6	—	3.4	—	—	7.4	6.9	3.4	—	7	MA, CA, WA, SEA, SWA
Trichoderma viride Pers.	—	7.4	6.9	—	7.1	—	3.4	—	—	7	WA, SEA, SWA

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]		
***Trichosporon lignicola* (Diddens) Fell et Scorretti**	3.6	—	—	—	—	—	—	—	—	1	CA
Umbelopsis isabellina (Oudem.) W. Gams	—	—	—	6.3	—	—	—	—	—	1	CA
Umbelopsis ramanniana (Möller) W. Gams	—	—	—	6.3	—	—	—	—	—	1	MA
Umbelopsis vinacea (Dixon-Stew.) Arx	—	—	—	6.3	—	—	—	—	—	1	CA
Umbelopsis sp.	—	—	—	6.3	—	—	—	—	—	1	SWA
Volutella sp.	—	—	—	—	—	7.4	—	—	—	2	AA
***Zythiostroma pinastri* (P. Karst.) Höhn.**	7.1	—	—	—	—	—	—	—	—	2	MA, CA
Cladosporium spp.[f] (3 morphotypes)	3.6	—	—	6.3	—	—	—	3.4	—	3	MA, WA, SEA
Lecanicillium spp.[f] (4 morphotypes)	—	3.7	—	12.5	3.6	—	—	—	—	4	MA, AA, SEA, SWA
Penicillium spp.[f] (6 morphotypes)	—	3.7	—	—	10.7	3.7	—	3.4	—	6	MA, CA, SWA
Phaeoacremonium spp.[f] (4 morphotypes)	—	—	3.4	6.3	—	3.7	—	6.9	—	5	MA, WA, SEA
Trichoderma 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 - Verchnee Peatland; B - Krugloe Peatland; C - Ershovskoe Peatland: C(1) - Ershovskoe Verchnee Lake, C(2) - Ershovskoe Nizhnee Lake; D - Kislosladkoe Peatland

Species which were not found in *Sphagnum* peat before this research are in bold

[a] Frequency was calculated as percent of 28 samples collected from peatland A

[b] Frequency was calculated as percent of 27 samples collected from peatland B

[c] Frequency was calculated as percent of 29 samples collected from peatland C

[d] Frequency was calculated as percent of 16 samples collected from peatland D

[e] Frequency was calculated as percent of 100 samples collected during the overall investigation

[f] Morphotypes were not determined to the species level.

[g] Sterile morphotypes were not determined to the division level

Abbreviation: MA - malt extract agar, CA - citric agar, AA - alkaline agar, WA - water agar, SEA - *Sphagnum* extract agar, SWA - sea water agar.

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 2). 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 2). The similarity of the fungal communities among the different peatlands ranged from 0.20 (Ershovskoe and Kislosladkoe) to 0.32 (Verkhnee and Krugloe) (Fig. 4).

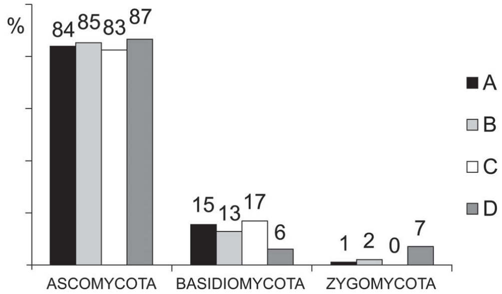

Figure 3. Abundance (%) of fungal divisions in four peatlands. A – Verkhnee; B – Krugloe; C – Ershovskoe; D – Kislosladkoe.

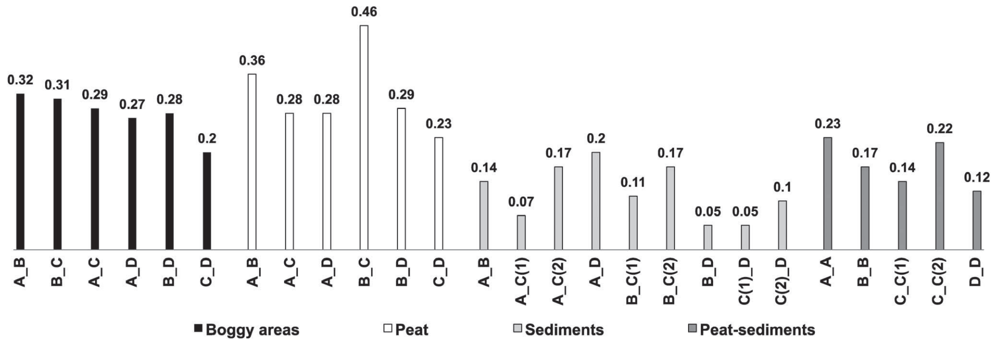

Figure 4. Similarity of fungal communities of the peatlands (Sørensen index). A – Verkhnee Peatland; B – Krugloe Peatland; C – Ershovskoe Peatland; C(1) – Ershovskoe Verkhnee Lake; C(2) – Ershovskoe Nizhnee Lake; D – Kislosladkoe Peatland.

Because the fungal communities of the peat and sediments of each of the four peatlands differed substantially, peat and sediments had to be analyzed 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*, *Oidiodendron griseum*, *Tolypocladium inflatum* and *Trichoderma harzianum*. We found 31 species that have not been observed before 2007 y in *Sphagnum* peat (Table 2) (Thormann and Rice 2007). In the bottom sediments sterile mycelia *Tolypocladium 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, *Antrodia* 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 2). 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.

Table 3. 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		
Acremonium sp. 1*	JQ780657	JQ768402		*Acremonium* sp., 499/505, 99% ITS	FJ571421
				Acremonium strictum, 1319/1337, 98% LSU	FJ176879
Acremonium sp. 2	JX535092	JX535093		*Acremonium* sp., 498/505, 99% ITS	FJ571421
				Sarocladium ochraceum, 800/813, 98% LSU	HQ232070
				Acremonium strictum, 1272/1299, 98% LSU	FJ176879
Acremonium sp. 2	JX507654	JX507655		*Acremonium* sp., 498/505, 99% ITS	FJ571421
				Sarocladium ochraceum, 800/813, 98% LSU	HQ232070
				Acremonium strictum, 1272/1299, 98% LSU	FJ176879
Acremonium sp. 3	JX535076	JX535077		*Acremonium potronii*, 443/443, 100% ITS	DQ865091
				Emericellopsis maritima, 1318/1321, 99% LSU	FJ176861
Agaricomycetes sp.	JQ780614	JQ768389		*Sistotrema brinkmannii*, 560/560, 100% ITS	JQ912675
				Antrodia gossypium, 1010/1016, 99% LSU	EU232298
				Phanerochaete lamprocystidiata, 898/903, 99% LSU	GQ470648
Alternaria sp.	JX507701			*Alternaria tenuissima*, 503/503, 100% ITS	JX406554
				Alternaria brassicae, 503/503, 100% ITS	JX290140
				Alternaria alternata, 503/503, 100% ITS	JF802121
Alternaria sp.	JX535139			*Alternaria tenuissima*, 503/503, 100% ITS	JX406554
				Alternaria brassicae, 503/503, 100% ITS	JX290140
				Alternaria alternata, 503/503, 100% ITS	JF802121
Amylostereum areolatum	JX507658			*Amylostereum areolatum*, 525/525, 100% ITS	JX049992
				Amylostereum areolatum, 525/525, 100% ITS	HQ864715
Antrodia xantha	JX507636	JX507637		*Antrodia xantha*, 531/531, 100% ITS	EU232210
				Antrodia xantha, 2087/2094, 99% LSU	AJ583430
Antrodia sp. 1	JQ780622	JQ780623	JQ780624	*Antrodia serialis*, 446/560, 98% ITS	AJ345010
				Antrodia serialis,1081/1092, 99% LSU	EU232293
				Antrodia variiformis, 1663/1668, 99% SSU	AY336783
Antrodia sp. 2	JX507729	JX507730		*Antrodia sinuosa*, 587/587, 100% ITS	GU991578.
				Antrodia xantha, 2015/2114, 95%, LSU	AJ583430
Antrodiella romellii	JQ780621	JQ768396		*Antrodiella romellii*, 587/587, 100% ITS	AF126902
				Antrodiella romellii, 879/879, 100% LSU	JN710520

Species	Genbank Accession No.			Blast	
Ascomycota sp. 1	JX535148	JX535149		*Helotiales* sp., 457/464, 98% ITS	FN548161
				Articulospora tetracladia, 1957/2051, 95% LSU	EU998928
Ascomycota sp. 2	JX535116			*Ascomycete* sp., 432/450, 96% ITS	AY805600
Ascomycota sp. 3	JX507652	JX507653		*Ascomycota* sp., 488/510, 96% ITS	JN120374
				Setomelanomma holmii, 700/701, 99% LSU	GQ387633
Ascomycota sp. 4	JX507689			*Articulospora atra*, 459/479, 96% ITS	FJ000402
Ascomycota sp. 5	JX507709			*Hirsutella* sp., 489/493, 99% ITS	EF029185
				Ascomycete sp., 448/450, 99% ITS	AM084797
Ascomycota sp. 6	JX507650	JX507651		*Lecythophora mutabilis*, 505/505, 100% ITS	HQ637304
				Hyalodendriella betulae, 757/779, 97% LSU	EU040232
Basidiomycota sp. 1	JQ780626	JQ780627	JQ780628	*Basidiomycota* sp., 490/492, 99% ITS	GU062230
				Leptosporomyces galzinii, 683/692, 99% LSU	EU118642
				Athelia sp., 994/1005, 99% SSU	GU187619
Basidiomycota sp. 2	JX507638	JX507639		*Basidiomycota* sp., 642/642, 100% ITS	FR682225
				Antrodia xantha, 1968/2096, 94% LSU	AJ583430
Basidiomycota sp. 3	JX507646			*Armillaria novae-zelandiae*, 536/592, 91% ITS	AF394919
				Coprinus sp., 526/590, 89% ITS	AY254874
Basidiomycota sp. 4	JX507631	JX507632		*Armillaria novae-zelandiae*, 536/592, 91% ITS	AF394919
				Coprinus sp., 526/590, 89% ITS	AY254874
				Multiclavula mucida, 1983/2059, 96% LSU	EU909345
Botryotinia sp.	JX535121			*Botryotinia fuckeliana*, 474/474, 100% ITS	KC172064
				Botrytis elliptica, 474/474, 100% ITS	AY684918
				Botrytis sp., 474/474, 100% ITS	FR822791
Cadophora fastigiata	JX535145			*Cadophora fastigiata*, 521/521, 100% ITS	JN689948
				Cadophora fastigiata, 521/521, 100% ITS	GU212371
Cadophora luteo-olivacea	JX535088			*Cadophora luteo-olivacea*, 563/564, 99% ITS	JQ796751
				Cadophora luteo-olivacea, 563/564, 99% ITS	FJ486274
Cadophora luteo-olivacea	JX535123			*Cadophora luteo-olivacea*, 565/565, 100% ITS	GU212374
				Cadophora luteo-olivacea, 565/565, 100% ITS	GU128589
Cadophora luteo-olivacea	JX535125			*Cadophora luteo-olivacea*, 563/564, 99% ITS	AB725391
				Cadophora luteo-olivacea, 563/564, 99% ITS	GU212374
Cadophora luteo-olivacea	JX535132			*Cadophora luteo-olivacea*, 560/560, 100% ITS	GU212374
Cadophora luteo-olivacea	JX535171			*Cadophora luteo-olivacea*, 567/568, 99% ITS	GU212374
Cadophora luteo-olivacea	JX535179			*Cadophora luteo-olivacea*, 581/581, 100% ITS	FJ430742
Cadophora sp.	JX507647			*Cadophora* sp., 555/564, 98% ITS	JN859254
Ceriporiopsis subvermispora	JX507705	JX507706		*Ceriopsiopsis subvermispora*, 580/580, 100% ITS	HQ659228
				Ceriporiopsis subvermispora, 840/842, 99% LSU	FJ496707
Cladosporium cladosporioides	JX535079			*Cladosporium cladosporioides*, 483/483, 100% ITS	JQ768327
Cladosporium cladosporioides	JX535084			*Cladosporium cladosporioides*, 481/481, 100% ITS	JQ768327
Cladosporium cladosporioides	JX535135			*Cladosporium cladosporioides*, 491/491, 100% ITS	JQ768327
Cladosporium cladosporioides	JX535166			*Cladosporium cladosporioides*, 480/480, 100% ITS	JQ768327
Cladosporium cladosporioides	JX535173			*Cladosporium cladosporioides*, 491/491, 100% ITS	HQ380766
Cladosporium cladosporioides	JQ780660			*Cladosporium cladosporioides*, 481/481, 100% ITS	JQ768327
Cladosporium herbarum	JX535143			*Cladosporium herbarum*, 494/494, 100% ITS	AF455517

Species	Genbank Accession No.		Blast	
Cladosporium herbarum	JX535172		*Cladosporium herbarum* (*Davidiella tassiana*), 408/408, 100% ITS	KC292373
Cladosporium langeronii	JQ780666		*Cladosporium langeronii*, 490/490, 100% ITS	DQ780380
Cladosporium langeronii	JQ780667		*Cladosporium langeronii*, 490/490, 100% ITS	DQ780380
Cladosporium sp. 1	JQ780649		*Cladosporium langeronii*, 501/502, 99% ITS	DQ780380
			Cladosporium cladosporioides, 486/490, 99% ITS	JN986780
Cladosporium sp. 2	JQ780629		*Cladosporium cladosporioides*, 487/488, 99% ITS	JN986780
			Cladosporium sp., 490/491, 99% ITS	GU395509
Cladosporium sp. 3	JX535124		*Cladosporium langeronii*, 463/467, 99% ITS	JQ780667
			Cladosporium cladosporioides, 463/467, 99% ITS	AF455525
Clavulinaceae sp.	JX507640	JX507641	*Clavulinaceae* sp., 608/609, 99% ITS	FJ475570
			Clavulina sp., 792/829, 96% LSU	AY745694
Clavulinaceae sp.	JX507727	JX507728	*Clavulinaceae* sp., 610/611, 99% ITS	FJ475570
			Clavulina sp., 812/850, 96% LSU	AY745694
Conichaeta sp.	JX507629	JX507630	*Coniochaeta* sp., 489/489, 100% ITS	HM595513
			Coniochaeta sp., 509/509, 100% LSU	HM595603
Crocicreas sp.	JQ780618	JQ768393	*Crocicreas* sp., 477/478, 99% ITS	FJ005100
			Cyathicula microspora, 1323/1339, 99% LSU	EU940088
Crocicreas sp.	JX507682		*Crocicreas* sp., 440/442, 99% ITS	FJ005098
			Crocicreas sp., 438/442, 99% ITS	FJ005099
Dothideales sp.	JX535090	JX535091	*Dothideales* sp., 510/511, 99% ITS	HM240804
			Dothideomycetes sp., 503/513, 98% ITS	GQ153228
			Dothideomycetes sp., 763/774, 99% LSU	GU323957
			Dothidea insculpta, 764/808, 95% LSU	NG027643
Dothideomycetes sp. 1	JX535078		*Paraconiothyrium* sp., 497/515, 97% ITS	HM999948
			Paraphaeosphaeria sp., 496/515, 96% ITS	KC208020
Dothideomycetes sp. 1	JX507635		*Paraconiothyrium* sp., 494/512, 96% ITS	HM999948
			Paraphaeosphaeria sp., 493/512, 96% ITS	KC208020
Dothideomycetes sp. 2	JX535162		*Mycosphaerella fragariae*, 472/476, 99% ITS	GU214691
			Ramularia grevilleana, 469/475, 99% ITS	GU939181
*Elaphocordyceps subsessilis**	JQ780640		*Elaphocordyceps subsessilis*, 493/494, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JX507695		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JX507696		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JX507697		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JX507698		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JQ780650		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JQ780652		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
*Elaphocordyceps subsessilis**	JQ780664		*Elaphocordyceps subsessilis*, 494/495, 99% ITS	JX488470
Fungus sp.	JX507690		*Hongkongmyces pedis*, 252/285, 88% ITS	JQ435790
Geomyces pannorum	JQ768386	JQ768405	*Geomyces pannorum*, 487/487, 100% ITS	HQ115661
			Geomyces pannorum, 575/576, 99% LSU	GU951694
Geomyces pannorum	JQ780644	JQ768404	*Geomyces pannorum*, 487/487, 100% ITS	HQ115661
			Geomyces pannorum, 575/576, 99% LSU	GU951694
Gloeophyllum sepiarium	JX507712	JX507713	*Gloeophyllum sepiarium*, 569/570, 99% ITS	JQ358803
			Gloeophyllum sepiarium, 821/821, 100% LSU	JN649344

Species	Genbank Accession No.		Blast	
Gnomoniaceae sp.	JX507716		*Gnomonia* cf. *ischnostyla*, 475/477, 99% ITS	EU254903
			Ophiognomonia sp., 474/477, 99% ITS	JQ414264
Gnomoniaceae sp.	JX507717		*Gnomonia* cf. *ischnostyla*, 475/477, 99% ITS	EU254903
			Ophiognomonia sp., 474/477, 99% ITS	JQ414264
Helotiales sp. 1	JQ780635		*Lachnum* sp., 416/435, 97% ITS	FJ378861
Helotiales sp. 2	JQ780665		*Gremmeniella* sp., 450/453, 99% ITS	FR715997
			Helotiales sp., 421/423, 99% ITS	AY354243
Helotiales sp. 3	JQ780658	JQ780659	*Godronia* sp., 439/453, 98% ITS	EF672237
			*Godronia urceulos*1320/1321, 99% LSU	EU754163
Helotiales sp. 4	JX535181		*Varicosporium elodeae*, 489/492, 99% ITS	GQ152148
Helotiales sp. 5	JX535100	JX535101	*Helotiales* sp., 480/490, 98% ITS	JN655578
			Mollisia cinerea, 801/811, 99% LSU	DQ470942
Helotiales sp. 6	JX535046	JX535047	*Hyaloscyphaceae* sp., 479/488, 98% ITS	GU393951
			Hyalodendriella betulae, 727/746, 97% LSU	EU040232
Helotiales sp. 7	JX535102	JX535103	*Catenulifera brevicollaris*, 479/507, 94% ITS	GU727561
			Catenulifera brachyconia, 784/800, 98% LSU	GU727559
Helotiales sp. 8	JX507674	JX507675	*Hymenoscyphus* sp., 472/487, 97% ITS	GU479911
			Hyaloscypha fuckelii, 766/780, 98% LSU	EU940154
Helotiales sp. 8	JX507670	JX507671	*Hymenoscyphus* sp., 471/486, 97% ITS	GU479911
			Hyaloscypha fuckelii, 806/820, 98% LSU	EU940154
Helotiales sp. 9	JX507660	JX507661	*Meliniomyces bicolor*, 480/480, 100% ITS	HQ157926
			Hyaloscypha hepaticola, 829/838, 99% LSU	EU940118
Helotiales sp. 9	JX507662	JX507663	*Meliniomyces* sp., 500/503, 99% ITS	JQ711936
			Hyaloscypha hepaticola, 830/839, 99% LSU	EU940118
Helotiales sp. 10	JX507720	JX507721	*Helotiales* sp., 488/542, 90% ITS	FJ378857
			Neobulgaria sp., 484/542, 89% ITS	HQ211726
			Neobulgaria pura, 752/788, 95% LSU	DQ257365
Helotiales sp. 11	JX507672	JX507673	*Helotiales* sp., 492/497, 99% ITS	JX852365
			Catenulifera brachyconia, 766/782, 98% LSU	GU727559
Helotiales sp. 12	JX507664	JX507665	*Acephala* sp., 478/483, 99% ITS	JN655564
			Mollisia sp., 771/797, 97% LSU	EU107273
Helotiales sp. 12	JX507666	JX507667	*Acephala* sp., 479/484, 99% ITS	JN655564
			Mollisia sp., 737/781, 94% LSU	EU107273
Helotiales sp. 13	JX507676	JX507677	*Cudoniella acicularis*, 435/470, 93% ITS	DQ202512
			Varicosporium giganteum, 737/747, 99% LSU	GQ477344
Helotiales sp. 14	JX507656	JX507657	*Acephala* sp., 481/489, 98% ITS	HQ889709
			Mollisia sp., 737/755, 97% LSU	EU107273
Helotiales sp. 15	JX507693		*Helotiales* sp., 531/534, 99% ITS	GU934595
Helotiales sp. 16	JX535119	JX535120	*Helotiales* sp., 424/426, 99% ITS	AY354243
			Godronia urceolus, 831/831, 100% LSU	EU754163
Helotiales sp. 17	JX507731	JX507732	*Helotiales* sp., 491/545, 90% ITS	FJ378857
			Neobulgaria sp., 487/545, 89% ITS	HQ211726
			Neobulgaria pura, 748/783, 96% LSU	DQ257365
Helotiales sp. 18	JX507688		*Dimorphospora* sp., 479/479, 100% ITS	JX077075
			Ascocoryne sp., 382/382, 100% ITS	JX077076

Species	Genbank Accession No.		Blast	
Helotiales sp. 18	JX507714	JX507715	*Dimorphospora* sp., 479/479, 100% ITS	JX077075
			Ascocoryne sp., 382/382, 100% ITS	JX077076
			Neobulgaria lilacina, 794/821, 97% LSU	EU940141
Helotiales sp. 19	JX507683		*Dimorphospora* sp., 479/479, 100% ITS	JX077075
			Ascocoryne sp., 382/382, 100% ITS	JX077076
Leotiomycetes sp. 1	JQ780634		*Leotiomycetes* sp., 471/529, 94% ITS	HQ212354
Leotiomycetes sp. 2	JQ780630	JQ768398	*Helotiaceae* sp., 463/478, 97% ITS	GU997932
			Helotiales sp., 463/478, 97% ITS	JN655588
			Hyaloscypha fuckelii, 1324/1336, 99% LSU	EU940154
Leotiomycetes sp. 3	JX507735		*Dimorphospora* sp., 474/479, 99% ITS	JX077075
			Ascocoryne sp., 377/382, 100% ITS	JX077076
Leotiomycetes sp. 4	JX507684	JX507685	*Leotiomycetes* sp., 521/531, 98% ITS	HQ211767
			Hyaloscypha sp., 810/831, 97% LSU	EU940092
Leotiomycetes sp. 5	JX507687		*Dimorphospora* sp., 473/478, 99% ITS	JX077075
			Ascocoryne sp., 370/377, 100% ITS	JX077076
Massarinaceae sp.	JQ780631	JQ780632	*Saccharicola bicolor*, 491/501, 98% ITS	AF455415
			Neottiosporina paspali, 813/822, 99% LSU	EU754172
Mollisia sp. 1	JX507704		*Mollisia minutella*, 488/493, 99% ITS	FR837920
Mollisia sp. 2	JX507644	JX507645	*Mollisia minutella*, 477/484, 99% ITS	FR837920
			Mollisia cinerea, 732/746, 98% LSU	DQ470942
Mollisia sp. 3	JX507668	JX507669	*Mollisia minutella*, 483/483, 100% ITS	FR837920
			Mollisia cinerea, 806/819, 98% LSU	DQ470942
Mortierella elongata	JX535038		*Mortierella elongata*, 468/468, 100% ITS	KC018241
Nectriaceae sp.	JX535175		*Cylindrocarpon obtusisporum*, 475/476, 99% ITS	GU726752
			Nectria lugdunensis, 475/477, 99% ITS	FJ000394
Nectriaceae sp.	JX535186		*Cylindrocarpon obtusisporum*, 480/481, 99% ITS	GU726752
			Nectria lugdunensis, 482/483, 99% ITS	FJ000394
Nectriaceae sp.	JX535187		*Cylindrocarpon obtusisporum*, 475/477, 99% ITS	GU726752
			Nectria lugdunensis, 476/477, 99% ITS	FJ000394
Neolentinus sp.	JX507691	JX507692	*Neolentinus lepideus*, 452/455, 99% ITS	AB615456
			Neolentinus lepideus, 849/856, 99% LSU	HM536077
*Penicillium spinulosum**	JQ780638		*Penicillium spinulosum*, 506/507, 99% ITS	KC167850
Penicillium spinulosum	JQ780639		*Penicillium spinulosum*, 510/510, 100% ITS	DQ888735
Peniophora piceae	JX507718	JX507719	*Peniophora piceae*, 545/545, 100% ITS	AY781264
			Peniophora sp., 1352/1357, 99% LSU	DQ094783
Peniophora sp. 1	JX507724	JX507725	*Peniophora pini*, 574/576, 99% ITS	EU118651
			Peniophora pini, 1313/1331, 99% LSU	EU118651
			Peniophora cinerea, 1290/1309, 99% LSU	DQ094786
Peniophora sp. 2	JX535110	JX535111	*Peniophora pini*, 569/572, 99% ITS	EU118651
			Peniophora pini, 1313/1331, 99% LSU	EU118651
			Peniophora cinerea, 1290/1309, 99% LSU	DQ094786
Pezizomycotina sp. 1	JQ780651		*Ramularia eucalypti*, 451/453, 99% ITS	EF394861
			Glomerella lagenaria, 451/453, 99% ITS	AJ301970
Pezizomycotina sp. 2	JQ780663		*Ramularia eucalypti*, 462/465, 99% ITS	EF394861
Phellinus sp.	JQ780625	JQ768397	*Phellinus cinereus*, 554/557, 99% ITS	AY340047

Species	Genbank Accession No.		Blast	
			Phellinus igniarius, 601/604. 99% ITS	AM269797
			Phellinus cinereus, 858/859, 99% LSU	AF311027
			Phellinus igniarius, 1838/1850, 99% LSU	AY839834
*Phlebiopsis gigantea**	JQ780612		*Phlebiopsis gigantea*, 626/626, 100% ITS	AF087487
*Phlebiopsis gigantea**	JQ780617	JQ768392	*Phlebiopsis gigantea*, 584/584, 100% ITS	AF087487
			Ceratobasidiaceae sp., 1291/1335, 97% LSU	JF799768
*Phlebiopsis gigantea**	JX507707	JX507708	*Phlebiopsis gigantea*, 598/598, 100% ITS	AF087487
			Antrodiella romellii, 1961/2058, 95% LSU	JQ768396
Pholiota sp.	JX507628		*Pholiota lenta*, 608/608, 100% ITS	AY281022
			Pholiota lubrica, 602/602, 100% ITS	JF908578
Phoma poolensis	JQ780633	JQ768399	*Phoma novae-verbascicola*, 468/468, 100% ITS	GU237753
			Phoma novae-verbascicola, 1323/1323, 100% LSU	GU238135
Phoma poolensis	JQ780648	JQ768403	*Phoma novae-verbascicola*, 455/455, 100% ITS	GU237753
			Phoma novae-verbascicola, 1319/1319, 100% LSU	GU238135
Piptoporus betulinus	JX507733	JX507734	*Piptoporus betulinus*, 600/600, 100% ITS	GU731570
			Piptoporus betulinus, 601/602, 99% LSU	JQ700297
			Piptoporus betulinus, 811/843, 96% LSU	JQ700297
Pochonia bulbillosa	JX535141		*Pochonia bulbillosa*, 537/539, 99% ITS	AB378551
Pochonia bulbillosa	JQ780661	JQ780662	*Pochonia bulbillosa*, 534/535, 99% ITS	AB378551
			Pochonia bulbillosa, 838/840, 99% LSU	HQ232164
Pochonia bulbillosa	JX535180		*Pochonia bulbillosa*, 538/540, 99% ITS	AB378551
Polyporus sp.	JX507702	JX507703	*Polyporus lepideus*, 592/593% ITS	GU731572
			Polyporus ciliatus, 560/567, 99% ITS	AB070883
			Polyporus arcularius, 831/840, 99% LSU	AF393067
Polyporales sp.	JX507648	JX507649	*Oligoporus placentus*, 596/597, 99% ITS	AJ416069
			Postia placenta, 590/597, 99% ITS	JQ700293
			Antrodia xantha, 2039/2092, 97% LSU	AJ583430
Resinicium bicolor	JQ780611	JQ768387	*Resinicium bicolor*, 518/518, 100% ITS	DQ218310
			Resinicium bicolor, 1260/1266, 99% LSU	AY700183
Resinicium bicolor	JQ780619	JQ768394	*Resinicium bicolor*, 495/495, 100% ITS	DQ218310
			Resinicium bicolor, 1221/1226, 99% LSU	AY700183
Resinicium sp.	JQ780620	JQ768395	*Resinicium furfuraceum*, 609/617, 99% ITS	DQ873648
			Resinicium furfuraceum, 1357/1364, 99% LSU	DQ873648
Sistotrema brinkmannii	JQ780616	JQ768391	*Sistotrema brinkmannii*, 605/605, 100% ITS	JQ912675
			Sistotrema brinkmannii, 1286/1303, 99% LSU	AF506473
Sistotrema brinkmannii	JX507642	JX507643	*Sistotrema brinkmannii*, 577/577, 100% ITS	JQ912675
			Sistotrema brinkmannii, 1275/1292, 99% LSU	AF506473
Sistotrema brinkmannii	JX535082	JX535083	*Sistotrema brinkmannii*, 570/571, 99% ITS	JQ912675
			Sistotrema brinkmannii, 1289/1306, 99% LSU	AF506473
Sistotrema brinkmannii	JX507686		*Sistotrema brinkmannii*, 563/563, 100% ITS	JQ912675
Sistotrema brinkmannii	JX535117	JX535118	*Sistotrema brinkmannii*, 568/569, 99% ITS	JQ912675
			Sistotrema brinkmannii, 1288/1305, 99% LSU	AF506473
Sistotrema brinkmannii	JX507710	JX507711	*Sistotrema brinkmannii*, 570/571, 99% ITS	AY089729
			Sistotrema brinkmannii, 1282/1300, 99% LSU	AF506473
Sistotrema sp.	JQ780613	JQ768388	*Sistotrema* sp., 530/530, ITS 100%	AY781271

Species	Genbank Accession No.			Blast	
				Sistotrema brinkmannii, 1282/1301, 99% LSU	AF506473
				Sistotrema coroniferum, 1247/1277, 98% LSU	AM259215
Sistotrema sp.	JQ780615	JQ768390		*Sistotrema* sp., 530/530, ITS 100%	AY781271
				Sistotrema brinkmannii, 1284/1303, 99% LSU	AF506473
				Sistotrema coroniferum, 1248/1278, 98% LSU	AM259215
Sistotrema sp.	JX507633	JX507634		*Sistotrema* sp., 522/522, 100% ITS	AY781271
				Sistotrema brinkmannii, 1288/1307, 99% LSU	AF506473
				Sistotrema coroniferum, 1252/1282, 98% LSU	AM259215
Sistotrema sp.	JX535108	JX535109		*Sistotrema* sp., 530/530, 100% ITS	AY781271
				Sistotrema brinkmannii, 1285/1304, 99% LSU	AF506473
				Sistotrema coroniferum, 1249/1279, 98% LSU	AM259215
Stereum sp.	JX535114	JX535115		*Stereum hirsutum*, 470/472, 99% ITS	JX501297
				Stereum annosum, 565/571, 99% ITS	DQ000294
				Stereum sp., 789/791, 99% LSU	EF600046
Strobilurus tenacellus	JX507722	JX507723		*Strobilurus tenacellus*, 686/686, 100% ITS	GQ892812
				Strobilurus tenacellus, 833/833, 100% LSU	AM946470
Sydowia polyspora	JQ780656	JQ768401		*Sydowia polyspora*, 536/537, 99% ITS	FR822985
				Sydowia polyspora, 1305/1305, 100% LSU	DQ678058
Sydowia polyspora	JX535167			*Sydowia polyspora*, 526/529, 99% ITS	FR822985
				Sydowia polyspora, 526/530, 99% ITS	FR717223
Talaromyces funiculosus	JX507726			*Penicillium funiculosum*, 516/516, 100% ITS	JX045839
*Teberdinia hygrophila**	JQ780641	JQ780642	JQ780643	*Teberdinia hygrophila*, 446/447, 99% ITS	AY129291
				Pseudoeurotium zonatum, 1311/1319, 99% LSU	DQ470988
				Pseudoeurotium sp, 785/791, 99% LSU	AB470594
				Teberdinia hygrophila, 733/734, 99% SSU	AY129282
*Teberdinia hygrophila**	JQ780645	JQ780646	JQ780647	*Teberdinia hygrophila*, 447/447, 100% ITS	AY129291
				Teberdinia hygrophila, 1053/1055, 99% SSU	AY129282
				Pseudoeurotium zonatum, 819/822, 99% LSU	AF096198
*Teberdinia hygrophila**	JQ780653	JQ780654	JQ780655	*Teberdinia hygrophila*, 448/449, 99% ITS	AY129291
				Pseudoeurotium zonatum, 1307/1315, 99% LSU	DQ470988
				Pseudoeurotium sp, 785/791, 99% LSU	AB470594
				Teberdinia hygrophila, 1045/1047, 99% SSU	AY129282
Tolypocladium cylindrosporum	JX535129			*Tolypocladium cylindrosporum*, 497/497, 100% ITS	FJ025179
Tolypocladium cylindrosporum	JX507699			*Tolypocladium cylindrosporum*, 499/499, 100% ITS	FJ025179
*Tolypocladium geodes**	JX507694			*Tolypocladium geodes*, 467/470, 99% ITS	FJ973059
*Trichoderma polysporum**	JQ780637			*Hypocrea pachybasioides*, 555/557, 99% ITS	FJ860796
				Trichoderma polysporum, 532/537, 99% ITS	DQ093710
*Trichoderma polysporum**	JQ780636	JQ768400		*Hypocrea parapilulifera*, 539/540, 99% ITS	FJ860799
				Trichoderma sp., 1018/1018, 100% LSU	AY283550
Volutella sp.	JX507700			*Volutella* sp., 517/521, 99% ITS	FR822789
				Volutella ciliata, 517/521, 99% ITS	GU479901

*species which names were identified by morphology

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 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 1, 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. maius*, *O. periconioides*, *Talaromyces funiculosus*, *Penicillium spinulosum*, *P. thomii*, *Pochonia bulbillosa* 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, *Tolypocladium* W. Gams, *Cladosporium* and *Acremonium* Link when compared to the peat of the other peatlands (Table 2). 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 2). The results of the diatom research confirm the difference between the Ersovskoe 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 2). 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 saprobes, aquatic saprobes, 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 *Tolypocladium 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 2). 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 *Tolypocladium cylindrosporum*, *T. geodes*, *T. nubicola*, *T. tundrense*, *Beauveria bassiana*, *B. brongniartii* and *Engyodontium album*.

Also, fungi that are known as typical soil saprobes for northern regions and species associated with insects such as *Tolypocladium inflatum*, *Tolypocladium cylindrosporum*, *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 1; 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.

Acknowledgments

We thank Alexander Tzetlin (director of the WSBS) for the opportunity to do this research, Elena Vortsepneva and Alexander Semenov for their help with sample collection, Bertha Koopmanschap, Marijke Slakhorst and Alex Grum-Grzhimaylo for technical assistance, and Denis Landin for image processing. The work was supported by Erasmus Mundus IAMONET-RU and the Laboratory of Genetics at Wageningen University, the research grants from St Peterburg State University No. 1.0.134.2010 and RFBR grants No. 15-29-02553, No.15-04-02722 (the field investigation and identification of the fungi), RSCF grant No. 14-50-00029 (the cultivation and collection of the fungi; Bilanenko, Grum-Grzhimaylo).

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CHAPTER 3

Mosaic structure of the fungal community in the Kislo-Sladkoe Lake that is detaching from the White Sea

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Published in Polar Biology, https://doi.org/10.1007/s00300-018-2347-9

The major part of the north polar region is intensely rising by postglacial crustal movement. This process gives rise to the separation of different basins from seas and oceans, which affects a combination of freshwater and marine organisms. Gradually losing contact with the seas, many near-shore lakes of the Arctic are mostly desalted and form bogs. Fungi as decomposers play an important role in all ecosystems. However, the diversity and role of fungi in Arctic aquatic ecosystems is largely unknown. It is also not clear how the taxonomic structure of the fungal community is affected by the process of gradual desalinization and waterlogging. We investigated the diversity of filamentous culturable fungi in different parts of the brackish Kislo-Sladkoe Lake (White Sea, Russia). Annually, 42 samples of the bottom and coastal soils have been collected at the lake from which fungi were recovered on standard and selective media. Based on morphological and molecular markers, a total of 127 taxa have been identified. The fungal community appeared to be influenced by its sea origin and comprised both marine (*Paradendryphiella salina*, *Acremonium* spp.) and terrestrial soil species of *Penicillium*, *Talaromyces*, *Mucor*, *Umbelopsis*, *Cladosporium*, *Cadophora*, *Sistotrema*, *Helotiales*, *Pleosporales*, *Sphagnum* moss destructors (*Oidiodendron* spp.) and insect-associated species of *Tolypocladium*. The results indicate that the composition of the fungal community in the rising polar White Sea region reflects the dynamics of global changes in physical–chemical parameters and animal and plant associations because of separation from the sea.

Key words
Fungal diversity, Brackish lake, Glacioisostatic movement, Coastal rising

Abstract

Introduction

Some Arctic oceanic and marine coastal zones are intensely rising because of glacio-isostatic movement (Krasnova et al. 2013). As a result, water bodies are detaching from seas and oceans and transforming to meromictic lakes in northern parts of North America and Eurasia (Fig. 1; Dickman 1978; Ludlam 1996; Gibson et al. 2002; Hakala 2004; Lutz and Kaulfuß 2006; Van Hove et al. 2006; Pouliot et al. 2009; Strelkov et al. 2014; Gulati et al. 2017). The coastal line of the White Sea (Russia) is a prominent example of this natural phenomenon. The shoreline of the western part of the White Sea is flat and indented; hence, the consequence of the coastal rising is the separation of the water bodies such as bays, armlets, and small lakes from coastal straits. These lakes gradually lose their connection with the sea and transform into different types of coastal basins varying in depth. Lakes with a depth of more than 6 m transform into meromictic lakes, while those with a depth of 1–6 m b transform into boggy fresh lakes. If the depth is less than 1 m, the lakes form marshes (Pantiulin and Krasnonva 2011).

Fig. 1 The studied meromictic lakes in in the Arctic region are marked by the circles; WSBS the White Sea biological station.

The lakes that are separating from the White Sea combine both marine and continental features and represent a unique environmental niche. These basins are still connected to the sea in a varying degree, while also having inflow of fresh water from inland. Therefore, the main feature of these lakes is a strong vertical stratification governed by dynamics of fresh and salt water influx (Vinogradov et al. 2015). As a result, such detaching lakes harbour unique biota comprising a combination of freshwater and marine organisms (Krasnova et al. 2013). The shore-lines of these lakes are equally interesting biotopes. Horizontal nearshore currents distribute inflowing marine and fresh water along the shores. Therefore, coastal soil and littoral ground are composed of different zones with fluctuating environmental conditions, such as humidity, salinity and pH values. The mosaic coastal vegetation of these lakes highlights the soil patchiness (Sidneva 2008). Consequently, these transitional ecosystems represent extreme habitats and good systems for studying the general regularities in the formation of anaerobic conditions. These water bodies also represent unique objects for investigations of the biogeochemical processes that take place in water and sediments, and the interaction of freshwater and marine organisms. Scientists from various disciplines have explored the hydrology, flora and fauna of the water bodies at different stages of isolation from the White Sea (Krasnova et al. 2013). However, the fungal diversity and the role of fungi in meromictic and brackish lakes are poorly studied, although some data are available on fungi from meromictic lakes of Canada, Japan, France and Germany (Takishitaa et al. 2007; McAndrews and Turton 2010; Oikonomou et al. 2015; Lepère et al. 2016). So far, there have been no studies on the fungal biodiversity in separating lakes in Russia. Yet, littoral zone and marine bottom sediments including polar marine waters are specific ecotopes for fungi, with respect to biodegradation, symbiotic relationships and other functions (Damare et al. 2006; Damare and Raghukumar 2008; Bubnova 2017; Furbino et al. 2017; Rämä et al. 2017).

In this study, we further explore the fungal biodiversity in the Kislo-Sladkoe Lake, which is detaching from Kandalaksha Bay of the White Sea. This lake is a wellinvestigated site as a model of separating water reservoirs located in this region. It is located near the Pertsov White Sea Biological Station (WSBS; 66°34′N, 33°08′E; Online Resource 1) of the Lomonosov Moscow State University and is at an initial stage of peatland formation because of its shallow waters (4.5 m maximum depth). Over recent years, the Kislo-Sladkoe Lake has been examined with a wide range of approaches (Sidneva 2008; Krasnova et al. 2013, 2014, 2015; Malyshko et al. 2015; Vinogradov et al. 2015). We began to study the diversity of fungi in this lake from the year 2008. Presumably, soil from the coast is more habitable for fungi than bottom sediments; therefore, we mainly focused on the investigation of the lake's shore-line, whereas fungi from the bottom sediments were described in less detail. The fungi were isolated from the peat, soil and sediment samples taken from the coast, littoral and bottom of the lake in 2008–2010. Our isolation method recovered culturable basidiomycetous, ascomycetous and zygomycetous fungi, which were identified using morphological and cultural features as well as DNA sequence data (ITS rDNA region, along with LSU rDNA). To make the present work more complete, we combined our new data with selected data from our previous studies of microfungi in the lake (Grum-Grzhimaylo et al. 2016). We characterized the composition, abundance and spatial distribution of fungal species from different parts of the lake and related these data to the ecological peculiarities of the lake, such as its freshening and a contact with the Sea.

Materials and methods

Description of the Kislo-Sladkoe Lake

The Kislo-Sladkoe Lake ["Sour–Sweet" Lake; its other name is Polupresnoe ("Brackish") Lake] is located near the Karelian coast of Kandalaksha Bay of the White Sea 2 km east of the Pertsov White Sea Biological Station (Online Recourse 1). The climatic and geomorphological characteristics of this area have been given earlier (Grum-Grzhimaylo et al. 2016). The Kislo-Sladkoe Lake is oval-shaped, 100 m long, 60 m wide, occupying 1.6 ha, with an average depth of 1.5 m and a maximum depth of 4.5 m. The drainage area of the lake is 157.0 m^2. In 2010, its elevation was 0.4 m above sea level (Schaporenko et al. 2005; Krasnova et al. 2014). Its basin is being formed as a result of separation of a water area between a small unnamed island covered with pines and the mainland shore of Kindo Cape (Fig. 2). In the past, the bed of the strait was bound from two sides by two submerged ridges, which rose to the surface because of the general rise of the land and formed isthmuses separating the lake area from the Great Salma Strait. One of the isthmuses is covered with grass and appears to be inundated only during seasonal snow melting when the lake is overfilled. The second isthmus consists of rolled boulders and pebble. A weak water exchange with Kandalaksha Bay takes place in the surface layer through this isthmus during high tides (once a month for 2–3 days). A weak water exchange is likely to exist through the entire northern shore of the lake. The southern shore is swampy and very weak though permanent creek flows into the sea over a steep slope of the peninsula. Underwater springs, which freshen the lake water, can also exist (Schaporenko et al. 2005). The vertical structure of the lake is characterized by seasonal and interannual variations (Vinogradov et al. 2015). Water characteristics from each of the layers in 2010 are shown in the Online Recourse 2.

Coastal vegetation of the lake is a mosaic. Different plant communities including littoral, bog and forest vegetation constantly change one after another along the shore. The circular position of the primary sea-coast vegetation is indicative for the coastal rising (Sidneva 2008; Grum-Grzhimaylo 2013; Yatzenko et al. 2017).

Sampling

The samples of soil, peat and bottom sediments were collected from several locations along the overgrown coast, littoral edge and bottom of the lake (Fig. 2; Tables 1, 2). Soil samples from the coast and littoral at the surface and 0.1 m depth, forest soil at the different horizons (two profile cuts), plants (living and dead parts of the moss *Sphagnum* spp.), and peat samples at 0.15 and 0.3 m depths were taken using a knife and transferred to sterile Petri dishes. The knife was cleaned with water and 96% alcohol following each extraction. The bottom sediment samples were collected every 0.5 m at different depths by SCUBA diving and placed in sterile tubes. All the samples were taken at one replication per season. Some locations were sampled twice (in different years). The collected samples were transported in a cold container to the laboratory and stored at 5 °C for 1–2 days until plating.

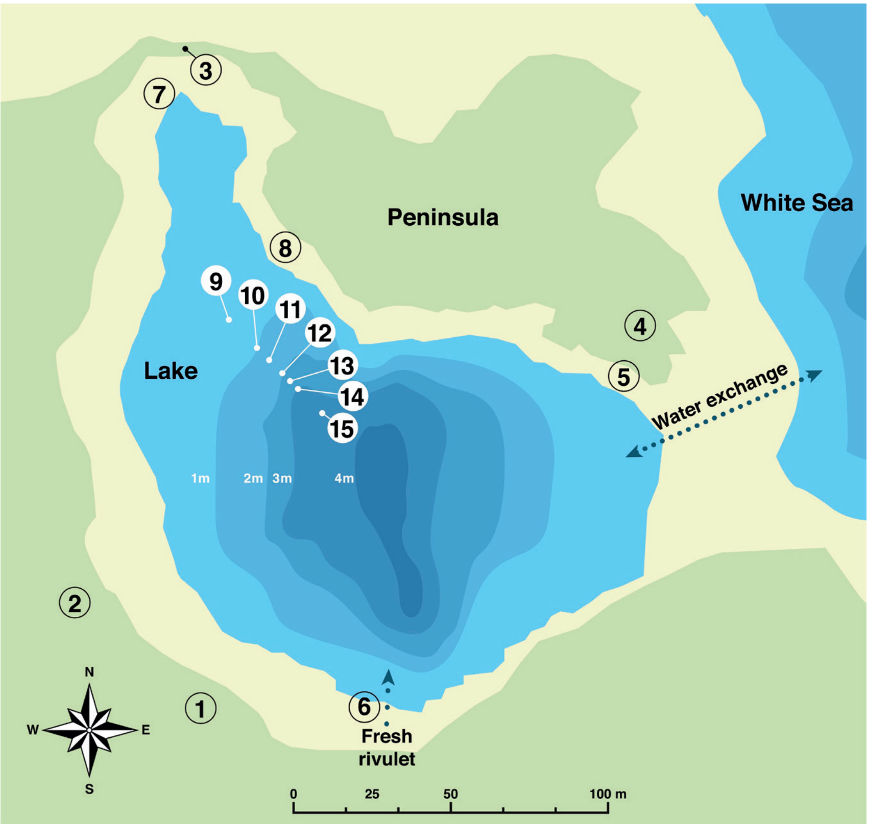

Fig. 2. Scheme of the Kislo-Sladkoe Lake, the sampling points are: 1 *Sphagnum* peat, 2 boreal podzol, 3 muck land, 4 seashore grassed soil, 5–7 ooze, 8 coastal sand, 9–15 bottom sediments.

Table 1. Characteristics of the samples of the different parts of the Kislo-Sladkoe Lake shore.

Characteristics	Soil from the coast				Soil from the littoral zone			
No. of sampling place (see Fig. 2)	1	2	3	4	5	6	7	8
Date of sampling	July 2008, July 2010	July 2008	July 2009, July 2010	July 2009, July 2010	July 2009, July 2010	July 2010	July 2010	July 2010
Location (compass point)	SSW	W	N	NE	ENE	S	N	NNE
Main vegetation	*Sphagnum* spp.	*Pinus sylvestris*, *Betula pubescens*	*Juncus atrofuscus*, *Triglochin maritima*, *Blysmus rufus*, *Eleocharis uniglumis*		–	*Carex* spp.	–	–
Type of ground	Peat	Boreal podzol	Muck land	Seashore soil		Ooze		Coarse sand
Sample (horizon/type/depth, m)	LS DS 0.2	0.3 L F + H B C	S 0.1	S 0.1	S 0.1	S 0.1	S	0.1 S 0.1
pH of samples	6.0	5.0 6.5	6.5	5.0	8.5 8.0	7.0 8.0	8.5	8.0 8.5

LS living part of *Sphagnum* spp., DS dead part of *Sphagnum* spp., L dead soil cover, ground litter, F + H fermentation and humification horizons, B illuvial horizon with surface gleying, C parent rock material (sand), S surface.

Table 2. Characteristics of the samples of the different parts of the Kislo-Sladkoe Lake bottom sediments.

No. of sampling place (see Fig. 2)	9	10	11	12	13	14	15
Date of sampling	July 2010						
Depth, m	0.5	1.0	1.5	2.0	2.5	3.0	3.5
Type of ground	Oozy bottom						
Sample (horizon)	Surface						
pH of samples	6.0	6.0	5.5	5.0	6.0	6.0	5.5

Fungal isolation, cultivation, identification and data analysis

Dilutions were prepared from all the samples using 1 g in 10 mL of sterile distilled water, pounded in a mortar, and further diluted 100-fold. From this final dilution, 0.25 mL was pipetted onto two Petri plates each of six media: malt extract agar, water agar, citric-acid buffer agar, *Sphagnum* extract agar, alkaline buffer agar and brackish water agar with the water from the lake. The media preparation and fungal cultivation were performed as described previously (Grum-Grzhimaylo et al. 2016). The identification of the fungi by morphologic and cultural characters was performed using manuals (Raper and Fennell 1965; Raper et al. 1968; Rifai 1969; von Arx 1981; Ellis 1971; Gams 1971, 2000; Barnett and Hunter 1972; Schipper 1978; Kohlmeyer and Kohlmeyer 1979; Carmichael et al. 1980; Bissett 1982, 1984; de Hoog et al. 2000; Schroers 2001; Zare and Gams 2001; Klich 2002; Samson et al. 2004; Crous et al. 2007; Domsch et al. 2007; Samson and Houbraken 2011; Seifert et al. 2011). The morphologycal analysis was carried out with light microscopes

(Mikmed-2, Carl Zeiss Axioskop 40 FL, Leica DM 2500). The information regarding fungal classification generally follows the Index Fungorum (http://www.indexfungorum.org) databases. The fungal strains which failed to sporulate following incubation (for 30 days) were considered sterile mycelia. A substantial part of the sterile mycelia and sporulating strains that were hard to identify by morphology were identified by DNA sequence analysis of the ITS and LSU regions of the nuclear-encoded rDNA. The same analysis was conducted for dominant fungal species in order to verify identification by morphological characters. Total genomic DNA (gDNA) was extracted from the mycelium of the 109 fungal strains using the chloroform/isopropanol method (Karakousis et al. 2006; Grum-Grzhimaylo et al. 2016). We amplified and sequenced the ITS rDNA for all strains and LSU rDNA for the most of them using common primer sets. The primer sets, thermocycling programs and sequencing procedures were performed as described previously (Grum-Grzhimaylo et al. 2016). Sequences were compared with the data from GenBank using BLAST similarity searches. Newly generated sequences were deposited in the GenBank. The GenBank Accession Numbers of 36 species from the lake are in our previous work (Grum- Grzhimaylo et al. 2016), and the others given in the Online Resource 3.

Data on the total number of fungi were expressed as colony-forming units (CFU) g^{-1} of dry peat, as described previously (Grum-Grzhimaylo et al. 2016). The Sørensen index was used to compare fungal communities between the different parts of the lake (Zak and Willig 2004).

Table 3. Isolated species with total number (CFU × 10^2 g^{-1} dry soil) and media of isolation.

	Soil from the coast				**Soil from the littoral zone**				**Bottom sediments**			
pH of the samples	5.0–6.0	6.5	6.5–8.5	5.0	8.0–8.5	7.0–8.0	8.5	8.0	5.5–6.0	5.0–6.0	5.5–6.0	
No. of sampling places (see Fig. 2)	1	2	3	4	5	6	7	8	9, 10	11–13	14,15	
Taxa												**Media**
Acremonium cf. *charticola*	–	–	5	–	–	–	–	–	–	–	–	WA
Acremonium cf. *fuci*	–	–	–	–	–	–	–	5	–	–	–	SWA
Acremonium sp. 1	10	5	–	10	10	20	–	–	–	800	–	WA, AA, SWA, MA
Acremonium sp. 2	–	–	20	–	20	–	50	5	–	–	–	AA, MA, SWA
Acremonium sp. 3	30	–	–	5	15	–	–	–	–	–	–	MA, AA
Acremonium sp. 4	–	–	–	–	5	–	–	–	–	–	–	MA
Acremonium sp. 5	–	–	10	–	50	10	–	–	–	–	–	SWA, MA
Acremonium sp. 6	–	–	–	–	28	10	–	5	–	–	–	AA
Alternaria alternata (Fr.) Keissl.	15	–	–	–	–	–	–	–	–	–	–	CA
Alternaria sp. 1	–	–	–	–	–	–	–	5	–	–	–	MA
Alternaria sp. 2	–	–	–	10	–	–	–	–	–	–	–	CA, MA
Antrodia sp.	–	–	–	–	15	–	–	–	–	–	–	CA
Ascomycota sp. 1	35	–	–	–	–	–	–	–	–	–	–	CA

	Soil from the coast				Soil from the littoral zone				Bottom sediments			
pH of the samples	5.0–6.0	6.5	6.5–8.5	5.0	8.0–8.5	7.0–8.0	8.5	8.0	5.5–6.0	5.0–6.0	5.5–6.0	
No. of sampling places (see Fig. 2)	1	2	3	4	5	6	7	8	9, 10	11–13	14,15	
Ascomycota sp. 2	–	–	–	–	–	–	–	5	–	–	–	MA
Ascomycota sp. 3	–	–	–	5	–	–	–	–	–	–	–	MA
Ascomycota sp. 4	–	–	–	–	–	–	–	–	–	–	20	WA
Ascomycota sp. 5	–	–	–	–	–	50	–	–	–	–	–	SWA
Aspergillus proliferans G. Sm.	–	–	–	–	–	45	–	–	–	–	–	SEA
***Aspergillus tubingensis* Mosseray**	–	–	–	–	–	–	15	–	–	–	65	MA
Aspergillus ustus (Bainier) Thom and Church	–	–	–	5	–	10	–	–	–	–	–	MA
Aspergillus versicolor (Vuill.) Tirab.	10	–	–	–	–	10	–	–	–	–	–	CA
***Aspergillus* sp.**	–	–	5	15	–	–	–	–	–	–	–	MA, SEA
Aureobasidium pullulans (de Bary and Löwenthal) G. Arnaud	–	5	–	–	–	–	–	–	–	–	–	MA
Basidiomycota sp.	–	–	–	–	–	–	5	–	–	–	–	MA
Beauveria bassiana (Bals.-Criv.) Vuill.	15	–	–	–	–	10	–	–	–	–	–	AA, CA, MA, SEA, WA
Beauveria brongniartii (Sacc.) Petch	21	–	–	–	–	–	–	–	–	–	–	MA
Beauveria sp.	–	–	–	14	–	–	–	–	–	–	–	MA
***Botryotinia* sp.**[a]	550	–	–	–	–	–	–	–	–	–	–	WA
Botrytis cinerea Pers.	50	–	–	–	–	–	–	–	–	–	–	CA
***Cadophora fastigiata* Lagerb. and VKM F-4772**[a,b]	5	–	–	5	–	–	–	–	–	–	–	AA, CA, SWA
***Cadophora luteo-olivacea* (J.F.H. Beyma) T.C. Harr. and McNew VKM F-4773**[b]	250	–	10	15	–	–	–	–	–	10	–	CA, SEA, WA
***Cadophora malorum* (Kidd and Beaumont) W. Gams**	–	–	–	–	–	–	–	5	–	–	–	CA
Cadophora melinii Nannf.	30	100	–	5	–	–	–	–	–	–	–	MA, SEA, WA
Cadophora sp. 1	25	–	–	–	–	–	–	–	–	–	–	SEA
Cadophora sp. 2	–	–	–	–	–	–	–	5	–	–	–	CA
***Chaetosphaeria* sp.**	–	–	–	–	–	10	–	–	–	–	–	CA
Cladosporium allicinum (Fr.) Bensch, U. Braun and Crous	400	–	–	5	–	–	–	–	–	–	–	AA, CA, MA, SWA
Cladosporium antarcticum K. Schub., Crous and U. Braun	200	–	–	5	–	–	–	–	–	–	–	AA
***Cladosporium cladosporioides* (Fresen.) G.A. de Vries**[a]	650	–	–	–	–	10	–	–	15	–	20	MA, SEA, SWA
***Cladosporium herbarum* (Pers.) Link**[a]	60	–	–	–	–	20	–	–	–	–	–	MA, SWA
Cladosporium oxysporum Berk. and M.A. Curtis	200	–	–	–	–	–	–	–	–	–	–	MA, SEA
***Cladosporium* sp. 1**	–	–	–	–	10	–	–	–	–	–	–	AA
Cladosporium sp. 2	10	–	–	–	–	–	–	–	–	–	–	SEA
Cladosporium sp. 3	–	–	5	–	–	–	–	–	–	–	–	CA
Cladosporium sphaerospermum Penz.	10	30	–	–	–	–	–	–	–	–	–	SEA
***Coniochaeta* sp.**	–	5	–	–	–	–	–	–	–	–	–	CA

pH of the samples	Soil from the coast				Soil from the littoral zone				Bottom sediments			
	5.0–6.0	6.5	6.5–8.5	5.0	8.0–8.5	7.0–8.0	8.5	8.0	5.5–6.0	5.0–6.0	5.5–6.0	
No. of sampling places (see Fig. 2)	1	2	3	4	5	6	7	8	9, 10	11–13	14,15	
Cordyceps militaris (L.) Fr.	–	–	–	–	10	–	–	–	–	–	–	AA
***Cylindrobasidium laeve* (Pers.) Chamuris**	–	–	5	–	–	–	–	–	–	–	–	WA
***Dothideales* sp.**[a]	–	–	–	–	–	–	–	–	–	5	–	MA
***Dothideomycetes* sp. 1**[a]	–	–	–	–	–	–	–	–	–	–	65	SWA
***Dothideomycetes* sp. 2**[a]	10	–	–	–	–	–	–	–	–	–	–	MA
Fusarium avenaceum (Fr.) Sacc.	–	–	10	–	–	–	–	–	–	–	–	MA
Fusarium graminearum Schwabe	–	–	10	–	–	–	–	–	–	–	–	CA
Fusicladium pini Crous and de Hoog	10	–	–	–	–	–	–	–	–	–	–	SEA
***Helotiaceae* sp.**[a]	10	–	–	–	–	–	–	–	–	–	–	WA
***Helotiales* sp. 1**[a]	35	–	–	–	–	–	–	–	–	–	–	CA, WA
***Helotiales* sp. 2**[a]	25	–	–	–	–	–	–	–	–	–	–	CA
***Helotiales* sp. 3**	–	–	–	15	–	–	–	–	–	–	–	MA
***Helotiales* sp. 4**[a]	–	–	5	–	–	–	–	–	–	–	–	SWA
***Helotiales* sp. 5**[a]	–	–	–	–	–	–	–	–	–	10	–	SEA
***Helotiales* sp. 6**	–	–	–	–	–	–	–	–	–	5	–	CA
Lecanicillium evansii Zare and W. Gams	–	–	–	–	15	–	–	–	–	–	–	CA
Lecanicillium sp. 1	10	–	–	–	–	–	–	–	–	–	–	AA
Lecanicillium sp. 2	35	–	–	–	–	–	–	–	–	–	–	SWA
Lecanicillium sp. 3	–	–	–	15	–	–	–	–	–	–	–	SEA
***Massarinaceae* sp.**[a]	25	–	–	–	–	–	–	–	–	–	–	CA
Memnoniella dichroa (Grove) L. Lombard and Crous	30	–	–	–	–	–	–	–	–	–	–	SEA
***Metapochonia bulbillosa* (W. Gams and Malla) Kepler, Rehner and Humber VKM F-4674**[a,b]	30	–	–	–	–	–	–	–	–	–	–	CA
***Mortierella elongata* Linnem.**[a]	–	–	–	–	–	–	–	–	–	200	–	MA
Mucor circinelloides Tiegh.	–	5	–	–	–	–	–	–	–	–	–	CA, MA
***Mucor hiemalis* WehmerVKM F-4774**[b]	–	25	–	15	15	–	–	–	–	–	–	MA, SEA, WA
Mucor racemosus Fresen.	–	–	5	–	–	–	–	–	–	–	–	WA
***Nectriaceae* sp.**	15	–	–	–	–	10	–	–	–	–	–	MA
Oidiodendron ambiguum Peyronel and Malan	25	–	–	–	–	–	–	–	–	–	–	MA
Oidiodendron griseum Robak	10	–	–	–	–	–	–	–	–	–	–	MA
***Paradendryphiella salina* (G.K. Sutherl.) Woudenb. and Crous**	–	–	5	–	–	–	–	5	–	–	–	MA
Parengyodontium album (Limber) C.C. Tsang, J.F.W. Chan, W.M. Pong, J.H.K. Chen, A.H.Y. Ngan, Cheung, C.K.C. Lai, D.N.C. Tsang, S.K.P. Lau, P.C.Y. Woo	30	–	–	–	15	–	–	–	–	–	–	CA, MA, SEA
Penicillium aurantiogriseum Dierckx	–	–	5	–	–	–	–	–	–	–	–	SEA
Penicillium decumbens Thom	–	–	–	–	–	35	–	–	–	–	–	CA

	Soil from the coast				Soil from the littoral zone				Bottom sediments			
pH of the samples	5.0–6.0	6.5	6.5–8.5	5.0	8.0–8.5	7.0–8.0	8.5	8.0	5.5–6.0	5.0–6.0	5.5–6.0	
No. of sampling places (see Fig. 2)	1	2	3	4	5	6	7	8	9, 10	11–13	14,15	
Penicillium dierckxii Biourge	10	–	–	–	–	–	–	–	–	–	–	WA
Penicillium glabrum (Wehmer) Westling	10	750	–	–	–	20	–	5	–	–	–	CA, MA, SEA, WA
Penicillium griseofulvum Dierckx	–	–	–	–	–	–	–	–	–	10	–	CA
***Penicillium montanense* M. Chr. and Backus**	100	250	–	15	–	10	–	–	–	–	–	CA, MA, SEA, SWA, WA
Penicillium multicolor Grig.-Man. and Porad.	–	–	–	–	–	–	–	–	15	–	–	WA
Penicillium restrictum J.C. Gilman and E.V. Abbott	–	50	–	–	–	–	–	–	–	–	–	WA
Penicillium roseopurpureum Dierckx	–	–	–	–	–	–	–	–	5	–	–	WA
***Penicillium thomii* Maire VKM F-4664**[b]	–	20	–	5	15	–	–	–	–	200	–	CA, MA
Penicillium waksmanii K.M. Zaleski	15	10	–	–	–	–	–	–	–	–	–	MA, SEA
Penicillium sp. 1	–	–	–	–	10	–	–	–	–	–	–	SWA
Penicillium sp. 2	–	–	–	–	–	20	–	–	–	–	–	CA, MA, SWA
Penicillium sp. 3	–	–	5	–	–	–	–	–	–	–	–	SWA
Penicillium sp. 4	–	–	–	–	–	–	10	–	–	–	–	CA, MA, SWA
Peniophora sp.	–	–	–	–	–	–	–	–	–	5	–	WA
Phaeoacremonium sp.	375	–	–	–	–	–	–	–	–	–	–	SEA
Phialophora sp.	–	–	–	5	–	–	–	–	–	–	–	SWA
Phialophora verrucosa Medlar	15	–	–	–	–	–	–	–	–	–	–	CA
***Plectosphaerella* sp.**	–	–	20	–	–	–	–	–	–	–	–	AA
Pleosporales sp. 1	–	–	–	–	–	–	–	5	–	–	–	MA
Pleosporales sp. 2	–	–	10	–	–	–	–	–	–	–	–	MA
Pleosporales sp. 3	–	–	–	–	–	–	–	5	–	–	–	MA
Pseudogymnoascus pannorum (Link) Minnis and D.L. Lindner	35	–	–	–	–	–	–	–	–	–	–	SEA
Sarocladium implicatum (J.C. Gilman and E.V. Abbott) Giraldo, Gené and Guarro	–	–	–	–	–	10	–	–	–	–	–	WA
Scopulariopsis brumptii Salv.-Duval	–	–	–	–	–	–	5	–	–	–	–	MA
***Sistotrema brinkmannii* (Bres.) J. Erikss. VKM F-4640**[b]	–	–	10	15	30	–	–	5	–	20	20	AA, CA, MA, SWA, WA
Sporothrix sp.	–	–	–	–	–	–	10	–	–	–	–	CA
Stachybotrys echinatus (Rivolta) G. Sm.	–	500	–	–	–	–	–	–	–	–	–	SEA, WA
***Sydowia polyspora* (Bref. and Tavel) E. Müll.**[a]	275	–	–	–	–	–	–	–	–	–	–	MA
Talaromyces aculeatus (Raper and Fennell) Samson, N. Yilmaz, Frisvad and Seifert	–	–	–	–	–	–	–	–	–	–	20	MA
Talaromyces funiculosus (Thom) Samson, N. Yilmaz, Frisvad and Seifert	–	–	–	250	30	20	10	5	–	–	100	CA, MA, SEA, WA
Talaromyces variabilis (Sopp) Samson, N. Yilmaz, Frisvad and Seifert	–	20	–	30	–	–	–	–	–	200	–	CA, SEA

pH of the samples	Soil from the coast				Soil from the littoral zone				Bottom sediments			
	5.0 – 6.0	6.5	6.5 – 8.5	5.0	8.0 – 8.5	7.0 – 8.0	8.5	8.0	5.5 – 6.0	5.0 – 6.0	5.5 – 6.0	
No. of sampling places (see Fig. 2)	1	2	3	4	5	6	7	8	9, 10	11 – 13	14,15	
Talaromyces verruculosus (Peyronel) Samson, N. Yilmaz, Frisvad and Seifert	–	10	–	–	15	–	–	–	–	5	–	CA, SWA
***Tolypocladium cylindrosporum* W. Gams VKM F-4627[b]**	25	–	–	–	–	10	10	5	–	–	65	AA, MA. SEA
***Tolypocladium inflatum* W. Gams VKM F-4675[b]**	5	60	5	15	5	–	5	5	–	200	–	AA, MA, WA
Tolypocladium nubicola Bissett	5	–	–	5	–	–	10	–	–	–	–	MA, SWA, WA
Trichoderma asperellum Samuels, Lieckf. and Nirenberg	–	–	–	–	–	10	–	–	–	–	–	WA
Trichoderma harzianum Rifai	50	–	–	–	10	–	10	–	–	–	–	CA, SEA, SWA, WA
Trichoderma koningii Oudem.	5	–	–	–	–	–	–	–	–	–	–	CA
***Trichoderma parapiluliferum* (B.S. Lu, Druzhin. and Samuels) Jaklitsch and Voglmayr**	–	5	–	–	–	–	–	–	–	–	–	MA
***Trichoderma polysporum* (Link) Rifai VKM F-4630[b]**	–	–	5	–	–	–	–	–	–	–	–	CA, WA
Trichoderma viride Pers.	–	–	5	–	–	10	–	–	–	–	–	SWA
Trichoderma sp.	–	–	–	–	–	10	–	–	–	–	–	CA
Umbelopsis isabellina (Oudem.) W. Gams	875	15	–	–	–	–	–	–	–	–	–	CA
Umbelopsis ramanniana (Möller) W. Gams	25	40	–	–	–	–	–	–	–	–	–	CA, WA
Umbelopsis vinacea (Dixon-Stew.) Arx	10	–	–	–	–	–	–	–	–	–	–	CA
Umbelopsis sp.	65	–	–	–	–	–	–	–	–	–	–	SWA
***Xylobolus* sp.**	–	–	–	–	–	–	10	–	5	–	–	AA, SEA
No of sterile isolates (28 morphotypes)	3	–	–	5	4	2	1	3	3	5	2	AA, CA, MA, SEA, SWA, WA

Species identified by morphological and molecular approach are in bold.
Abbreviation: MA malt extract agar, CA citric agar, AA alkaline agar, WA water agar, SEA *Sphagnum* extract agar, SWA semi-saltwater agar.
[a] GenBank Accession Numbers of these species are in our previous work (Grum-Grzhimaylo et al. 2016).
[b] Species deposited to All-Russian Collection of Microorganisms—VKM (the numbers are near the species names).

Results

In total, 313 fungal isolates were obtained from the 42 samples of different types of soils around the lake and its bottom sediments. These isolates belonged to 127 taxa, representing 40 genera and 28 sterile unidentified morphotypes (Table 3). Of these taxa, 111 (71.2%) were *Ascomycota*, 8 (5.1%) *Basidiomycota*, and 8 (5.1%) *Zygomycota*. The number of viable fungal propagules ranged from 10^2 to 10^5 CFU g^{-1} of the sample dry weight. Taxonomic identification of all taxa was based on morphological characters, while 40 of them (109 isolates) were identified using molecular markers (ITS and LSU rDNA), including the majority of the sterile mycelia (86 of 114 isolates), together with 13 species which were impossible to identify by morphology and a few frequent species (10 taxa).

The dominance of the fungi from the *Ascomycota* division was a common characteristic of the mycobiota from all parts of the lake due to abundance of the anamorphic species. The predominant genera were *Penicillium* (mostly *Monoverticillata*) and *Talaromyces* (Table 3).

The following genera were widely represented in all parts of the lake: *Acremonium, Cladosporium, Cadophora, Trichoderma, Lecanicillium, Mucor, Umbelopsis, Aspergillus, Tolypocladium, Cordyceps* (was presented by anamorphic stages from the genera *Beauveria и Parengyodontium*), *Talaromyces* and *Penicillium*.

In the *Sphagnum* peat (Fig. 2, point 1), the following species dominated: *Acremonium* spp., *Cadophora luteo-olivacea*, *Hypocreales* sp., *Penicillium montanense*, *Metapochonia bulbillosa, Tolypocladium cylindrosporum*, *Cladosporium antarcticum*, *C. allicinum*, *C. cladosporioides*, and *C. herbarum*. *Cadophora luteo-olivacea*, *Talaromyces funiculosus* and *Tolypocladium inflatum* were frequently found in grassed soil (Fig. 2, point 4); *Penicillium glabrum*, *P. montanense*, *Trichoderma polysporum* and *Umbelopsis ramanniana* in the forest soil (Fig. 2, point 2). *Acremonium* spp., *Antrodia* sp., *Paradendryphiella salina*, *Sistotrema brinkmannii*, *Penicillium aurantiogriseum*, *P. funiculosum*, *P. glabrum*, *P. thomii*, *Penicillium* sp., *Tolypocladium cylindrosporum*, *T. inflatum*, *Trichoderma harzianum* and *T. viride* predominated in the littoral soils (Fig. 2, points 5–8, 3), and *Cladosporium cladosporioides* in the benthic ooze (Figs. 2, points 9–15). The sterile mycelium morphotypes were often isolated from all components of the lake, except for the forest and silted soils.

The greatest level of similarity in the fungal species composition was identified for the mycobiota of littoral zone and the lake benthic ooze, while the lowest level was found between the ooze and the *Sphagnum* peat. The similarity of the fungal communities between the different parts of the lake ranged from 0.09 (between the *Sphagnum* peat and the bottom sediments) to 0.23 (between the littoral zone and the bottom sediments) (Table 4).

Table 4. Similarity of fungal communities of the different parts of the Kislo-Sladkoe Lake (Sørensen index).

	Grassland soil	Forest soil	Littoral zone	Lake bottom
Sphagnum peat	0.20	0.18	0.21	0.09
Grassland soil	–	0.21	0.20	0.15
Forest soil	–	–	0.11	0.12
Littoral zone	–	–	–	0.23

In the 24 samples taken from different points along the lakeshore that were not flooded during high tides (Fig. 2, points 1–4; Table 1), 88 fungal morphotypes were distinguished. The largest number of fungal taxa was found in samples of the living part of the *Sphagnum* moss and *Sphagnum* peat (Fig. 2, point 1) and grass-overgrown soil (Fig. 2, point 4). *Penicillium montanense* was identified in all layers of the *Sphagnum* peat deposit, and all horizons of the forest and grass-overgrown soil. *Penicillium glabrum* and *Trichoderma polysporum* were also isolated from all the horizons of the forest soil (Fig. 2, point 2). *Cladosporium antarcticum*, *C. allicinum*, *C. herbarum*, *Tolypocladium cylindrosporum* and *Acremonium* spp. were recovered from the peat-bog layers (Fig. 2, point 1). *Talaromyces funiculosus* and *Tolypocladium inflatum* were found to be common in the grass-overgrown soil (Fig. 2, point 4), and *Acremonium* sp. 2 and *Plectosphaerella* sp. in the silted soil (Fig. 2, point 3). *Cladosporium*, *Cordyceps* (*Beauveria* spp., *Parengyodontium album*), *Tolypocladium*, *Penicillium*, *Umbelopsis*, *Cadophora* and sterile mycelium were the most widely represented fungi in the *Sphagnum* peat (Fig. 2, point 1). In the grass overgrown soil (Fig. 2, point 4), *Acremonium*, *Cadophora*, *Cordyceps* and *Penicillium* were found with high frequency, while *Penicillium* was maximally represented in the forest soil (Fig. 2, point 2; Fig. 3), and *Acremonium*, *Fusarium* and *Trichoderma* in the silted soil (Fig. 2, point 3). Two species of *Oidiodendron* were found only in the *Sphagnum* peat (Fig. 2, point 1; Table 3).

The littoral zone of the lake (Fig. 2, points 5–8) is characterized by different soil properties and plant communities, which vary depending on the distance to the sea or freshwater basins. Eleven soil samples from the littoral zone of the lake yielded 63 morphotypes of fungi. Samples that were collected from the surface yielded about 3–4 times more fungal taxa than in samples collected at a depth. The maximum number of fungal taxa (21) was observed in a sample of surface silt taken close to the river confluence area (Fig. 2, point 6). In general, the soils at the lake always contained *Penicillium* spp. and sterile mycelia. Genera such as *Acremonium*, *Tolypocladium*, *Trichoderma*, *Aspergillus* and *Cladosporium* were also widely represented (Table 3). The analysis of the spatial frequency of occurrence showed that the predominant fungi in the soil of the Kislo-Sladkoe Lake littoral were *Acremonium* spp., *Talaromyces funiculosus*, *Sistotrema brinkmannii*, *Tolypocladium* *cylindrosporum*, *T. inflatum*, *Paradendryphiella salina*, *Penicillium glabrum*, *P. thomii,* and *Trichoderma viride* (Fig. 3, 4).

In total, 33 fungal taxa were identified in the samples collected from the lake's bottom sediment (Fig. 2, points 9–15). The number of fungi from the bottom sediment in various samples varied from 4 to 7. The lake benthic ooze harbored *Cladosporium* spp., *Talaromyces* spp., *Penicillium* spp., *Tolypocladium* spp., and *Sistotrema* spp., while the remaining genera were represented by a single species, and the sterile mycelia by 10 morphotypes (Table 3).

Discussion

The Kislo-Sladkoe Lake is an interesting system to study, as it shares features of both fresh- and seawater environments. We hypothesized that such a transitional ecosystem would contain a unique composition of fungal biodiversity. Earlier studies on typical terrestrial peatlands in the same area showed a drastically different set of fungi (Grum- Grzhimaylo and Bilanenko 2012; Bilanenko and Grum- Grzhimaylo 2016; Grum-Grzhimaylo et al. 2016). Thus, our current study highlights the unusual hydrology of the lake, which in turn has resulted in the establishment of a specific fungal community. This could be explained by the distinctive physical, chemical and hydrological conditions, characteristic to the lake, which possesses a direct connection to the sea and, as a consequence, contains coastal vegetation, algoflora, microorganisms and animals different from the continental water basins that serve as a source of food for the fungi. At the level of higher rank taxa, such as divisions and classes, the fungal communities in the peatlands of the Kindo peninsula are characterized by a similar taxonomy. As the distance from the sea increases, the composition of the dominant species of fungi in the peat and swamp ooze of the peatlands changes. We found similar species of fungi in a specific component (e.g., peat or ooze) between the peatlands, rather than in the peat and ooze of a single peatland. The *Sphagnum* peat of the lake coast (Fig. 2, point 1) is thin in comparison with other studied peat bogs in the area (Grum-Grzhimaylo et al. 2016). From the lake, despite the unfavorable conditions of the *Sphagnum* peat (recalcitrant cell walls of *Sphagnum* moss, abundant phenolic compounds, anoxia), we isolated a large diversity of fungi, including *Acremonium* spp., *Alternaria* spp., *Aspergillus versicolor*, *Beauveria* spp., *Botryotinia* sp., *Botrytis cinerea*, *Cadophora* spp., *Cladosporium* spp., *Oidiodendron* spp., *Lecanicillium* spp., *Penicillium* spp., *Talaromyces funiculosus*, *Tolypocladium spp., Trichoderma spp., Umbelopsis* spp., sterile mycelia, some of which *(Cadophora* sp. 1*, Cadophora luteo-olivacea, Cladosporium* sp. 2, *Cladosporium sphaerospermum, Fusicladium pini*, *Helotiales* sp. 5*, Lecanicillimm* sp. 3, *Penicillium aurantiogriseum*, *Phaeoacremonium* sp, *Pseudogymnoascus pannorum*, and *Stachybotrys dichroa*) appeared only on the media which were based on the *Sphag-*

num extract (Table 3). Contrary to typical terrestrial peat, the *Sphagnum* peat of the lake harbored a substantially larger fraction of fungi which are indicative of marine habitats, such as *Acremonium*, *Cadophora*, *Cladosporium*, and *Tolypocladium* (Online Resource 4). The fungal composition in the peat bogs of the terrestrial lakes in the area (Verkhneye, Krugloye and Yershovskoye Lakes), which have already separated from the sea, is similar, despite the different age and altitude above sea level (Grum-Grzhimaylo et al. 2016).

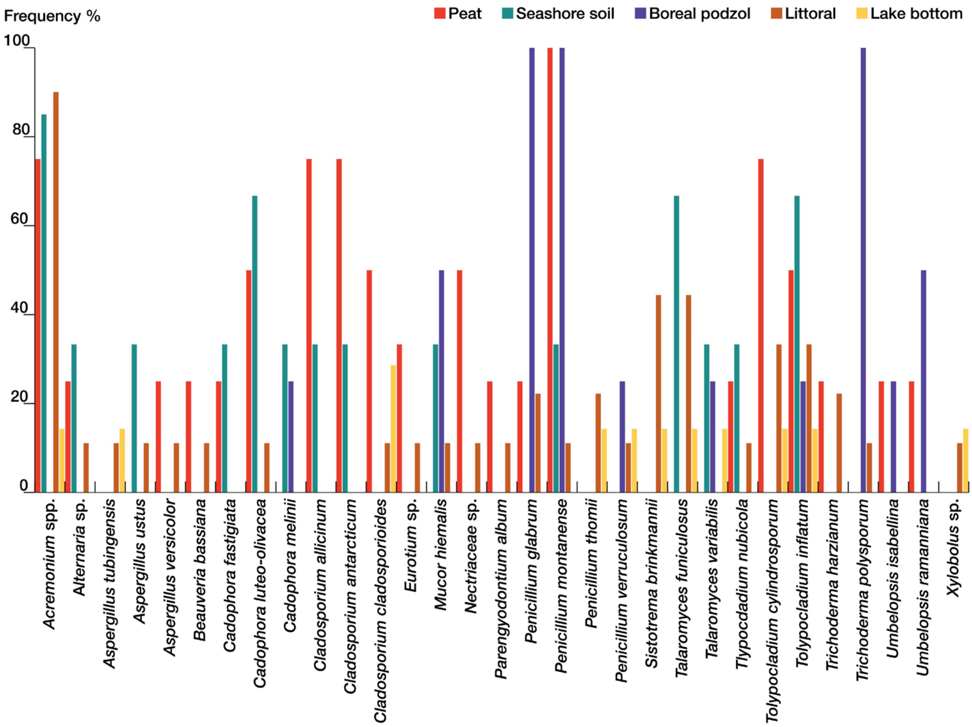

Fig. 3. The spatial frequency of the most abundant fungal species in the Kislo-Sladkoe Lake.

The benthic ooze (Fig. 2, points 9–15) is a more dynamic system due to differences in the organic matter inflow, exposure to external physical, chemical and hydrological conditions, and to the presence of marine sediments therein. Therefore, the fungal composition of the ooze was unique and differed between different lakes, except for sterile mycelia, the proportion of which was much higher compared to the peat. The ooze of both the terrestrial lakes and brackish lakes contained typical marine fungi of *Acremonium* which, by BLAST similarity search, are close to *A. fuci*, *A. potronii* and *A. strictum* (Jones et al. 2009). Thus, the presence of typical marine-borne fungi in the ooze of all the studied lakes reflects the process of their separation from the sea.

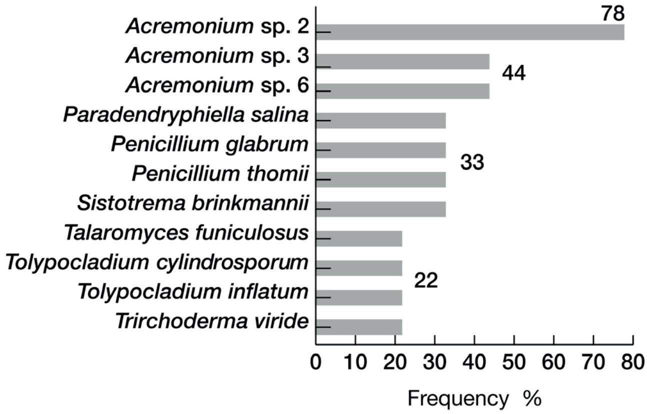

Fig. 4. The spatial frequency of fungal species (with the spatial frequency ≥ 22%) in the littoral of the Kislo-Sladkoe Lake

To make a direct comparison with the marine habitats, we compared the fungal composition of the lake with the fungal community in the bottom sediments of the Velikaya Salma Strait (part of the White Sea near the lake). Bubnova et al. (2014) detected three obligate marine species in the sediments (*Acremonium fuci*, *Paradendryphiella arenaria* and *P. salina*), all the rest were classified as land-origin species. The fungal composition was represented mainly by the cosmopolitan species (*Penicillium* spp.) and typical soil species for this region (*Pseudogymnoascus pannorum*, *Penicillium* spp., *Tolypocladium* spp., and *Trichoderma* spp.). The distinctive feature of the fungal composition in the bottom sediments was a high abundance and rich diversity of *Acremonium* spp., which are known to often occupy marine-borne habitats (Bubnova et al. 2014). These fungi were also found in our samples taken from the littoral zone of the lake, especially at sites where sea water flows in. BLAST search results showed that all of them were close to the obligate and facultative marine species of *Acremonium*.

Many of the dominating and frequent species distinguished from different components of the lake appeared to be typical representatives of nearby habitats (*Acremonium* spp., *Penicillium* spp., *Tolypocladium* spp., and *Trichoderma* spp.).

Of note, the littoral samples, which are the closest to the sea (Fig. 2, points 5, 7), were enriched with the fungi typically found in marine habitats (*Paradendryphiella salina*, *Acremonium* cf. *fuci*, and *Cadophora* spp.). Conversely, the peat samples from the shore, which are desalinated and covered with vegetation (Fig. 2, points 1, 2, 4), contained fungal species commonly associated with peat bogs (*Oidiodendron* spp., *Penicillium thomii*, *P. montanense*). *Penicillium montanense* was recovered from all the samples of the coastal area (forest soil, *Sphagnum* peat, meadow soil and the place of the freshwater brook confluence), but was not found in samples taken at places connected to the sea or in benthic ooze sediments. It can be assumed that pH values inhibit the spread of this species. *Penicillium montanense* is often noted in acidic habitats, such as decomposing bogs and fens, needle litter, and the rhizosphere of coniferous (Thormann et al. 2004; Osono et al. 2006), while sea water has an alkaline reaction.

Table 5. Helotiales taxa distribution in the Kislo-Sladkoe Lake, and the Yershovskoye, Krugloye and Verkhneye lakes.

Lake	Number of taxa
Kislo-Sladkoe	15
Ershovskoye	8
Krugloye	2
Verkchneye	9

Selective media makes it possible to recover slowly growing oligotrophic and acid-tolerant species that are able to thrive under unfavorable conditions, such as low pH and the presence of recalcitrant compounds of *Sphagnum* moss. The highest number of species was isolated on malt extract agar and citric acid buffer agar media. However, the use of alkaline and neutral media allowed us to identify the alkalitolerant and neutrophilic species (*Acremonium* spp., *Plectosphaerella* sp.) characteristic of many parts of the lake. The results of using the different media are shown in Online Resource 5. DNA-based identification was most useful with basidiomycetous fungi, though also with ascomycetous species of the *Helotiales* and *Pleosporales*. BLAST search results showed that many of our pleosporalean isolates from the lake were close to known marine species, such as *Bissothecium circinans* and *Loratospora aestuarii* (Schoch et al. 2009). Similarly, fungi from the *Helotiales* have often been found in marine habitats (Wang et al. 2006). In our studies of the fungi in the Kindo peninsula pealtland lakes, the major part of the *Helotiales* were found in the lake (Table 5). Presumably, this is related to the fact that conditions in this lake are more similar to the sea conditions in comparison with the other lakes of the Kindo peninsula. The most common basidiomycete in the lake was *Sistotrema brinkmannii*, which is widely distributed in deciduous and coniferous forests, and known as a late-stage wood destructor. In the current study, this species was found in the swamp peat along the peninsula and from most of the samples taken from different parts of the lake. The presence of *Sistotrema brinkmannii* both in the littoral soil and benthic sediments of the water basins is intriguing, and its exact role in these wood-free habitats warrants further research.

Our investigations revealed that the fungal communities in the Kindo peninsula peat and lakes depend on their origin. Since the lake is similar in its properties to the other lakes that we studied in the WSBS area (depth less than 5 m and presence of a freshwater flow), it could be assumed that the lake would develop in the same way — from eutrophic to oligotrophic, through the mesotrophic and upper aapa-type swamp stages (Olunina 2008). Hence, in the process of their waterlogging, as well as in other swamps, there will be a respective change in plant communities, the organic composition of sediments, and, consequently, in the fungal content. The presence of both typical marine species and species characteristic for freshened water basins, soil and peat, indicates the lake's transitional stage from the sea to a groundwater basin, resulting in a combination of abiotic factors. In future research, it would be of interest to study the functional role and adaptation trajectories of fungi in such environments.

Acknowledgements

We thank Alexander Tzetlin (director of the WSBS) for the opportunity to carry out this research, Elena Vortsepneva and Alexander Semenov for their help with sample collection, Bertha Koopmanschap, Marijke Slakhorst and Alex Grum-Grzhimaylo for technical assistance, and Denis Landin for image processing. The work was supported by the Laboratory of Genetics at Wageningen University (molecular research; OG, AD), the Russian Foundation for Basic Research (# 15-29-02553; the field investigation and identifica- tion of the fungi; EB, OG), the Russian Science Foundation (# 14-50- 00029; the cultivation and collection of the fungi; OG) and the Erasmus Mundus IAMONET-RU. Light microscopy study was conducted using equipment of the Center of microscopy WSBS MSU.

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Online Resources

Online Resource 1. Location of the Kislo-Sladkoe Lake; WSBS – the White Sea biological station

Online Resource 2. Parameters of water in the Kislo–Sladkoe Lake from each layer in 2010

Parameters	Mixolimnion (~0.0–1.0 m)	Pycnocline (~1.0 m)	Monimolimnion (~1.0–4.5 m)		
			Salt aerobic layer (~1.0–2.5 m)	Redox zone (~2.5 m)	Salt anaerobic layer (~2.7–4.5 m)
T, °C (Pantulin and Krasnova 2011)	21.0–22.5	21.0	12.5–22.5	12.5	7.5–12.5
S, ‰ (Pantulin and Krasnova 2011)	12.0–21.5	21.5	21.5–22.0	22.0	22.5
pH (Krasnova et al. 2014)	8.3–8.5	8.3	7.3–8.3	7.3	7.1–7.5
O2, mg/L (Krasnova et al. 2014)	12.0–14.5	13.0	11.0–13.0	8.0–11.0	2.0

Online Resource 3. Results of the molecular analysis of 73 taxa including accession numbers of DNA sequences and the closest match from the GenBank database

Taxa	**Genbank Accession No.**		**Blast results**	
	ITS	LSU		
Acremonium cf. *fuci*	JX535068	JX535069	*Acremonium fuci*, 512/513, 99% ITS	KT207762
			Acremonium fuci, 474/475, 99% ITS	AY632652
			Acremonium sp., 2039/2040, 99% LSU	KC987248
Acremonium sp. 1	JX535106	JX535107	*Acremonium* sp., 500/500, 100% ITS	KC987141
			Acremonium sp., 2038/2040, 99% LSU	KC987248
Acremonium sp. 1	JX535076	JX535077	*Acremonium* sp., 498/498, 100% ITS	KC987141
			Acremonium sp., 2025/2027, 99% LSU	KC987248
Acremonium sp. 1	JX535096	JX535097	*Acremonium* sp., 500/500, 100% ITS	KC987141
			Acremonium sp., 2038/2040, 99% LSU	KC987248
Acremonium sp. 1	JX535176		*Acremonium* sp., 500/500, 100% ITS	KC987141

Taxa	Genbank Accession No.		Blast results	
	ITS	LSU		
Acremonium sp. 2	JX535074	JX535075	*Acremonium* sp., 496/496, 100% ITS	KC987145
			Acremonium sp., 2032/2033, 99% LSU	KC987248
Acremonium sp. 2	JX535054	JX535055	*Acremonium* sp., 499/499, 100% ITS	KC987145
			Acremonium sp., 2036/2037, 99% LSU	KC987248
Acremonium sp. 2	JX535152		*Acremonium* sp., 499/499, 100% ITS	KC987145
Acremonium sp. 2	JX535048	JX535049	*Acremonium* sp., 506/506, 100% ITS	KR425654
			Acremonium sp., 497/497, 100% ITS	KC987145
			Acremonium sp., 2013/2037, 99% LSU	KC987248
Acremonium sp. 2	JX535064	JX535065	*Acremonium potronii*, 458/458, 100% ITS	AY632655
			Acremonium sp., 2040/2040, 100% LSU	KC987248
Acremonium sp. 2	JX535066	JX535067	*Acremonium potronii*, 505/505, 100% ITS	AY632655
			Acremonium sp., 2040/2040, 100% LSU	KC987248
Acremonium sp. 3	JX535062	JX535063	*Acremonium* sp., 507/510, 99% ITS	KP269047
			Acremonium sp., 383/391, 99% ITS	JX076976
			Acremonium sp., 1919/2053, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 3	JX535092	JX535093	*Acremonium* sp., 499/506, 99% ITS	FJ571421
			Acremonium sp., 2017/2050, 98% LSU	GQ867783
			Sarocladium sp., 2007/2039, 98% LSU	KC987243
Acremonium sp. 4	JX535182		*Acremonium* sp., 426/431, 99% ITS	FN386307
			Acremonium sp., 499/506, 99% ITS	FJ571421
Acremonium sp. 5	JX535044	JX535045	*Acremonium* sp., 507/510, 99% ITS	KP269047
			Acremonium sp., 1919/2053, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 5	JX535050	JX535051	*Acremonium* sp., 508/511, 99% ITS	KP269047
			Acremonium sp., 1911/2044, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 5	JX535072	JX535073	*Acremonium* sp., 507/510, 99% ITS	KP269047
			Acremonium sp., 1902/2035, 93% LSU	GQ867783
			Sarocladium sp., 1896/2029, 93% LSU	KC987243
Acremonium sp. 5	JX535056	JX535057	*Acremonium* sp., 507/510, 99% ITS	KP269047
			Acremonium sp., 1915/2049, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 5	JX535058	JX535059	*Acremonium* sp., 506/510, 99% ITS	KP269047
			Acremonium sp., 1915/2049, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 5	JX535060	JX535061	*Acremonium* sp., 507/510, 99% ITS	KP269047
			Acremonium sp., 1911/2044, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 5	JX535156		*Acremonium* sp., 515/519, 99% ITS	KP269047
Acremonium sp. 5	JX535070	JX535071	*Acremonium* sp., 507/510, 99% ITS	KP269047

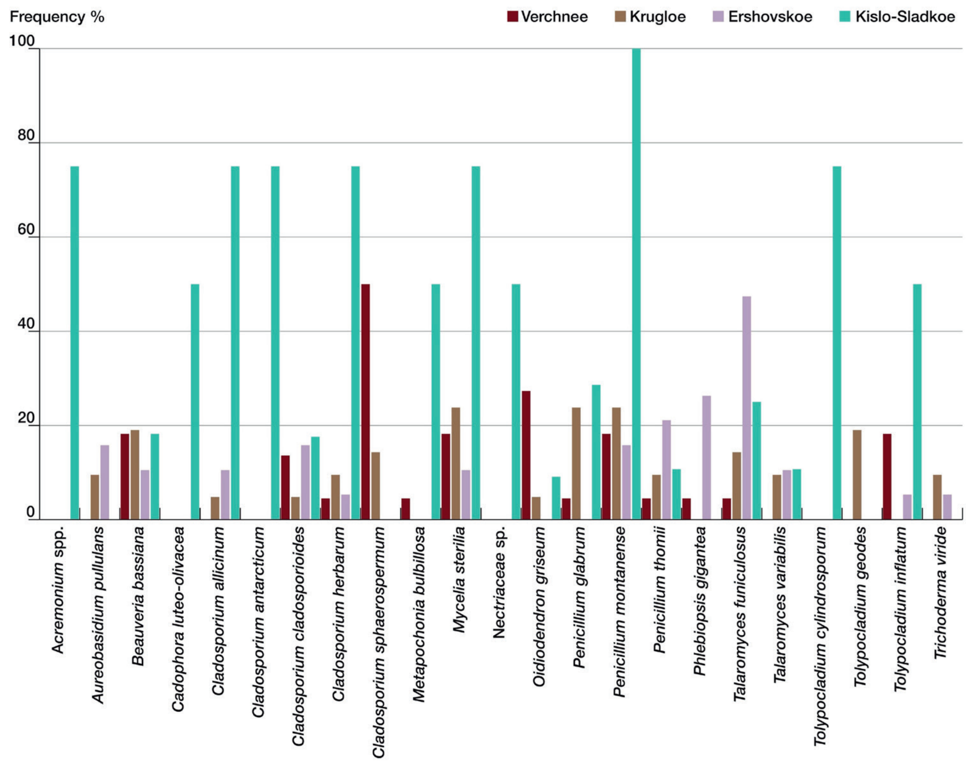
Taxa	Genbank Accession No.		Blast results	
	ITS	LSU		
			Acremonium sp., 1915/2048, 93% LSU	GQ867783
			Sarocladium sp., 1909/2042, 93% LSU	KC987243
Acremonium sp. 6	JX535052	JX535053	*Emericellopsis terricola*, 505/506, 99% ITS	ETU57676
			Emericellopsis minima, 505/506, 99% ITS	KT290876
			Acremonium sp., 2027/2036, 99% LSU	KC987248
			Acremonium sp., 2027/2036, 99% LSU	KC987223
Acremonium sp. 6	JX535094	JX535095	*Emericellopsis terricola*, 505/505, 99% ITS	FJ430737
			Emericellopsis minima, 505/506, 99% ITS	KT290876
			Acremonium sp., 2027/2035, 99% LSU	KC987248
			Acremonium sp., 2027/2035, 99% LSU	KC987223
Acremonium sp. 6	JX535153		*Emericellopsis terricola*, 512/513, 99% ITS	FJ430737
			Emericellopsis minima, 516/518, 99% ITS	KT290876
Alternaria sp. 1	JX535138		*Alternaria brassicae*, 503/503, 100% ITS	KT803065
			Alternaria porri, 503/503, 100% ITS	KT803064
			Alternaria alternata, 503/503, 100% ITS	KT366738
Alternaria sp. 2	JX535139		*Alternaria tenuissima*, 503/503, 100% ITS	KT291415
			Alternaria alternata, 503/503, 100% ITS	KT238888
Alternaria sp. 2	JX535178		*Alternaria tenuissima*, 503/503, 100% ITS	KT291415
			Alternaria alternata, 503/503, 100% ITS	KT238888
Antrodia sp.	JX535080	JX535081	*Antrodia primaeva*, 564/566, 99% ITS	JQ700272
			Antrodia xantha, 2016/2089, 97% LSU	AJ583430
Ascomycota sp. 1	JX535148	JX535149	*Fungal* sp., 514/524, 98% ITS	EU725705
			Helotiales sp., 457/464, 98% ITS	FN548161
			Articulospora atra, 1975/2057, 96% LSU	KP234353
Ascomycota sp. 2	JX535087		*Ascomycota* cf. *Helotiales*, 432/439, 98% ITS	HE998712
			Ascomycota sp., 461/489, 94% ITS	HQ008924
Ascomycota sp. 3	JX535098	JX535099	*Ascomycete* sp., 479/483, 99% ITS	AM084519
			Ascomycota sp., 501/521, 96% ITS	JN655575
			Articulospora atra, 1975/2057, 96% LSU	KP234353
Ascomycota sp. 4	JX535116		*Pseudocercosporella fraxini*, 439/448, 98% ITS	LN808860
			Ascomycota sp., 456/474, 96% ITS	KC460802
Ascomycota sp. 5	JX535144		*Tricladium* sp., 493/493, 100% ITS	HQ623448
			Helotiales sp., 494/499, 99% ITS	KF428422
Aspergillus tubingensis	JX535043		*Aspergillus tubingensis*, 474/474, 100% ITS	KT277272
			Aspergillus pseudoglaucus, 492/492, 100% ITS	KT222020
			Aspergillus glaucus, 492/492, 100% ITS	AY373887
Aspergillus sp.	JX535174		*Aspergillus pseudoglaucus*, 492/492, 100% ITS	KT222020
			Aspergillus glaucus, 492/492, 100% ITS	AY373887
Cadophora luteo-olivacea	JX535085		*Cadophora luteo-olivacea*, 567/567, 100% ITS	KU141395
Cadophora luteo-olivacea	JX535089		*Cadophora luteo-olivacea*, 574/575, 99% ITS	KU141395
			Cadophora luteo-olivacea, 574/575, 99% ITS	KP903599

Taxa	Genbank Accession No.		Blast results	
	ITS	LSU		
Cadophora luteo-olivacea	JX535159		*Cadophora luteo-olivacea*, 568/568, 100% ITS	KU141395
Cadophora malorum	JX535086		*Cadophora malorum*, 543/543, 100% ITS	GU212432
Chaetosphaeria sp.	JX535168		Uncultured *Melanopsammella* (*Chaetosphaeria*) clone, 490/490, 100% ITS	JF519556
Cladosporium sp. 1	JX535160		*Cladosporium langeronii*, 489/489, 100% ITS	KP701931
			Cladophialophora bantiana, 489/489, 100% ITS	KM232500
Coniochaeta sp.	JX535133	JX535134	*Coniochaeta* sp., 507/507, 100% ITS	HQ829070
			Coniochaeta sp., 502/502, 100% ITS	HQ657291
			Coniochaeta sp., 1512/1544, 98% LSU	JX507630
Cylindrobasidium laeve	JX535036	JX535037	*Cylindrobasidium laeve*, 680/680, 100% ITS	KJ652553
			Cylindrobasidium laeve, 680/680, 100% ITS	DQ097354
			Cylindrobasidium laeve, 1385/1386, 99% LSU	DQ234541
Helotiales sp. 3	JX535161		*Phialocephala* sp., 496/497, 99% ITS	AY606294
			Phaeomollisia piceae, 489/494, 99% ITS	LN714584
Helotiales sp. 6	JX535102	JX535103	*Helotiales* sp., 478/505, 95% ITS	JX852365
			Catenulifera brevicollaris, 479/507, 94% ITS	NR_121471
			Helotiales sp., 2027/2043, 99% LSU	JX507673
*Mucor hiemalis**	JX535127		*Mucor hiemalis* f. *silvaticus*, 588/589, 99% ITS	AY243948
			Mucor hiemalis f. *silvaticus*, 569/570, 99% ITS	JN206122
Nectriacea sp.	JX535154		*Neonectria obtusispora*, 478/479, 99% ITS	KP411558
			Cylindrocarpon lucidum, 456/457, 99% ITS	AY805555
Paradendryphiella salina	JX535142		*Paradendryphiella salina*, 526/526, 100% ITS	KU214560
Paradendryphiella salina	JX535165		*Paradendryphiella salina*, 510/510, 100% ITS	KU214560
*Penicillium montanense**	JX535126		*Penicillium montanense*, 504/504, 100% ITS	JN376150
*Penicillium thomii**	JX535130		*Penicillium thomii*, 512/512, 100% ITS	KT200277
Plectosphaerella sp.	JX535155		*Plectosphaerella cucumerina*, 489/490, 99% ITS	KP686178
			Plectosphaerella sp., 487/488, 99% ITS	KP714372
Plectosphaerella sp.	JX535151		*Plectosphaerella cucumerina*, 489/490, 99% ITS	KP686178
			Plectosphaerella sp., 487/488, 99% ITS	KP714372
Plectosphaerella cucumerina	JX535104	JX535105	*Plectosphaerella cucumerina*, 490/490, 100% ITS	KP686178
			Plectosphaerella cucumerina, 924/934, 99% LSU	U17399
Pleosporales sp. 1	JX535157	JX535158	*Stagonospora pseudovitensis*, 481/482, 99% ITS	KF251262
			Pleosporales sp., 476/477, 99% ITS	AB809642
			Pleosporaceae sp., 1958/2046, 96% LSU	KJ443134
Pleosporales sp. 2	JX535136	JX535137	*Pleosporales* sp., 465/471, 99% ITS	KP963609
			Pleosporaceae sp., 1965/2053, 96% LSU	KJ443134
Pleosporales sp. 3	JX535184		*Stagonospora pseudovitensis*, 481/482, 99% ITS	KF251262
			Pleosporales sp., 476/477, 99% ITS	AB809642
Sistotrema brinkmannii	JX535039	JX535040	*Sistotrema brinkmannii*, 606/606, 100% ITS	KM232461
			Sistotrema brinkmannii, 2060/2060, 100% LSU	JX535083
Sistotrema brinkmannii	JX535169	JX535170	*Sistotrema brinkmannii*, 570/570, 100% ITS	KM232461

Taxa	**Genbank Accession No.**		**Blast results**	
	ITS	LSU		
			Sistotrema brinkmannii, 2056/2056, 100% LSU	JX535083
Sistotrema brinkmannii	JX535117	JX535118	*Sistotrema brinkmannii*, 524/524, 100% ITS	JX946668
			Sistotrema brinkmannii, 2062/2062, 100% LSU	JX535083
Sistotrema brinkmannii	JX535146	JX535147	*Sistotrema brinkmannii*, 569/569, 100% ITS	LN714605
			Sistotrema brinkmannii, 1197/1199, 99% LSU	KF218967
Sistotrema brinkmannii	JX535041	JX535042	*Sistotrema brinkmannii*, 570/570, 100% ITS	JX507710
			Sistotrema brinkmannii, 1199/2000, 99% LSU	KF218967
Sistotrema brinkmannii	JX535183		*Sistotrema brinkmannii*, 573/573, 100% ITS	LN714605
Sistotrema brinkmannii	JX535177		*Sistotrema brinkmannii*, 576/576, 100% ITS	LN714605
*Tolypocladium cylindrosporum**	JX535140		*Tolypocladium cylindrosporum*, 504/504, 100% ITS	KJ028796
*Tolypocladium cylindrosporum**	JX535150		*Tolypocladium cylindrosporum*, 498/498, 100% ITS	FJ025179
*Tolypocladium inflatum**	JX535185		*Tolypocladium inflatum*, 494/494, 100% ITS	JQ780650
*Tolypocladium inflatum**	JX535128		*Tolypocladium inflatum*, 487/488, 99% ITS	JQ780650
			Tolypocladium inflatum, 487/488, 99% ITS	JQ266196
*Trichoderma parapiluliferum**	JX535122		*Trichoderma parapiluliferum*, 539/539, 100% ITS	NR_134341
*Trichoderma polysporum**	JX535131		*Hypocrea pachybasioides*, 557/557, 100% ITS	JQ780637
Xylobolus sp.	JX535112		*Stereum hirsutum*, 470/472, 99% ITS	JX501297

* species names identified also by morphology

Online Resource 4. The spatial frequency of fungal species (with the spatial frequency in the *Sphagnum* peat samples ≥ 4.5%) in the *Sphagnum* peat of the Verkhnee, Krugloe, Yershovskoe and Kislo-Sladkoe Lakes



Online Resource 5. Fungi from the Kislo-Sladkoe Lake isolated on different culture media

	Media					
Taxa	**MA**	**CA**	**AA**	**WA**	**SEA**	**SWA**
Acremonium cf. *charticola*	—	—	—	+	—	—
Acremonium cf. *fuci*	—	—	—	—	—	+
Acremonium sp. 1	+	—	+	+	—	+
Acremonium sp. 2	+	—	+	—	—	+
Acremonium sp. 3	+	—	+	—	—	—
Acremonium sp. 4	+	—	—	—	—	—
Acremonium sp. 5	+	—	—	—	—	+
Acremonium sp. 6	—	—	+	—	—	—
Alternaria alternata	—	+	—	—	—	—
Alternaria sp. 1	+	—	—	—	—	—
Alternaria sp. 2	+	+	—	—	—	—
Antrodia sp.	—	+	—	—	—	—

	Media					
Taxa	**MA**	**CA**	**AA**	**WA**	**SEA**	**SWA**
Ascomycota sp. 1	—	+	—	—	—	—
Ascomycota sp. 2	+	—	—	—	—	—
Ascomycota sp. 3	+	—	—	—	—	—
Ascomycota sp. 4	—	—	—	+	—	—
Ascomycota sp. 5	—	—	—	—	—	+
Aspergillus proliferans	—	—	—	—	+	—
Aspergillus tubingensis	+	—	—	—	—	—
Aspergillus ustus	+	—	—	—	—	—
Aspergillus versicolor	—	+	—	—	—	—
Aspergillus sp.	+	—	—	—	+	—
Aureobasidium pullulans	+	—	—	—	—	—
Basidiomycota sp.	+	—	—	—	—	—
Beauveria bassiana	+	+	+	+	+	—
Beauveria brongniartii	+	—	—	—	—	—
Beauveria sp.	+	—	—	—	—	—
Botryotinia sp.	—	—	—	+	—	—
Botrytis cinerea	—	+	—	—	—	—
Cadophora fastigiata	—	+	+	—	—	+
Cadophora luteo-olivacea	—	+	—	+	+	—
Cadophora malorum	—	+	—	—	—	—
Cadophora melinii	+	—	—	+	+	—
Cadophora sp. 1	—	—	—	—	+	—
Cadophora sp. 2	—	+	—	—	—	—
Chaetosphaeria sp.	—	+	—	—	—	—
Cladosporium allicinum	+	+	+	—	—	+
Cladosporium antarcticum	—	—	+	—	—	—
Cladosporium cladosporioides	+	—	—	—	+	+
Cladosporium herbarum	+	—	—	—	—	+
Cladosporium oxysporum	+	—	—	—	+	—
Cladosporium sp. 1	—	—	+	—	—	—
Cladosporium sp. 2	—	—	—	—	+	—
Cladosporium sp. 3	—	+	—	—	—	—
Cladosporium sphaerospermum	—	—	—	—	+	—
Coniochaeta sp.	—	+	—	—	—	—
Cordyceps militaris	—	—	+	—	—	—
Cylindrobasidium laeve	—	—	—	+	—	—
Dothideales sp.	+	—	—	—	—	—
Dothideomycetes sp. 1	—	—	—	—	—	+
Dothideomycetes sp. 2	+	—	—	—	—	—

Taxa	Media					
	MA	CA	AA	WA	SEA	SWA
Fusarium avenaceum	+	—	—	—	—	—
Fusarium graminearum	—	+	—	—	—	—
Fusicladium pini	—	—	—	—	+	—
Helotiaceae sp.	—	—	—	+	—	—
Helotiales sp. 1	—	+	—	+	—	—
Helotiales sp. 2	—	+	—	—	—	—
Helotiales sp. 3	+	—	—	—	—	—
Helotiales sp. 4	—	—	—	—	—	+
Helotiales sp. 5	—	—	—	—	+	—
Helotiales sp. 6	—	+	—	—	—	—
Lecanicillium evansii	—	+	—	—	—	—
Lecanicillium sp. 1	—	—	+	—	—	—
Lecanicillium sp. 2	—	—	—	—	—	+
Lecanicillium sp. 3	—	—	—	—	+	—
Massarinaceae sp.	—	+	—	—	—	—
Memnoniella dichroa	—	—	—	—	+	—
Metapochonia bulbillosa	—	+	—	—	—	—
Mortierella elongata	+	—	—	—	—	—
Mucor circinelloides	+	+	—	—	—	—
Mucor hiemalis	+	—	—	+	+	—
Mucor racemosus	—	—	—	+	—	—
Nectriaceae sp.	+	—	—	—	—	—
Oidiodendron ambiguum	+	—	—	—	—	—
Oidiodendron griseum	+	—	—	—	—	—
Paradendryphiella salina	+	—	—	—	—	—
Parengyodontium album	+	—	—	—	—	—
Penicillium aurantiogriseum	—	—	—	—	+	—
Penicillium decumbens	—	+	—	—	—	—
Penicillium dierckxii	—	—	—	+	—	—
Penicillium glabrum	+	+	—	+	+	—
Penicillium griseofulvum	—	+	—	—	—	—
Penicillium montanense	+	+	—	+	+	+
Penicillium multicolor	—	—	—	+	—	—
Penicillium restrictum	—	—	—	+	—	—
Penicillium roseopurpureum	—	—	—	+	—	—
Penicillium thomii	+	+	—	—	—	—
Penicillium waksmanii	+	—	—	—	+	—
Penicillium sp. 1	—	—	—	—	—	+
Penicillium sp. 2	+	+	—	—	—	+

Taxa	**Media**					
	MA	**CA**	**AA**	**WA**	**SEA**	**SWA**
Penicillium sp. 3	—	—	—	—	—	+
Penicillium sp. 4	+	+	—	—	—	+
Peniophora sp.	—	—	—	+	—	—
Phaeoacremonium sp.	—	—	—	—	+	—
Phialophora sp.	—	—	—	—	—	+
Phialophora verrucosa	—	+	—	—	—	—
Plectosphaerella sp.	—	—	+	—	—	—
Pleosporales sp. 1	+	—	—	—	—	—
Pleosporales sp. 2	+	—	—	—	—	—
Pleosporales sp. 3	+	—	—	—	—	—
Pseudogymnoascus pannorum	—	—	—	—	+	—
Sarocladium implicatum	—	—	—	+	—	—
Scopulariopsis brumptii	+	—	—	—	—	—
Sistotrema brinkmannii	+	+	+	+	—	+
Sporothrix sp.	—	+	—	—	—	—
Stachybotrys echinatus	—	—	—	+	+	—
Sydowia polyspora	—	+	—	—	+	—
Talaromyces aculeatus	+	—	—	—	—	—
Talaromyces funiculosus	+	+	—	+	+	—
Talaromyces variabilis	—	+	—	—	+	—
Talaromyces verruculosus	—	+	—	—	—	+
Tolypocladium cylindrosporum	+	—	+	—	+	—
Tolypocladium inflatum	+	—	+	+	—	—
Tolypocladium nubicola	+	—	—	+	—	+
Trichoderma asperellum	—	—	—	+	—	—
Trichoderma harzianum	—	+	—	+	+	+
Trichoderma koningii	—	+	—	—	—	—
Trichoderma parapiluliferum	+	—	—	—	—	—
Trichoderma polysporum	—	+	—	+	—	—
Trichoderma viride	—	—	—	—	—	+
Trichoderma sp.	—	+	—	—	—	—
Umbelopsis isabellina	—	+	—	—	—	—
Umbelopsis ramanniana	—	+	—	+	—	—
Umbelopsis vinacea	—	+	—	—	—	—
Umbelopsis sp.	—	—	—	—	—	+
Xylobolus sp.	—	—	+	—	+	—
No of taxa	51	43	16	29	27	24

Abbreviations: MA = malt extract agar, CA = citric agar, AA = alkaline agar, WA = water agar, SEA = *Sphagnum* extract agar, SWA = semi-saltwater agar.

CHAPTER 4

A comparative analysis of the cultured micromycetes in oligotrophic peatlands of natural biosphere reservations located in the Northern and Central parts of Russia

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Published in Nature Conservation Research. Zapovednaya nauka, 2016. 1 (2): 90–95

Abstract

The current study addresses the fungal diversity of the peatlands that vary geographically and geologically, in the central and northern parts of Russia. The central (Smolenskaya area, National Park «Smolenskoye Poozerie») and northern (White Sea Biological Station area) peatlands have a different geological history, the former have a glacial origin, while the latter are of marine origin. Our aim was to investigate the fungal biota of these zones full of *Sphagnum* mosses, and possibly reveal the species that are pertinent to these particular habitats. In both investigated areas, we found an overall poor species diversity with a high fraction of sterile mycelia. Many penicillia species were dominating in all peat samples – *P. thomii*, *P. spinulosum*, *P. glabrum*, *P. funiculosum*, *P. aurantiogriseum* (together with *Geotrichum candidum*), many of them are known to degrade *Sphagnum*. We were particularly interested in the dynamics of the species from the genus *Oidiodendron* that have been shown to be involved in primary *Sphagnum* degradation. The northern area contained a larger species diversity of *Oidiodendron*, as compared to the central zone. Interestingly, insect-associated species of the genus *Tolypocladium* and *Beauveria*, along with the psychrotolerant species of *Geomyces* and *Tolypocladium* were recovered only from the northern peatlands. *Aspergillus* spp. were found in peatlands of the central zone only. We link this result to the climatic features of the area, but also different invertebrate contents that may be utilized by fungi. We detected a tendency of an increasing diversity of *Oidiodendron* species, psychrotolerant and entomopathogenic fungal species as well as a proportion of sterile forms in the northern area.

Key words
Entomopathogenic fungi, fungi decomposing *Sphagnum*, fungi in peatlands, micromycetes in peatlands, *Oidiodendron* spp., psychrotolerant fungi, *Tolypocladium* spp.

Introduction

Oligotrophic peatlands cover more than 10% of Russia's territory and are the largest reservoirs of peat among peatland types in Russia (Yurkovskaya, 2004). Although oligotrophic peatlands are prevalent in northern areas such as taiga and tundra zones, they also occur more southerly, to the extent of the steppe zone. The peat accumulation is caused by microorganisms that decompose organic matter at a relatively slow rate. The slow rate is corroborated by extremely unfavourable abiotic conditions: low oxygen, low temperature, low pH, high humidity and presence of inhibitory phenolic compounds from a local vegetation, mostly *Sphagnum* mosses. Specific groups of fungi and bacteria are the main players involved in the process of organic matter decomposition in peat (Kachalkin et al., 2005; Gilbert, Mitchell, 2006; Thormann, Rice, 2007; Andersen et al., 2010; Golovchenko et al., 2013). However, the diversity of fungi inhabiting oligotrophic peatland remains understudied, especially in the northern regions. The comparison of the fungal biota between oligotrophic peatlands of both central and northern areas would allow to evaluate the fungal species that are shared (or different) among habitats, possibly shedding some light on their physiology in peat. Existing studies suggest that the fungal diversity among oligotrophic peatlands may vary significantly (Thormann et al., 2004; Thormann, Rice, 2007). The reason is believed to be the unique associations of fungi with specific plants, which are pertinent to a given area (Nilsson et al., 1992; Thormann et al., 2004; Filippova, 2015).

Materials and methods

We have been monitoring fungi at the White Sea coastal and Smolensk region peatlands for a number of years now. Using various approaches, we sought to recover most of the culturable fungal species from that area (Bilanenko, Grum-Grzhimaylo, 2007; Grum-Grzhimaylo et al., 2010, 2012, 2016). Since the *Sphagnum* mosses are the main ingredient of peat, we collected and analyzed the samples from the vertical columns of peat deposits where dominated by *Sphagnum* spp. Hence, our comparative analysis of the fungal biota in differently located oligotrophic peats was accounting for the climatic factors (mainly temperature) rather than plant-associated differences of fungal communities. The pH values of the samples in both regions were similar and varied from 4.0 to 4.5. Climatic factors globally affect the distribution of biota, including one of the most prominent inhabitants of the oligotrophic peats – an arctic mosquito (*Aedes* spp., *Culex* spp.). During warm season, these species reproduce in bulk, and along with the plant material, can act as a food source for fungi (Bubnova et al., 2014). Our research attempts to compare fungal diversity of the two distinct following types of peatlands – the White Sea coastal peatlands (White

Sea Biological Station, WSBS, northern, 66°34'N, 33°08'E) and the Smolensk region peatlands (National Park «Smolenskoye Poozerie», SP, central, 55°53'N, 31°40'E) (Fig. 1).

Fig 1. The map of both research locations

The first type appears to have been formed as a result of a part of the sea becoming isolated in the course of a land uplift, followed by both demineralization and bogging (Shaporenko et al., 2005; Pantyulin, Krasnova, 2011), whereas the central type shows boggy depressions of glacial origin (Grum-Grzhimaylo et al., 2016). The comparison of the fungal biota between the two boggy areas may give us a clue about the shared species, but also unique ones that may contribute to local ecology of a given peatland.

The climate of the SP is moderately continental with well-defined seasons. Wet air masses from the Atlantic release frosts and snowfalls in winter and a high temperature and rain in summer. The average yearly temperature here is about 4.3°C (Grum-Grzhimaylo et al., 2016). The climate of the WSBS region is transitional from marine polar to moderately continental. There are long winter and spring, short summer and long autumn at the WSBS. The average yearly temperature here is about 0.5°C (Shilovtseva, 2009). In June 2006 29 and 25 peat samples from three SP peatlands were taken and from three WSBS peatlands in June 2007, subsequently. The detailed description of the peatlands and taking, storing and cultivation of the samples has been exposed in our earlier works (Bilanenko, Grum-Grzhimaylo, 2007; Grum-Grzhimaylo et al., 2016). Only the differences in the methods are remarked here. The peat samples from the SP were stored at deep freeze until the cultivation, whereas the samples from the WSBS were processed immediately after collecting.

Results and Discussion

Our results indicate that the explored peatlands of both regions show low species diversity of the cultured micromycetes. The analysis of the SP samples helped to identify 39 species of fungi and to reveal 3 sterile isolates. The samples of the WSBS peatlands contained 31 species and 8 sterile mycelia. Only 8 fungal species were found in both regions (sterile isolates excluded) (Table 1).

Table 1. Fungal species isolated from the peatlands (No 1, 2, 3)

Species	SP			WSBS		
	1	2	3	1	2	3
Acrodontium crateriforme (J.F.H. Beyma) de Hoog	–	–	–	+	–	–
Alternaria alternata (Fr.) Keissl.	–	+	–	+	–	–
Aureobasidium pullulans (de Bary & Löwenthal) G. Arnaud	+	+	+	+	–	–
Aspergillus fischeri Wehmer	–	+	–	–	–	–
Aspergillus fumigatus Fresen.	–	+	–	–	–	–
Aspergillus niger Tiegh.	+	–	–	–	–	–
Beauveria bassiana (Bals.-Criv.) Vuill.	–	–	–	–	+	–
Botrytis cinerea Pers.	–	–	–	+	–	+
Cadophora fastigiata Lagerb. & Melin	+	–	–	–	–	–
Cladosporium cladosporioides (Fresen.) G.A. de Vries	–	–	–	+	–	+
Cladosporium herbarum (Pers.) Link	–	–	–	+	+	+
Clonostachys rosea (Link) Schroers, Samuels, Seifert & W. Gams	+	–	–	–	–	–
Diplodascus geotrichum (E.E. Butler & L.J. Petersen) Arx	+	+	–	+	–	–
Gibellulopsis nigrescens (Pethybr.) Zare, W. Gams & Summerb.	–	–	–	+	–	–
Lecanicillium evansii Zare & W. Gams	+	–	–	–	–	–
Lecanicillium sp.	–	–	–	–	+	–
Mucor hiemalis Wehmer	+	+	+	–	–	–
Mucor plumbeus Bonord.	+	–	–	–	–	–
Oidiodendron cereale (Thüm.) G.L. Barron	+	–	–	–	–	–
Oidiodendron griseum Robak	–	–	–	+	+	–
Oidiodendron periconioides Morrall	–	–	–	–	+	–
Paecilomyces divaricatus (Thom) Samson, Houbraken & Frisvad	–	+	+	–	–	–
Penicillium aurantiogriseum Dierckx	+	+	+	–	+	–
Penicillium brevicompactum Dierckx	–	–	–	+	+	–
Penicillium chermesinum Biourge	+	–	–	–	–	–
Penicillium citreonigrum Dierckx	–	–	–	+	+	–

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Species	SP			WSBS		
	1	2	3	1	2	3
Penicillium citrinum Thom	–	+	–	–	–	–
Penicillium dierckxii Biourge	+	+	+	–	–	–
Penicillium dipodomyis (Frisvad, Filt. & Wicklow) Banke, Frisvad & S. Rosend.	+	+	–	–	–	–
Penicillium glabrum (Wehmer) Westling	+	–	–	+	+	–
Penicillium implicatum Biourge	–	–	–	–	–	+
Penicillium lividum Westling	–	+	–	–	–	–
Penicillium nalgiovense Laxa	–	–	–	–	+	–
Penicillium oxalicum Currie & Thom	–	+	–	–	–	–
Penicillium purpurascens (Sopp) Biourge	+	–	–	–	–	–
Penicillium restrictum J.C. Gilman & E.V. Abbott	–	–	–	+	–	–
Penicillium rolfsii Thom	–	–	–	–	+	–
Penicillium spinulosum Thom	+	+	+	+	+	+
Penicillium thomii Maire	–	+	–	+	+	+
Penicillium velutinum J.F.H. Beyma	+	–	–	–	–	–
Penicillium vinaceum J.C. Gilman & E.V. Abbott	–	–	–	+	+	+
Penicillium waksmanii K.M. Zaleski	+	+	–	–	–	–
Pseudogymnoascus pannorum (Link) Minnis & D.L. Lindner	–	–	–	+	–	–
Phialophora europaea de Hoog, Mayser & Haase	–	+	–	–	–	–
Rhizopus stolonifer (Ehrenb.) Vuill.	+	–	–	–	–	–
Sclerotinia sp.	–	–	–	+	+	–
Talaromyces aculeatus (Raper & Fennell) Samson, N. Yilmaz, Frisvad & Seifert	–	+	–	–	–	–
Talaromyces diversus (Raper & Fennell) Samson, N. Yilmaz & Frisvad	–	–	–	–	+	–
Talaromyces funiculosus (Thom) Samson, N. Yilmaz, Frisvad & Seifert	+	+	+	–	+	+
Talaromyces purpureogenus Samson, Yilmaz, Houbraken, Spierenb., Seifert, Peterson, Varga & Frisvad	+	–	–	–	–	–
Talaromyces rugulosus (Thom) Samson, N. Yilmaz, Frisvad & Seifert	+	–	–	–	–	–
Talaromyces variabilis (Sopp) Samson, N. Yilmaz, Frisvad & Seifert	+	+	–	–	–	–
Talaromyces verruculosus (Peyronel) Samson, N. Yilmaz, Frisvad & Seifert	–	–	–	+	–	–
Thyronectria cucurbitula (Tode) Jaklitsch & Voglmayr	–	–	–	+	–	–
Tolypocladium geodes W. Gams	–	–	–	–	+	–
Tolypocladium inflatum W. Gams	–	–	–	+	–	–
Trichoderma koningii Oudem.	–	–	+	–	–	–
Umbelopsis ramanniana (Möller) W. Gams	+	–	–	–	–	–
Sterile isolates (12 morphotypes)	3	–	–	3	5	1

Abbreviation: SP – the National Park «Smolenskoye Poozerie». WSBS – the White Sea Biological Station. Common species for SP and WSBS are in boldface

It is known that specific conditions of peatlands restrict the diversity of fungi (Grum-Grzhimaylo, Bilanenko, 2010). The prevailing number of anamorphic species belonged to *Ascomycota*, mostly *Penicillium* spp. These results do not disprove the existing view on the mycobiota of peatlands (Thormann, Rice, 2007). The following species were found in both regions: *P. thomii*, *P. spinulosum*, *P. glabrum*, *P. funiculosum*, *P. aurantiogriseum*. The capacity of *P. spinulosum* and *P. thomii* to decompose *Sphagnum* was mentioned in a number of earlier mycological works (Chastuchin, 1967; Dickinson, Maggs, 1974). *P. spinulosum* is regarded as a typical species for a humus soil horizon and oligotrophic peatlands (Summerbell, 2005). This species is widely spread in the soils of tundra and taiga and in bogs of various types. *P. spinulosum* is capable to grow in a wide range of temperatures (from 5°C to 42°C). The upper layers of peatlands, including the peatlands of temperate zones, are characterized by drastic changes in temperature regime. *P. thomii* is capable to develop in the temperature range of 5–37°C. It is found in all complexes of filamentous fungi isolated from acidic soils, in peatlands and from bog plants (Domsh et al., 2007). *P. glabrum* is a common species in podsolic and other acidic soils, raised bogs and fens. *P. glabrum* is widely spread in northern regions, including the soils of the Arctic tundra (Nilsson et al., 1992; Domsh et al., 2007). In our research this species was found in two WSBS peatlands and in one SP peatland. The cosmopolitan species *P. funiculosum* (*Talaromyces funiculosus)* was among the dominating species in all SP peatlands (frequency of occurrence was up to 20–30% and the colony-forming units (CFU) value up to 10^4 CFU per 1 gram of a dry sample). *P. funiculosum* was found in all WSBS peatlands and dominated in one of them (frequency of occurrence up to 100%, CFU value up to 10^6 CFU per 1 gram of a dry sample). *P. funiculosum* can grow in a broad temperature range (5–42°C). This species survives in extremely cold and acidic conditions, in low oxygen conditions (Domsh et al., 2007; Grum-Grzhimaylo, 2013). It can be found in all types of soils, in oligotrophic peatlands and in taiga marsh soils. *P. funiculosum* is capable to destroy *Sphagnum* mosses (Dickinson, Maggs, 1974; Thormann et al., 2004; Thormann, Rice, 2007).

We found *Geotrichum candidum* (*Diplodascus geotrichum*) in both peatland systems mentioned in this work. This fungus is also known as a destructor of *Sphagnum* mosses (Dickinson, Maggs, 1974; Karunen, Kalviainen, 1985). It can exist in highly moist conditions (Dix, Webster, 1995). In further research we managed to isolate it in all WSBS peatlands samples we explored.

Oidiodendron species are known as primary destructors of *Sphagnum* mosses (Tsuneda et al., 2001). *Oidiodendron* spp. grow at acidic and even extremely acidic conditions (pH-values from 1.5 to 6.0) (Gross, Robbins, 2000; Domsh et al., 2007). In our research *O. griseum* and *O. periconioides* were found in northern peatlands, *O. cereale* was found in peatlands of the central zone. *O. griseum* was one of the dominant species in WSBS peatlands. *O. griseum* is a typical species of the ericales rhizosphere, peat and podsolic soils. *O. periconioides* and *O. cereale* are also known as typical species for *Sphagnum* bogs (Thormann, Rice, 2007). In frost peatlands of the Kola Peninsula we discovered even greater *Oidiodendron* species diversity than in WSBS peatlands (our unpublished data).

The psychrotolerant species *Geomyces pannorum* was identified in WSBS samples with high frequency and abundance. However, it was not revealed in SP samples at all. *G. pannorum* is a psychrotolerant species and it can be found predominantly in northern soils of tundra and in conditions of the natural cryopreservation (Tosi et al., 2002; Kochkina et al., 2007). This species is known as polyextremotolerant, capable to develop under the influence of numerous stress factors such as low temperature, low water activity and lack of oxygen. This allowed it to survive in anaerobic conditions, which are common for cryopegs in permafrost (Kochkina et al., 2007; Shcherbakova et al., 2010). *G. pannorum* can grow in a wide range of pH values (3.5–8.0) (van Oorschot, 1980). This species was isolated in large quantities (CFU value up to 10^5 for 1 gram of a dry sample) at the depth of 1 metre from a peat sample of a northern bog, which supports the conditions of low temperatures and low oxygen content. Psychrotolerant type of temperature adaptation is also common for *Tolypocladium* spp. (Bisset, 1982). *Tolypocladium* spp. were found in the WSBS samples, but not in the SP ones.

Tolypocladium spp. and *Beauveria* spp. (*T. inflatum*, *T. geodes*, *B. bassiana*) are known as associated with insects. These species were found in the northern peatlands only. This fact was also demonstrated in our later works (Grum-Grzhimaylo et al., 2016). One of the possible reasons for such abundance of *Tolypocladium* spp. and *B. bassiana* in the northern peatlands may be connected with considerable populations of invertebrates, including larvae of sanguivorous mosquitoes, on which these species can grow.

Aspergillus spp. (*A. fischeri*, *A. fumigatus*, *A. niger*) known as typical in the southern regions were found in SP peatlands only.

A considerable share in fungi societies of both regions is represented by sterile mycelia. Their number is higher in northern regions. Using molecular methods we showed later that the majority of sterile forms are basidiomycetes (Grum- Grzhimaylo et al., 2016).

The fact is that the absence of some species in the samples could be explained by the low number of samples or by other methodological errors. For example, the absence of *Trichoderma* spp. in WSBS samples was quite surprising. In the following years we consistently discovered *T. piluliferum*, *T. polysporum, T. harzianum, T. viride* in WSBS peatlands.

We assume that the detected tendency of the increasing diversity and the abundance of *Oidiodendron* spp., psychrotolerant and entomopathogenic fungal species (*Geomyces* *pannorum*, *Tolypocladium* spp., *Beauveria* spp.) as well as the proportion of sterile forms in the northern area is clear.

Acknowledgements

The work was supported by the research grant RFBF No. 15-29-02553 and RSF grant No. 14-50-00029 (the cultivation and collection of the fungi, Grum-Grzhimaylo; identification of fungi, Bilanenko). The work on collecting samples of peatlands was supported by the Program of Government jobs, parts 2 no. 01 10 (No AAAA-A16-116021660088-9).

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CHAPTER 5

Biogeography and Uniqueness of filamentous terrestrial Fungi in the Polar Regions

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Published in Fungal Biology Reviews, https://doi.org/10.1016/j.fbr.2024.100382

Abstract

Fungi are widely distributed on our planet, including in extremely harsh habitats, such as the polar regions. The extreme conditions of those habitats limit the number of organisms capable of living there, but some fungi are adapted to the polar conditions and play essential roles in nutrient cycling. However, knowledge about their diversity, distribution, and functioning is fragmented, and approaches used to study them are diverse, often yielding difficult-to-compare results. We present maps with locations of mycological studies in the Arctic and Antarctica, as well as a list of mycelial fungi found on various terrestrial substrates through cultivation on nutrient media and/or molecular methods. These fungi were identified to the species level based on morphological-cultural features or gene-sequence analysis. Analysis of the methods applied to study fungi in different substrates shows that a combination of multiple methods is optimal to study species composition. The taxonomic affiliation of the identified species to different fungal divisions is largely determined by habitat conditions and research methods. The largest number of species belongs to the divisions Ascomycota and Basidiomycota. The predominant ecological groups were saprotrophic and symbiotic fungi. The majority of 1324 discovered fungal species are known as cosmopolitan species. Approximately one-fifth of the fungi were identical between the Arctic and Antarctica, only a few species are known to be endemic to Antarctica or Arctic, and there are 1-6 identified bipolar species. Claims of endemism of polar-region fungi are relatively weakly supported.

Keywords
Fungal diversity, mycological approaches, polar fungi, polar and bipolar endemic fungi.

Introduction

Being the polar regions of our planet, the Arctic and Antarctic regions contain extreme conditions for life (Cox et al., 2016), such as low average annual temperatures, long periods of darkness and light, widespread permafrost, high ultraviolet radiation, frequent freeze and thaw cycles during the vegetation period, and low water and nutrient availability (Canini et al., 2021; Govani et al., 2022; Hassan et al., 2016). However, the polar regions also have significant differences in landscape areas, hydrological features, climatic conditions, types of ice and snow covering, soils and permafrost (Dobinski, 2011; Dobiński, 2020; Govani et al., 2022). The Arctic is often defined as a land of tundra with climatic conditions restricting tree growth (Robinson, 2001; Walker et al., 2005); however, a big part of the areas above the Arctic Circle also contains taiga forests (Montesano et al., 2009). Vast peatland coverage storing huge carbon reserves is a characteristic feature of the arctic region (Chaudhary et al., 2020; Tarnocai, 2009). Antarctica is a predominantly rocky continent more than 98% occupied by ice and characterized by irregularly developed soil or its absence (Bockheim and Haus, 2014; Pires et al., 2017). Bockheim and Haus (2014) noted organic, ornithogenic and mineral type of soils storing organic carbon in ice-free Antarctic areas. Arctic permafrost is an uneven environment, generally abundantly moistened and containing mineral and organic soils. In contrast, Antarctic permafrost has large differences between the deep continental and maritime parts and is highly influenced by regional climate, proximity to the glaciers, age, vegetation, snow cover, and surface albedo (Ottoni et al., 2022). Increasing warming in high-latitude regions affects Arctic permafrost peatlands, which are sensitive to climatic changes and provokes permafrost thawing, changing in plant composition and soil microorganism communities (Zhang et al., 2018). In different parts of Antarctica, the processes of climate change are contradictory. The Antarctic continental deserts, specifically McMurdo Dry Valleys, are considered the coldest and driest on the World (Goordial et al., 2016) comprising the only permafrost with a dry soil layer over ice-cemented ground (Canini et al., 2021; Ottoni et al., 2022). Intriguingly, Doran et al. (Doran et al., 2006) registered the large-scale perennial cooling in this area. However, the increasing warming in the Antarctic Peninsula and some other parts of Maritime Antarctica is reported at the same time (Doran et al., 2006; Pires et al., 2017; Royles et al., 2012). All of the processes in the polar regions generated by climate changing listed above affect the living-organism communities (Makhalanyane et al., 2016) and global carbon fluxes (Jenny Angel et al., 2022; Liu et al., 2022).

An exploration of research articles has shown the presence of fungi in the polar regions on a variety of substrates. Makhalanyane et al. (2016) notified: "in cold environments, microorganisms (bacteria, archaea and fungi) are major constituents of the total biomass, and are estimated to mediate the cycling of key biogeochemical elements such as nitrogen and carbon, with potentially important implications for the productivity of these systems" (Makhalanyane et al., 2016). However, we still have a very limited understanding of fungal diversity and distribution (Eisenhauer et al., 2017; Tedersoo et al., 2021), especially in such extreme habitats as polar regions (Bölter et al., 2002; da Silva et al., 2019; Hassan et al., 2016; Makhalanyane et al., 2016). Additionally, we have insufficient knowledge on the contribution of fungi to carbon fluxes (Tveit et al., 2013), as well as on their ecological role and evolution in the polar regions (Botnen et al., 2020; Cox et al., 2016; da Silva et al., 2019). It is not entirely clear which fraction of the fungi found in the extreme ecosystems of the Arctic and Antarctic is present in a living active mycelial state, and which as spores (Bölter et al., 2002; Robinson, 2001; Schmidt and Bölter, 2002). However, there is a significant part of the work showing that the psychrotolerant[2] species of fungi predominate over psychrophilic[3] ones in polar regions (Frisvad, 2008; Hassan et al., 2016; Ludley and Robinson, 2008; Nikitin and Semenov, 2022; Robinson, 2001; Zucconi et al., 1996). Furthermore, investigations show that the community structure within the consortia of bacteria, yeasts and fungi is also similar to that of temperate soils (Bölter et al., 2002). Therefore, it is assumed that with warming, the overall activity of microorganisms, including fungi, in the polar regions will increase (Ozerskaya et al., 2008), which presumably boosts the intensity of the nitrogen and carbon cycles (Arenz et al., 2011; Siciliano et al., 2009; Wild et al., 2014).

We found that most past studies present lists of fungi identified both to the species level as well as to higher taxonomic level, such as the genus (Bridge and Spooner, 2012; Penton et al., 2013), family and order (Stephenson et al., 2007). In this work, only names of fungi identified to the species level are included, since the species is the relevant level for our work. Species of a single genus often differ from each other in their physiological characteristics and ecological confinement, which is valuable for understanding the ability of these species, rather than entire genera, to live in such extreme habitats as the polar regions.

This review summarizes our knowledge about the diversity of terrestrial filamentous fungi in Polar regions detected and identified to species names by culture-based and molecular methods. The overall aim of this study was to evaluate the claim that the poles have unique fungal communities with many endemic species. To achieve the aim the following objectives were formulated:

1) to create a comprehensive list of terrestrial filamentous fungi that have been reported from Arctic and Antarctic regions;

2 Psychrotolerant fungi can grow close to 0°C, with optimum growth temperatures of >15°C and maximum growth temperatures of >20°C (Coleine et al., 2022).

3 Psychrophilic can grow at or below 0°C, with optimum growth temperatures of ≤15°C and maximum growth temperatures of ≤20°C (Coleine et al., 2022).

2) to analyze methods used for sample storage, detection and identification of fungi from these regions and to discuss the influence of the applied methods on the results obtained;
3) to compare the fungal communities of both polar regions with each other and with more global fungal communities;
4) to collect information about endemic fungal species in polar regions to evaluate claims of endemism.

Information retrieval and processing

In order to compile information about fungi known from the polar regions, we reviewed mycological and ecological manuscripts mainly using Google Scholar searches throughout the research time of fungi in these regions. Additionally, we used a list of fungi and manuscripts from the British Antarctic Survey site (https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use) in order to find more studies of Antarctic fungi.

We employed the following criteria to compile this list: (1) The report had to be verified in a peer-reviewed publication. Unpublished, mimeographed, and locally distributed reports, herbarium information, anecdotal references, and checklists were not included; (2) The fungi had to be filamentous. (3) The fungi had to be detected by cultural and/or molecular approaches. (4) Fungi had to be identified up to the species level. (5) Only terrestrial fungi and fungi detected in driftwood were included. Generally we included fungi detected on or above/under the boundaries of the Arctic and Antarctic polar circles (66°33′49.3″N and 66°33′49.3″S, respectively), but in several cases we included fungal species of near subpolar locations as well.

In addition to the geographic locations of the investigations we also tried to find information about methods of sample storage, detection and taxonomic identification from the studied manuscripts. Moreover, our list of fungi was intended to serve as a compilation of those fungi that have been found growing in the polar regions from different substrates. We relied mostly on the habitat descriptions of each fungus in the appropriate publications. However, we realize that these data are likely incomplete. In some instances, the above information could not be determined from the available literature; these records are marked as "n.i." (no information).

Fungal taxonomies follow the Index Fungorum (http://www.indexfungorum.org). When the names of the fungal species in the Index Fungorum differed from the name of this species in the articles, we cited both names. If the article indicated the fungal name as the genus sp., which has only one species, according to the Index Fungorum and data from the GenBank (https://www.ncbi.nlm.nih.gov/genbank/), then we indicated this species instead of the genus sp. in our list of fungi. There is some of species present in the articles are not in the Index Fungorum or have archaic status, we marked them by * (Supplem. Tables 1).

The data were processed using Excel 14.6.1 and SketchBook 8.7.0 softwares. Maps of fungi investigations and sampling were created in open-source software QGIS 3.22. Papers we studied contained three types of georeferencing: geographic coordinates in degree-minutes-seconds format, text descriptions of the place and maps. Only 46% of the descriptions we used had coordinates and thus could be accurately reproduced on the map. Furthermore, 44% of the sources described vast territories in text only and another 10% were also accompanied by maps. In such cases we located points in the centers of research areas or according to the maps.

General description of the fungal community obtained by culture-based and molecular methods in both polar regions

The list of filamentous terrestrial fungal species of the polar regions presented in this article was obtained from 221 scientific publications. A greater number of the articles, 145 dealt with the study of fungi in Antarctica, 71 articles with fungi of Arctica, and five research papers with fungi from both poles. A complete list of discovered fungal species and locations of the investigations is presented in Supplemental Tables 1 and on the maps of Fig. 1, 2. Detailed information about these fungi is given in additional materials, which indicate the places and substrates of detecting the species, methods for their sampling and identification, as well as methods for storing samples (Supplem. Tables 1).

Of the analyzed investigations, 1324 identified species of terrestrial filamentous fungi have been reported from Arctic and Antarctic regions (Supplem. Tables 1, Fig. 3). Ascomycota and Basidiomycota species form the largest component of this assemblage with ~68% and ~28% of species, respectively; ~4% of species are mucoromycetes, one species is an entomophthoromycete, one species is a glomeromycete, and one species is a zoopagomycete. The presence of multiple types of sterile mycelium detected by cultural methods was pointed out in many studies of both polar regions (Supplem. Tables 1).

We found that the majority of fungal species (853) were recorded in the polar regions once, and 471 fungal species were noted in two or more studies (Supplem. Tables 1, 2). *Pseudogymnoascus pannorum* is the most common species in both Polar regions, mentioned in 77 analyzed papers and obtained by all methods described in this article (Supplem. Tables 1, 2). Other taxa commonly isolated in both polar regions that were noted in 45 – 53 papers (*Cladosporium cladosporioides, C. herbarum, Penicillium chrysogenum*), 23 – 40 papers (*Alternaria alternata, Antarctomyces psychrotrophicus, Aspergillus versicolor, Aureobasidium pullulans, Cadophora fastigiata, C. luteo-olivacea, C. malorum, Cladosporium sphaerospermum, Mortierella alpine, Mucor hiemalis, Phoma herbarum, Penicillium aurantiogriseum, P. brevicompactum, P. glabrum, Thelebolus microspores*) or in less papers (Supplem. Tables 2).

In the process of reviewing the literature on fungal diversity in the polar regions, we identified several difficulties associated with the analysis of available information: i) while some areas have been explored more frequently and in more detail, most have not been explored at all due to inaccessibility; ii) the fungi of the Arctic and Antarctic have been studied with different intensity; iii) different methods of sampling and storage of samples, isolation and determination of fungi were used, which affected the results obtained.

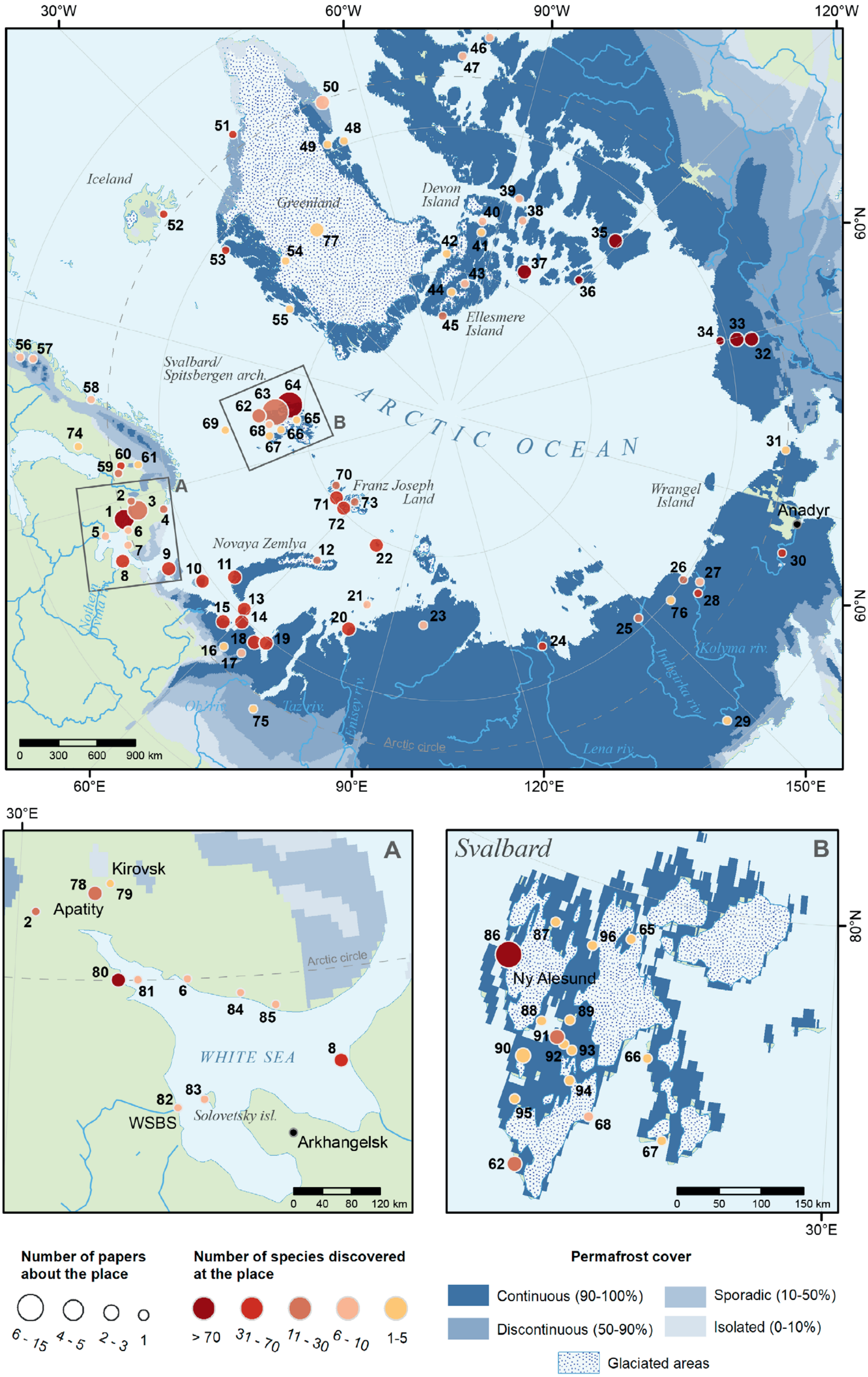
30°W
60°W
90°W
120°W
60°N
60°E
90°E
120°E
150°E
Iceland
Greenland
Devon Island
Ellesmere Island
Svalbard/ Spitsbergen arch.
ARCTIC OCEAN
Franz Joseph Land
Novaya Zemlya
Wrangel Island
Anadyr
Kolyma riv.
Indigirka riv.
Lena riv.
Ob riv.
Taz riv.
Enisey riv.
Arctic circle
0 300 600 900 km
A
B
30°E
Kirovsk
Apatity
WHITE SEA
Solovetsky isl.
WSBS
Arkhangelsk
0 40 80 120 km
Svalbard
Ny Alesund
80°N
0 50 100 150 km
Number of papers about the place
6 - 15
4 - 5
2 - 3
1
Number of species discovered at the place
> 70
31 - 70
11 - 30
6 - 10
1-5
Permafrost cover
Continuous (90-100%)
Discontinuous (50-90%)
Sporadic (10-50%)
Isolated (0-10%)
Glaciated areas

Fig. 1. The map of Arctic with locations of the investigations; 1 – (Bubnova, 2017; Bubnova and Velikanov, 2004; Grum-Grzhimaylo et al., 2018, 2016); 2 – (Santalahti et al., 2018); 3 – (Korneykova et al., 2022, 2020) Tkachenko, 2013; 4 – (Bubnova and Konovalova, 2018); 5, 6, 7 – (Bubnova, 2017); 8, 9, 10, 11 – (Kirtsideli et al., 2016, 2011); (Nikitin, 2021); 13,14,15 – (Kirtsideli et al., 2016, 2011); 16 – (Lapteva et al., 2017); 17 – (Kirtsideli et al., 2010); 18, 19, 20 – (Kirtsideli et al., 2016, 2011); 21 – (Kirtsideli et al., 2014); 22 – (Kirtsideli et al., 2016, 2011); 23 – (Kirtsideli, 1999); 24 – (Blanchette et al., 2016); 25 – (Miyamoto et al., 2022); 26 – (Ozerskaya et al., 2008); 27 – (Stakhov et al., 2008); 28 – (Bellemain et al., 2013); 29 – (V. Iliushin et al., 2022); 30 – (Bellemain et al., 2013); 31 – (Lydolph et al., 2005); 32 – (Geml et al., 2012; Semenova et al., 2016, 2015; Timling et al., 2014); 33 – (Dunleavy and Mack, 2021; Geml et al., 2012; Timling et al., 2014); 34 – (Timling et al., 2014); 35 – (Timling et al., 2014; Geml et al., 2012); 36 – (Timling et al., 2014); 37 – (Timling et al., 2014; Geml et al., 2012); 38, 39, 40 – (Robicheau et al., 2019); 41 – (Jurgens et al., 2009); 42 – (Day et al., 2006); 43 – (Osono et al., 2012); 44 – (Jurgens et al., 2009; Blanchette et al., 2021; Smith et al., 2017); 45 – (Tsuji et al., 2022); 46, 47 – (Robicheau et al., 2019); 48 – (Meyling et al., 2012); 49 – (Meyling et al., 2012; Pedersen et al., 2020) ; 50 – (Perini et al., 2021, 2019); 51, 52, 53 – (Blanchette et al., 2016); 54, 55 – (Meyling et al., 2012); 56 – (Borchhardt et al., 2019); 57, 58 – (Bjorbækmo et al., 2010); 59 – (Santalahti et al., 2018); 60 – (Poosakkannu et al., 2017), 61 – (Juottonen et al., 2020); 62 - (Borzęcka et al., 2022; Botnen et al., 2020); 63 – (Botnen et al., 2020; Iliushin, 2020; V. A. Iliushin et al., 2022; Kurek et al., 2007; Lorberau et al., 2017); 64 – (Botnen et al., 2020; Edwards et al., 2013; Frossard et al., 2021; Geml et al., 2012; Gunde-Cimerman et al., 2003; Perini et al., 2021; Singh et al., 2015, 2012; Tsuji et al., 2016; Zalar et al., 2008; Zhang et al., 2015a, 2015b; Zhang and Yao, 2015; Svalbardkatalogen, 1996); 65, 66, 67 – (Botnen et al., 2020); 68 – (Bjorbækmo et al., 2010); 69 – (Crous et al., 2022); 70 – (Nikitin and Semenov, 2022); 71 – (Bergero et al., 1999; Nikitin and Semenov, 2022); 72 – (Bergero et al., 1999; Kirtsideli et al., 2011; Nikitin and Semenov, 2022); 73 – (Bergero et al., 1999); 74 – (Conery, 2021); 75 – (Yakushev et al., 2019); 76 – (Kochkina et al., 2011); 77 – (Knowlton et al., 2013; Ma et al., 1999); 78 – (Korneykova et al., 2022, 2020); 79 – (Tkachenko, 2013); 80 – (Bubnova and Velikanov, 2004; Grum-Grzhimaylo et al., 2018, 2016); 81 – (Bubnova and Konovalova, 2018); 82, 83, 84, 85 – (Bubnova, 2017); 86 – (Botnen et al., 2020; Edwards et al., 2013; Frossard et al., 2021; Geml et al., 2012; Gunde-Cimerman et al., 2003; Perini et al., 2021; Singh et al., 2015, 2012; Tsuji et al., 2016; Zalar et al., 2008; Zhang et al., 2015a, 2015b; Zhang and Yao, 2015; Svalbardkatalogen, 1996); 87, 88, 89 – (Botnen et al., 2020); 90 – (Iliushin, 2020; V. A. Iliushin et al., 2022); 91 – (Botnen et al., 2020; Lorberau et al., 2017); 92, 93, 94 – (Botnen et al., 2020); 95 – (Kurek et al., 2007); 96 – (Botnen et al., 2020).

Methods used in the investigations

Due to the remoteness of the polar regions, most samples were stored for several weeks or months before laboratory processing. It is also worth noting that a variety of substrates were examined in different studies.

Substrates from which fungi were obtained

Analysis of the investigations showed that fungi identified in polar regions through molecular and cultural methods included species associated with both living organisms and dead organic matter (Table 1). The majority of species were isolated from substrates formed by bioinert matter which represent materials generated as a result of living organisms activity and inert processes of the biosphere (Ostroumov, 2008). Some of the bioinert substrates were dominated by organic matter and others by inorganic matter. Substrates subjected to anthropogenic influence and airborne fungi were classified into distinct categories. Each substrate group added new fungal species to the overall list that were not detected on other materials. The majority of fungal species were isolated from Arctic material, with the exception of species obtained from animal remains and airborne fungi, which predominated in Antarctica (Table 1). A more detailed table with the studied substrates is given in the appendices (Supplem. Tables 1).

Storage of samples, detection and identification of fungi

Only in rare cases was laboratory work with the samples done immediately or in 3-10 days after collection (Baublis et al., 1991; Dunleavy and Mack, 2021; Gonçalves et al., 2015, 2012; Grum-Grzhimaylo et al., 2016, 2018; Gunde-Cimerman et al., 2003; Kirtsideli et al., 2011; Poosakkannu et al., 2017). The researchers occasionally did not indicate the duration of sample storage (e.g., Blanchette et al., 2016; Held and Blanchette, 2017; Iliushin et al., 2022a,b; Tosi et al., 2005) or information regarding the storage method (Kirtsideli et al., 2016, 2010; Lapteva et al., 2017; Mercantini et al., 1989; Perini et al., 2019; Zhang and Yao, 2015). The studies we found indicated that researchers mainly stored collected samples until laboratory treatment in one of three ways: freezing, cooling (several degrees above zero), or drying, and in some cases samples were processed in 24 hours after collection (Supplem. Fig. 1, 2; Supplem. Tables 1).

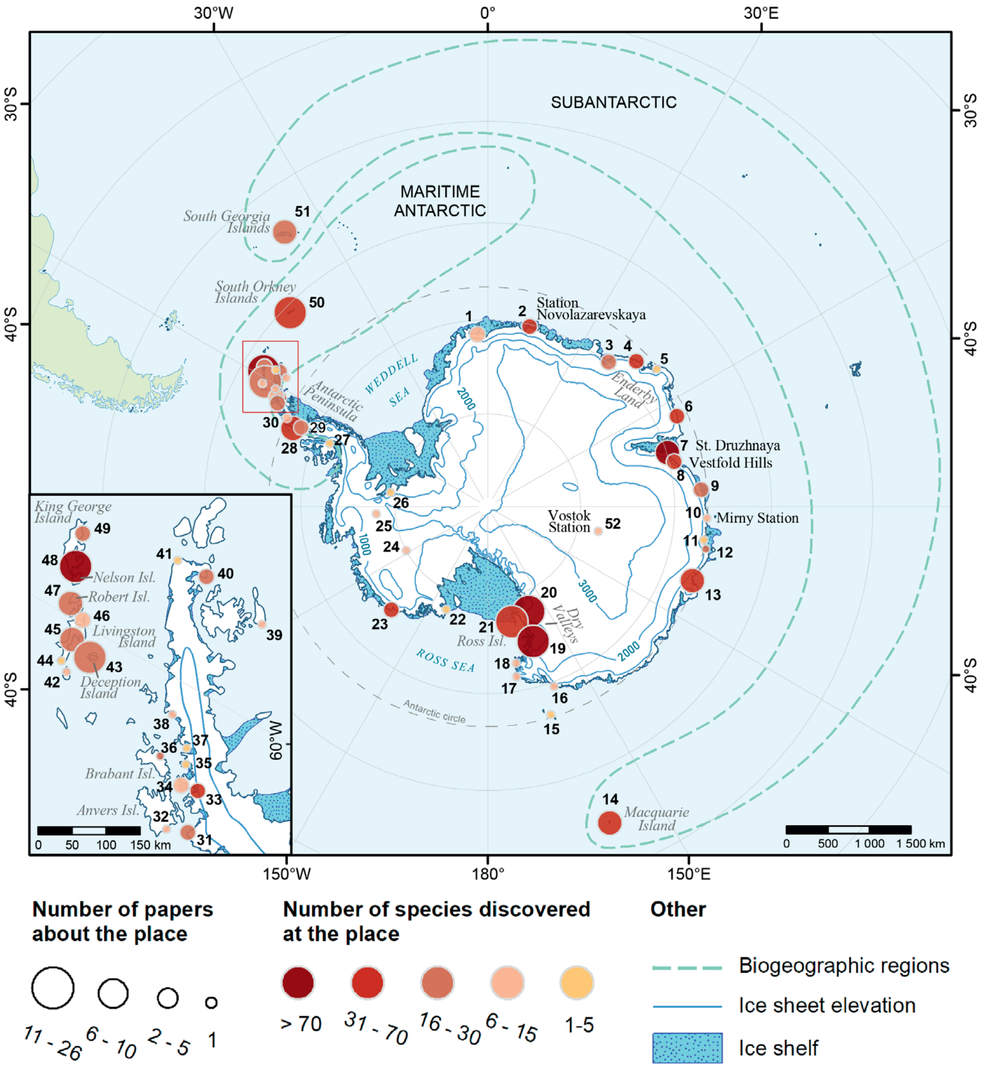
30°W
0°
30°E
30°S
40°S
SUBANTARCTIC
MARITIME ANTARCTIC
South Georgia Islands
51
South Orkney Islands
50
Station Novolazarevskaya
1
2
3
4
5
Enderby Land
6
WEDDELL SEA
Antarctic Peninsula
2000
30
29
28
27
7 St. Druzhnaya
Vestfold Hills
8
9
10 Mirny Station
11
12
13
Vostok Station
52
26
25
24
1000
3000
20
Dry Valleys
23
22
21
Ross Isl.
19
ROSS SEA
18
17
16
15
Antarctic circle
14
Macquarie Island
King George Island
49
48
Nelson Isl.
47
Robert Isl.
46
45
Livingston Island
44
43
42
Deception Island
41
40
39
38
37
36
35
Brabant Isl.
34
33
Anvers Isl.
32
31
60°W
0 50 100 150 km
0 500 1 000 1 500 km
150°W
180°
150°E
Number of papers about the place
11 - 26
6 - 10
2 - 5
1
Number of species discovered at the place
> 70
31 - 70
16 - 30
6 - 15
1-5
Other
Biogeographic regions
Ice sheet elevation
Ice shelf

Fig. 2. The map of Antarctica with locations of the investigations; 1 – (Ryan et al., 1989; Steele et al., 1994); 2 – (Kochkina et al., 2012, 2014; Nikitin, 2018; Singh et al., 2006); 3 – (Hirose et al., 2016, 2013; Tsuji et al., 2013; Tubaki, 1961); 4 – (Kochkina et al., 2019; Nikitin, 2018); 5 – (Hirose et al., 2016); 6 – (Fletcher et al., 1985; Kerry, 1990; Line, 1988); 7 – (Brunati et al., 2009; De Hoog et al., 2005; Ellis, 1980; Kerry, 1990; Kochkina et al., 2012, 2019, 2014; Line, 1988); 8 – (Kochkina et al., 2019; Marfenina et al., 2016; Nikitin, 2018); 9 – (Brunati et al., 2009; Kochkina et al., 2012); 10 – (Kochkina et al., 2014); 11 – (Olech and Alstrup, 1996); 13 – (Azmi and Seppelt, 1998; Chambers et al., 1999; Ellis, 1980; Kerry, 1990; McRae et al., 1999; McRae and Seppelt, 1999; Pudasaini et al., 2017); 14 – (Chambers et al., 1999; Ellis, 1980; Kerry, 1990; Kerry and Weste, 1985; Roddam and Rath, 1997); 15 – (Ellis, 1980); 16 – (Kochkina et al., 2014); 17, 18 – (Arenz and Blanchette, 2011); 19 – (Broady et al., 1987; Coleine et al., 2018; Del Frate and Caretta, 1990; Fenice et al., 1997; Mercantini et al., 1993, 1989; Montemartini Corte et al., 2000; Selbmann et al., 2021, 2008, 2005; Tosi et al., 2005, 2004, 2002; Zucconi et al., 1996; Held et al., 2006); 20 – (Arenz et al., 2011, 2006; Baublis et al., 1991; Brunati et al., 2009; Christner et al., 2003; Coleine et al., 2018, 2017; Connell et al., 2006; De Hoog et al., 2005; Fell et al., 2006; Gilichinsky et al., 2005, 2007; Houbraken et al., 2012; Kochkina et al., 2021, 2012; Onofri, 1999; Selbmann et al., 2021, 2008, 2005; Sugiyama et al., 1967; Sun et al., 1978; Tubaki and Asano, 1965; Visagie et al., 2016; Vishniac, 1996; Kudalkar, 2016); 21 – (Alias et al., 2013; Arenz and Blanchette, 2011; Blanchette et al., 2010, 2004; Broady et al., 1987; Connell and Staudigel, 2013; Duncan, 2007; Duncan et al., 2010, 2006; Laichmanová, 2020); 22 – (Zucconi et al., 2012); 23 – (Crous et al., 2019; Kochkina et al., 2012; Marfenina et al., 2016; Nikitin, 2018); 24 – (Knowlton et al., 2013); 25 – (Gonçalves et al., 2017); 26 – (Godinho et al., 2015); 27 – (Hughes and Lawley, 2003; Malosso et al., 2006); 28 – (Arenz and Blanchette, 2011; Bridge et al., 2005; Christie and Nicolson, 1983; Hughes et al., 2007, 2003; Jumpponen et al., 2003; Bridge et al., 2008); 29 – (Arenz and Blanchette, 2011; Christie and Nicolson, 1983); 30 – (Arenz and Blanchette, 2011); 31 – (Christie and Nicolson, 1983; Gray et al., 1982; Gray and Lewis Smith, 1984); 32 – (Arenz and Blanchette, 2009, 2011); 33 – (Arenz and Blanchette, 2011; Coleine et al., 2017; Ogaki et al., 2020a); 34 – (Christie and Nicolson, 1983; de Menezes et al., 2019); 35 – (Abneuf et al., 2016); 36 – (Arenz et al., 2011); 37 – (Christie and Nicolson, 1983); 38 – (Brito Devoto et al., 2022); 39 – (Arenz and Blanchette, 2011); 40 – (Arenz and Blanchette, 2011; de Menezes et al., 2019); 41 – (Caretta and Piontelli, 1977); 42 – (de Menezes et al., 2019); 43 – (Abneuf et al., 2016; Alves et al., 2019; Arenz and Blanchette, 2011; da Silva et al., 2022; de Menezes et al., 2019; Gonçalves et al., 2015, 2012; Held and Blanchette, 2017; Lindsay, 1976; Rosa et al., 2020); 44 – (da Silva et al., 2022); 45 – (Alves et al., 2019; Caretta and Piontelli, 1977; Kostadinova et al., 2009; Litova et al., 2014; Upson et al., 2007); 46 – (Alves et al., 2019; Houbraken et al., 2012; Lucini et al., 2022), 47 – (Abneuf et al., 2016; Alves et al., 2019; da Silva et al., 2022; de Menezes et al., 2019, 2017; Gomes et al., 2018); 48 – (Alves et al., 2019; Bridge and Worland, 2004; Caretta and Piontelli, 1977; Crous et al., 2021b, 2021a; Czarnecki and Bialasiewicz, 1987; da Silva et al., 2022; de Carvalho et al., 2020; de Menezes et al., 2019; Ding et al., 2016; Gomes et al., 2018; Gonçalves et al., 2015, 2012; Kochkina et al., 2012, 2019; Krishnan et al., 2016; Lucini et al., 2022; Möller and Dreyfuss, 1996; Nikitin, 2018; Ogaki et al., 2020b; Schubert et al., 2007; Stchigel et al., 2003, 2001; Upson et al., 2007; Wang et al., 2015; Yu et al., 2014; Bertini et al., 2022); 49 – (Alves et al., 2019; Crous et al., 2017, 2013; Gomes et al., 2018); 50 – (Bailey and Wynn-Williams, 1982; Bridge and Denton, 2007; Christie and Nicolson, 1983; Duddington et al., 1973; Gaiser et al., 2021; Gray et al., 1982; Gray and Lewis Smith, 1984; Latter and Heal, 1971; Lindsay, 1976; Upson et al., 2007; Weinstein et al., 2000, 1997); 51 – (Bridge et al., 2008; Christie and Nicolson, 1983; Hurst et al., 1983; Lindsay, 1976; Smith, 1994; Upson et al., 2007), 52 – (Knowlton et al., 2013).

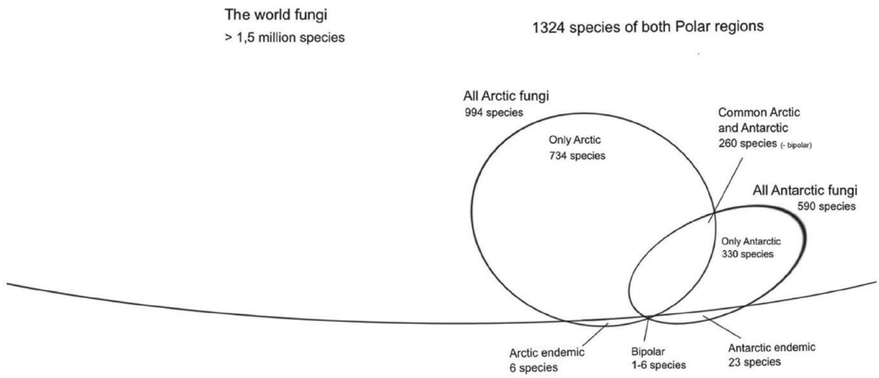

Fig. 3. Schematic illustration of the number of fungal species found in the polar regions.

Most fungal species were obtained only from frozen samples, but this was also the most common way to store samples, while drying was the rarest method (Supplem. Fig. 1, 2; Supplem. Tables 1). Furthermore, we observe that many fungal species were discovered only after samples were stored by any one method (Supplem. Fig. 1, 2).

We examined studies in which fungi were detected and identified mainly by one of the following methods: direct cultivation of environmental samples on standard and selective media, or metabarcoding after isolation of eDNA from the samples. After cultivation of the samples identification of the fungi were provided by morphological features or ITS or/and LSU regions of the rDNA sequencing. The majority of fungal species were obtained by cultivation and eDNA sequencing (~45% and ~43%, respectively), and ~10% of the species were found with both approaches. However, of studies to detect fungi, cultivation was used in 78%, eDNA was used in 14%, and both approaches were applied in 3% (Supplem. Fig. 3, 4). Approximately ~59% of the discovered fungi species were identified by the rDNA sequencing method, while ~24% of species were identified using morphological features. Both methods were used to identify ~14% of species (Supplem. Fig. 5). Approximately equal numbers of fungal species were identified by molecular and morphological methods, while only in 5% of the cases both methods were used (Supplem. Fig. 5, 6).

Effect of storage and detection methods on the discovered composition of fungi

The complex of methodological approaches for storing and analysing samples undoubtedly affects the result of detecting and identifying fungi (Bölter et al., 2002; Frisvad, 2008). To reveal the most complete picture of species diversity, distribution, quantity, and ecological role of fungi, long-term studies of the most diverse types of substrates (Kochkina et al., 2012) are needed, in numerous replications and throughout all seasons, as seasonal conditions and vegetation directly affect the fungal community (Wallenstein et al., 2007). Despite the wide range of different sample types studied in polar regions (Table 1, Supplem. Tables 1), usually only a small number of them were analyzed in each individual study, and most studies were conducted only once. In addition, a significant part of the polar regions has not been studied at all (Fig. 1, 2).

Table 1. Substrates of fungal isolation.

Substrate	Arctic	Antarctica	Both poles	Only from this substrate (from either of the poles)
Dead material				
Plants (wood material, fallen leave and litter, fossil plants, peat)	193	37	37	86
Animals (corpses, skeleton remains, faeces, feathers)	13	28	6	8
Living material				
Plants (algae, mosses, wood, leaves, herbaceous plants, roots, lichens)	309	179	27	253
Animals (seals)	1	16	0	5
Substraites dominated by organic substances				
Soil, birds spots and nests, lake sediments, microbial mats	454	282	170	449
Substraites dominated by inorganic substances				
Rocks, ice and snow, cryoconites, water	117	38	11	22
Substraites with antropogenic influence				
Settlements and different materials from its, soil with kerosene and oil, food, coal mine spoils	112	16	25	35
Airborne fungi	17	28	10	8

The method and duration of storage of samples affect the detection of the fungal community (Cui et al., 2014; Delavaux et al., 2020; Frisvad, 2008). Presumably, during freezing and drying, some species and colony-forming units (CFU) are lost, and during long-term storage of cooled samples the fungal community changes since growth of some species continues. Studies showing the effect of sample drying on the number or detected colonies and fungal species were not found. Nikitin et al. (2017) conducted a study showing the effect of sample storage temperature on the length of mycelium visible under a microscope and the number of fungal spores in soil samples. He recommends dividing each sample into several parts and storing each part at different temperatures (+5, -18…-20, -70…-80°C) separately. Each of these temperature values had a different effect on the preservation of mycelia length and number of spores (Nikitin et al., 2017). The effect of storing samples at low temperatures on the overall picture of the fungal community may seem unlikely to be significant when studying fungi from the polar regions, since psychrophilic and psychrotolerant species will be common. However, mesophilic species are active during the growing season in the polar regions. Therefore, when samples are stored at low temperatures, they are suppressed by cold-loving ones, which results in an overall distorted picture. Thus, it is ideal to use all methods of sample storage or to study the samples quickly after collecting to obtain a complete picture of fungal species diversity.

Moreover, the methods of fungal detection in substrates strongly influence the results of fungal species composition (Frisvad, 2008). When using the culture-based approach, only cultivable fungal species are isolated. in practice, 1 % is easily cultivable using standard lab protocols (Frey et al., 2016), although it has been estimated that 2/3 of all fungi can in principle be cultivated (Arenz and Blanchette, 2011). Furthermore, species composition and quantity of isolated fungi using culture-based approaches are affected by the number of samples and their dilution, the repetition of each sample seeding, the composition of nutrient media (Arenz et al., 2006), and cultivation conditions (Kochkina et al., 2012). The temperature of cultivation influences the detection of psychrophilic or mesophilic fungi (e.g., McRae1999 and Seppelt, 1999; Weinstein, 1997), while different pH values can detect acid-tolerant or acidophilic species (Grum-Grzhimaylo 2016, 2018). The application of molecular methods has made it possible to understand the non-cultivable fraction (Frey, 2016). By using metatranscriptomic analysis of extremely short-lived mRNA, it is more likely to detect fungi that were in an active stage during sample collection. However, in most studies, samples are analyzed through the extraction of total DNA, which can remain preserved for thousands of years in permafrost soils (Coolen and Orsi, 2015). Additionally, the results of fungal detection by DNA depend on many analytical variables, such as sample volume and amount, DNA extraction methods, primers for PCR and sequencing technology, fungal life cycle stages, and other factors (Tedersoo et al., 2021).

Cultivation methods suffer from several disadvantages. On the one hand, many of the species obtained through cultivation were not in an active state under natural conditions; however, their isolation from the substrate enables a deeper examination of the physiology of these fungi in laboratories (Arai et al., 2022; Ianutsevich et al., 2023a,b), as well as sequencing and studying their genomes (Coleine et al., 2020, 2017), creating databases and culture collections (Kochkina et al., 2021). On the other hand, although collection of fruiting bodies of basidiomycetes confirms their activity, it does not give a clear idea of the distribution and biomass, since the fruiting bodies are formed irregularly and it is not clear how much mycelium is present in the material. Furthermore, numerous fungi are in symbiosis with higher plants (Vohník, 2020) and others infect plants (Doehlemann et al., 2017) and animals (Gnat et al., 2021) and these species frequently cannot cultivated on standard nutrient media, and their detection and identification is feasible either through direct microscopy or molecular methods, which are constrained by insufficient genomic data and primarily rely on identification to higher taxonomic categories than the species level.

Many studies we examined used either culture methods or eDNA isolation from samples. We were able to find single studies in which several approaches would be applied simultaneously. Arenz et al., (2006) used culture-based and molecular methods to study antropogenic samples of wood, artifacts including straw, paper, floor, rope, burlap collected butter, biscuits, and soils in Antarctica. They analyzed 164 samples by plating them on three different culture media and 48 of these samples were analyzed using denaturing gradient gel electrophoresis (DGGE). In total, 284 fungal ITS sequences were identified; including 184 from culturing and 100 from DGGE. In summary, 25 taxa were detected by traditional culturing methods and not by DGGE. Conversely, 28 taxa, including the four unknown types, were detected and identified by DGGE and not by culturing (Arenz et al., 2006). Malosso et al. (2006) analyzed soils from Antarctica using molecular methods and by cultivating the same soil samples on nutrient media. Nucleic acids from both the community DNA and colony extracts were amplified using PCR with primers specific to the 18S rRNA gene. Amplicons were separated on denaturing gradient gels (DGGE) or after restriction digestion with endonucleases (ARDRA). The obtained fungal clones, showing unique ARDRA and DGGE bands, were sequenced. The fungal species compositions obtained from the same samples varied depending on the fungal detection method utilized (Malosso et al., 2006). Kochkina et al. (2012) analyzed 36 samples of ancient deposits from Antartctica using a diverse range of culture-based techniques, and for nine samples, they employed both culture-based and molecular approaches. When using culture-based methods, fungi were not found in about half of the samples, and total-DNA was only isolated from one third of the analyzed samples. Both culture-based and molecular methods were able to identify fungi from only one sample, while no common fungal species were identified by both methods. These data indicate that different species are identified using different methods (Kochkina et al., 2012). Pudasaini et al. (2017) explored the microbial diversity of an ice-free Antarctic desert using traditional cultivation methods, an approach of the soil substrate membrane system (SSMS; (Ferrari et al., 2005), and culture-independent 454-tag pyrosequencing for 18 soils samples. This study found that fungal OTUs were not shared between culture-dependent and independent techniques. A total of 663 fungal OTUs were recovered using three approaches with distinct methods, yet not a single common OTU was identified across all three methods (Pudasaini et al., 2017). Selbmann et al. (2021) investigated Antarctic cryptoendolithic black fungi using cultivation и the high-throughput sequencing approaches. "Both methods applied showed advantages and disadvantages; for instance, the use of amplicon sequencing captured the diversity of environmental microbiota in deeper detail, but several black fungi that were successfully isolated were not detected by this approach" (Selbmann et al., 2021). Nikitin and Semenov (2022) explored the fungal diversity of the Franz Josef Land archipelago using the classical plating techniques and real-time PCR methods for samples from five islands of the archipelago. They estimated the abundance of fungal rRNA gene ITSs, the CFU numbers, and the taxonomic diversity of culturable micromycetes in cryosols of the islands. The number of copies of the fungal rRNA gene ITS significantly exceeded CFU/g of soil in the same samples (Nikitin and Semenov, 2022). Edwards et al., (2013) investigated the fungal community in Svalbard cryoconite holes with both traditional cultivation methods and multivariate analysis of terminal-restriction fragment length polymorphism (T-RFLP) profiles of rRNA ITS amplicons and showed differences in the results obtained by these different approaches (Edwards et al., 2013). All the authors of the aforementioned studies acknowledge the significance of employing diverse methodologies to attain the most comprehensive identification of the species diversity of fungi. Furthermore, these examples demonstrate that researchers, using different methods can achieve different and almost incomparable results.

About a half of fungal cultures isolated from the material of the polar regions are sterile mycelium (e.g., Bölter et al., 2002; Kochkina et al., 2012), which limits the drawing of a taxonomic picture. Moreover, many species of fungi are characterized by significant variability in taxonomic characters, and hence their identification by morphology can be difficult (Grum-Grzhimaylo et al., 2016; Kaitera et al., 2019). These cases require isolation of DNA from the mycelium, followed by sequencing of the internal transcribed spacer (ITS) region, which has been used in the most studies on the diversity of fungi in the polar regions (Supplem. Fig. 6). However, other difficulties arise when using molecular identification methods. In some cases, the ITS region is not sufficient for identifying species, and other DNA regions require additional sequencing (Bölter et al., 2002). Furthermore, there is not enough information in the databases to identify all detected species with DNA data (Hyde et al., 2010). For these reasons, it is frequently feasible to identify samples based on DNA sequences up to higher taxonomic categories than the species (Tedersoo et al., 2020). It has been noted that it is useful to combine molecular techniques and morphological observations to identify many fungal species (Baturo-Cieśniewska et al., 2020). The limitation of combining these two identification methods is that it is only possible for fungi obtained through cultivation. Even when fungi were detected through cultivation in a very small number of polar studies, they were identified both by morphological features and by sequencing DNA regions (e.g., Grum-Grzhimaylo et al., 2016, 2018; Kaitera et al., 2019; Kochkina et al., 2019).

It is therefore difficult to obtain an understanding of the biogeography and functioning of fungi living in the Arctic and Antarctic from the available data, obtained by various methods. Therefore, at present we still need to employ multiple methods to get a good picture. More research is needed to understand the relationship between different sampling methods, and particularly to distinguish active mycelia from spores.

Taxonomy and ecology of fungi in the polar regions

More fungal species have been detected in the Arctic region than in Antarctica (717 and 326 unique species, respectively) and the number of species common to both polar regions was 250 species (Fig. 3), corresponding to approximately 19%. Such differences can be attributed to both the geographical distance between polar regions and the unique ecological characteristics specific to these regions. In this section, we provide a brief comparative overview of the taxonomy of fungal communities in the Arctic and Antarctic, as well as their ecological associations. Additional information about the ecological significance of fungi from our list was taken from 358 articles and 16 Internet resources (Supplem. Tables 1).

Taxonomic description and abundance of fungi in the polar regions

There is a large difference between the Arctic region and Antarctica in the distribution of different fungal divisions (Table 2). The highest number of species common to the two poles belongs to the divisions Mucoromycota and Ascomycota (~37% and ~25%, respectively), while shared Basidiomycota species account for only ~3%. According to our data only a few species are known to be endemic to Antarctica or Arctic, and there are 1-6 identified bipolar species, i.e. species occurring at both poles, but not at intermediate latitudes (Fig. 3). General information on the taxonomic composition of fungi found in the polar regions is given in the Supplementary materials 3. Ascomycota species represent the largest group of fungi reported from both polar regions. The discovered species belong to 12 classes, and 31 species have an unclear taxonomic position (incertae sedis; Supplem. Tables 3). Basidiomycota species are the second-largest taxonomic group of fungi in the polar regions mostly recorded in Arctica and mainly represented by species belonging to the class *Agaricomycetes* (Supplem. Tables 3). The most species-rich were genera *Cortinarius* (Pers.) Gray (65 species), *Inocybe* (Fr.) Fr. (33 species), *Russula* Pers. (28 species), *Lactarius* Pers. (15 species) and *Mycena* (Pers.) Roussel (12 species; Supplem.

Tables 1, 3). The biggest part of Mucoromycetes belongs to *Mortierella* Coem. and *Mucor* P. Micheli genera, species of which were found in both polar regions, predominantly in Arctica (Supplem. Tables 3).

Table 2. Abundance of fungal divisions in the polar regions.

Division	No of species			
	Arctic	Antarctica	Common for both poles	Total
Ascomycota	388	279	229	896
Basidiomycota	326	34	12	372
Mucoromycota	20	14	19	53
Glomeromycota	0	1	0	1
Entomophthoromycota	0	1	0	1
Zoopagomycota	0	1	0	1
Total	734	330	260	1324

A brief sketch of the ecology of fungi in the polar regions

A significant cause of the difference between fungal communities in the Arctic and Antarctic regions, as described in section 5.1, may be the various ecological factors specific to these regions. Interesting reviews characterizing different groups of fungi and their ecology in polar regions and permafrost already exist in scientific literature (Table 3). We did not intend to provide a complete picture of the ecology of fungal communities in polar regions, partly due to the fact that certain ecologically important groups of fungi in polar regions, such as yeasts (Buzzini et al., 2017), snow mold (Hoshino et al., 2019; Tkachenko, 2013), lichenicolous fungi (Brackel, 2010; Brinker, 2020; Santiago et al., 2015), certain species associated with animals (Bridge and Worland, 2004), and many macrofungi (Denchev et al., 2020), were not considered because they were detected using methods that we did not take into account. Another complicating factor in data analysis was that many fungal species can perform multiple roles in ecosystems simultaneously (Supplem. Tables 1). To investigate certain patterns of fungal distribution in polar regions based on their ecological associations according to our data, we only included species whose role in ecosystems has been studied the most.

Table 3. The list of reviews characterizing different groups of fungi and their ecology in polar regions and permafrost.

Titles	References
Microbial Life in Permafrost	(Altshuler et al., 2017)
Microbial Life in Supraglacial Environments	(Edwards and Cameron, 2017)
Heterotrophic Microbes, Microbial and Enzymatic Activity in Antarctic Soils	(Bölter et al., 2002)
Arctic soil microbial diversity in a changing world	(Blaud et al., 2015)
Permafrost active layer	(Dobiński, 2020)
Fungi in cold ecosystems	(Frisvad, 2008)
Mycorrhizal diversity in arctic and alpine tundra: an open question	(Gardes and Dahlberg, 1996)
Psychrophilic and psychrotrophic fungi: a comprehensive review	(Hassan et al., 2016)
How will thawing permafrost affect the microbial abundant and diversity in the Arctic?	(Maria and Langvad, 2020)
Decomposer' Basidiomycota in Arctic and Antarctic ecosystems	(Ludley and Robinson, 2008)
Microbialdiversity and functional capacity in polar soils	(Makhalanyane et al., 2016)
Microbial diversity and biogeography in Arctic soils	(Malard and Pearce, 2018)
Root-associated fungi and carbon storage in Arctic ecosystems	(Robinson et al., 2020)
Cold adaptation in Arctic and Antarctic fungi	(Robinson, 2001)
Snow moulds in polar environments	(Tojo and Newsham, 2012)
Adapting the changing environment: microbial way of life	(Aley et al., 2022)
Trends in yeast diversity discovery	(Boekhout et al., 2021)
Introduced and indigenous fungi of the Ross Island historic hutsand pristine areas of Antarctica	(Farrell et al., 2011)
No need for speed: slow development of fungi inextreme environments	(Gostinčar et al., 2022)
Structure and function of alpine and arctic soil microbial communities	(Nemergut et al., 2005)
Mycorrhizas and dark septate root endophytes inpolar regions	(Newsham et al., 2009)
Antarctic microfungi	(Onofri, 1999)
The Role of Ectomycorrhiza in Boreal Forest Ecosystem	(Qu et al., 2010)
Biodiversity in the dark: root-associated fungi in the Arctic	(Botnen, 2020)
Fungi in Antarctica	(Ruisi et al., 2007)
Fungi of Antarctica: Diversity, Ecology and Biotechnological Applications	(Rosa et al., 2019)
Resurrection of inactive microbes and resistome present in the naturalfrozen world: Reality or myth?	(Sajjad et al., 2020)
Seasonal dynamics of previously unknown fungal lineages in tundra soils	(Schadt et al., 2003)
Antarctic permafrost: An unexplored fungal microhabitat at the edge of life	(da Silva et al., 2019)
Fungi in hot and cold deserts with particular referenceto microcolonial fungi	(Sterflinger et al., 2012)
Global diversity and geography of soil fungi	(Tedersoo et al., 2014)
Peeking through a frosty window: molecular insights into theecology of Arctic soil fungi	(Timling and Taylor, 2012)
Natural products from polar organisms: Structural diversity, bioactivitiesand potential pharmaceutical applications	(Tripathi et al., 2018)
Microbial Communities and Processes in Arctic Permafrost Environment	(Wagner, 2008)

Approximately half of the polar fungal species are saprotrophs (Supplem. Fig. 7). It is among these species that the greatest number of species shared between both polar regions has been found. The second largest group in the Arctic consists of symbionts, dominated by mycorrhizal species associated with a much larger number of Arctic plant species than Antarctic ones. Pathogenic species for plants and animals follow (Supplem. Fig. 7). The ecological role of about 8.2% of the identified fungal species remains unknown. Interestingly, approximately 3.5% (47 species) of the identified fungi are known to be pathogenic, as well as potentially or conditionally pathogenic for humans and warm-blooded animals (Supplem. Fig. 7; da Silva et al., 2022). The list of these species, their frequency of occurrence in studies, and the substrate of detection are provided in Supplementary Table 4. It is impossible to determine with certainty how these species reached the polar regions, but it can be assumed that they were introduced by humans, animals, or migratory birds (Supplem. Table 4). It is also unknown whether pathogenic fungi are active in polar regions or remain in the form of spores. The presence of thermophilic species, such as *Acaulium caviariforme*, *Collariella gracilis*, *Mycothermus thermophilus*, *Thermomyces lanuginosus*, and *Thermothelomyces thermophiles* (Supplem. Tables 1), is intriguing. It can be confidently assumed that with global warming, the activity of both pathogenic species and thermophilic and thermotolerant species will increase.

It is interesting to compare the fungal complexes of two polar regions isolated from similar substrates, such as drifting wooden material in the Arctic (Blanchette et al., 2016) and wooden structures in Antarctica (Arenz et al., 2006; Blanchette et al., 2004; Duncan et al., 2006; Gaiser et al., 2021), bird feathers from high Canada (Robicheau et al., 2019) and Svalbard (Singh et al., 2015) and Antarctica (Brito Devoto et al., 2022; Del Frate and Caretta, 1990), mosses, vascular plants, and lichens (e.g. de Carvalho et al., 2020; Jumpponen et al., 2003; Kerry, 1990a; McRae and Seppelt, 1999; Möller and Dreyfuss, 1996; Osono et al., 2012; Park et al., 2015; Rosa et al., 2020b; Tosi et al., 2002; Zhang et al., 2015b), peat Grum-Grzhimaylo et al., 2016; Lapteva et al., 2017; Semenova et al., 2015; Yakushev et al., 2019), ice, snow, and cryoconites (Borzęcka et al., 2022; Christner et al., 2003; de Menezes et al., 2019; Edwards et al., 2013; Gilichinsky et al., 2005; Gunde-Cimerman et al., 2003; Knowlton et al., 2013; Ozerskaya et al., 2008; Perini et al., 2021, 2019; Tsuji et al., 2022), aerial dispersal of fungi (Czarnecki and Bialasiewicz, 1987; Duncan, 2007; Duncan et al., 2010; Kirtsideli et al., 2011; Sun et al., 1978). Interesting comparative descriptions of fungi on plants and mosses in the Arctic and Antarctica are presented in the book by Tsuji and Hoshino (2019) and in the publication by de Carvalho et al. (2020), but they cover a limited number of studies. Separate interest is raised by studies of mycorrhizal fungi and their movement together with symbiotic plants, mainly characteristic of the Arctic (Bjorbækmo et al., 2010; Botnen et al., 2020; Chlebicki et al., 2005; Dunleavy and Mack, 2021; Geml et al., 2012; Kaitera et al., 2019; Lorberau et al., 2017; Miyamoto et al., 2022) and to a lesser extent for Antarctica, as there are only two species of vascular plants

(*Colobanthus quitensis* (Kunth) Bartl. and *Deschampsia Antarctica Desv.*), but they also form mycorrhizae (Barbosa et al., 2017; Christie and Nicolson, 1983; Lucini et al., 2022; Upson et al., 2008). The results of studies on the biogeography of fungi along transects from temperate to cold latitudes (Timling et al., 2014), the adaptive features of fungi in polar regions, such as optimal temperature for growth (Alias et al., 2013; da Silva et al., 2022; Gaiser et al., 2021; Kerry, 1990b; Kostadinova et al., 2009; Krishnan et al., 2016; Latter and Heal, 1971; Litova et al., 2014; Lucini et al., 2022; Singh et al., 2006; Stakhov et al., 2008; Tosi et al., 2002; Wang et al., 2015; Weinstein et al., 2000, 1997; Zucconi et al., 2012, 1996), their enzymatic and antimicrobial activity (Abneuf et al., 2016; Ding et al., 2016; Duncan, 2007; Duncan et al., 2006; Krishnan et al., 2016; Lindsay, 1976; Mercantini et al., 1993; Montemartini Corte et al., 2000; Singh et al., 2012), resistance to extreme factors such as high UV radiation and radiation, freezing, dryness, oligotrophic conditions (Bergero et al., 1999; Fell et al., 2006; Gunde-Cimerman et al., 2003; Hughes et al., 2003; Sazanova et al., 2019; Selbmann et al., 2015, 2008; Singh et al., 2006; Tosi et al., 2005; Tsuji et al., 2013), their associations with vertebrates and invertebrates (Bridge et al., 2005; Bridge and Denton, 2007; Bridge and Worland, 2004; Brito Devoto et al., 2022; Meyling et al., 2012; Roddam and Rath, 1997), as well as the physiological response of fungi to global warming (Geml et al., 2015; Semenova et al., 2015; Tosi et al., 2005; Weinstein et al., 2000), changes in snow cover thickness (Morgado et al., 2016), succession dynamics (Juottonen et al., 2020; Kerry and Weste, 1985; Poosakkannu et al., 2017), changes in fungal communities due to anthropogenic influence (Blanchette et al., 2010, 2004; Czarnecki and Bialasiewicz, 1987; Gaiser et al., 2021; Kirtsideli et al., 2016; Korneykova et al., 2022; Line, 1988; Ogaki et al., 2020; Tsuji et al., 2022) undoubtedly deserve attention.

It is impossible not to mention the works relating to paleontological studies of fungi in polar regions. For example, we encountered such an interesting case: *Eucasphaeria capensis*, firstly obtained in South Africa in living leaves and leaf litter of *Eucalyptus* sp. and described by Crous et al. (2007), was detected by metabarcoding of DNA in ancient arctic permafrost a few years later (Bellemain et al., 2013). Analysis of paleontological studies can help understand the biogeography of fungi in polar regions hundreds and thousands of years ago (Bellemain et al., 2013; Gilichinsky et al., 2007; Knowlton et al., 2013; Lydolph et al., 2005; Ma et al., 1999; Ozerskaya et al., 2008; Stakhov et al., 2008).

Thus, a more detailed description of the ecological role and adaptive features of fungi in polar regions deserves a separate research work.

Are these fungi endemic?

Some fungi in polar regions have not been recorded in other parts of our planet. Fungi that occur only in one of the polar regions, according to one definition of endemism (Shipley and McGuire, 2022), will be referred to as endemic species in this work. For the Arctic, this will be the area within the polar circle, and for Antarctica, it will be the continent itself and the islands of the Antarctic and sub-Antarctic seas. Species known in both polar regions but not recorded in other parts of the planet will be referred to as bipolar endemics (Cox et al., 2016).

When attempting to assess the presence and number of endemic species and bipolar endemics, we encountered several problems: 1) some species that were originally described as Antarctic fungi (e.g., *Penicillium antarcticum*, *Drechmeria coniospora*, *D.obovata*, *Phialophora dancoi*, *Sclerococcum dobrowolskii, Thelebolus mircosporus*) were later found in other regions, in certain instances including the Arctic (e.g., *Conidiobolus antarcticus*, *Drechmeria balanoides*, and *Thelebolus ellipsoideus*), or only in the Arctic, making them bipolar endemics (*Acrodontium antarcticum*, *Antarctomyces pellizariae*, *A. psychrotrophicus*, *Cadophora antarctica*, *Cladosporium antarcticum* and *Mortierella antarctica*); 2) species that were once considered boreal and only found in the circumpolar regions of the Arctic and subarctic zones have since been discovered in high mountainous areas (e.g., *Inocybe arctica, I. borealis*); (Kokkonen and Vauras, 2012; Cripps and Horak, 2006), or known from Antarctic and high alpine areas (e.g., *Psychrophila antarctica*, Wang et al., 2015); 3) there are species that were previously considered bipolar endemics but were later found in other places, such as *Penicillium amphipolaria*; 4) as the number of studies analyzed increased, the number of unique fungal species for the poles decreased, and more species became common to both the Arctic and Antarctic; 5) the later the species were described, the fewer regions they were recorded from, suggesting that over time, the unique fungal species presently found in polar regions may be discovered in other places. All of these issues are closely linked to researchers' noted incomplete understanding of fungal distribution worldwide (Tedersoo et al., 2021), and especially in polar regions (e.g., Bridge and Spooner, 2012; Newsham et al., 2016; Cox et al., 2016), so the concept of endemic fungal species has to be considered relative and tentative.

In this section, we have attempted to gather information about fungal species that are currently considered endemic to polar regions, or were believed to be so for a long time until they were found at the opposite pole or in inter-polar regions.

Characteristic Antarctic Fungi

Antarctica, along with its surrounding islands, represents extreme and well-isolated regions on our planet that are challenging for survival. As a result, unique plant and animal communities have formed here. It would be logical to expect unique fungi in this area, many of which are parasitic and symbiotic species that are commonly found in association with plants and animals. The distribution of saprotrophic fungi, as heterotrophic organisms that feed on ready-made organic materials, is closely associated with the presence of suitable substrates, whose chemical composition is closely linked to the enzymatic apparatus of fungi capable of breaking down specific substances thus determining substrate specialization. Extreme sub-zero temperatures, dryness, and intense UV radiation also have a significant impact on the growth and metabolic activity of Antarctic fungi. The complex combination of these factors determines the species composition of fungi inhabiting this area.

Out of the more than 300 Antarctic fungi we have found in various studies, 23 species in the table are considered endemic until today. Part of these species are actively being studied, while others have only been found in Antarctic substrates, described and studied little. The characteristic Antarctic fungi identified in these studies were isolated from typical substrates in this region, such as plants, lichens, soil, lake sediments, bird and insect waste, nematodes, and rocks. Among the species with certain physiological characteristics, keratinophilic fungi have been identified, which can potentially degrade animal keratin structures, and psychrophilic and psychrotolerant fungi, capable of functioning at low temperatures (Table 4).

Table 4. Endemic fungal species of Antarctica; endolithics are in bold.

Species of fungi (modern names from the Index Fungorum)	Names of species from articles (archaic), if different	Substrate of detection	Ecology	References
Acremonium psychrophilum	-	Lichens	Lichenicolous, psychrophilic	(Etayo et al., 2023; Möller and Dreyfuss, 1996; Vishniac, 1996)
Apenidiella antarctica	-	Permafrost soil	n.i.	(Crous et al., 2019)
Arthroderma magnisporum	*Chrysosporium magnasporum*	Bird pellet	Keratinolytic, psychrotolerant	(Crous et al., 2013)
Arthroderma oceanitis	*Chrysosporium oceanitesii*	Dead bird, lake sediments	Keratinolytic, psychrotolerant	(Crous et al., 2013; Ogaki et al., 2020a)
Chalara antarctica	-	Rhizosphere of Deschampsia antarctica and Colobanthus quitensis	Vascular plant associated	(Vishniac, 1996; Onofri, 1999; Newsham et al., 2020)
Cladosporium austrolitorale	-	Coastal sea sand	Saprotrophic, psychrotolerant	(Crous et al., 2021b)
Comoclathris antarctica	-	Soil	n.i.	(Crous et al., 2021a)

Cryomyces antarcticus	-	Sandstone, soil, rocks	Endolithic, psychrophilic	(Selbmann et al., 2005; Nikitin, 2023)
Cryomyces minteri	-	Soil	Endolithic, psychrophilic	(Selbmann et al., 2005)
Drechmeria bactrospora	*Acrostalagmus bactrosporus*	Soil with Deschampsia antarctica	Endoparasitic nematophagous	(Gray and Lewis Smith, 1984)
Extremus antarcticus	*Extremus antarcticus*	Rocks, sandstones	Endolithic	(Selbmann et al., 2021)
Friedmanniomyces endolithicus	-	Granite or pegmatite, sandston, rocks, soil	Endolithic, psychrophilic	(Onofri et al., 1999; Selbmann et al., 2005; Nikitin, 2023)
Friedmanniomyces simplex	-	Sandstone	Endolithic, psychrophilic	(Selbmann et al., 2005; Nikitin, 2023)
Humicola marvinii	-	Soil	Psychrophilic	(Weinstein et al., 1997; Weinstein et al., 2000)
Jugulospora antarctica	*Apiosordaria antarctica*	Soil, bird colonies	Bird associated	(Stchigel et al., 2003; Nikitin, 2023)
Laetinaevia colobanthi	-	Plant tissues	Plant associated	(Onofri, 1999)
Paecilomyces antarcticus	-	Invertebrate animals (springtail)	Entomogenous	(Bridge et al., 2005; Song et al., 2017)
Psychronectria hyperantarctica	*Thyronectria antarctica* var. *hyperantarctica*	Mossess	Bryophilous	(Hawksworth, 1973; Pawlowska et al., 2017; Hoshino et al., 2019; Rosa et al., 2020b; Rosa et al., 2021)
Rachicladosporium antarcticum	-	Rocks	Endolithic	(Coleine et al., 2017; Laichmanová, 2020)
Rachicladosporium mcmurdoi	-	Rocks, sandstones	Endolithic	(Selbmann et al., 2021)
Rhizophagus antarcticus	*Glomus antarcticum*	Plants roots	Endomycorrhizal	(Cabello et al., 1994; Barbosa et al., 2017)
Sclerotinia antarctica	*Sclerotium antarcticum*	Soil, Deschampsia antarctica	Plant associated	(Onofri, 1999; Bridge et al., 2008; Hoshino et al., 2019)
Trichocladium antarcticum	*Thielavia antarctica*	Lichens, birds spots, lake sediments	Lichen associated, bird associated, psychrotolerant	(Stchigel et al., 2003; Ogaki et al., 2020a; Nikitin, 2023; van den Brink et al., 2015)

A separate group represents fungi associated with typical and endemic Antarctic plants. De Carvalho et al. (2020), studying the cultivable fungi in mosses, demonstrated that mosses provide a favorable habitat for survival, colonization and establishment of symbionts and decomposer fungi in various extreme Antarctic conditions. However, no endemic fungi were found in this study, except for the species *Antarctomyces psychrotrophi-*

cus, but according to our data, the endemism of this species is disputable, which will be discussed below. The authors also note that the mycobiota of Antarctic mosses is poorly understood, and further research is likely to lead to the discovery of new fungal species (de Carvalho et al., 2020). Osono et al. (2019) investigated the mycobiota of mosses and dead tissues of introduced *Salix* spp. in Antarctica and compared it with the mycobiota of the same substrates in the Arctic. They identified several similarities and differences, but no endemic fungi were found in their study. There are studies of fungi causing diseases in Antarctic moss "fairy ring", among which the species *Psychronectria hyperantarctica* is noted, known only for Antarctica to date (de Menezes et al., 2019; Pawłowska et al., 2017; Rosa et al., 2020b). The parasitic species *Sclerotinia antarctica* and *Laetinaevia colobanthi* were isolated from the two known and endemic Antarctic vascular plants *Deschampsia antarctica* and *Colobanthus quietensis*, respectively, and has not been reported elsewhere in the literature. However, Hoshino et al. (2019), noting *S. antarctica* morphological similarity to the Arctic species *S. borealis*, suggest that a comparative study of these two species is necessary.

The parasitic fungus *Paecilomyces antarcticus* was isolated from the Antarctic springtail *Cryptopygus antarcticus* and described by Bridge et al. (2005). We could not find mentions of this species elsewhere, but it is possible that this fungus associated with the Antarctic springtail inhabits only its habitats - Antarctica, subantarctic islands, and Australia. The genome study of *C. antarcticus* by Song et al. (2017) shows that *C. antarcticus* contains an endogenous fungal gene acquired through horizontal transfer from a fungal parasite to its host. The authors also demonstrated the potential for horizontal transfer of cellulase genes from fungal parasites to hosts at an early stage of evolution in distantly related species of Arctic (*Onychiurus arcticus*) and Antarctic (*C. antarcticus*) springtails. We were unable to find other studies of parasitic fungi in Arctic springtails to determine the species of these fungi. However, the studies by Song et al. (2017) indicate long-term coevolutionary relationships between fungi and springtails, suggesting that fungi associated with endemic springtail species (and other animals) may also be endemic. Overall, a very limited number of studies on fungi associated with Antarctic animals have been noted (Simões et al., 2019), although potentially new and endemic fungal species could exist in this niche.

The study of the physiology of cryptoendolithic fungi, isolated from rocks, has become a topic of significant interest among researchers. Cryptoendolithic microorganisms form a small community that has adapted to live inside rocks in the smallest pores of rocks up to 10 mm deep, where conditions are milder than outside. Cryptoendolithic fungi have a melanized, thick-walled mycelium that protects against desiccation and intense UV radiation and have a highly reduced morphology with scarce differentiation. Exopolysaccharides secreted by hyphae may also protect them from desiccation and frost. As the living conditions of Antarctic cryptoendolithic fungi are believed to be similar to those on Mars, their physiological and genetic characteristics are actively studied. Selbmann et al. (2005) described four cryptoendolithic species (*Cryomyces antarcticus*, *C. minteri*, *Friedmanniomyces endolithicus*, *F. simplex*), among which *F. endolithicus*, noted as the most common and well adapted species to the harshest conditions of the Antarctic cryptoendolithic community (Selbmann et al., 2005), is studied the most intensively. *F. endolithicus* has been shown to be resistant to acute doses of gamma radiation, accompanied by an increase in metabolic activity (Pacelli et al., 2018). Coleine et al. (2020) sequenced the genome of *F. endolithicus* to study gene content and genomic patterns that can be associated with its specialization and found that some stress-resistance features, such as meristematic growth and cold tolerance, are enriched in *F. endolithicus*, which could be attributed to the adverse conditions of Antarctica. They also identified genomic features in response to salt, X-ray radiation, cold, and DNA damage, confirming the exceptional polyextremotolerance and ability to survive various stresses of this species.

The cryptoendolithic species *Cryomyces antarcticus* has been extensively studied for over a decade (Onofri et al., 2020). The genome project of *C. antarcticus* has been published (Sterflinger et al., 2014), and analysis of the genome did not reveal significant deviations from mesophilic fungi, but it suggests that the fungus possesses a unique set of previously unknown proteins that exhibit high stress resistance. The authors emphasize the need for a deep analysis of the *C. antarcticus* genome (Sterflinger et al., 2014). Selbmann et al. (2011) found that the DNA of *C. antarcticus* and *C. minteri* species exhibited high resistance to prolonged (up to 240 minutes) UV-B radiation compared to *Saccharomyces pastorianus*. Studies have been published on the radiation-protective pigments melanin of *C. antarcticus*, demonstrating its enhanced radioresistance (Pacelli et al., 2020). This fungus also maintained survival, DNA integrity, ultrastructure stability, and rapid recovery of metabolic activity after 18 months of exposure to space and Martian conditions in low-Earth orbit (Onofri et al., 2020). The authors of these studies note that their findings have astrobiological value and warrant reconsideration of the possibility of extraterrestrial life. *Rachicladosporium antarcticum, R. mcmurdoi* and *Extremus antarcticus* appears to be the least endolithic species studied for now (Table 4).

Based on these findings, it can be summarized that the Antarctic region harbors scientifically intriguing fungal species, including those with potential biotechnological applications. However, further research is needed to explore the overall diversity of fungi in Antarctica, as well as in similar habitats, to ascertain the endemism of Antarctic species. Additionally, the physiology and genome of the fungi already described in Antarctica require further investigation.

Characteristic Arctic Fungi

The identification of information about endemic fungi in the Arctic has proven to be more challenging than the search for Antarctic endemics. This may be due to the fact that the investigated Arctic regions are less isolated, except for islands, many of which have been sporadically or not studied at all for their mycota. Additionally, the Arctic region is inhabited by numerous mycorrhizal fungal species, the distribution of which is often studied by collecting fruiting bodies or direct microscopy, which was not included in this review. As a result of our study, only a few unique fungal species specific to the Arctic region were identified (Table 5), and there is practically no information about these species. The parasitic fungus *Comoclathris arctica*, which parasitizes herbaceous plants, is known from the high Arctic of Canada (Shoemaker and Babcock, 1992). The name of this species in Index Fungorum is marked as obsolete (http://www.indexfungorum.org/Names/NamesRecord.asp?RecordID=360252), and no DNA sequences or other studies of this fungus could be found. The species *Monodictys arctica* was found in the roots of *Saxifraga oppositifolia* in the high Arctic of Canada in 2006 and described by Day et al. (2006). It was later found in Alaska (Timling et al., 2014) and Svalbard (Zhang et al., 2015a,b; Zhang and Yao, 2015), but we could not find any mentions of its distribution in other regions. Three species of the genus *Penicillium* (*P. arcticum*, *P. groenlandense, P. svalbardence*) were discovered and identified as potentially new to science by Gunde-Cimerman et al. (2003) in the ice and seawater of Svalbard. We could not find any further mentions of *P. arcticum*, including its name in Indexfungorum or DNA sequences in the GenBank. *P. svalbardence* was described as a new species a few years later and noted as psychrotolerant (Sonjak et al., 2007), but we could not find more information about its distribution and physiology. The dimorphic fungus *Psychromyces glacialis* was recently discovered in the ice and cryoconites of Svalbard and Greenland, and described and noted as psychrophilic by Perini et al. (2021). Arai et al. (2022) isolated and characterized proteins from *P. glacialis* that bind ice, which are necessary for the fungus to survive freezing temperatures.

Table 5. Endemic fungal species of Arctic; * - these names are not on the Indexfungorum or are outdated.

Species of fungi (modern names from the Index Fungorum)	Substrate of detection	Ecology	References
*Comoclathris arctica**	Plants: *Festuca brachyphylla*, *Puccinellia angustata*	Plant parasitic	(Shoemaker and Babcock, 1992; Crous et al., 2021a)
Monodictys arctica	Roots of *Saxifraga oppositifolia*, lichens, plant tissues, soil, lake water	Endophytic, lichen associated, water	(Day et al., 2006; Timling et al., 2014; Zhang et al., 2015a,b; Zhang and Yao, 2015)
*Penicillium arcticum**	Ice, water	Saprotrophic	(Gunde-Cimerman et al., 2003)
Penicillium svalbardence	Ice, water	Saprotrophic, psychrotolerant	(Gunde-Cimerman et al., 2003)
*Penicillium groenlandense**	Ice, water	Saprotrophic	(Gunde-Cimerman et al., 2003)
Psychromyces glacialis	Ice, cryoconite	Psychrophilic	(Perini et al., 2021)

Bipolar endemic fungi

Fungi that we refer to as putative bipolar endemics were identified by researchers exclusively in two polar regions. We were able to identify six such species of fungi (Table 6), while Cox et al. (2016), through the analysis of Antarctic fungal eDNA (ITS region) and comparison with similar data from other regions, discovered approximately 20 bipolar fungi identified to the genus or higher taxonomic category. In our study, all bipolar species were initially found in Antarctica, and then, usually after a significant time lapse, they were also observed in the Arctic (Table 6). In attempting to ascertain the complete identity of putative bipolar endemic species, we encountered a number of challenges: 1) for *Acrodontium antarcticum* and *Antarctomyces pellizariae*, only sequences from Antarctic cultures are known, and Arctic studies (Conery, 2021; Nikitin and Semenov, 2022) only mention the names of these species, with the DNA sequences themselves not deposited in GenBank; 2) the well-known endemic Antarctic species, *Antarctomyces psychrotrophicus*, was recorded in Arctic soil studies by Timling et al. (2014), but BLAST results show similarity of ITS regions of the Arctic fungus with the type strain at 96.21%, which is insufficient for species identification; 3) *Cladosporium antarcticum* was recorded in Arctic peat (Grum-Grzhimaylo et al., 2016, 2018) and on feathers of Arctic birds (Robicheau et al., 2019), but in the first case, sequences were not deposited in GenBank, and in the second case, the BLAST results showed 100% identity of the ITS region of the Arctic fungus not only with *C. antarcticum*, but also with several other species of the genus *Cladosporium*; 4) for Arctic specimens of *Mortierella antarctica*, the similarity of the ITS region ranges from 98.5 to 99.92%, and no other evidence was found to suggest that they are the same species. As a result, only one species, *Cadophora antarctica*, initially found in Antarctica (Crous et al., 2017), was soon discovered in the Arctic (Svalbard) and described as a bipolar species based on the sequencing results of ITS and LSU rDNA sequences (99.21% and 100% similarity to the type material, respectively) and cultural-morphological characteristics (Iliushin, 2020). However, this species has been recently described and there is no guarantee that it will not be found later in other regions, especially given that both occurrences of this fungus are associated with anthropogenic substrates.

Thus, despite the available information on common fungal species in Antarctica and the Arctic, and attempts to hypothesize the influence of ecological selection and geographic distribution on fungal communities in geographically distant polar regions (Bridge and Spooner, 2012; Cox et al., 2016), there is currently very little evidence for fungi that are polar or bipolar endemics.

Table 6. Presumably bipolar endemic species of fungi; proved bipolar species is in bold.

Species of fungi (modern names from the Index Fungorum)	Substrate of detection	Ecology	GenBank number of antarctic strains (ITS)	GenBank numbers of arctic strains (ITS)	Similarity	References of articles with sequences of Arctic strains	material of DNA isolation of Arctic fungi	Comments	References (Antarctica)	References (Arctic)
Acrodontium antarcticum	Rhizosphere, wood	Plant pathogenic	MH862213	-	> 97%	(Conery, 2021)	eDNA	no sequences of Arctic strains in a GenBank	(Vishniac, 1996; Onofri, 1999)	(Conery, 2021)
Antarctomyces pellizariae	Soil, snow, rocks, lake sediments, antropogenic substrartes	Psychrophilic	NR_164245	-	-	(Nikitin and Semenov, 2022)	pure culture	no sequences of Arctic strains in a GenBank	(de Menezes et al., 2017, 2017; Gomes et al., 2018; Alves et al., 2019; Ogaki et al., 2020a,b; Nikitin, 2023)	(Nikitin and Semenov, 2022)
Antarctomyces psychrotrophicus	Soil, antropogenic substrates, moss, peat, lichens, gut of Eretmoptera murphyi, air, penguins feathers, animal seals, lake water and sediments, snow	Psychrophilic	MH874317	KC965756	96.21%	(Timling et al., 2014)	eDNA	-	(Stchigel et al., 2001; Arenz et al., 2006, 2011; Bridge and Denton, 2007; Duncan et al., 2010; Arenz and Blanchette, 2011; Gonçalves et al., 2012; Yu et al., 2014; Kochkina et al., 2014; Abneuf et al., 2016; Ding et al., 2016; Krishnan et al., 2016; Nikitin, 2018; Nikitin, 2023; de Menezes et al., 2019; de Carvalho et al., 2020; Ogaki et al., 2020a; Devoto et al., 2022)	(Timling et al., 2014; Kirtsideli et al, 2014, 2016; Nikitin et al., 2021)
Cadophora antarctica	Soil with diesel, coal mine spoil	Psychrotolerant	NR_156381	MN833351	99.21%	(Iliushin, 2020)	pure culture	similarity of LSU (MT362720) with a type material is 100%, morphological description is also provided	(Crous et al., 2017)	(Iliushin, 2020; Iliuchin et al., 2022a)
Cladosporium antarcticum	Permafrost sediments, peat, soil, feathers	n.i.	OR046553	MK049894	100%	(Robicheau et al., 2019)	pure culture	similarity 100% with 5 or more species of *Cladosporium* including *C.antarcticum*	(Kochkina et al., 2012; Schubert et al., 2007)	(Grum-Grzhimaylo et al., 2016, 2018; Robicheau et al., 2019)

Species of fungi (modern names from the Index Fungorum)	Substrate of detection	Ecology	GenBank number of antarctic strains (ITS)	GenBank numbers of arctic strains (ITS)	Similarity	References of articles with sequences of Arctic strains	material of DNA isolation of Arctic fungi	Comments	References (Antarctica)	References (Arctic)
Mortierella antarctica	Soil, mosses, lake sediments, antropogenic	Saprotrophic	MH859873	KC965343	99.45%	(Timling et al., 2014)	eDNA	-	(Frate and Caretta, 1990; Onofri, 1999; Tosi et al., 2002; Ding et al., 2016; Ogaki et al., 2020a,b; Nikitin, 2023; Gomes et al., 2018)	(Timling et al., 2014; Semenova et al., 2016; Tsuji et al., 2022)
				LC514998	99.69%	(Tsuji et al., 2022)	pure culture	-		
				LC515021	99.69%		pure culture	-		
				LC515040	99.92%		pure culture	-		
				LC515137	99.85%		pure culture	-		
				-	98.5%	(Semenova et al., 2016)	eDNA	number of the strain is among KX401620-KX404870		

Conclusions

The Arctic and Antarctic regions are extreme environments to life in general, and fungi in particular, whether as saprotrophs or symbionts and parasites. Of the many studies that reported on fungi in the polar regions, only those that used cultivation and/or molecular characterisation of eDNA provide useful information for answering the main questions of whether there are fungi unique and endemic to the Artic, Antarctica or both.

Based on available literature in which cultivation and isolation methods of eDNA were applied, 1324 species of fungi have been iden- tified in polar regions, with the fungal biodiversity being higher in the Arctic compared to Antarctica. The difference in fungal species diversity between the two polar regions can largely be explained by variations in substrates specific to the Arctic and Antarctica. The methods employed for detecting fungi limit the detected biodiversity, thus a comprehensive approach is preferred. Most fungal species discovered are cosmopolitan, while the presence of endemic species in polar regions is mostly poorly supported, therefore caution should be exercised when claiming certain fungi as endemic to the polar regions or both poles. We believe that the statement made for microorganisms "Everything is everywhere, but the environment selects" (Baas Becking, 1934) may remain relevant for almost a century. However, for fungi, we would slightly rephrase this statement as: "Fungi are everywhere but the environment selects those that can become established".

Acknowledgements

The authors thank Marina Georgieva for her help in verifying the species names of fungi during compiling a list of fungi of the polar regions. This work was supported by the Wageningen University [3100000842]; the Russian Science Foundation [19-14-00102]; the Government basic research program of MSU [121032500077-8, 121051400061-9].

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Supplemental materials

Here is just a part of the Supplemental materials. All the rest are available at this link:
https://www.sciencedirect.com/science/article/pii/S1749461324000277#appsec1

Supplemental Tables 1A, 1E, 4.

Supplem. Table 1A. Fungi reported from the polar regions. F - frozen; D - dry; C - cooling, Cul - by plating, eDNA - by isotation total DNA from samples, Morph - morphology; M - molecular; n.i. - no information; ** - the abbreviations are in the Supplem. Table 1E.

Divisions of fungi	Species of fungi (modern names from the Index Fungorum)	Archaic names of species from articles, if different	Soil type(s); Substrate	Location of studies in the North pole	Location of studies in the South pole	Storage of samples	Method(s) of detection	Method(s) of identification	Role(s) and/or ecological associating**	Reference(s) of species detection and ecology in Arctic	Reference(s) of species detection and ecology in Antarctica	Additional reference(s) of species ecological features
Mucoromycota	*Absidia cylindrospora* Hagem	-	Mosses	Arctic: Canada	-	D	Cul	Morph	S	Osono et al., 2012	-	-
Mucoromycota	*Absidia glauca* Hagem	-	Driftwood	Arctic: Iceland	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Mucoromycota	*Absidia psychrophilia* Hesselt. & J.J. Ellis	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Acaulium caviariforme* (Malloch & Hubart) Sand.-Den., Guarro & Gené	*Microascus caviariformis* Malloch & Hubart	Bird colonies	-	Antarctica	n.i.	Cul	n.i.	S,TF	-	Nikitin, 2021 (in Russian) = Nikitin, 2023	Novakova et al., 2018; Zhang et al., 2018; Karunarathna et al., 2020
Ascomycota	*Acremonium alternatum* Link	-	Stones with algae, regoliths	-	Antarctica: Larsemann Hills oasis, Russkaya Station	F	Cul	Morph	S	-	Marfenina et al., 2016	-
Ascomycota	*Acremonium berkeleyanum* (P. Karst.) W. Gams	-	Soil	-	Antarctica: Antarctic Peninsula	F	Cul	Morph	S	-	Kochkina et al., 2019	-
Ascomycota	*Acremonium charticola* (Lindau) W. Gams	*Acremonium* cf. *charticola*	Tundra soils, cryophylic alpine meadow, soil, coal mine spoil	Arctic: Svalbard, White Sea area, WSBS, Novaya Zemlya, Polar Urals	Antarctica: Victoria Land, Ross Sea region, Deception Iasland	C,D	Cul,eDNA	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsidely et al., 2010 (in Russian); Grum-Grzhimaylo et al., 2018; Nikitin et al., 2021; Iluchin et al., 2022a	Zucconi et al., 1996; Rosa et al., 2020	-
Ascomycota	*Acremonium chrysogenum* (Thirum. & Sukapure) W. Gams	-	Littoral soil	Arctic: Barents Sea coast	-	F	Cul	Morph	S,PF	Bubnova and Konovalova, 2018 (in Russian)	-	-

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Divisions of fungi	Species of fungi (modern names from the Index Fungorum)	Archaic names of species from articles, if different	Soil type(s); Substrate	Location of studies in the North pole	Location of studies in the South pole	Storage of samples	Method(s) of detection	Method(s) of identification	Role(s) and/or ecological associating**	Reference(s) of species detection and ecology in Arctic	Reference(s) of species detection and ecology in Antarctica	Additional reference(s) of species ecological features
Ascomycota	*Acremonium egyptiacum* (J.F.H. Beyma) W. Gams	-	Rocks	-	Antarctica: Heritage Range	F	Cul	M	S	-	Gonçalves et al., 2017	-
Ascomycota	*Acremonium felinum* (Marchal) Kiyuna, K.D. An, R. Kigawa & Sugiy.	-	Soil	Arctic: Apatiti	-	F	Cul	Morph	S	Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	-	-
Ascomycota	*Acremonium fuci* Summerb., Zuccaro & W. Gams	*Acremonium* cf. *fuci*	Soil, lake sediments, littoral sand	Arctic: White Sea area, WSBS, Barents Sea coast	-	C,D,F	Cul	Morph	S	Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Grum-Grzhimaylo et al., 2018	-	-
Ascomycota	*Acremonium fusidioides* (Nicot) W. Gams	-	Soil, air	Arctic: Svalbard, Barents Sea, Varandey, Shoyna	-	I,C	Cul	Morph,M	S,PF	Kirtsideli et al., 2011 (in Russian); Singh et al., 2012	-	-
Ascomycota	*Acremonium murorum* (Corda) W. Gams	*Gliomastix murorum* (Corda) S. Hughes	Permafrost soil, littoral soil	Arctic: Barents Sea coast	Antarctica: McMurdo Dry Valleys, S. Victoria Land	C,F	Cul	Morph	S,PF	Bubnova and Konovalova, 2018 (in Russian)	Baublis et al., 1991	-
Ascomycota	*Acremonium potronii* Vuill.	-	Antropogenic substrates (settlements)	Arctic: Izvestiy TSIK Ilands	-	n.i.	Cul	Morph	S	Kirtsidely et al., 2016 (in Russian)	-	-
Ascomycota	*Acremonium psychrophilum* C. Möller & W. Gams	-	Lichens	-	Antarctica: Ilands near the Antarctic Peninsula, Schirmacher Oasis	C,D	Cul	Morph	S,LA	-	Möller and Dreyfuss, 1996; Vishniac, 1996	-
Ascomycota	*Acremonium roseolum* (G. Sm.) W. Gams	-	Soil	Arctic: Svalbard, Barents Sea coast	-	F,C	Cul	Morph,M	S	Singh et al., 2012; Bubnova and Konovalova, 2018 (in Russian)	-	-
Ascomycota	*Acremonium rutilum* W. Gams	-	Plant tissues, mosses, lichens, soil	Arctic: Svalbard, White Sea area, WSBS	Antarctica: Iaslands near the Antarctic Peninsula	C,D	eDNA,Cul	M,Morph	S,LA,PA,E,PF	Bubnova and Velikanov, 2004 (in Russian); Zhang and Yao, 2015	Möller and Dreyfuss, 1996	-
Ascomycota	*Acremonium salmoneum* W. Gams & Lodha	-	Cryopeg	Arctic: Kolyma	-	n.i.	Cul	Morph	S	Ozerskaya et al., 2008	-	-
Ascomycota	*Acremonium sclerotigenum* (Moreau & R. Moreau ex Valenta) W. Gams	-	Soil	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Acremonium zonatum* (Sawada) W. Gams	-	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985; Kerry, 1990a	-

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Ascomycota	*Acrodontium antarcticum* Cabello	-	Rhizosphere, wood	Arctic: Sweden	Antarctica: Danko Coast	n.i.	eDNA	M	PP	Conery, 2021	Vishniac, 1996 (cyt. Cabello, 1989); Onofri, 1999	-
Ascomycota	*Acrodontium crateriforme* (J.F.H. Beyma) de Hoog	-	Peat, lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	M	PF,PP	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Acrodontium luzulae* Videira & Crous	-	Dark ice with algae	Arctic: Greenland	-	n.i.	Cul	M	IF,AI	Perini et al., 2019	-	-
Ascomycota	*Acrodontium simplex* (F. Mangenot) de Hoog	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	M	PF,PP	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Aequabiliella effusa* (Damm & Crous) Crous	*Phaeomoniella effusa*	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Akanthomyces lecanii* (Zimm.) Spatafora, Kepler & B. Shrestha	*Lecanicillium lecanii* (Zimm.) Zare & W. Gams; *Verticillium* cf. *lecanii*; *Cordyceps confragosa*	Permafrost sediments, moss, gypsum crust, littoral soil, soil, rocks, conifer wood	Arctic: Finland, White Sea area, WSBS, Barents Sea coast	Antarctica: McMurdo Dry Valleys, Victoria Land, Gondvana Lake, Prior Iland, Adelie Cove, Kay Iland, Kohler Head, Antarctic Peninsula	F,D	Cul	Morph,M	S,PA,EP,PF	Bubnova and Velikanov, 2004 (in Russian); Kaitera et al., 2019	Fenice et al., 1997; Onofri et al., 2000; Tosi et al., 2002; Hughes and Lawley, 2003; Bridge et al., 2008b; Kochkina et al., 2012	Bridge et al., 2005
Ascomycota	*Akanthomyces muscarius* (Petch) Spatafora, Kepler & B. Shrestha	*Lecanicillium muscarium* (Petch) Zare & W. Gams	Permafrost sediments, lake sediments, soil	Arctic: White Sea area, WSBS	Antarctica: McMurdo Dry Valleys, Iland Livingstone, Deception Island	F,C	Cul,eDNA	Morph,M	S,PF	Grum-Grzhimaylo et al., 2016	Kostadinova et al., 2009; Kochkina et al., 2012; Rosa et al., 2020	-
Ascomycota	*Alatospora acuminata* Ingold	-	Lichens, soil, peat, permafrost soil	Arctic: Svalbard, Siberia, Canada/ Alaska	-	F	eDNA	M	W,S,PF	Lydolph et al., 2005; Timling et al., 2014; Semenova et al., 2015; Zhang et al., 2015a	-	-
Ascomycota	*Alatospora flagellata* (Gönczöl) Marvanová	-	Lichens, plant tissues, lake water	Arctic: Svalbard	-	F	eDNA	M	S,W,LA,PA,E	Zhang et al., 2015a,b; Zhang and Yao, 2015	-	-
Ascomycota	*Albifimbria verrucaria* (Alb. & Schwein.) L. Lombard & Crous	*Myrothecium verrucaria* (Alb. & Schwein.) Ditmar	Soil	-	Antarctica: Warren Cave	F	eDNA	M	E	-	Connel and Staudigel, 2013	Li et al., 2020
Ascomycota	*Allantophomopsiella pseudotsugae* (M. Wilson) Crous	*Phacidium coniferarum* (G.G. Hahn) DiCosmo, Nag Raj & W.B. Kendr.	Moss, conifer wood	Arctic: Finland	Antarctica: Antarctic Peninsula, Rothera Point	F	eDNA,Cul	M	S,PA,PP	Kaitera et al., 2019	Jumpponen et al., 2003	-

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Ascomycota	*Allantophomopsis cytisporea* (Fr.) Petr.	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Allantophomopsis lycopodina* (Höhn.) Carris	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	E,PP	Timling et al., 2014	-	-
Ascomycota	*Alternaria alternata* (Fr.) Keissl.	-	Cryopeg, permafrost and tundra soils, cryophylic alpine meadow, anchient sediments, soil, frozen sediments, lichens, antropogenic substrates, air, plants, driftwood, peat, littoral sand, stones with algae, roots	Arctic: Kolyma, Polar Urals, Izvestiy TSIK Iaslands, Novaya Zemlya, Greenland, White Sea, WSBS, Sonsnovetz Iland, Barents Sea, Beliy nos, Novaya Zemlya, Toolik Lake;	Antarctica: McMurdo Dry Valleys, McMurdo Station, Ross Iland, Windmill Ilands, Ilands near the Antarctic Peninsula, Macquarie Iland, King George Iland, Signy Iland, Vestfold Hills, Edmonson Point, Victoria Land, Edmonson Point, Mac Robertson Land, Vestfold Hills, Dronning Maud Land, Robertskollen, Larsemann Hills oasis, Russkaya Station, Iland Livingstone	F,C	Cul	Morph,M	S,LA,W,PF	Bubnova and Velikanov, 2004 (in Russian); Gilichynsky et al., 2005; Ozerskaya et al., 2008; Kirtsidely et al., 2010, 2011,2016 (in Russian); Kochkina et al., 2011 (in Russian); Knowlton et al., 2013; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Dunleavy and Mack, 2021; Nikitin et al., 2021	Sun et al., 1978; Kerry and Weste, 1985; Ryan et al., 1989; Kerry, 1990b; Chalmers et al., 1996; Möller and Dreyfuss, 1996; Azmi and Seppelt, 1998; Tosi et al., 2005; Gilichinsky et al., 2007; Kostadinova et al., 2009; Zucconi et al., 2012; Connel and Staudigel, 2013; Knowlton et al., 2013; Marfenina et al., 2016	-
Ascomycota	*Alternaria arborescens* E.G. Simmons	-	Animal seals	-	Antarctica: King George Iland	F	Cul	Morph,M	S,AA	-	Devoto et al., 2022	-
Ascomycota	*Alternaria atra* (Preuss) Woudenb. & Crous	*Ulocladium atrum* Preuss	Antropogenic substrates, permafrost soil, wood	Arctic: Kara Sea region (Yamal), Kolyma	Antarctica: Deception Iland	C	Cul	Morph,M	S	Ozerskaya et al., 2008; Kirtsidely et al., 2016	Held and Blanchette, 2017	-
Ascomycota	*Alternaria botrytis* (Preuss) Woudenb. & Crous	*Ulocladium botrytis* Preuss	Cryopeg, permafrost anchient sediments	Arctic: Kolyma	Antarctica: McMurdo Dry Valleys	F	Cul	Morph	S,W	Gilichinsky et al., 2005; Ivanushkina et al., 2005; Ozerskaya et al., 2008	Gilichinsky et al., 2007	-
Ascomycota	*Alternaria chartarum* Preuss	*Ulocladium chartarum* (Preuss) E.G. Simmons	Soil, antropogenic substrates	Arctic: Franz Joseph Land, Taymyr, Severnaya Zemlya	Antarctica: Ross Sea region	F	Cul	M	S	Kirtsideli et al., 2016 (in Russian)	Arenz et al., 2006	-
Ascomycota	*Alternaria chlamydospora* Mouch.	*Alternaria* cf. *chlamydospora* Mouchacca	Lichens	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	S,LA	-	Möller and Dreyfuss, 1996	-
Ascomycota	*Alternaria citri* Ellis & N. Pierce	-	Permafrost soil	-	Antarctica: McMurdo Dry Valleys	C	Cul	Morph	S	-	Baublis et al., 1991	-

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Ascomycota	*Alternaria consortialis* (Thüm.) J.W. Groves & S. Hughes	*Ulocladium consortiale* (Thüm.) E.G. Simmons	Antropogenic substrates, air, driftwood, littoral soil, coal mine spoil, tundra soil	Arctic: Greenland, Barents Sea coast, Franz Joseph Land, Kara Sea, Vaygach Iland, Amderma, Taymyr, Magadan, Alaskan Arctic	Antarctica: Edmonson Point	C,F,I	Cul	Morph,M	S	Kirtsideli et al., 2011, 2016 (in Russian); Blanchette et al., 2016; Bubnova and Konovalova, 2018 (in Russian); Iluchin et al., 2022b	Onofri, 1999	-
Ascomycota	*Alternaria embellisia* Woudenb. & Crous	*Embellisia allii*	Soil	-	Antarctica: Skarvsnes, East Antarctica	F	Cul	M	PP	-	Tsuji et al., 2013; Tsuji, 2019	Corlett, 1996
Ascomycota	*Alternaria infectoria* E.G. Simmons	*Lewia infectoria* (Fuckel) M.E. Barr & E.G. Simmons	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PP	-	Connel and Staudigel, 2013	
Ascomycota	*Alternaria maritima* G.K. Sutherl.	-	Soil	-	Antarctica: Livingston Island	n.i.	Cul	n.i.	S	-	Litova et al., 2014	Saccardo et al, 1931
Ascomycota	*Alternaria multiformis* (E.G. Simmons) Woudenb. & Crous	-	Snow	-	Antarctica: Antarctic Peninsula	C	Cul	M	PP	-	de Menezes et al., 2019	Karimzadeh and Fotouhifar, 2021
Ascomycota	*Alternaria oudemansii* (E.G. Simmons) Woudenb. & Crous	-	Antropogenic substrates	Arctic: Izvestiy TSIK Iaslands	-	n.i.	Cul	Morph	S	Kirtsidely et al., 2016	-	-
Ascomycota	*Alternaria phragmospora* Emden	-	Coal mine spoil	Arctic: Magadan	-	C	Cul	M	S	Iluchin et al., 2022b	-	-
Ascomycota	*Alternaria tellustris* (E.G. Simmons) Woudenb. & Crous	*Embellisia tellustris* E.G. Simmons	Soil	-	Antarctica: Victoria Land, Edmonson Point	C	Cul	Morph	S	-	Tosi et al., 2005	-
Ascomycota	*Alternaria tenuissima* (Kunze) Wiltshire	*Helminthosporium tenuissimum* Kunze; *Macrosporium tenuissimum* (Kunze) Fr.	Air, driftwood, ice core	Arctic: Greenland, Iceland, Kara Sea, Vaygach Iland, Barents Sea, Novaya Zemlya	Antarctica: King George Iland, Vostok Station	C,I	Cul	Morph,M	I,S,PF	Kirtsideli et al., 2011 (in Russian); Knowlton et al., 2013; Blanchette et al., 2016	Lasiewicz and Czarnecki, 1999 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/flista.html#Aa	-
Ascomycota	*Amarenomyces ammophilae* (Lasch) O.E. Erikss.	*Camarosporium metableticum* Trail	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985; Kerry, 1990a	-
Mucoromycota	*Ambomucor seriatoinflatus* X.Y. Liu & R.Y. Zheng	-	Driftwood	Arctic: Greenland	-	C	Cul	M	S	Blanchette et al., 2016	-	-

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Ascomycota	*Amorphotheca resinae* Parbery	*Hormoconis resinae* (Lindau) Arx & G.A. de Vries; *Cladosporium resinae* (Lindau) G.A. de Vries	Oil, wooden debris, Soil with kerosene	-	Antarctica: Schirmacher Oasis, Mac Robertson Land, Vestfold Hills, Mawson Base	D,F	Cul	Morph	S	-	Line, 1988; Kerry, 1990b	-
Basidiomycota	*Amphinema byssoides* (Pers.) J. Erikss.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Amylostereum areolatum* (Chaillet ex Fr.) Boidin	-	Lake sediments, conifer wood	Arctic: Finland, White Sea area, WSBS	-	C,F	Cul	M	AA,PP,PF,S	Grum-Grzhimaylo et al., 2016; Kaitera et al., 2019	-	-
Ascomycota	*Antarctomyces pellizariae* G.C.A. de Menezes, Godinho, B.A. Porto, P. Gonç. & C.A. Rosa	-	Soil, snow, rocks, lake sediments, antropogenic	Arctic: Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: Ilands near the Antarctic Peninsula, Robert Island, South Shetland Islands, King George Island	F	Cul	M	S, E, IF,EL,PsF	Nikitin and Semenov, 2022	de Menezes et al., 2017, 2019; Gomes et al., 2018; Alves et al., 2019; Ogaki et al., 2020a,b; Nikitin, 2021 (in Russian) = Nikitin, 2023	Rosa et al., 2019; Coelho et al., 2021
Ascomycota	*Antarctomyces psychrotrophicus* Stchigel & Guarro	-	Soil, antropogenic substrates, moss, peat, lichens, gut of Eretmoptera murphyi, air, penguins feathers, animal seals, lake water and sediments, snow	Arctic: Canada/ Alaska, Franz Josef Land, Novaya Zemlya, Izvestiy TSIK Iaslands	Antarctica: Ross Sea region, Antarctic Peninsula, Yankee Bay, Dronnin Maud Land, King George Iland, Signy Iland, Factory Cove, Hut Point, Potter Cove	F,C,I	eDNA,Cul	M,Morph	S,BA,AA,E,W,PsF	Timling et al., 2014; Kirtsideli et al, 2014, 2016 (in Russian); Nikitin et al., 2021; Nikitin and Semenov, 2022	Stchigel et al., 2001; Bridge and Denton, 2007; Duncan et al., 2010; Arenz et al., 2006, 2011; Arenz and Blanchette, 2011; Gonc alves et al., 2012; Yu et al., 2014; Kochkina et al., 2014; Abneuf et al., 2016; Ding et al., 2016; Krishnan et a., 2016; Nikitin, 2018, 2021 (in Russian) = Nikitin, 2023; de Menezes et al., 2019; de Carvalho et al.,2020; Ogaki et al., 2020a; Devoto et al., 2022	Rosa et al., 2019
Basidiomycota	*Antrodiella romellii* (Donk) Niemelä	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	M	S,PF	Grum-Grzhimaylo et al., 2016	-	-

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Ascomycota	*Apenidiella antarctica* Ivanushkina, Kochkina, Vasilenko & Ozerskaya	-	Permafrost soil	-	Antarctica: Russkaya Station	n.i.	Cul	M,Morph	n.i.	-	Crous et al., 2019	-
Ascomycota	*Aphanoascus fulvescens* (Cooke) Apinis	-	Dust	-	Antarctica: Edmonson Point, Newfoundland	n.i.	Cul	Morph	K	-	Mercantini, 1993	-
Ascomycota	*Aphanoascus keratinophilus* Punsola & Cano	*Chrysosporium keratinophilum*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	K,BA,AA	-	Caretta and Piontelli, 1977; Rosa et al., 2020	Ulfig et al., 1996; Bohacz et al., 2020
Ascomycota	*Aphanoascus terreus* (H.S. Randhawa & R.S. Sandhu) Apinis	*Chrysosporium indicum* Garg.	Soil	-	Antarctica: South Shetland Iland	n.i.	Cul	Morph	S,K,BA	-	Caretta and Piontelli, 1977	-
Ascomycota	*Apiognomonia errabunda* (Roberge ex Desm.) Höhn.	*Apiognomonia* cf. *errabunda*	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA,E	Zhang and Yao, 2015	-	-
Ascomycota	*Apiospora hydei* (Crous) Pintos & P. Alvarado	*Arthrinium hydei*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	En	-	Rosa et al., 2020	-
Ascomycota	*Arachnomyces kanei* Gibas, Sigler & Summerb.	*Onychocola kanei* Gibas, Sigler & Summerb.	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	OHP	Bellemain et al., 2013	-	Gibas et al., 2002
Basidiomycota	*Armillaria borealis* Marxm. & Korhonen	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Basidiomycota	*Arrhenia auriscalpium* (Fr.) Fr.	-	Soil, soil with Bryum algens	Arctic: Canada/ Alaska	Antarctica: James Ross Iland	F	eDNA	M	n.i.	Timling et al., 2014	https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#RAAS	-
Basidiomycota	*Arrhenia lobata* (Pers.) Kühner & Lamoure ex Redhead	*Leptoglossum lobatum* (Pers.) Ricken, *Leptotus lobatus* (Pers.) P. Karst.	Lichens, mosses, soil, Drepanocladus uncinatus, Pseudoleskea with bryophytes	Arctic: Svalbard	Antarctica: South Georgia	F	eDNA	M	S,PP,PF	Zhang et al., 2015a	https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#RAAS	-
Basidiomycota	*Arrhenia retiruga* (Bull.) Redhead	*Arrhenia retirugis*	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,PP	Zhang et al., 2015b	-	Davey and Currah, 2006

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Ascomycota	*Arthonia rufidula* (Hue) D. Hawksw., R. Sant. & Øvstedal	-	Lichens	-	Antarctica: Bunger Oasis, King George Iland	n.i.	n.i.	n.i.	LF	-	Olech and Alstrup, 1996	-
Ascomycota	*Arthrinium arundinis* (Corda) Dyko & B. Sutton	-	Permafrost soil, anchient sediments, lichens	Arctic: Svalbard	Antarctica: McMurdo Dry Valleys	F	eDNA,Cul	Morph	E,PP	Zhang et al., 2015a	Gilichinsky et al., 2007	Chen et al., 2014
Ascomycota	*Arthrinium phaeospermum* (Corda) M.B. Ellis	-	Soil	Arctic: Svalbard	Antarctica, continental	F,C	Cul	Morph,M	PP,PA	Singh et al., 2012	Göttlich et al., 2003 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	Li et al., 2020
Ascomycota	*Arthrinium sphaerospermum* Fuckel	-	Permafrost sediments, soil	Arctic	Antarctica	F	Cul	Morph	S,PA	Ivanushkina et al., 2005	Nikitin, 2018 (in Russian)	Minter and Cannon, 2018
Ascomycota	*Arthrobotrys psychrophilus* (Drechsler) M. Scholler, Hagedorn & A. Rubner	*Monacrosporium psychrophilum* (Drechsler) R.C. Cooke & C.H. Dickinson	Soil, plants	-	Antarctica: Galindez Iland	F	Cul	Morph	N	-	Gray et al., 1982	-
Ascomycota	*Arthrobotrys robustus* Dudd.	*Arthrobotrys robusta* Dudd.	Bird associated soil and lichens, feathers	-	Antarctica: Signy Iland, Scar Hills, Hope Bay	F	Cul	Morph	NP	-	Gray and Smith, 1984	-
Ascomycota	*Arthrobotrys superbus* Corda	*Arthrobotrys superba* Corda	Mosses	-	Antarctica: Victoria Land, Harrow Peaks, Terra Nova Bay	F	Cul	Morph	PA	-	Tosi et al., 2002	-
Ascomycota	*Arthroderma cuniculi* C.O. Dawson	*Arthroderma* cf. *cuniculi*	Mosses	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	PA,K	-	Möller and Dreyfuss, 1996	Al-Musallam, 1989
Ascomycota	*Arthroderma eboreum* (Brasch & Y. Gräser) Y. Gräser & de Hoog	*Trichophyton eboreum* Brasch & Y. Gräser	Soil	-	Antarctica: Ross Sea region	F	eDNA	M	K	-	Arenz et al., 2011 (ITS identification 93%)	Ogorek et al., 2022
Ascomycota	*Arthroderma magnisporum* (Stchigel, Cano, Mac Cormack & Guarro) Rahul Sharma & Hubka	*Chrysosporium magnasporum* Stchigel, Cano, Mac Cormack & Guarro	Bird pellet	-	Antarctica: King George Island, Potter Cave	n.i.	n.i.	M,Morph	K	-	Crous et al., 2013	-

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Ascomycota	*Arthroderma oceanitis* (Stchigel, Cano, Archuby & Guarro) Rahul Sharma & Hubka	*Chrysosporium oceanitesii* Stchigel, Cano, Archuby & Guarro	Dead bird, lake sediments	-	Antarctica: King George Island, Three Brothers Hill, Antarctic Peninsula	F	Cul	M,Morph	K,BA	-	Crous et al., 2013; Ogaki et al., 2020a	-
Ascomycota	*Ascochyta manawaorae* Verkley, Woudenb. & Gruyter	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PP,S	Bellemain et al., 2013	-	https://scd.landcareresearch.co.nz/Specimen/PDD_98412
Ascomycota	*Ascochyta phacae* (Corbaz) Qian Chen & L. Cai, in Chen, Jiang, Zhang, Cai & Crous	*Didymella phacae*	Coal mine spoil, driftwood	Arctic: Svalbard, Siberia	-	C	Cul	M	E,PA	Blanchette et al., 2016; Iluchin et al., 2022a	-	-
Ascomycota	*Ascochyta skagwayensis* (R. Sprague) Punith.	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PP	Bellemain et al., 2013	-	Schlatter et al., 2018
Ascomycota	*Ascochyta stilbocarpae* Syd.	-	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985; Kerry, 1990a	-
Ascomycota	*Ascocoryne albida* (Berk.) Seifert	*Ascocoryne solitaria*	Wood, conifer wood	Arctic: Finland	Antarctica: Deception Iland	C,F	Cul	M	S,PA	Kaitera et al., 2019	Held and Blanchette, 2017	-
Ascomycota	*Ascocoryne cylichnium* (Tul.) Korf	-	Driftwood, conifer wood	Arctic: Iceland, Finland, Siberia	-	C,F	Cul	M	S,PA	Blanchette et al., 2016; Kaitera et al., 2019	-	-
Ascomycota	*Ascocoryne sarcoides* (Jacq.) J.W. Groves & D.E. Wilson	-	Driftwood, conifer wood	Arctic: Greenland, Finland, Siberia	-	C,F	Cul	M	S,PA	Blanchette et al., 2016; Kaitera et al., 2019	-	-
Ascomycota	*Ascotricha erinacea* Zambett.	*Dicyma olivacea* (Emoto & Tubaki) Arx	Soil	-	Antarctica: Victoria Land, Edmonson Point	C	Cul	Morph	S	-	Onofri et al., 2000; Tosi et al., 2005	-
Ascomycota	*Aspergillus aculeatus* Iizuka	-	Soil	Arctic: Svalbard	Antarctica: King George Iland	F,C	Cul	Morph,M	S	Singh et al., 2012	Ding et al., 2016	-
Ascomycota	*Aspergillus amstelodami* (L. Mangin) Thom & Church	*Eurotium amstelodami* L. Mangin	Permafrost soil, frozen sediments, lake water	Arctic: Svalbard, Kolyma, Siberia	Antarctica: McMurdo Dry Valleys	F	eDNA,Cul	M,Morph	S,PF,W	Ozerskaya et al., 2008; Bellemain et al., 2013; Zhang et al., 2015b	Zucconi et al., 2012	-
Ascomycota	*Aspergillus candidus* Link	-	Soil	Arctic: Murmansk region	-	n.i.	Cul	Morph	S,PF	Marfenina et al., 2014 (in Russian)	-	-
Ascomycota	*Aspergillus carneus* Blochwitz	-	Soil	Arctic: Murmansk region	-	n.i.	Cul	Morph	S	Marfenina et al., 2014 (in Russian)	-	-

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Ascomycota	*Aspergillus clavatus* Desm.	-	Soil, microbial mat	Arctic: Murmansk region	Antarctica: continental, lakes in the Larsemann Hills, Vestfold Hills and the McMurdo Dry Valleys	n.i.	Cul	Morph,M	S	Marfenina et al., 2014 (in Russian)	Brunati et al., 2009; Göttlich et al., 2003 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Aspergillus conicus* Blochwitz	-	Ice core, dark ice	Arctic: Greenland	-	n.i.	Cul	M	IF,OHP,E,W,AA	Knowlton et al., 2013; Perini et al., 2019	-	Bharathidasan and Panneerselvam, 2012; Kannan et al., 2022
Ascomycota	*Aspergillus fischeri* Wehmer	*Neosartorya fischeri* (Wehmer) Malloch & Cain; *Aspergillus thermomutatus* (Paden) S.W. Peterson	Soil, permafrost soil	Arctic: Franz Joseph Land	Antarctica: South Shetland Ilands, King George (EACF), Deception Island	C,F	Cul,eDNA	Morph,M	S,PHAOF,PF,PtF	Bergero et al., 1999	Rosa et al., 2020; de Silva et al., 2022	-
Ascomycota	*Aspergillus flavipes* (Bainier & R. Sartory) Thom & Church	-	Tundra soils	Arctic: Polar Urals	-	n.i.	Cul	n.i.	S	Kirtsidely et al., 2010 (in Russian)	-	-
Ascomycota	*Aspergillus flavus* Link	*Aspergillus oryzae* (Ahlb.) Cohn	Soil, lake water, air, permafrost sediments, peat, stones with agae, animal seals	Arctic: Svalbard, White Sea area, WSBS, Western Siberia	Antarctica: King George Iland, East, Lake Vanda, Arctowski Station, King George Iland, Larsemann Hills oasis, Russkaya Station, Potter Cove, Deception Island	F,C,D	Cul,eDNA	Morph,M	S,AA,PF	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Singh et al., 2012; Marfenina et al., 2014 (in Russian); Yakushev et al., 2019	Czarnecki and Bialasiewicz, 1987; Ding et al., 2016; Marfenina et al., 2016; Kochkina et al., 2019; Rosa et al., 2020; Devoto et al., 2022	-
Ascomycota	*Aspergillus fumigatus* Fresen.	-	Permafrost soil, guano, soil, moss, animal seals, penguins	Arctic: White Sea area, WSBS, Apatiti, Kolyma, Svalbard	Antarctica: McMurdo Dry Valleys; Ellsworth Base, Taylor Valley, Lake Hoare, Vestfold Hills near Davis Station, Antarctic Peninsula, Rothera Point, Deception Iland, King George Iland	C,F,D	eDNA,Cul	Morph,M	S,AA,AP,AI,PF,OHP,TF,MsF,PtF	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Ozerskaya et al., 2008; Marfenina et al., 2014 (in Russian); Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Frossard et al., 2021	Appleby, 1962; Ellis, 1980; Greenfield, 1981 cyt. by Onofri, 1999; Baublis et al., 1991; Jumpponen et al., 2003; Litova et al., 2014; Abneuf et al., 2016; Nikitin, 2018 (in Russian); Kochkina et al., 2019; Devoto et al., 2022	Rosa et al., 2019

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Ascomycota	*Aspergillus glaucus* (L.) Link	*Eurotium herbariorum* (Weber ex F.H. Wigg.) Link ex Nees; *Aspergillus glaucus* var. *olivascens* (Sacc.) Sacc.	Permafrost soil, permafrost sediments, lake water	Arctic: Kolyma	Antarctica: McMurdo Dry Valleys, Lake Vanda, S. Victoria Land, Iland Livingstone	F	Cul	Morph	S	Ozerskaya et al., 2008; Marfenina et al., 2014 (in Russian)	Kostadinova et al., 2009; Kochkina et al., 2012; Litova et al., 2014	-
Ascomycota	*Aspergillus gracilis* Bainier	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Aspergillus heteromorphus* Bat. & H. Maia	-	Permafrost soil	-	Antarctica: McMurdo Dry Valleys, Victoria Land	C	Cul	Morph	S	-	Baublis et al., 1991	-
Ascomycota	*Aspergillus hiratsukae* Udagawa, Tsub. & Y. Horie	-	Permafrost soil	-	Antarctica: South Shetland Ilands, King George (Arctowski)	F	Cul	M	S,PHAOF	-	de Silva et al., 2022	-
Ascomycota	*Aspergillus nidulans* (Eidam) G. Winter	Emericella nidulans (Eidam) Vuill.	Soil, antropogenic substrates, moss, lake water	Arctic: Svalbard, Siberia, Kara Sea region (Yamal)	Antarctica: Windmill Ilands, Larsemann Hills oasis	F,C	eDNA,Cul	Morph,M	S,PF,W	Singh et al., 2012; Bellemain et al., 2013; Zhang et al., 2015b; Kirtsideli et al., 2016 (in Russian)	Azmi and Seppelt, 1998; Marfenina et al., 2016	-
Ascomycota	*Aspergillus niger* Tiegh.	-	Permafrost and tundra soils, lichens, air, antropogenic substrates, lake water, soil, coal mine spoil, microbial mat	Arctic: Kolyma, Polar Urals, Svalbard, White Sea area, WSBS, Kara Sea, Vaygach Iland, Marre-Sale, Dikson, Izvestiy TSIK Iaslands, Sonsnovetz Iland, Barents Sea, Kolguyev Iland, Beliy nos, Novaya Zemlya, Arctic Ocean, Franz Josef Land, Vize Iland, Taymyr, Komi	Antarctica: Lake Vanda, Cao Primavera, Continental Antarctica, Russian Station, Deception Iland, South Shetland Ilands; lakes in the Larsemann Hills, Vestfold Hills and the McMurdo Dry Valleys	F,C,D	eDNA,Cul	Morph,M	S,PF,PP	Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Ozerskaya et al., 2008; Singh et al., 2012, 2015; Zhang et al., 2015a; Marfenina et al., 2014 (in Russian); Iluchin et al., 2022a	Brunati et al., 2009; Marfenina et al., 2016; Nikitin, 2018 (in Russian); Rosa et al., 2020; Göttlich et al., 2003 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Aspergillus niveoglaucus* Thom & Raper	*Eurotium niveoglaucum* (Thom & Raper) Malloch & Cain	Soil	-	Antarctica	F	Cul	M	S	-	Nikitin, 2018 (in Russian)	-
Ascomycota	*Aspergillus penicillioides* Speg.	-	Permafrost soil	Arctic: Siberia	Antarctica: Warren Cave on Mt. Erebus, Deception Island	F	eDNA	M	S,XF,HF,TtF	Bellemain et al., 2013	Connel and Staudigel, 2013; Rosa et al., 2020	Ianutsevich et al., 2023
Ascomycota	*Aspergillus proliferans* G. Sm.	-	Soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S	Grum-Grzhimaylo et al., 2018	-	-

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Ascomycota	*Aspergillus pseudoglaucus* Blochwitz	-	Cryoconite, feathers	Arctic: Svalbard, Canada	-	F	Cul	M	IF,W,BA	Robicheau et al., 2019; Borze cka et al., 2022	-	-
Ascomycota	*Aspergillus repens* (Corda) Sacc.	*Eurotium repens*	Ice core, soil, air, lake sediments	Arctic: White Sea area, WSBS	Antarctica: Continental and Antarctic peninsula, McMurdo Sound, McMurdo Station, Ross Iland, S. Victoria Land, Vostok Station	C,F	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	Sun et al., 1978; Tubaki and Asano, 1965	-
Ascomycota	*Aspergillus restrictus* G. Sm.	-	Lake water, soil, ice core, dark ice	Arctic: Greenland	Antarctica: Cape Evans, Lake Vanda, S. Victoria Land, Deception Island	C?,F	Cul,eDNA	Morph,M	S,IF	Knowlton et al., 2013; Perini et al., 2019	Tubaki and Asano, 1965; Rosa et al., 2020	-
Ascomycota	*Aspergillus ruber* (Jos. König, Spieck. & W. Bremer) Thom & Church	*Eurotium rubrum* Jos. König, Spieck. & W. Bremer	Permafrost sediments	Arctic	Antarctica	F	Cul	Morph	S	Ivanushkina et al., 2005	https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use	-
Ascomycota	*Aspergillus sclerotiorum* G.A. Huber	-	Permafrost sediments, fossil seeds	Arctic: Kolyma	-	F	Cul	Morph	S	Stakhov et al., 2008	-	-
Ascomycota	*Aspergillus spinulosus* Warcup	*Warcupiella* sp. =*Warcupiella spinulosa* (Warcup) Subram.	Permafrost soil	Arctic: Siberia	Antarctica: McMurdo Dry Valleys, S. Victoria Land	C	eDNA,Cul	Morph,M	S	Lydolph et al., 2005	Baublis et al., 1991	-
Ascomycota	*Aspergillus sydowii* (Bainier & Sartory) Thom & Church	-	Permafrost soil, anchient sediments, permafrost sediments, soil, glacier sand, Ice core, air, stones with algae, cryoconite	Arctic: Svalbard, White Sea area, WSBS, Novaya Zemlya, Kolyma, Franz Josef Land, Taymyr, Fersman Iland, Hooker Iland near the Tikhaya Bay, Barents Sea, Kolguyev Iland, Varandey, Shoyna, Kara Sea, Ust'-Kara	Antarctica: McMurdo Dry Valleys, S. Victoria Land, Taylor Valley, Lake Hoare, Ross Sea region, Antarctic Peninsula, East, Macquarie Iland, Vostok Station, Larsemann Hills oasis, Ellsworth Mountains, Deception Iland, South Shetland Ilands	F,C,D,I	eDNA,Cul	Morph,M	S,PF,AA,OHP,W,IF	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Ozerskaya et al., 2008; Kirtsideli et al., 2011 (in Russian); Kochkina et al., 2011 (in Russian); Marfenina et al., 2014 (in Russian); Nikitin et al., 2021; Borze cka et al., 2022; Nikitin and Semenov, 2022	Baublis et al., 1991; Vishniac, 1996 (cyt. Bunt, 1965); Gilichinsky et al., 2007; Arenz and Blanchette, 2011; Kochkina et al., 2012, 2019; Godinho et al., 2015; Marfenina et al., 2016; Rosa et al., 2020	-
Ascomycota	*Aspergillus tennesseensis* Jurjević, S.W. Peterson & B.W. Horn	-	Animal seals	-	Antarctica: Primavera Cape	F	Cul	Morph,M	S,AA	-	Devoto et al., 2022	-
Ascomycota	*Aspergillus terreus* Thom	-	Soil, coal mine spoil	Arctic: Magadan	Antarctica: King George Iland, Deception Iland, South Shetland Ilands	C,F	eDNA,Cul	M,Morph	S,OHP,AP	Iluchin et al., 2022b	Ding et al., 2016; Rosa et al., 2020	-

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Ascomycota	*Aspergillus tubingensis* Mosseray	-	Lake sediments, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016, 2018	-	-
Ascomycota	*Aspergillus unguis* (Émile-Weill & L. Gaudin) Thom & Raper	-	Soil	-	Antarctica: Ross Sea region	F	eDNA	M	S	-	Arenz and Blanchette, 2011	-
Ascomycota	*Aspergillus ustus* (Bainier) Thom & Church	-	Permafrost soil, antropogenic substrates, peat, lake sediments, soil	Arctic: White Sea area, WSBS, Izvestiy TSIK laslands	Antarctica: McMurdo Dry Valleys	C	Cul	Morph	S,PF	Marfenina et al., 2014 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al, 2016 (in Russian)	Baublis et al., 1991; Steele et al., 1994	-
Ascomycota	*Aspergillus versicolor* (Vuill.) Tirab.	-	Tundra soils, permafrost sediments, bird feathers, soil, antropogenic substrates, lake water, ice core, air, peat, moss, animal seals	Arctic: White sea area, WSBS, Novaya Zemlya, Polar Urals, Svalbard, Taymyr, Franz Josef Land, Izvestiy TSIK laslands, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Siberia	Antarctica: McMurdo Dry Valleys, McMurdo Station, Ross Iland, Antarctic Peninsula, King George Iland, Macquarie Iland, Lake Vanda, Wright Valley, Northern Victoria Land, Lamplugh Iland, Vostok Station, Larsemann Hills oasis, Russkaya Station, Primavera Cape	F,C,D	eDNA,Cul	Morph,M	S,AA,BA,PF,W	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Lydolph et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008; Kirtsidely, 2010 (in Russian); Kochkina et al., 2011 (in Russian); Kirtsideli et al, 2010, 2014, 2016 (in Russian); Singh et al., 2015; Zhang et al., 2015b; Grum-Grzhimaylo et al., 2016, 2018; Nikitin et al., 2021; Nikitin and Semenov, 2022	Sun et al., 1978; Zucconi et al., 1996; Fenice et al., 1997; Kochkina et al., 2012; Ding et al., 2016; Marfenina et al., 2016; Nikitin, 2018 (in Russian); Devoto et al., 2022	-
Ascomycota	*Aspergillus wentii* Wehmer	-	Soil	Arctic: White Sea area, WSBS	-	D	Cul	Morph	S	Bubnova and Velikanov, 2004 (in Russian); Marfenina et al., 2014 (in Russian)	-	-
Basidiomycota	*Athelia arachnoidea* (Berk.) Jülich	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-
Basidiomycota	*Athelia epiphylla* Pers.	-	Soil, leaf	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Basidiomycota	*Athelopsis lembospora* (Bourdot) Oberw.	-	Roots, soil	Arctic: Svalbard, Finland	-	F,I	eDNA	M	S	Lorberau et al., 2017; Poosakkannu et al., 2017	-	-
Ascomycota	*Atradidymella muscivora* M.L. Davey & Currah	*Phoma muscivora* M.L. Davey & Currah	Lichens, lake water	Arctic: Svalbard	-	F	eDNA	M	PP,W	Zhang et al., 2015a,b	-	-

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Ascomycota	*Aureobasidium bupleuri* (Bills) Haelew. & Aime	*Kabatiella* cf. *bupleuri*	Snow	-	Antarctica: Antarctic Peninsula	C	Cul	M	IF	-	Menezes et al., 2019	-
Ascomycota	*Aureobasidium melanogenum* (Herm.-Nijh.) Zalar, Gostinčar & Gunde-Cim.	*Aureobasidium pullulans* var. *melanigenum*	Permafrost soil, soil, ice, melt water, sea water	Arctic: Kolyma, Svalbard	Antarctica: East, W. Queen Maud Land, Laurie Island, in the South Orkney Islands	F,C	Cul	Morph,M	S,IF,W	Ozerskaya et al., 2008; Zalar et al., 2008	Steele et al., 1994; Kochkina et al., 2019; Gaiser et al., 2021	-
Ascomycota	*Aureobasidium microstictum* (Bubák) W.B. Cooke	-	Tundra soils	Arctic: Polar Urals	-	n.i.	Cul	Morph	E,PP,W	Kirtsidely et al., 2010 (in Russian)	-	-
Ascomycota	*Aureobasidium proteae* (Joanne E. Taylor & Crous) Joanne E. Taylor & Crous	-	Soil, leaf	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Aureobasidium pullulans* (de Bary & Löwenthal) G. Arnaud	*Aureobasidium pullulans* var. *pullulans* (de Bary & Löwenthal) G. Arnaud	Cryopeg, permafrost and tundra soils, permafrost and frozen sediments, mosses, antropogenic substrates, air, leaves, plants, peat, lichens, soil with recreational plant community, ice, melt water, sea water, driftwood, lake sediments, stones with algae, snow, ice core	Arctic: Greenland, Novaya Zemlya, Kolyma, Polar Urals, Canada,White Sea, Sonsnovetz Iland, Barents Sea, WSBS, Kolguyev Iland, Beliy nos, Shoyna, Western Siberia, Komi, Kara Sea region, Yamal, Vaygach Iland, Marre-Sale, Ust'-Kara, Amderma, Kolba, Dikson, Taymyr Izvestiy TSIK Iaslands, Franz Josef Land, Fersman Iland, Zenith Cape of Heiss Iland, Svalbard, Siberia	Antarctica: McMurdo Dry Valleys, South Georgia, Macquarie Iland, Signy Iland, Mount Melbourne, Mac Robertson Land, Vestfold Hills, Mawson, Edmonson Point, Victoria Land, Taylor Valley, Lake Hoare, Lake Vanda, Marble Point, Brown Iland, Maraine Canyon, Larsemann Hills oasis, Deception Island	F,C,D	Cul,eDNA	Morph,M	S,PA,IF,W,PF	Ma et al., 1999; Bubnova and Velikanov, 2004 (in Russian); Gilichinsky et al., 2005; Ivanushkina et al., 2005; Lydolph et al., 2005; Ozerskaya et al., 2008; Zalar et al., 2008; Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Osono et al., 2012; Knowlton et al., 2013; Semenova et al., 2015; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Lapteva et al., 2017 (in Russian); Perini et al., 2019; Yakushev et al., 2019; Nikitin et al., 2021; Iluchin et al., 2022a; Nikitin and Semenov, 2022	Sun et al., 1978; Hurst et al., 1983; Kerry and Weste, 1985; Kerry, 1990a,b; Baublis et al., 1991; Chalmers et al., 1996; Vishniac, 1996 (cyt. Hurst et al., 1983); Tosi et al., 2002, 2005; Kochkina et al., 2012; Zucconi et al., 2012; Connel and Staudigel, 2013; Marfenina et al., 2016; Rosa et al., 2020	-
Ascomycota	*Aureobasidium subglaciale* (Zalar, de Hoog & Gunde-Cim.) Zalar, de Hoog & Gunde-Cim.	*Aureobasidium pullulans* var. *subglaciale* Zalar, de Hoog & Gunde-Cim.	Ice	Arctic: Svalbard	-	n.i.	Cul	M	IF	Zalar et al., 2008	-	-
Basidiomycota	*Aureonarius limonius* (Fr.) Niskanen & Liimat.	*Cortinarius luteus*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Austropaxillus squarrosus* (McNabb) Bresinsky & Jarosch	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA	-	Rosa et al., 2020	https://scd.landcareresearch.co.nz/Specimen/PDD_26292
Ascomycota	*Beauveria bassiana* (Bals.-Criv.) Vuill.	*Cordyceps bassiana* Z.Z. Li, C.R. Li, B. Huang & M.Z. Fan	Soil, soil with recreational plant community, frozen sediments, peat, ornothogenic soil, coal mine spoil	Arctic: Greenland, Svalbard, White sea area, WSBS, Izvestiy TSIK Iaslands, Alaska	Antarctica: Macquarie Iland, Continental Antarctica, McMurdo Dry Valleys, Deception Iland	C,F,D,I	Cul,eDNA	M,Morph	EP,PF	Bubnova and Velikanov, 2004 (in Russian); Meyling et al., 2012; Kirtsideli et al, 2014 (in Russian); Semenova et al., 2015; Grum-Grzhimaylo et al., 2016, 2018; Iluchin et al., 2022a	Roddam and Rath, 1997; Zucconi et al., 2012; Gonçalves et al., 2015	Bridge et al., 2005
Ascomycota	*Beauveria brongniartii* (Sacc.) Petch	-	Peat, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	EP,PF	Grum-Grzhimaylo et al., 2016, 2018	-	Zimmermann, 2007
Ascomycota	*Beauveria pseudobassiana* S.A. Rehner & Humber	-	Soil, cryoconite	Arctic: Greenland, Svalbard	-	C,F	Cul	M	EP,IF,W	Meyling et al., 2012; Borze cka et al., 2022	-	-
Ascomycota	*Belonidium solenia* (Sacc.) Raitv.	*Solenopezia solenia* Sacc.	Wood	-	Antarctica: Ross Sea region	C	Cul	M	S	-	Blanchette et al., 2010	-
Ascomycota	*Berkeleyomyces basicola* (Berk. & Broome) W.J. Nel, Z.W. de Beer, T.A. Duong & M.J. Wingf.	*Thielaviopsis basicola* (Berk. & Broome) Ferraris	Soil	Arctic: Apatiti	-	F	Cul	Morph	PA	Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	-	Nel et al., 2018
Ascomycota	*Bipolaris sorokiniana* Shoemaker	*Cochliobolus sativus*	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,PP	Zhang et al., 2015b	-	-
Ascomycota	*Bispora antennata* (Pers.) E.W. Mason	-	Permafrost sediments	Arctic	-	F	Cul	Morph	S	Ivanushkina et al., 2005	-	-
Basidiomycota	*Bjerkandera adusta* (Willd.) P. Karst.	-	Soil, dark ice with algae, cryoconite	Arctic: Greenland, Svalbard	Antarctica: East	F	Cul	Morph,M	S,PF,IF,W	Perini et al., 2019; Borze cka et al., 2022	Kochkina et al., 2019	-
Ascomycota	*Blodgettia bornetii* E.P. Wright	-	Soil	-	Antarctica: Showa Base, East and West Ongul, Continental Antarctica	C ?	Cul	Morph	WF,PA,AI	-	Tubaki, 1961	-
Ascomycota	*Boeremia exigua* (Desm.) Aveskamp, Gruyter & Verkley	*Phoma exigua* Desm.	Litter, plants, soil, driftwood	Arctic: Iceland, Novaya Zemlya, Franz Josef Land, Zenith Cape of Heiss Iland, Melekhov Cape of Alexandra Land	Antarctica: Macquarie Iland	F,C	Cul	Morph,M	S	Blanchette et al., 2016; Nikitin et al., 2021; Nikitin and Semenov, 2022	Kerry and Weste, 1985; Kerry, 1990a	-

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Basidiomycota	*Boletellus obscurecoccineus* (Höhn.) Singer	*Boletellus obscurococcineus*	Lichens, lake water	Arctic: Svalbard	-	F	eDNA	M	LA,Ec,W	Zhang et al., 2015a,b	-	-
Basidiomycota	*Boletinus asiaticus* Singer	*Suillus asiaticus*	Roots	Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Boletinus spectabilis (Peck)* Murrill	*Suillus (Fuscoboletinus) spectabilis*	Roots	Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Bostrichonema polygoni* (Unger) J. Schröt.	-	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	n.i.	Elvebakk and Prestrud, 1996	-	-
Basidiomycota	*Botryobasidium chilense* Hol.-Jech.	-	Air	-	Antarctica: Signy Iland	n.i.	n.i.	n.i.	S	-	Chalmers et al., 1996	http://www.indexfungo rum.org/Names/Names Record.asp?RecordID=112751
Ascomycota	*Botryotinia fuckeliana* (de Bary) Whetzel	-	Soil, driftwood	Arctic: Canada/ Alaska, Iceland	-	F,C	eDNA,Cul	M	S	Timling et al., 2014; Blanchette et al., 2016	-	-
Ascomycota	*Botrytis caroliniana* Xing P. Li & G. Schnabel	-	Soil	Arctic: Svalbard	-	C	eDNA	M	S	Frossard et al., 2021	-	-
Ascomycota	*Botrytis cinerea* Pers.	-	Permafrost soil, soil, air, leaves, plants, peat, coal mine spoil, glacier, cryoconite	Arctic: Canada, Svalbard, Kolyma, White Sea, WSBS, Sonsnovetz Iland, Barents Sea, Kolguyev Iland, Kara Sea, Ust'-Kara, Amderma, Varandey, Magadan	Antarctica: Windmill Ilands, South Georgia, Macquarie Iland, Arctowski Station, King George Iland	C,D,F,I	Cul	Morph,M	S,PF,IF,W	Elvebakk and Prestrud, 1996; Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008; Kirtsideli et al., 2011 (in Russian); Kochkina et al., 2011 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Borze cka et al., 2022; Iluchin et al., 2022b; Tsuji et al., 2022	Hurst et al., 1983; Kerry and Weste, 1985; Czarnecki and Bialasiewicz, 1987; Vishniac, 1996 (cyt. Hurst et al., 1983); Azmi and Seppelt, 1998; Nikitin, 2018 (in Russian)	-
Ascomycota	*Bryochiton monascus* Döbbeler & Poelt	-	Soil, ice	Arctic: Greenland, Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Bryoscyphus aestivalis* Gamundí & Spinedi	-	Plant tissues	-	Antarctica: Danco Coast	n.i.	n.i.	n.i.	PP	-	Onofri, 1999	-

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Ascomycota	*Byssochlamys spectabilis* (Udagawa & Shoji Suzuki) Houbraken & Samson	*Talaromyces spectabilis*	Rocks, soil	-	Antarctica: Heritage Range, Deception Island	F	Cul,eDNA	M	PHOF,S	-	Gonçalves et al., 2017; Rosa et al., 2020	-
Basidiomycota	*Byssomerulius corium* (Pers.) Parmasto	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	https://mycology.su/byssomerulius-corium.html
Ascomycota	*Cadophora antarctica* Rodr.-Andr., Stchigel, Mac Corm. & Cano	-	Soil with diesel, coal mine spoil	Arctic: Svalbard	Antarctica: South Shetland archipelago, King George Iland	C	Cul	M	S?	Iliushin, 2020; Iluchin et al., 2022a	Crous et al., 2017	-
Ascomycota	*Cadophora bubakii* (Laxa) Damm & S. Bie	*Phialophora bubakii* (Laxa) Schol-Schwarz	Antropogenic substrates, ice core	Arctic: Franz Joseph Land	Antarctica: Vostok Station	n.i.	Cul	Morph	n.i.(IF?)	Kirtsideli et al., 2016 (in Russian)	Abyzov, 1993 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Cadophora fastigiata* Lagerb. & Melin	*Phialophora fastigiata* (Lagerb. & Melin) Conant	Wood, soil, driftwood, feathers, sand, wooden huts, copepods, peat, lake sediments, littoral sand, coal mine spoil, conifer wood, fossil seeds	Arctic: Greenland, Iceland, Svalbard; Finland, White Sea area, WSBS; Barents Sea coast, Siberia	Antarctica: Ross Sea region, Victoria Land, Endsmon Point, Antarctic Peninsula, East, Sea near the Italian Base, Mowson Beach, Davis Station, Davis Beach, Mac Robertson Land, Vestfold Hills, Mawson, Edmonson Point, Winter Quarters Bay, McMurdo dump, Ross Iland, Cape Evans, Iland Livingstone, King George Iland, Primavera Cape	F,C,D	Cul	M,Morph	S,BA,AA,PA,PF	Kurek et al., 2007; Stakhov et al., 2008; Singh et al., 2012; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Kaitera et al., 2019; Iluchin et al., 2022a	Sun et al., 1978; Frate and Caretta, 1990; Kerry, 1990b; Zucconi et al., 1996; Onofri, 1999; Blanchette et al., 2004, 2010; Tosi et al., 2005; Arenz et al., 2006; Kostadinova et al., 2009; Arenz and Blanchette, 2011; Kochkina et al., 2019; Devoto et al., 2022	-
Ascomycota	*Cadophora gregata* (Allington & D.W. Chamb.) T.C. Harr. & McNew	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP,S	Lydolph et al., 2005	-	Hughes et al., 2002

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Ascomycota	*Cadophora luteo-olivacea* (J.F.H. Beyma) T.C. Harr. & McNew	*Cadophora* cf. *luteo-olivacea*	Soil, wood, lichens, plant tissues, antropogenic substrates, peat, driftwood, lake sediments, algobacterial mat, penguins feathers, lake water, dead plants (Salix sp.)	Arctic: Greenland, Iceland, Svalbard, White Sea area, WSBS, Novaya Zemlya, Barents Sea coast, Canada/ Alaska, Franz Joseph Land, Izvestiy TSIK Iaslands, Melekhov Cape of Alexandra Land	Antarctica: Ross Sea region, Ross Iland, Cape Evans, Antarctic Peninsula, East, Nimrod, Deception Iland, King George Iland, East Ongul Island, Syowa Station	F,C,I	eDNA,Cul	M,Morph	S,BA,E,PA,PF,W	Blanchette et al., 2016; Kirtsideli et al., 2014, 2016 (in Russian); Timling et al., 2014; Zhang et al., 2015a,b; Zhang and Yao, 2015; Grum-Grzhimaylo et al., 2016, 2018; Bubnova and Konovalova, 2018 (in Russian); Nikitin et al., 2021; Nikitin and Semenov, 2022	Blanchette et al., 2004, 2010; Arenz et al., 2006; Duncan, 2007; Arenz and Blanchette, 2011; Goncalves et al., 2012; Hirose et al., 2013; Held and Blanchette, 2017; Kochkina et al., 2019; Tsui, 2019; Nikitin, 2021 (in Russian) = Nikitin, 2023; Devoto et al., 2022	Travadon et al., 2015
Ascomycota	*Cadophora malorum* (Kidd & Beaumont) W. Gams	*Phialophora malorum* (Kidd & Beaumont) McColloch; *Sporotrichum malorum* Kidd & Beaumont	Soil, wood, moss, antropogenic substrates, lichens, plants, peat, algae, driftwood, littoral sand, algobacterial mat, lake sediment, animal seals, coal mine spoil, feathers	Arctic: Canada/ Alaska, Iceland, White Sea area, WSBS, Novaya Zemlya, Franz Joseph Land, Izvestiy TSIK Iaslands, Barents Sea coast, Melekhov Cape of Alexandra Land	Antarctica: Ross Sea region, Ross Iland, Cape Royds, Cape Evans, Antarctic Peninsula, East, King George Iland, Victoria Land, Edmonson Point, Adelie Cove, Starr Nunatak, Kay Iland, Harrow Peaks, Terra Nova Bay, Windmill Ilands, Ilands near the Antarctic Peninsula, Deception Iland, Machu Picchu station, Primavera Cape	F,C,D,I	eDNA,Cul	M,Morph	S,AA,LA,PA,PF,K,PtF	Bergero et al., 1999; Blanchette et al., 2016; Kirtsideli et al., 2014, 2016 (in Russian); Timling et al., 2014; Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Grum-Grzhimaylo et al., 2018; Robicheau et al., 2019; Nikitin et al., 2021; Iluchin et al., 2022a; Nikitin and Semenov, 2022	Azmi and Seppelt, 1998; Onofri, 1999; Möller and Dreyfuss, 1996; Tosi et al., 2002, 2005; Blanchette et al., 2004, 2010; Duncan et al., 2006; Duncan, 2007; Arenz et al., 2006, 2011; Arenz and Blanchette, 2011; Gonc alves et al., 2012, 2015; Hirose et al., 2016; Held and Blanchette, 2017; Kochkina et al., 2019; Rosa et al., 2020; Nikitin, 2021 (in Russian) = Nikitin, 2023; Devoto et al., 2022	-
Ascomycota	*Cadophora melinii* Nannf.	*Phialophora melinii* (Nannf.) Conant	Soil, permafrost soil, mosses, driftwood, coal mine spoil	Arctic: Greenland, Iceland, White Sea area, WSBS, Kolyma, Magadan	Antarctica: East, Antarctic Peninsula, King George Iland	F,C	Cul	Morph,M	S,PA,PF	Ozerskaya et al., 2008; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2018; Iluchin et al., 2022b	Möller and Dreyfuss, 1996; Held and Blanchette, 2017; Kochkina et al., 2019	Travadon et al., 2015
Ascomycota	*Cadophora novi-eboraci* Travadon, D.P. Lawr., Roon.-Lath., Gubler, W.F. Wilcox, Rolsh. & K. Baumgartner	-	Soil	Arctic: Franz Joseph Land, Melekhov Cape of Alexandra Land	Antarctica	F	Cul	M	S,PA	Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian)	Travadon et al., 2015

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Ascomycota	*Cadophora orchidicola* (Sigler & Currah) M.J. Day & Currah	*Leptodontidium orchidicola* Sigler & Currah	Soil, Colobanthus quitensis	Arctic: Canada/ Alaska	Antarctica: Grytviken South Georgia	F	eDNA	M	E	Timling et al., 2014	Pugh and Jones, 1986 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	Stroheker et al., 2021
Ascomycota	*Cadophora viticola* Gramaje, L. Mostert & Armengol	-	Soil	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Calycina discreta* (P. Karst.) Kuntze	*Pezizella discreta* (P. Karst.) Dennis	Lichens	Arctic: Svalbard	-	F	eDNA	M	LA,S	Zhang et al., 2015a	-	-
Ascomycota	*Calycina ellisii* (Dennis) Raitv.	-	Soil, roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Camposporium antennatum* Harkn.	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PA,S	Bellemain et al., 2013	-	-
Ascomycota	*Cenococcum geophilum* Fr.	-	Lichens, plant roots, soil, peat	Arctic: Svalbard, Finland, Siberia, Canada/Alaska, Toolik Lake	-	F,C,I	eDNA	M	Ec,LA,PF	Bjorbækmo et al., 2010; Timling et al., 2014; Semenova et al., 2015; Zhang et al., 2015a; Poosakkannu et al., 2017; Dunleavy and Mack, 2021; Frossard et al., 2021; Miyamoto et al., 2022	-	-
Ascomycota	*Cephalotrichum asperulum* (J.E. Wright & S. Marchand) Sand.-Den., Guarro & Gené	*Doratomyces asperulus* J.E. Wright & S. Marchand	Air	Arctic: Kara Sea, Kolba	-	I	Cul	Morph	S	Kirtsideli et al., 2011 (in Russian)	-	-
Ascomycota	*Cephalotrichum heliciforme* T.Y. Zhang	*Trichurus spiralis* Hasselbr.	Lichens, soil, littoral sand, stones with algae	Arctic: White Sea area	Antarctica: Ilands near the Antarctic Peninsula/ King George Iland, Larsemann Hills oasis	C,D,F	Cul	Morph	S,LA,Al	Bubnova, 2017	Möller and Dreyfuss, 1996; Marfenina et al., 2016	-
Ascomycota	*Cephalotrichum hinnuleum* Sand.-Den., Guarro & Gené	-	Coal mine spoil	Arctic: Svalbard	-	C	Cul	M	S	Iluchin et al., 2022a	-	-

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Ascomycota	*Cephalotrichum microsporum* (Sacc.) P.M. Kirk	*Doratomyces microsporus* (Sacc.) F.J. Morton & G. Sm.	Soil, stones with algae	-	Antarctica: Larsemann Hills oasis, Russkaya Station	F	Cul	Morph	S,PF	-	Marfenina et al., 2016	-
Ascomycota	*Cephalotrichum nanum* (Ehrenb.) S. Hughes	*Doratomyces nanus* (Ehrenb.) F.J. Morton & G. Sm.	Plants (litter), soil, littoral sand	Arctic: White Sea area, Barents Sea coast	Antarctica: South Georgia	D,F	Cul	Morph	S	Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian)	Hurst et al., 1983	Hurst et al., 1983
Ascomycota	*Cephalotrichum stemonitis* (Pers.) Nees	-	Antropogenic substrates, freshwater mud	Arctic: Kara Sea region (Yamal), Taymyr, Izvestiy TSIK Iaslands	Antarctica: Ross Sea area	n.i.	Cul	Morph	S	Kirtsideli et al., 2016 (in Russian)	Corte and Gestro, 1994	-
Ascomycota	*Ceratocystis piceae* (Münch) B.K. Bakshi	Ophiostoma piceae	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	Peng et al., 1996
Basidiomycota	*Cerinosterus luteoalbus* (de Hoog) R.T. Moore	-	Wood	-	Antarctica: Deception Iland, Lau- rie Island, in the South Orkney Islands	C	Cul	M,Morph	S	-	Held and Blanchette, 2017; Gaiser t al., 2021	-
Basidiomycota	*Ceriporiopsis subvermispora* (Pilát) Gilb. & Ryvarden	-	Lake sediments	Arctic: White Sea area, WSBS	Antarctica: Warren Cave on Mt. Erebus	C,F	Cul,eDNA	M	PF,PA,S	Grum-Grzhimaylo et al., 2016	Connel and Staudigel, 2013	Fukushima and Kirk, 1995
Basidiomycota	*Cerrena unicolor* (Bull.) Murrill	-	Soil	-	Antarctica: Ross Sea region	F	eDNA	M	PP,S	-	Arenz et al., 2011	Pawlik et al., 2018
Ascomycota	*Chaetocapnodium placitae* (Cheew. & Crous) Abdollahz. & Crous	*Antennariella placitae*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Chaetomium elatum* Kunze	-	Tundra soils	Arctic: Polar Urals	-	n.i.	Cul	Morph	S	Kirtsidely et al., 2010 (in Russian)	-	-
Ascomycota	*Chaetomium globosum* Kunze	-	Permafrost and tundra soils, cryophylic alpine meadow, anchient sediments, lichens, antropogenic substrates, peat, coal mine spoil, cryoconite	Arctic: Svalbard, Kolyma, Polar Urals, Taymyr, Franz Joseph Land, Izvestiy TSIK Iaslands	Antarctica: McMurdo Dry Valleys, Ross Sea region, Ilands near the Antarctic Peninsula, Browning Peninsula, Windmill Islands	F,C	Cul	M,Morph	S,LA,PF,IF,W,E,OHP	Ivanushkina et al., 2005; Ozerskaya et al., 2008; Kirtsidely, 2010 (in Russian); Kirtsidely et al., 2010, 2014, 2016 (in Russian); Borze cka et al., 2022; Iluchin et al., 2022a	Möller and Dreyfuss, 1996; Gilichinsky et al, 2007; Blanchette et al., 2010; Pudasaini et al., 2017	Qin et al., 2009; Raguchander et al., 2014

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Ascomycota	*Chaetomium piluliferum* J. Daniels	*Botryotrichum piluliferum* Sacc. & Marchal	Antropogenic substrates, horse dung from Shackleton's horses	Arctic: Taymyr, Kara Sea region (Yamal)	Antarctica: Ross Iland, Cape Royds	C?	Cul	Morph	S	Kirtsideli et al., 2016 (in Russian)	Tubaki and Asano, 1965	-
Ascomycota	*Chalara antarctica* Cabello	-	Rhizosphere	-	Antarctica: Danko Coast	n.i.	n.i.	n.i.	S,PA	-	Vishniac, 1996 (cyt. Cabello, 1989); Onofri, 1999	-
Ascomycota	*Chalara constricta* Nag Raj & W.B. Kendr.	-	Lichens	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	LA	-	Möller and Dreyfuss, 1996	-
Ascomycota	*Chalara holubovae* Koukol	-	Soil	Arctic: Svalbard	-	C	eDNA	M	PP	Frossard et al., 2021	-	Dietzel et al., 2019
Ascomycota	*Chalara longipes* (Preuss) Cooke	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Chalara microspora* (Corda) S. Hughes	-	Peat	Arctic: Alaska	-	F	eDNA	M	PA	Semenova et al., 2015	-	Koukol, 2011
Ascomycota	*Chalara pseudoaffinis* Koukol	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA	-	Rosa et al., 2020	Koukol, 2011
Ascomycota	*Chloridium phaeophorum* (W. Gams) Réblová & W. Gams	-	Antropogenic substrates	Arctic: Franz Joseph Land	-	n.i.	Cul	Morph	n.i.	Kirtsideli et al., 2016 (in Russian)	-	-
Ascomycota	*Choiromyces meandriformis* Vittad.	-	Ice core (cryoconite)	-	Antarctica: McMurdo Dry Valleys, Canada Clacier	F	eDNA	M	IF	-	Christner et al., 2003	-
Ascomycota	*Chromelosporium fulvum* (Link) McGinty, Hennebert & Korf	*Chromelosporium ollare* (Pers.) Hennebert	Vascular plants	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	PA	-	Möller and Dreyfuss, 1996	-
Ascomycota	*Chrysosporium carmichaelii* Oorschot	-	Dust	-	Antarctica: Edmonson Point, Newfoundland	n.i.	Cul	Morph	K	-	Mercantini, 1993	-
Ascomycota	*Chrysosporium europae* Sigler, Guarro & Punsola	-	Permafrost sediments	-	Antarctica: McMurdo Dry Valleys	F	Cul	Morph	K	-	Kochkina et al., 2012	-
Ascomycota	*Chrysosporium merdarium* (Ehrenb.) J.W. Carmich.	-	Permafrost and tundra soils, antropogenic substrates, peat	Arctic: Kolyma, Komi, Polar Urals, Franz Joseph Land, Kara Sea region (Yamal), Izvestiy TSIK Iaslands	Antarctica: McMurdo Station, Dronning Maud Land, Robertskollen	F	Cul	Morph	S,K,PF	Ozerskaya et al., 2008; Kirtsidely, 2010 (in Russian); Kirtsideli et al, 2016; Lapteva et al., 2017 (in Russian)	Sun et al., 1978; Ryan et al., 1989; Onofri, 1999	Chabasse, 1988

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Ascomycota	*Chrysosporium pseudomerdarium* Oorschot	-	Permafrost soil, soil	Arctic: Siberia, Canada/Alaska	-	F	eDNA	M	S,K	Bellemain et al., 2013; Timling et al., 2014	-	-
Ascomycota	*Chrysosporium vallenarense* Oorschot & Piont.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	K	-	Rosa et al., 2020	Currah et al., 1996
Ascomycota	*Cistella acuum* (Alb. & Schwein.) Svrček	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Cistella albidolutea* (Feltgen) Baral	-	Soil	Arctic: Svalbard	-	C	eDNA	M	PA	Frossard et al., 2021	-	-
Ascomycota	*Cistella grevillei* (Berk.) Raitv.	*Discocistella grevillei* (Berk.) Svrček	Soil	Arctic: Canada/ Alaska	Antarctica: Danco Coast	F	eDNA	M	PA	Timling et al., 2014	Gamundí and Spinedi,1988	-
Ascomycota	*Cistella polytrichi* (Velen.) Gamundí & Spinedi	*Cistella polytrichi* var. *antarctica* Gamundí & Spinedi	Plant tissues	-	Antarctica: Danko Coast	n.i.	n.i.	n.i.	PA	-	Onofri, 1999	-
Ascomycota	*Cistella spicicola* Huhtinen & Söderh.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PA	Timling et al., 2014	-	-
Ascomycota	*Cladophialophora arxii* Tintelnot	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	OHP	Timling et al., 2014	-	-
Ascomycota	*Cladophialophora boppii* (Borelli) de Hoog, Kwon-Chung & McGinnis	-	Antropogenic substrates	Arctic: Kara Sea region (Yamal)	-	n.i.	Cul	Morph	AP	Kirtsideli et al., 2016 (in Russian)	-	-
Ascomycota	*Cladophialophora chaetospira* (Grove) Crous & Arzanlou	-	Soil	Arctic: Finland	-	I	eDNA	M	S,PA,W	Poosakkannu et al., 2017	-	Crous et al., 2007b
Ascomycota	*Cladophialophora humicola* Crous & U. Braun	-	Lichens, soil, peat, coal mine spoil	Arctic: Svalbard, White Sea area, WSBS; Franz Josef Land, Alger Iland, Melekhov Cape of Alexandra Land, Magadan	Antarctica: Deception Iland, South Shetland Ilands	F,C	eDNA,Cul	M,Morph	S,PF	Zhang et al., 2015a; Grum-Grzhimaylo et al., 2016; Iluchin et al., 2022b; Nikitin and Semenov, 2022	Rosa et al., 2020	Crous et al., 2007b
Ascomycota	*Cladophialophora minutissima* M.L. Davey & Currah	-	Soil, moss, animal seals	Arctic: Canada/ Alaska, Finland	Antarctica: East, Primavera Cape	F,D,I	eDNA,Cul	M,Morph	S,AA	Timling et al., 2014; Poosakkannu et al., 2017	Hirose et al., 2016; Devoto et al., 2022	-
Ascomycota	*Cladorrhinum hyalocarpum* (Arx) X. Wei Wang & Houbraken	*Thielavia hyalocarpa* Arx	Wood	-	Antarctica: Ross Sea region	C	Cul	M	S	-	Blanchette et al., 2010	-

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Ascomycota	*Cladosporium allicinum* (Fr.) Bensch, U. Braun & Crous	*Cladosporium bruhnei* Linder	Soil, leafs, peat, lake sediments, cryoconite	Arctic: Svalbard, Finland, White Sea area, WSBS	-	C,F,I	eDNA,Cul	M,Morph	S,PF,IF,W	Grum-Grzhimaylo et al., 2016, 2018; Poosakkannu et al., 2017; Borze cka et al., 2022	-	-
Ascomycota	*Cladosporium antarcticum* K. Schub., Crous & U. Braun	-	Permafrost sediments, peat, soil, feathers	Arctic: Canada, White Sea area, WSBS	Antarctica: McMurdo Dry Valleys, Arctowski King George Iland	F,C	Cul	Morph,M	S,PF	Grum-Grzhimaylo et al., 2016, 2018; Robicheau et al., 2019	Kochkina et al., 2012; Schubert et al., 2007	-
Ascomycota	*Cladosporium austrolitorale* C. Gil-Durán & L. Sanhueza	-	Coastal sea sand	-	Antarctica: King George Island, Fildes Bay	n.i.	Cul	M,Morph	S	-	Crous et al., 2021b	-
Ascomycota	*Cladosporium cladosporioides* (Fresen.) G.A. de Vries	-	Cryopeg, permafrost and tundra soils, anchient sediments, wood, permafrost and frozen sediments, plants+bird fecas, antropogenic substrates, plants, peat, lichens, soil with recreational plant community, air, driftwood, lake sediments, penguin feathers, animal seals, coal mine spoil, glacier	Arctic: Kolyma, Komi, Polar Urals, Svalbard, Siberia, Canada/Alaska, Iceland, White Sea, WSBS, Sonsnovetz Iland, Barents Sea, Kolguyev Iland, Beliy nos, Novaya Zemlya, Varandey, Shoyna, Arctic Ocean, Franz Joseph Land, Vize Iland, Kara Sea, Yamal, Vaygach Iland, Marre-Sale, Ust'-Kara, Amderma, Kolba, Dikson, Taymyr, Izvestiy TSIK Iaslands, Magadan, Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: McMurdo Dry Valleys, Ross Sea region, Crater Cirque, Antarctic Peninsula, King George Iland; Signy Iland, Edmonson Point, Mac Robertson Land, Mawson, Gondwana Lake, Prior Iland, Bruce Point, Cape Irizar, Starr Nunatak, Kay Iland, Kohler Head, Harrow Peaks, Victoria Land, Cape Evans Ross Iland, Dronning Maud Land, Robertskollen, Macquarie Iland, Hut Point, Russkaya Station, Iland Livingstone, Primavera Cape, Browning Peninsula, Windmill Islands	F,C,D	eDNA,Cul	Morph,M	S,AA,BA,PA,PF	Kirtsidely, 1999 (in Russian); Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008; Kirtsideli et al., 2010, 2011, 2014, 2016 (in Russian); Kochkina et al., 2011 (in Russian); Singh et al., 2012; Bellemain et al., 2013; Timling et al., 2014; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Tsuji et al., 2016; Lapteva et al., 2017 (in Russian); Bubnova and Konovalova, 2018 (in Russian); Yakushev et al., 2019; Nikitin et al., 2021; Borze cka et al., 2022; Iluchin et al., 2022a,b; Nikitin and Semenov, 2022; Tsiji et al., 2022	Kerry and Weste, 1985; Ryan et al., 1989; Kerry, 1990b; Vishniac, 1996 (cyt. Pugh and Allsopp, 1982); Zucconi et al., 1996; Fenice et al., 1997; Tosi et al., 2002, 2005; Duncan et al., 2006, 2010; Arenz et al., 2006, 2011; Gilichinsky et al., 2007; Kostadinova et al., 2009; Blanchette et al., 2010; Gonc alves et al., 2012; Kochkina et al., 2012; Zucconi et al., 2012; Litova et al., 2014; Ding et al., 2016; Marfenina et al., 2016; Pudasaini et al., 2017; Kochkina et al., 2021; Devoto et al., 2022	-
Ascomycota	*Cladosporium delicatulum* Cooke*	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA,S	-	Rosa et al., 2020	-
Ascomycota	*Cladosporium halotolerans* Zalar, de Hoog & Gunde-Cim.	*Cladosporium* cf. *halotolerans*	Rocks, animal seals, soil	-	Antarctica: Heritage Range, Primavera Cape, South Shetlands Islands, Deception Island	F	Cul,eDNA	M,Morph	S,AA,EL	-	Gonçalves et al., 2017; Alves et al., 2019; Rosa et al., 2020; Devoto et al., 2022	-

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Ascomycota	*Cladosporium grevilleae* Crous & Summerell	-	Soil	-	Antarctica: Warren Cave on Mt. Erebus, Browning Peninsula, Windmill Islands	F	eDNA,Cul	M	E	-	Connel and Staudigel, 2013; Pudasaini et al., 2017	Sun et al., 2023
Ascomycota	*Cladosporium herbarum* (Pers.) Link	*Cladosporium herbarum* var. *macrocarpum* (Preuss) M.H.M. Ho & Dugan	Cryopeg, permafrost and tundra soils, cryophylic alpine meadow, anchient sediments, permafrost and frozen sediments, feathers, lichens, penguin dung, mosses, antropogenic substrates, air, plants, soil with recreational plant community, driftwood, ice core, peat, stones with algae, coal mine spoil, cryoconite, lake water, microbial mat	Arctic: Greenland, Svalbard, White Sea area, WSBS, Novaya Zemlya, Kolyma, Polar Urals, Franz Joseph Land, Taymyr, Izvestiy TSIK laslands, Kara Sea, Kolba, Magadan, Canada, Iceland	Antarctica: McMurdo Dry Valleys, Ross Sea region, Ilands near the Antarctic Peninsula, Antarctic Peninsula, East, South Georgia, Kerguelen Iland, Signy Iland, King George Iland, MacRobertson, Land, Kohler Head, Harrow Peaks, Victoria Land, Crater Cirque, Whitmer Peninsula, Enderby Land, Edmonson Point, Mac Robertson Land, Vestfold Hills, Macquarie Iland, Larsemann Hills oasis, Russkaya Station, Iland Livingstone, lakes in the Larsemann Hills, Vestfold Hills and the McMurdo Dry Valleys	F,C,D,I	eDNA,Cul	Morph,M	S,BA,K,LA,PA, PF,W,PtF	Elvebakk and Prestrud, 1996; Bergero et al., 1999; Ma et al., 1999; Bubnova and Velikanov, 2004 (in Russian); Gilichinsky et al., 2005; Ivanushkina et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008; Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Kochkina et al., 2011 (in Russian); Osono et al., 2012; Singh et al., 2015; Zhang et al., 2015a; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Kochkina et al., 2021; Nikitin et al., 2021; Iluchin et al., 2022a,b; Nikitin and Semenov, 2022	Fletcher et al., 1985; Kerry and Weste, 1985; Frate and Caretta, 1990; Kerry, 1990b; Chalmers et al., 1996; Möller and Dreyfuss, 1996; Vishniac, 1996 (cyt. Hurst et al., 1983); Zucconi et al., 1996; Fenice et al., 1997; Onofri, 1999; Tosi et al., 2002, 2005; Gilichinsky et al., 2007; Brunati et al., 2009; Kostadinova et al., 2009; Hirose et al., 2016; Kochkina et al., 2012, 2019; Zucconi et al., 2012; Litova et al., 2014; Marfenina et al., 2016	-
Ascomycota	*Cladosporium langeronii* (Fonseca, Leão & Nogueira) Vuill.	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	M	S,PF	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Cladosporium macrocarpum* Preuss	*Cladosporium* cf. *macrocarpum*	Permafrost sediments, soil, air	Arctic: White Sea area, WSBS, Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: W. Queen Maud Land	F,D	Cul	Morph	S	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005	Steele et al., 1994; Chalmers et al., 1996	-
Ascomycota	*Cladosporium nigrellum* Ellis & Everh.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-
Ascomycota	*Cladosporium ossifragi* (Rostr.) U. Braun & K. Schub.	-	Leafs	Norway	-	n.i.	n.i.	n.i.	S,PP	Schubert et al., 2007	-	

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Ascomycota	*Cladosporium oxysporum* Berk. & M.A. Curtis	*Cladosporium* sp. *oxysporum* group (Tosi et al., 2005)	Wood or artefacts from expedition hut, antropogenic substrates, soil	Arctic: White Sea area, WSBS	Antarctica: Ross Iland, Terra Nova, Iland Livingstone, Browning Peninsula, Windmill Islands	C	Cul	Morph,M	S	Grum-Grzhimaylo et al., 2018	Tosi et al., 2005; Duncan, 2007; Kostadinova et al., 2009; Pudasaini et al., 2017	-
Ascomycota	*Cladosporium phaenocomae* Crous	-	Rocks	-	Antarctica: Heritage Range	F	Cul	M	S	-	Gonçalves et al., 2017	-
Ascomycota	*Cladosporium pseudocladosporioides* Bensch, Crous & U. Braun	-	Soil, leafs, roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Cladosporium ramotenellum* K. Schub., Zalar, Crous & U. Braun	-	Cryoconite	Arctic: Svalbard	-	F	Cul	M	IF,W	Borze cka et al., 2022	-	-
Ascomycota	*Cladosporium sinuosum* K. Schub., C.F. Hill, Crous & U. Braun	-	Coal mine spoil	Arctic: Magadan	-	C	Cul	M	E	Iliushin et al., 2022b	-	Jannati et al., 2022
Ascomycota	*Cladosporium sphaerospermum* Penz.	-	Permafrost sediments, soil, antropogenic substrates, air, freshwater mud, peat, ice core, lake sediments, littoral sand, coal mine spoil, fossil seeds	Arctic: Greenland, White sea area, WSBS, Barents Sea coast, Franz Joseph Land, Izvestiy TSIK Iaslands, Kara Sea region (Yamal), Severnaya Zemlya, Magadan, Subarctic region	Antarctica: McMurdo Dry Valleys and Station, Ross Iland, King George Iland, East; Signy Iland, Prior Iland, S. Victoria Land, Continental and peninsula Antarctica, Mac Robertson Land, Mawson, Don Juan Pond, Wright Valley, Dronning Maud Land, Robertskollen, Deception Island	F,C,D,I	Cul,eDNA	Morph,M	S,BA,PA,PF,PtF	Ma et al., 1999; Bubnova and Velikanov, 2004 (in Russian); Stakhov et al., 2008; Ozerskaya et al., 2009; Kirtsideli et al., 2011, 2014, 2016 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Iluchin et al., 2022b	Sun et al., 1978; Ryan et al., 1989; Kerry, 1990b; Chalmers et al., 1996; Vishniac, 1996 (cyt. Möller and Gams, 1993); Tosi et al., 2002; Kochkina et al., 2012; Connel and Staudigel, 2013; Ding et al., 2016; Kochkina et al., 2019; Rosa et al., 2020	Rosa et al., 2019
Ascomycota	*Cladosporium tenuissimum* Cooke	-	Soil, lichens, ice core	Arctic: Greenland, Svalbard, Franz Josef Land, Alger Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica	F,C	eDNA,Cul	Morph,M	S,LA,I	Singh et al., 2012; Knowlton et al., 2013; Zhang et al., 2015a; Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian)	-
Ascomycota	*Clathrosphaerina zalewskii* Beverw.	-	Soil	-	Antarctica: Dronnin Maud Land	F	Cul	Morph	S	-	Kochkina et al., 2014	-

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Ascomycota	*Clathrosporium intricatum* Nawawi & Kuthub.	-	Dead plants (Salix sp.)	-	Antarctica: East Ongul Island	C	Cul	M	PA	-	Hirose et al., 2013	-
Basidiomycota	*Clavaria argillacea* Pers.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	n.i.	Timling et al., 2014	-	-
Basidiomycota	*Clavaria falcata* Pers.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	n.i.	Timling et al., 2014	-	-
Ascomycota	*Clavariopsis aquatica* De Wild.	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	W	Bellemain et al., 2013	-	Heeger et al., 2021
Basidiomycota	*Clavulina cinerea* (Bull.) J. Schröt.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Clavulina coralloides* (L.) J. Schröt.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Clavulina rugosa* (Bull.) J. Schröt.	*Clavulina* cf. *rugosa*	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014	-	-
Ascomycota	*Cleistothelebolus nipigonensis* Malloch & Cain	*Hyphozyma variabilis* (var. *variabilis*) de Hoog & M.T. Sm.	Soil	Arctic: Franz Joseph Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: Deception Iland, South Shetland Ilands	C,F	eDNA,Cul	Morph,M	PP	Bergero et al., 1999; Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian); Rosa et al., 2020	-
Basidiomycota	*Climacocystis borealis* (Fr.) Kotl. & Pouzar	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Basidiomycota	*Clitocybe dryadicola* (J. Favre) Harmaja	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PA	Timling et al., 2014	-	Brunner et al., 2017
Ascomycota	*Clonostachys rosea* (Link) Schroers, Samuels, Seifert & W. Gams	*Gliocladium roseum* Bainier	Antropogenic substrates, moss, soil, lichens, stones with algae	Arctic: Kara Sea region (Yamal), Severnaya Zemlya	Antarctica: Signy Iland, Larsemann Hills oasis, Russkaya Station	F	Cul	Morph	S,PF	Kirtsideli et al., 2016 (in Russian)	Vishniac, 1996 (cyt. Pugh and Allsopp, 1982); Marfenina et al., 2016; Nikitin, 2018 (in Russian)	-
Ascomycota	*Cochliobolus heliconiae* Alcorn	-	Soil	-	Antarctica: Taylor Valley McMurdo Land	C	eDNA	M	PP	-	Fell et al., 2006	Manamgoda et al., 2011
Ascomycota	*Coleophoma empetri* (Rostr.) Petr.	-	Leafs	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Coleophoma eucalyptorum* Crous & Summerell	-	Lake water	Arctic: Svalbard	-	F	eDNA	M	PP	Zhang et al., 2015b	-	-

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Ascomycota	*Collariella gracilis* (Udagawa) X.Wei Wang & Samson	*Chaetomium gracile* Udagawa	Mosses, soil, penguin excreta	-	Antarctica: Mount Melbourne, Terra Nova Bay, Victoria Land, Sabrina Iland	F	Cul	Morph	S,PA,BA,TF	-	Ellis, 1980; Tosi et al., 2002	-
Ascomycota	*Colletotrichum annellatum* DamM,P.F. Cannon & Crous	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Colletotrichum brevisporum* Noireung, Phouliv., L. Cai & K.D. Hyde	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	Duan et al., 2018
Ascomycota	*Colletotrichum cliviicola* Damm & Crous	*Colletotrichum cliviae*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	Li et al., 2019
Ascomycota	*Colletotrichum gigasporum* Rakotonir. & Munaut	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.	-	Plants (living leaves)	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S,PP,PtF	-	Kerry and Weste, 1985	Kumar, 2014; Rosa et al., 2019
Ascomycota	*Comoclathris arctica** Shoemaker & C.E. Babc.	-	Plants	Arctic: Canada, Banks Island, Christopher Peninsula	-	n.i.	n.i.	Morph	PP	Shoemaker and Babcock, 1992	-	-
Ascomycota	*Comoclathris antarctica* Ł. Istel, J. Pawłowska & Wrzosek	-	Soil	-	Antarctica: King George Island	n.i.	Cul	M,Morph	PtF	-	Crous et al., 2021a	-
Ascomycota	*Comoclathris lini* Wanas., E.B.G. Jones, Camporesi & K.D. Hyde	-	Glacier, dark ice with algae	Arctic: Canada, Greenland	-	F	Cul	M	IF	Perini et al., 2019; Tsuji et al., 2022	-	-
Basidiomycota	*Conferticium ochraceum* (Fr.) Hallenb.	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Entomophthoromycota	*Conidiobolus antarcticus* S. Tosi, Caretta & Humber	-	Mosses	-	Antarctica: Kohler Head, Terra Nova Bay, Victoria Land	F	Cul	Morph	PA,S	-	Tosi et al., 2004	-

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Ascomycota	*Coniochaeta hoffmannii* (J.F.H. Beyma) Z.U. Khan, Gené & Guarro	*Lecythophora hoffmannii* (J.F.H. Beyma) W. Gams & McGinnis	Moss, pond mud, soil, driftwood, wood, lake sediments	Arctic: Iceland, Siberia, Franz Josef Land, Zenith Cape of Heiss Iland	Antarctica: King George Iland, Ross Sea area, Deception Iland, Lake Whillans	C,F	Cul	M	S,PP,OHP	Blanchette et al., 2016; Nikitin and Semenov, 2022	Yu et al., 2014; Kudalkar, 2016; Held and Blanchette, 2017	Leonhardt et al., 2018; Kabtani et al., 2022
Ascomycota	*Coniochaeta leucoplaca* (Sacc.) Cain	-	Tundra soils	Arctic: Polar Urals	-	n.i.	Cul	Morph	S,CF	Kirtsidely et al., 2010 (in Russian)	-	Chang and Wang, 2011
Ascomycota	*Coniochaeta ligniaria* (Grev.) Cooke	-	Moss, soil, dead plants (Salix sp.)	-	Antarctica: King George Iland, Taylor Valley McMurdo Land, East Ongul Island	C	Cul	M	S,E	-	Fell et al., 2006; Hirose et al., 2013; Yu et al., 2014; Tsui, 2019	Rogers, 1965; Kokaew et al., 2011
Ascomycota	*Coniochaeta lignicola* (Nannf.) Z.U. Khan, Gené & Guarro	*Lecythophora lignicola* Nannf.	Soil	-	Antarctica: Edmonson Point Victoria Land	C	Cul	Morph	S,E	-	Onofri et al., 2000; 2005; Tosi et al., 2005	Costa et al., 2021
Ascomycota	*Coniochaeta mutabilis* (J.F.H. Beyma) Z.U. Khan, Gené & Guarro	*Lecythophora mutabilis* (J.F.H. Beyma) W. Gams & McGinnis	Soil, permafrost soil	Arctic: Kolyma, Finland	-	I	eDNA,Cul	M,Morph	S,E,OHP	Ozerskaya et al., 2008; Poosakkannu et al., 2017	-	Oremosu et al., 2023; Lee and Eom, 2017; Kabtani et al., 2022; Tienaho et al., 2020
Ascomycota	*Coniochaeta rosae* Wanas., Gafforov, E.B.G. Jones & K.D. Hyde	-	Snow	Arctic: Greenland	-	n.i.	Cul	M	IF,S	Perini et al., 2019	-	Souza et al., 2022
Ascomycota	*Coniochaeta savoryi* (C. Booth) Dania García, Stchigel & Guarro	-	Peat	Arctic: Alaska	-	F	eDNA	M	n.i.	Semenova et al., 2015	-	-
Basidiomycota	*Coniophora puteana* (Schumach.) P. Karst.	-	Driftwood, wood, conifer wood	Arctic: Finland, Siberia	Antarctica: Deception Iland	C,F	Cul	M	S,PA	Blanchette et al., 2016; Kaitera et al., 2019	Held and Blanchette, 2017	-
Basidiomycota	*Coprinellus disseminatus* (Pers.) J.E. Lange	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Basidiomycota	*Coprinellus micaceus* (Bull.) Vilgalys, Hopple & Jacq. Johnson	-	Soil	-	Antarctica: Dronnin Maud Land	F	Cul	Morph	S	-	Kochkina et al., 2014	Wang et al., 2021
Basidiomycota	*Coprinellus xanthothrix* (Romagn.) Vilgalys, Hopple & Jacq. Johnson	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-

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Ascomycota	*Corallomycetella repens* (Berk. & Broome) Rossman & Samuels	*Nectria mauritiicola* (Henn.) Seifert & Samuels	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	EP	Bellemain et al., 2013	-	Yamoah et al., 2008
Ascomycota	*Cordyceps farinosa* (Holmsk.) Kepler, B. Shrestha & Spatafora	*Isaria farinosa* (Holmsk.) Fr.; *Paecilomyces farinosus* (Holmsk.) A.H.S. Br. & G. Sm.	Soil, birds fecas, mosses, air, stone, driftwood, littoral sand, animal seals, coal mine spoil	Arctic: Canada/ Alaska, Greenland, White Sea area, WSBS, Barents Sea, Novaya Zemlya, Izvestiy TSIK Iaslands	Antarctica: East, Ross Sea region, Edmonson Point, Kohler Head, Mount Melbourne, Terra Nova Bay, Victoria Land, Antarctic Peninsula, Primavera Cape	F,C,D,I	eDNA,Cul	Morph,M	S,AA,EP,PA,EL	Bubnova and Velikanov, 2004 (in Russian); Meyling et al., 2012; Kirtsideli et al, 2011, 2014 (in Russian); Timling et al., 2014; Blanchette et al., 2016; Bubnova, 2017; Iluchin et al., 2022a	Frate and Caretta, 1990; Tosi et al., 2002; Hughes and Lawley, 2003; Kochkina et al., 2019; Devoto et al., 2022	Bridge et al., 2005
Ascomycota	*Cordyceps fumosorosea* (Wize) Kepler, B. Shrestha & Spatafora	*Isaria fumosorosea*	Soil	Arctic: Greenland	-	C	Cul	M	EP	Meyling et al., 2012	-	-
Ascomycota	*Cordyceps javanica* (Bally) Kepler, B. Shrestha & Spatafora	*Isaria javanica* (Bally) Samson & Hywel-Jones	Antropogenic substrates	Arctic: Izvestiy TSIK Ilands, Franz Joseph Land	-	n.i.	Cul	Morph	EP	Kirtsideli et al., 2016 (in Russian)	-	Wu et al., 2021
Ascomycota	*Cordyceps militaris* (L.) Fr.	-	Soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	EP	Grum-Grzhimaylo et al., 2018	-	Kryukov et al., 2018
Ascomycota	*Corinectria fuckeliana* (C. Booth) C.D. González & P. Chaverri	*Neonectria fuckeliana*	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA,PP	Kaitera et al., 2019	-	Salgado-Salazar et al., 2019
Basidiomycota	*Cortinarius acutovelatus* Rob. Henry	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius acutus* (Pers.) Fr.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Cortinarius alpinus* Boud.	*Cortinarius favrei* D.M. Hend.	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014; Lorberau et al., 2017	-	-
Basidiomycota	*Cortinarius angustisporus* Kytöv., Niskanen & Liimat.	*Cortinarius angustinusporus*	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Cortinarius anisatus* H. Lindstr., Kytöv. & Niskanen	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius anomalus* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Cortinarius armeniacus* (Schaeff.) Zawadzki	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius armillatus* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius atrocaeruleus* M.M. Moser	*Cortinarius atrocoeruleus*	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Cortinarius atropusillus* J. Favre	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius badioflavidus* Ammirati, Beug, Niskanen, Liimat. & Bojantchev	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius biformis* Fr.	-	Soil	Arctic: Finland, Russia, Yakutia	-	F,C	eDNA	M	Ec	Santalahti et al., 2018; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius bivelus* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius boreotrichus* Kytöv., Niskanen & Liimat.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius bouldererensis* A.H. Sm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius brunneus* (Pers.) Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius caesioarmeniacus* Kytöv., Niskanen & Liimat.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius caperatus* (Pers.) Fr.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Cortinarius casimirii* (Velen.) Huijsman	-	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021	-	-
Basidiomycota	*Cortinarius centrirufus* Kytöv., Niskanen & Liimat.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius cicindela* Kytöv., Niskanen & Liimat.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-

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Basidiomycota	*Cortinarius clarobrunneus* (H. Lindstr. & Melot) Niskanen, Kytöv. & Liimat.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius coleoptera* H. Lindstr. & Soop	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Cortinarius comptulus* M.M. Moser	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius croceus* (Schaeff.) Gray	-	Roots	Arctic: Russia, Yakutia, Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius decipiens* (Pers.) Fr.	-	Soil	Arctic: Norway, Svalbard, Russia, Yakutia	-	F,C	eDNA	M	Ec	Bjorbækmo et al., 2010; Geml et al., 2012; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius delibutus* Fr.	-	Soil, roots	Arctic: Svalbard, Russia, Yakutia, Alaska, Toolik Lake	-	F,C	eDNA	M	Ec	Geml et al., 2012; Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius diasemospermus* Lamoure	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius floccopus* Bidaud	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius flos-paludis* Melot	*Cortinarius* cf. *flos-paludis*	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014	-	-
Basidiomycota	*Cortinarius fulvescens* Fr.	-	Soil, roots	Arctic: Svalbard, Canada/Alaska, Russia, Yakutia	-	F,C	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius gentilis* (Fr.) Fr.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018		-
Basidiomycota	*Cortinarius glandicolor* (Fr.) Fr.	-	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021	-	-
Basidiomycota	*Cortinarius helobius* Romagn.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Cortinarius hemitrichus* (Pers.) Fr.	-	Soil	Arctic: Finland	-	I	eDNA	M	Ec	Poosakkannu et al., 2017	-	-
Basidiomycota	*Cortinarius heterodepressus* Kytöv., Niskanen & Liimat.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Cortinarius imbutus* Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius inconspicuus* J. Favre	*Cortinarius erubescens*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius laetissimus* Rob. Henry	-	Soil, roots	Arctic: Canada/ Alaska, Russia, Yakutia	-	F,C	eDNA	M	Ec	Timling et al., 2014; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius laetus* M.M. Moser	*Cortinarius erubescens*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius minutulus* J. Favre	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Cortinarius murinascens* Kytöv., Niskanen & Liimat.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius neofurvolaesus* Kytöv., Niskanen, Liimat. & H. Lindstr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius obtusus* (Fr.) Fr.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Cortinarius olivaceofuscus* Kühner	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Cortinarius paragaudis* Fr.	-	Roots	Arctic: Rassia, Yakutia, Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius parvannulatus* Kühner	-	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014	-	-
Basidiomycota	*Cortinarius praestigiosus* (Fr.) E. Berger	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius pseudocandelaris* (M.M. Moser) M.M. Moser	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius pseudofallax* Carteret	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius roseivelatus* Kytöv., Liimat. & Niskanen	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Cortinarius rubricosus* (Fr.) Fr.	*Cortinarius rubriscosus*	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Cortinarius rubrobrunneus* Ammirati, Liimat. & Niskanen	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius saniosus* (Fr.) Fr.	*Cortinarius rufoanuliferus* M.M. Moser & McKnight	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014	-	-
Basidiomycota	*Cortinarius saturninus* (Fr.) Fr.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Cortinarius scandens* Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius semisanguineus* (Fr.) Gillet	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Cortinarius septentrionalis* Bendiksen, K. Bendiksen & Brandrud	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius suberi* Soop	-	Soil, roots	Arctic: Finland, Russia, Yakutia	-	F,C	eDNA	M	Ec	Santalahti et al., 2018; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius tabularis* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia, Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius tenebricus* J. Favre	-	Roots	Arctic: Svalbard	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010	-	-
Basidiomycota	*Cortinarius traganus* (Fr.) Fr.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Cortinarius valgus* Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius venustus* P. Karst.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Cortinarius vernus* H. Lindstr. & Melot	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Corynespora cassiicola* (Berk. & M.A. Curtis) C.T. Wei	-	Soil, lake water	Arctic: Svalbard	-	F,C	Cul,eDNA	Morph,M	PP,W	Singh et al., 2012; Zhang et al., 2015b	-	-

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Ascomycota	*Cosmospora berkeleyana* (P. Karst.) Gräfenhan, Seifert & Schroers	-	Soil, coal mine spoil	Arctic: Svalbard, Magadan	-	C	Cul	M,Morph	MF	Iluchin et al., 2022a,b	-	Cordin et al., 2021
Ascomycota	*Cosmospora butyri* (J.F.H. Beyma) Gräfenhan, Seifert & Schroers	*Acremonium butyri* (J.F.H. Beyma) W. Gams	Soil, lichens	Arctic: Novaya Zemlya, Franz Joseph Land, Izvestiy TSIK Iaslands	Antarctica: Ilands near the Antarctic Peninsula	C,F	Cul	Morph,M	LA,PtF	Bergero et al., 1999; Kirtsideli et al, 2014 (in Russian); Nikitin et al., 2021	Möller and Dreyfuss, 1996	-
Ascomycota	*Cosmospora viridescens* (C. Booth) Gräfenhan & Seife	*Nectria viridescens* C. Booth	Soil, driftwood, coal mine spoil, conifer wood	Arctic: Svalbard, Finland, Siberia	Antarctica: Signy Iland	C,F	Cul	Morph,M	S,PA	Blanchette et al., 2016; Kaitera et al., 2019; Iluchin et al., 2022a	Bailey and Wynn-Williams, 1982	-
Basidiomycota	*Craterellus lutescens* (Fr.) Fr.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010	-	-
Ascomycota	*Cryomyces antarcticus* Selbmann, de Hoog, Mazzaglia, Friedmann & Onofri	-	Sandstone, soil, rocks	-	Antarctica: Linnaeus Terrace, McMurdo Dry Valleys, Southern Victoria Land	F	Cul,eDNA	M	EL,PsF	-	Selbmann et al., 2005, 2021; Coleine et al., 2018; Nikitin, 2021 (in Russian) = Nikitin, 2023	Pacelli et al., 2017; Rosa et al., 2019
Ascomycota	*Cryomyces minteri* Selbmann, de Hoog, Mazzaglia, Friedmann & Onofri	-	Soil	-	Antarctica:"Cirque 2", Battleship Promontory, Alatna Valley, McMurdo Dry Valleys, Southern Victoria Land	F	Cul,eDNA	M	EL	-	Selbmann et al., 2005, 2021	Selbmann et al., 2012
Ascomycota	*Cryptendoxyla hypophloia* Malloch & Cain	-	Soil	-	Antarctica	F	Cul	M	E,AP,PHOF	-	Nikitin, 2018 (in Russian)	Danagoudar et al., 2018; Greif et al., 2004; Suh et al., 1999
Mucoromycota	*Cunninghamella echinulata* (Thaxt.) Thaxt. ex Blakeslee	*Cunninghamella antarctica* Caretta & Piont.	Soil	-	Antarctica: South Shetland Iland	n.i.	Cul	Morph	S	-	Caretta and Piontelli, 1977	-
Basidiomycota	*Curvibasidium cygneicollum* J.P. Samp.	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Curvularia inaequalis* (Shear) Boedijn	-	Soil	-	Antarctica: Ross Sea region	F	eDNA	M	PP	-	Arenz et al., 2011	Chen et al., 2022
Ascomycota	*Curvularia lunata* (Wakker) Boedijn	*Cochliobolus lunatus*	Soil	-	Antarctica: Warren Cave, Deception Iland, South Shetland Ilands	F	eDNA	M	PP,OHP,AP	-	Connel and Staudigel, 2013; Rosa et al., 2020	-
Basidiomycota	*Cylindrobasidium laeve* (Pers.) Chamuris	*Athelia* sp. (*pellicularis*) // *Athelia pellicularis* (P. Karst.) Donk	Permafrost soil, wood, soil	Arctic: White Sea area, WSBS, Siberia	-	F,C	eDNA,Cul	M,Morph	PP	Bellemain et al., 2013; Grum-Grzhimaylo et al., 2018	-	Mattock, 2014

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Ascomycota	*Cyphellophora laciniata* G.A. de Vries	-	Soil	-	Antarctica: Warren Cave	F	eDNA	M	OHP	-	Connel and Staudigel, 2013	De Vries, 1962
Ascomycota	*Cyphellophora pluriseptata* G.A. de Vries, Elders & Luykx	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PHOF	-	Rosa et al., 2020	De Vries et al., 1986
Basidiomycota	*Cystinarius crassus* (Fr.) Niskanen & Liimat.	*Cortinarius* cf. *crassus*	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Zoopagomycota	*Cystopage lateralis* Drechsler ?	-	Moss, soil	-	Antarctica: Signy Iland, Marble Knolls	F	Cul	Morph	N	-	Gray et al., 1982	-
Ascomycota	*Cytospora chrysosperma* (Pers.) Fr.	*Valsa sordida* Nitschke	Cryopeg	Arctic: Kolyma	-	n.i.	Cul	Morph	W,PP	Gilichinsky et al., 2005; Ozerskaya et al., 2008	-	-
Basidiomycota	*Dacrymyces deliquescens* (Bull.) Duby	*Dacrymyces* cf. *deliquescens*	Wood	-	Antarctica: South Georgia, Grytviken, Signy Iland, Factory Cove	n.i.	n.i.	n.i.	S	-	Lindsay, 1976	-
Ascomycota	*Dactylaria candida* (Nees) Sacc.	-	Mosses	-	Antarctica: Signy Iland, Marble Knolls	F	Cul	Morph	N	-	Gray et al., 1982	-
Ascomycota	*Dactylellina cionopaga* (Drechsler) Ying Yang & Xing Z. Liu	*Dactylella cionopaga* Drechsler; *Monacrosporium cionopagum* (Drechsler) Subram.	Soil, plants, mosses	-	Antarctica: South Shetland Ilands, Livingstone Iland, Byers Peninsula, Factory Cove, Deception Iland, Livingstone Iland, Joinville Iland, Charlotte Bay, Danco Coast, Argentine Ilands, Lahille Iland, Signy Iland, Galindez Iland, South Orkney Iland	F	Cul	Morph	N,NP	-	Duddington et al., 1973; Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Dactylellina ferox* (Onofri & S. Tosi) M. Scholler, Hagedorn & A. Rubner	*Arthrobotrys ferox* Onofri & Tosi	Soil, moss	-	Antarctica: Schirmacher Oasis, Northen Victoria Land, Edmonson Point	D	Cul	Morph	n.i	-	Zucconi et al., 1996; Fenice et al., 1997	-
Ascomycota	*Dactylellina gephyropaga* (Drechsler) Ying Yang & Xing Z. Liu	*Dactylella gephyropaga* Drechsler	Soil, plants	-	Antarctica: South Shetland Ilands, Livingstone Iland, Byers Peninsula	F	Cul	Morph	NP	-	Gray and Smith, 1984	Labiadh et al., 2021
Ascomycota	*Dactylellina leptospora* (Drechsler) M. Morelet	*Dactylella leptospora*	Soil, plants	-	Antarctica: South Shetland Ilands, Livingstone Iland, Byers Peninsula	F	Cul	Morph	NP	-	Gray and Smith, 1984	-

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Ascomycota	*Dactylellina lobata* (Dudd.) Yan Li	*Dactylella lobata* (Dudd.) Yan Li; *Gamsylella lobata* (Dudd.) M. Scholler, Hagedorn & A. Rubner	Soil, wood	-	Antarctica: Ross Sea region	F	Cul	M	n.i	-	Arenz et al., 2006 (ITS identification 94.7%)	-
Ascomycota	*Dactylellina phymatopaga* (Drechsler) Yan Li	*Dactylella phymatopaga* Drechsler	Moss, soil	-	Antarctica: Signy Iland, Mardle Knolls, Pinero Iland	F	Cul	Morph	N,NP	-	Gray et al., 1982; Gray and Smith, 1984	Wairimu et al., 2022
Ascomycota	*Dactylonectria macrodidyma* (Halleen, Schroers & Crous) L. Lombard & Crous	*Neonectria macrodidyma* Halleen, Schroers & Crous	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Probst et al., 2019
Basidiomycota	*Daedalea xantha* (Fr.) A. Roy & A.B. De	*Antrodia xantha* (Fr.) Ryvarden	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	M	PF,S,PP	Grum-Grzhimaylo et al., 2016	-	Stienen et al., 2014
Ascomycota	*Darksidea epsilon* D.G. Knapp, Kovács, J.Z. Groenew. & Crous	-	Soil	Arctic: Svalbard	-	C	eDNA	M	E	Frossard et al., 2021	-	Vujanovic et al., 2020
Ascomycota	*Dasyscyphella longistipitata* Hosoya	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PA	Bellemain et al., 2013	-	Gasca-Pineda et al., 2020
Basidiomycota	*Deconica merdaria* (Fr.) Noordel.	*Psilocybe merdaria* (Fr.) Ricken	Permafrost soil; tussock peat by elephant seal wallow, reindeer dung	Arctic: Svalbard	-	F	eDNA	M	S	Bellemain et al., 2013	-	-
Ascomycota	*Dermea viburni* J.W. Groves*	-	Lichens	Arctic: Svalbard	-	F	eDNA	M	LA,PP,S	Zhang et al., 2015a	-	-
Ascomycota	*Dichotomopilus funicola* (Cooke) X.Wei Wang & Samson	*Chaetomium funicola* Cooke	Wood	-	Antarctica: Ross Sea region, Edmonson Point	F	Cul	M	S,PF	-	Arenz et al., 2006 (ITS identification 94.7%)	-
Ascomycota	*Dichotomopilus indicus* (Corda) X.Wei Wang & Samson	*Chaetomium indicum* Corda	Permafrost sediments	Arctic	-	F	Cul	Morph	S,PA	Ivanushkina et al., 2005	-	Moisan et al., 2020
Ascomycota	*Didymella glomerata* (Corda) Qian Chen & L. Cai	*Phoma glomerata* (Corda) Wollenw. & Hochapfel; *Coniothyrium glomeratum* Corda	Antropogenic substrates, sandy soil, peat, soil	Arctic: Kara Sea, Marre-Sale, Ust'-Kara, Amderma, Izvestiy TSIK Ilands, Novaya Zemlya, Franz Joseph Land	Antarctica	F,I	Cul	Morph,M	PF,S	Kirtsideli et al., 2011, 2014, 2016 (in Russian); Nikitin et al., 2021	Nikitin, 2018 (in Russian)	-

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Ascomycota	*Didymella pisi* Chilvers, J.D. Rogers & Peever	*Ascochyta pisi* Lib.	Soil	-	Antarctica	F	Cul	Morph	PP	-	Nikitin, 2018 (in Russian)	Owati et al., 2019
Ascomycota	*Didymella proximella* (P. Karst.) Sacc.	-	Plants (living leaves)	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985	-
Ascomycota	*Discostroma corticola* (Fuckel) Brockmann	*Seimatosporium lichenicola* (Corda) Shoemaker & E. Müll.	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	PP	Elvebakk and Prestrud, 1996	-	Tanaka et al., 2010; Göre and Bucak, 2006
Ascomycota	*Dissoconium dekkeri* (de Hoog & Hijwegen) Crous	-	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,PP	Zhang et al., 2015b	-	-
Ascomycota	*Dothiora europaea* Froid.	-	Cryoconite	Arctic: Greenland	-	n.i.	Cul	Morph	PP	Perini et al., 2019	-	https://wi.knaw.nl/page/fungal_display/name/CBS%20739.71
Ascomycota	*Dothiora prunorum* (C. Dennis & Buhagiar) Crous	*Hormonema prunorum*	Soil	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Drechmeria bactrospora* (Drechsler) Spatafora & Kepler	*Acrostalagmus bactrosporus* Drechsler	Soil with Deschampsia antarctica	-	Antarctica: South Georgia, Deception Iland, King Edward Cove	C	Cul	Morph	NEP	-	Gray and Smith, 1984	-
Ascomycota	*Drechmeria balanoides* (Drechsler) Spatafora & Kepler	*Cephalosporium balanoides* Drechsler; *Haptocillium balanoides* (Drechsler) Zare & W. Gams; *Verticillium balanoides* (Drechsler) Dowsett, J. Reid & Hopkin	Soil, plants, antropogenic substrates, soil with plants, soil from bird associated sites	Arctic: Franz Joseph Land	Antarctica: South Orkney Ilands, Lynch Iland; Livingstone Iland, Astrolabe Iland, Galindez Iland, Argentine Ilands, Charlotte Bay, Cuverville Iland, Graham Coast, Margueritte Bay	F,C	Cul	Morph	N,NEP,S,PF,MsF	Bergero et al., 1999; Kirtsideli et al., 2016 (in Russian)	Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Drechmeria coniospora* (Drechsler) W. Gams & H.-B. Jansson	*Meria coniospora* Drechsler	Mosses	-	Antarctica: Signy Iland, Galindez Iland, Jane Peak, South Orkney Ilands	F	Cul	Morph	N	-	Gray et al., 1982; Duddington et al., 1973	-

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Ascomycota	*Drechmeria obovata* (Drechsler) Spatafora & Kepler	*Acrostalagmus obovatus* Drechsler	Soil, mosses	-	Antarctica: Signy Iland, Factiry Cove, Livingstone Iland, Deception Iland, Galindez Iland, Argentine Ilands, Charlotte Bay, Graham Coast, Dismal Iland, Refuge Iland, King Edward Cove, South Orkney Ilands	F,C	Cul	Morph	N	-	Gray et al., 1982; Gray and Smith, 1984; Duddington et al., 1973	-
Ascomycota	*Drechslerella stenobrocha* (Drechsler) M. Scholler, Hagedorn & A. Rubner	*Dactylella stenobrocha* Drechsler	Moss, soil	-	Antarctica: Signy Iland, Jane Peak, South Orkney Ilands, Lynch Iland	F	Cul	Morph	N,NP	-	Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Duplicaria empetri* (Pers.) Fuckel	*Hysterodiscula empetri* (White) Petr.	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	n.i.	Elvebakk and Prestrud, 1996	-	-
Ascomycota	*Elaphomyces asperulus* Vittad.	-	Soil	Arctic: Svalbard	-	C	eDNA	M	Ec	Frossard et al., 2021	-	Ławrynowicz et al., 2006
Ascomycota	*Elaphomyces decipiens* Vittad.	-	Soil	Arctic: Svalbard	-	C	eDNA	M	Ec	Frossard et al., 2021	-	Molia et al., 2020
Ascomycota	*Elasticomyces elasticus* Zucconi & Selbmann	-	Lichens, plant tissues	Arctic: Svalbard	Antarctica: Kay Iland Inexpressible Iland Edmonson Point and Tarn Flat Northern Victoria Land	F	eDNA	M	S,LA,E,PA	Zhang et al., 2015a; Zhang and Yao, 2015	Selbmann et al., 2008, 2021	-
Ascomycota	*Eleutheromyces subulatus* (Tode) Fuckel	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA,E	Zhang and Yao, 2015	-	-
Ascomycota	*Emericellopsis minima* Stolk	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF,AA,W	Grum-Grzhimaylo et al., 2016	-	Pinheiro et al., 2012
Ascomycota	*Endoconidioma populi* Tsuneda, Hambl. & Currah	-	Soil	Arctic: Finland	-	I	eDNA	M	S,PA	Poosakkannu et al., 2017	-	-
Ascomycota	*Entimomentora hyalina* (W. Gams) Unter. & Réblová	*Phialophora hyalina* W. Gams	Mosses	-	Antarctica: King George Iland	C	Cul	Morph	PA	-	Möller and Dreyfuss, 1996	-
Basidiomycota	*Entoloma caeruleopolitum* Noordel. & Brandt-Ped.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Entoloma politum* (Pers.) Noordel.	-	Soil, roots	Arctic: Russia, Yakutia, Canada/Alaska	-	F,C	eDNA	M	PA,PF	Timling et al., 2014; Miyamoto et al., 2022	-	-

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Basidiomycota	*Entoloma sericatum* (Britzelm.) Sacc.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Entyloma polysporum* (Peck) Farl.	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PP	Bellemain et al., 2013	-	Rooney-Latham et al., 2017
Ascomycota	*Epicoccum italicum* Qian Chen, Crous & L. Cai	-	Lake sediments	-	Antarctica: Antarctic Peninsula	F	Cul	M	PA	-	Ogaki et al., 2020a	Rivera-Vega et al., 2022
Ascomycota	*Epicoccum nigrum* Link	*Epicoccum purpurascens* Ehrenb. ex Schltdl.	Soil, lichens, permafrost soil, plants, leafs, conifer wood	Arctic: Siberia, Finland, Novaya Zemlya, subarctic region	Antarctica: Ross Sea region, Ilands near the Antarctic Peninsula, Signy Iland, King George Iland, Mac Robertson Lans, Mawson, Edmonson Point, Victoria Land, Dronning Maud Land, Robertskollen, Macquarie Iland, Warren Cave, Iland Livingstone	F,C,I	eDNA,Cul	M,Morph	S,BA,LA,PF,PA	Bellemain et al., 2013; Poosakkannu et al., 2017; Kaitera et al., 2019; Nikitin et al., 2021	Latter and Heal, 1971; Kerry and Weste, 1985; Ryan et al., 1989; Kerry, 1990b; Chalmers et al., 1996; Möller and Dreyfuss, 1996; Onofri, 1999; Tosi et al., 2005; Arenz et al., 2006; Kostadinova et al., 2009; Connel and Staudigel, 2013; Kochkina et al., 2014	-
Ascomycota	*Epicoccum sorghinum* (Sacc.) Aveskamp, Gruyter & Verkley	*Phoma sorghina* (Sacc.) Boerema, Dorenb. & Kesteren	Moss, soil	-	Antarctica: Victoria Land, Kay Iland, Dronning Maud Land, Robertskollen	F	Cul	Morph	BA	-	Ryan et al., 1989; Zucconi et al., 1996; Fenice et al., 1997	-
Ascomycota	*Epipolaeum longisetosum* (Volkart) Nüesch	*Raciborskiomyces longisetosus*	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP,AP	Lydolph et al., 2005	-	Shin, E.C. et al., 2004; Nüesch, 1960
Ascomycota	*Erioscyphella sclerotii* (A.L. Sm.) Baral, Šandová & B. Perić	*Lachnum sclerotii*	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	n.i.	Lydolph et al., 2005	-	-
Ascomycota	*Erysiphe astragali* DC.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	PP	Miyamoto et al., 2022		Bradshaw et al., 2022
Ascomycota	*Erysiphe polygoni* DC.	-	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PP	-	Connel and Staudigel, 2013	Segarra et al., 2009
Ascomycota	*Erysiphe quercicola* S. Takam. & U. Braun	-	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,PP	Zhang et al., 2015b	-	-
Ascomycota	*Eucasphaeria capensis* Crous	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PP	Bellemain et al., 2013	-	Crous et al., 2007c

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Ascomycota	*Exophiala cancerae* de Hoog, V.A. Vicente, Najafz., Harrak, Badali, Seyedm. & Boeger	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	AP	-	Rosa et al., 2020	Orélis-Ribeiro et al., 2012
Ascomycota	*Exophiala castellanii* Iwatsu, Nishim. & Miyaji	*Phialophora gougerotii* (Matr.) Borelli	Soil	-	Antarctica: McMurdo Station, Ross Iland	F	Cul	Morph	S,OHP	-	Sun et al., 1978	Ghisolfi et al., 1980
Ascomycota	*Exophiala dermatitidis* (Kano) de Hoog	*Phialophora dermatitidis* (Kano) C.W. Emmons	Soil	-	Antarctica: McMurdo Station, Ross Iland	F	Cul	Morph	S,OHP	-	Sun et al., 1978	Kirchhoff et al., 2019
Ascomycota	*Exophiala heteromorpha* (Nannf.) de Hoog & Haase	*Exophiala jeanselmei* var. *heteromorpha* (Nannf.) de Hoog	Soil, antropogenic substrates, littoral soil	Arctic: Canada/ Alaska, Barents Sea, Beliy nos, Kara Sea, Marre-Sale, Dikson, Izvestiy TSIK Ilands, Taymyr, Arctic Ocean, Franz Josef Land	-	F,I	eDNA,Cul	Morph,M	S	Ozerskaya et al., 2009; Timling et al., 2014; Kirtsideli et al., 2011, 2014, 2016 (in Russian); Bubnova and Konovalova, 2018 (in Russian)	-	Domsh et al., 2007
Ascomycota	*Exophiala jeanselmei* (Langeron) McGinnis & A.A. Padhye	-	Sandy soil	Arctic: Isvestiy TSIK Ilands	-	F	Cul	Morph	OHP	Kirtsideli et al, 2014 (in Russian)	-	Ghisolfi et al., 1980
Ascomycota	*Exophiala mesophila* Listemann & Freiesl.	-	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA	M	EL	-	Selbmann et al., 2021	-
Ascomycota	*Exophiala moniliae* de Hoog	-	Peat	Arctic: Alaska	-	F	eDNA	M	OHP	Semenova et al., 2015	-	Matsumoto et al., 1984
Ascomycota	*Exophiala pisciphila* McGinnis & Ajello	*Exophiala* cf. *pisciphila*	Air	-	Antarctica: Signy Iland	n.i.	Cul	Morph	E	-	Chalmers et al., 1996	Li et al., 2011
Ascomycota	*Exophiala salmonis* J.W. Carmich.	-	Dead plants (Salix sp.)	-	Antarctica: East Ongul Island	C	Cul	M	PA	-	Hirose et al., 2013	-
Ascomycota	*Exophiala spinifera* (H.S. Nielsen & Conant) McGinnis	-	Soil, wood	-	Antarctica: Ross Sea region	F	eDNA,Cul	M	OHP	-	Arenz et al., 2006	Daboit et al., 2012
Ascomycota	*Exophiala tremulae* Wei Wang	-	Soil	Arctic: Franz Joseph Land	Antarctica	F	Cul	M,Morph	OHP,PA,S	Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian)	Maciá-Vicente et al., 2016

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Ascomycota	*Exophiala xenobiotica* de Hoog, J.S. Zeng, Harrak & Deanna A. Sutton	-	Soil, driftwood, wood	Arctic: Greenland	Antarctica: East, Deception Iland	F,C	Cul	Morph,M	S	Blanchette et al., 2016	Held and Blanchette, 2017; Kochkina et al., 2019	-
Ascomycota	*Extremus antarcticus* Quaedvl. & Crous	-	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA,Cul	M	EL	-	Selbmann et al., 2021	
Ascomycota	*Fagicola fagi* (Crous & de Hoog) Crous, M. Shen & Y. Zhang	*Fusicladium fagi* Crous & de Hoog; *Venturia barriae* Rossman & Crous	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Shen et al., 2020
Ascomycota	*Fimetariella rabenhorstii* (Niessl) N. Lundq.	-	Cryoconite	Arctic: Svalbard	-	F	Cul	M	IF,W,E	Borze cka et al., 2022	-	Bashiri et al., 2020
Basidiomycota	*Fistulina hepatica* (Schaeff.) With.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP,S	-	Rosa et al., 2020	-
Basidiomycota	*Flammula alnicola* (Fr.) P. Kumm.	-	Soil	Arctic: Norway, Hardangervidda	-	F	Cul	M	n.i.	Borchhardt et al., 2019	-	-
Basidiomycota	*Fomitopsis betulina* (Bull.) B.K. Cui, M.L. Han & Y.C. Dai	*Piptoporus betulinus* (Bull.) P. Karst.	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	M	S,PF	Grum-Grzhimaylo et al., 2016	-	-
Basidiomycota	*Fomitopsis pinicola* (Sw.) P. Karst.	-	Soil, conifer wood	Arctic: Finland	Antarctica: East	F	Cul	Morph,M	S,PA	Kaitera et al., 2019	Kochkina et al., 2019	-
Ascomycota	*Friedmanniomyces endolithicus* Onofri	-	Pegmatite, granite, sandston, rock, soil	-	Antarctica: Inexpressible Iland, Close to Boomerang Glacier, Timber Peak Northern Victoria Land, Promontory between Widowmaker Pass and Olson Nunatak, 200 m a.s.l., Northern Victoria Land, Battleship Promontory, McMurdo Dry Valleys, Southern Victoria Land, Nova Hedwigia, Trio Nunataks	F	Cul,eDNA	Morph,M	S,EL,PsF	-	Onofri et al., 1999; Onofri et al., 2000; Selbmann et al., 2005, 2021; Nikitin, 2021 (in Russian) = Nikitin, 2023; Coleine et al., 2018	Rosa et al., 2019
Ascomycota	*Friedmanniomyces simplex* Selbmann, de Hoog, Mazzaglia, Friedmann & Onofri	-	Sandstone	-	Antarctica: Battleship Promontory, McMurdo Dry Valleys, Southern Victoria Land	F	Cul,eDNA	Morph,M	EL,PsF	-	Selbmann et al., 2005, 2021; Nikitin, 2021 (in Russian) = Nikitin, 2023	Rosa et al., 2019

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Ascomycota	*Furcaspora eucalypti* Crous & Verkley	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S,LA	Timling et al., 2014	-	Ca ceres et al., 2020
Ascomycota	*Furcasterigmium furcatum* (C. Moreau & Moreau ex W. Gams) Giraldo López & Crous	*Acremonium furcatum* C. Moreau & Moreau ex W. Gams	Littoral sand	Arctic: White Sea area, WSBS	-	D	Cul	Morph	S	Bubnova, 2017	-	Babic and Gunde-Cimerman, 2021
Ascomycota	*Fusarium acuminatum* Ellis & Everh.	-	Peat	Arctic: Alaska	-	F	eDNA	M	PF,PP	Semenova et al., 2015	-	Marín et al., 2012
Ascomycota	*Fusarium asiaticum* O'Donnell, T. Aoki, Kistler & Geiser	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al, 2020	-
Ascomycota	*Fusarium avenaceum* (Fr.) Sacc.	-	Driftwood, soil	Arctic: Iceland, White Sea area, WSBS	-	C	Cul	M,Morph	S,PF	Blanchette et al., 2016; Grum-Grzhimaylo et al., 2018	-	-
Ascomycota	*Fusarium chlamydosporum* Wollenw. & Reinking	*Fusarium fusarioides* (Gonz. Frag. & Cif.) C. Booth	Permafrost soil, antropogenic substrates, microbial mat	Arctic: Isvestiy TSIK Ilands	Antarctica: McMurdo Dry Valleys, S. Victoria Land	C	Cul	Morph	S,PF	Kirtsideli et al., 2016 (in Russian)	Baublis et al., 1991	-
Ascomycota	*Fusarium cortaderiae* O'Donnell, T. Aoki, Kistler & Geiser	*Fusarium cortaeriae*	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,PP	Zhang et al., 2015b	-	-
Ascomycota	*Fusarium culmorum* (Wm.G. Sm.) Sacc.	-	Ice core	Arctic: Greenland	-	n.i.	Cul	M	PP	Knowlton et al., 2013	-	Wagacha and Muthomi, 2007
Ascomycota	*Fusarium fujikuroi* Nirenberg	*Gibberella fujikuroi* (Sawada) Wollenw.; *Gibberella moniliformis* Wineland	Cryophylic alpine meadow, coal mine spoil, soil, lake water	Arctic: Polar Urals, Magadan	Antarctica: King George Island	I	Cul	Morph,M	S,W	Kirtsidely et al., 2010 (in Russian); Iliushin et al., 2022b	Gonc alves et al., 2012	-
Ascomycota	*Fusarium gibbosum* Appel & Wollenw.	*Gibberella intricans*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Fusarium graminearum* Schwabe	*Gibberella zeae*	Soil	Arctic: White Sea area, WSBS	Antarctica: Deception Iland, South Shetland Ilands	F,C	eDNA,Cul	M	PP	Grum-Grzhimaylo et al., 2018	Rosa et al., 2020	-
Ascomycota	*Fusarium heterosporum* Nees & T. Nees	*Gibberella gordonii* C. Booth	Littoral soil	Arctic: Barents Sea coast	-	F	Cul	Morph	S	Bubnova and Konovalova, 2018 (in Russian)	-	-

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Ascomycota	*Fusarium lateritium* Nees	*Gibberella baccata* (Wallr.) Sacc.	Plants, feathers	Arctic: Canada	Antarctica: South Georgia, Lynch Iland	F	Cul	Morph	S,BA	Robicheau et al., 2019	Hurst et al., 1983	-
Ascomycota	*Fusarium oxysporum* Schltdl.	-	Cryophylic alpine meadow, wood, permafrost sediments, soil, littoral sand, coal mine spoil	Arctic: White Sea area, Polar Urals, Magadan	Antarctica: Ross Sea region, McMurdo Dry Valleys, Windmill Ilands, Lagotellerie Iland, Dronning Maud Land, Robertskollen, Deception Iland, South Shetland Ilands	F,C,D	eDNA,Cul	M,Morph	S,BA,PF,PP	Ivanushkina et al., 2005; Kirtsideli et al., 2010 (in Russian); Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Iliushin et al., 2022b	Ryan et al., 1989; Azmi and Seppelt, 1998; Arenz et al., 2006; Kochkina et al., 2012; Rosa et al., 2020	-
Ascomycota	*Fusarium poae* (Peck) Wollenw.	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	S	Bellemain et al., 2013	-	-
Ascomycota	*Fusarium proliferatum* (Matsush.) Nirenberg ex Gerlach & Nirenberg	-	Antropogenic substrates	Arctic: Kara Sea region (Yamal)	Antarctica: Victoria Land	n.i.	Cul	Morph,M	S	Kirtsideli et al., 2016 (in Russian)	Coleine et al., 2018	-
Ascomycota	*Fusarium roseum* Link	-	Coal mine spoil	Arctic: Svalbard	-	C	Cul	Morph	S	Iluchin et al., 2022a	-	-
Ascomycota	*Fusarium solani* (Mart.) Sacc.	-	Cryopeg, antropogenic substrates, moss, stones with algae	Arctic: Kolyma, Kara Sea region (Yamal)	Antarctica: Larsemann Hills oasis, Deception Iland, South Shetland Ilands	F	eDNA,Cul	Morph	S,PP	Ozerskaya et al., 2008; Kirtsideli et al., 2016 (in Russian)	Marfenina et al., 2016; Rosa et al., 2020	-
Ascomycota	*Fusarium sporotrichioides* Sherb.	-	Antropogenic substrates	Arctic: Isvestiy TSIK Ilands	-	n.i.	Cul	Morph	S,PF	Kirtsideli et al., 2016 (in Russian)	-	-
Ascomycota	*Fusarium torulosum* (Berk. & M.A. Curtis) Nirenberg	-	Soil, driftwood	Arctic: Finland, Iceland	-	C,I	eDNA,Cul	M	S	Blanchette et al., 2016; Poosakkannu et al., 2017	-	-
Ascomycota	*Fusarium tricinctum* (Corda) Sacc.	*Gibberella tricincta*	Coal mine spoil, soil	Arctic: Svalbard, Magadan	Antarctica: Deception Iland, South Shetland Ilands	C,F	eDNA,Cul	Morph,M	S,PP	Iluchin et al., 2022a,b	Rosa et al., 2020	-
Basidiomycota	*Fuscoporia gilva* (Schwein.) T. Wagner & M. Fisch.	*Phellinus gilvus*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Fusicladium peltigericola* Crous & Diederich	-	Soil	-	Antarctica: East	F	Cul	Morph	n.i.	-	Kochkina et al., 2019	-
Ascomycota	*Fusicladium radiosum* var. *radiosum* (Lib.) Lind*	-	Soil	-	Antarctica: East	F	Cul	Morph	n.i.	-	Kochkina et al., 2019	-

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Ascomycota	*Fusicolla aquaeductuum* (Radlk. & Rabenh.) Gräfenhan, Seifert & Schroers	*Fusarium aquaeductum* Lagerheim	Air, coal mine spoil	Arctic: Magadan	Antarctica: King George Iland, South Orkney Ilands	C	Cul	Morph	S	Iluchin et al., 2022b	Czarnecki and Bialasiewicz, 1987	Gräfenhan et al., 2011
Ascomycota	*Fusicolla merismoides* (Corda) Gräfenhan, Seifert & Schroers	-	Leafs, roots, coal mine spoil	Arctic: Svalbard, Finland, Magadan	-	C,I	eDNA,Cul	M,Morph	S	Poosakkannu et al., 2017; Iluchin et al., 2022a,b	-	-
Ascomycota	*Fusidium griseum* Ditmar ex Link	*Cylindrium griseum* (Ditmar ex Link) Bonord.	Soil	-	Antarctica: East Ongul Iland	C	Cul	Morph	S	-	Tubaki, 1961	-
Basidiomycota	*Galerina marginata* (Batsch) Kühner	*Galerina autumnalis* (Peck) A.H. Sm. & Singer; *Galerina unicolor* (Vahl) Singer	Soil, lichens	Arctic: Canada/ Alaska, Svalbard	-	F	eDNA	M	S	Timling et al., 2014; Zhang et al., 2015a	-	-
Basidiomycota	*Galerina mniophila* (Lasch) Kühner	-	Soil	Arctic: Finland	-	I	eDNA	M	S,PF	Poosakkannu et al., 2017	-	-
Basidiomycota	*Ganoderma applanatum* (Pers.) Pat.	-	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PP	-	Connel and Staudigel, 2013	-
Basidiomycota	*Gautieria morchelliformis* Vittad.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Geltingia associata* (Th. Fr.) Alstrup & D. Hawksw.	-	Lichens	Arctic: Svalbard	-	F	eDNA	M	LF	Zhang et al., 2015a	-	-
Ascomycota	*Geoglossum fallax* E.J. Durand	-	Soil	Arctic: Finland	Antarctica: King George Iland	I	eDNA,Cul	M	S	Poosakkannu et al., 2017	Krishnan et al., 2016	-
Ascomycota	*Geomyces asperulatus* Sigler & J.W. Carmich.	-	Air	Arctic: Kara Sea, Dikson	-	I	Cul	Morph	S	Kirtsideli et al., 2011 (in Russian)	-	Carreiro et al., 1992
Ascomycota	*Geomyces cretaceus* Traaen	-	Soil, soil+mosses, plants	-	Antarctica: Signy Iland	F,C	Cul	Morph	S	-	Bailey and Wynn-Williams, 1982	Nicholson et al., 1966
Ascomycota	*Geomyces fujianensis* Wan H. Chen, G.P. Zeng, Y. Luo, Z.Q. Liang & Y.F. Han	-	Wood	-	Antarctica: Laurie Island, in the South Orkney Islands	C	Cul	Morph,M	S?	-	Gaiser et al., 2021	http://www.indexfungorum.org/Names/NamesRecord.asp?RecordID=818287

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Ascomycota	*Geomyces vinaceus* Dal Vesco	*Geomyces pannorum* var. *vinaceus* (Dal Vesco) Oorschot	Cryopeg, soil, permafrost soil, mosses, lichens, coal mine spoil, dead plants (Salix sp.)	Arctic: Svalbard, Kolyma, Franz Joseph Land, Magadan	Antarctica: Ross Sea region, Ilands near the Antarctic Peninsula, King George Iland, Gondwana Lake, Bruce Point, Adelie Cove, Tinker Glacier, Snowy Point, Edmonson Point, Cape Icare, Harrow Peaks, Terra Nova Bay, Victoria Land, East Ongul Island	C,F	Cul	Morph,M	S,K,PA,LA	Bergero et al., 1999; Gilichinsky et al., 2005; Ozerskaya et al., 2008; Iluchin et al., 2022a,b	Mercantini et al., 1993; Fenice et al., 1997; Ding et al., 2016; Möller and Dreyfuss, 1996; Tosi et al., 2002; Hirose et al., 2013; Kochkina et al., 2019; Tsui, 2019	-
Ascomycota	*Geopora arenicola* (Lév.) Kers	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Kers, 1974
Ascomycota	*Geopora nicaeensis* (Boud.) M. Torre	-	Soil	Arctic: Canada/ Alaska, Svalbard	-	F,C	eDNA	M	Ec	Timling et al., 2014; Frossard et al., 2021	-	Hrynkiewicz et al., 2012
Ascomycota	*Geotrichum candidum* Link	*Dipodascus geotrichum*; *Galactomyces geotrichum* (E.E. Butler & L.J. Petersen) Redhead & Malloch	Permafrost anchient sediments, soil, melt water, peat, lake sediments	Arctic: White Sea area, WSBS, Novaya Zemlya	Antarctica: McMurdo Dry Valleys, Victoria Land, Edmonson Point, Taylor Valley, Lake Hoare	F,C	Cul	Morph,M	PF	Ivanushkina et al., 2005; Kochkina et al., 2011 (in Russian); Grum-Grzhimaylo et al., 2016; Bubnova and Konovalova, 2018 (in Russian); Nikitin et al., 2021	Baublis et al., 1991; Tosi et al., 2005; Gilichinsky et al., 2007	-
Ascomycota	*Gibellulopsis nigrescens* (Pethybr.) Zare, W. Gams & Summerb.	-	Peat, lake sediments	Arctic: White Sea area, WSBS	Antarctica: Warren Cave	C,F	Cul,eDNA	Morph,M	PP,PF	Grum-Grzhimaylo et al., 2016	Connel and Staudigel, 2013	Alisaac and Götz, 2022
Ascomycota	*Gibellulopsis piscis* Bat. & H. Maia	-	Soil	Arctic: Svalbard	-	C	eDNA	M	S,PP	Frossard et al., 2021	-	Wahdan et al., 2021; Ahmed et al., 2021
Ascomycota	*Gilmaniella humicola* G.L. Barron	-	Antropogenic substrates	Arctic: Taymyr	-	n.i.	Cul	Morph	S,HR	Kirtsideli et al., 2016 (in Russian)	-	Romero et al., 2020
Ascomycota	*Gliomastix cerealis* (P. Karst.) C.H. Dickinson	*Acremonium cerealis* (P. Karst.) W. Gams	Lichens	-	Antarctica: King George Iland, Ilands near the Antarctic Peninsula	C	Cul	Morph	LA	-	Möller and Dreyfuss, 1996	
Ascomycota	*Gliomastix roseogrisea* (S.B. Saksena) Summerb.	*Acremonium roseogriseum* (S.B. Saksena) W. Gams	Tundra soils, cryophylic alpine meadow	Arctic: Polar Urals	-	n.i.	Cul	Morph	S	Kirtsidely et al., 2010 (in Russian)	-	Pérez-Cantero and Guarro, 2020; Ruiz-Jiménez et al., 2019

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Ascomycota	*Gliomastix tumulicola* (Kiyuna, K.D. An, R. Kigawa & Sugiy.) Summerb.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Basidiomycota	*Gloeophyllum sepiarium* (Wulfen) P. Karst.	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	M	PF,PP,S	Grum-Grzhimaylo et al., 2016	-	Achal et al., 2011
Ascomycota	*Gnomonia acaenae* Spooner	-	Plants	-	Antarctica: South Georgia	n.i.	n.i.	Morph	PA	-	Smith, 1994	-
Ascomycota	*Godronia cassandrae* Peck	-	Lichens, driftwood, lake water	Arctic: Greenland, Svalbard, Finland	-	F,C.I	eDNA,Cul	M,Morph	S	Zhang et al., 2015a,b; Blanchette et al., 2016; Poosakkannu et al., 2017	-	-
Ascomycota	*Gorgomyces honrubiae* A. Roldán	-	Lichens	Arctic: Svalbard	-	F	eDNA	M	LA, W	Zhang et al., 2015a	-	-
Ascomycota	*Gremmenia infestans* (P. Karst.) Crous	-	Roots	Arctic: Finland	-	I	eDNA	M	PA,PP	Poosakkannu et al., 2017	-	-
Mucoromycota	*Gryganskiella cystojenkinii* (W. Gams & Veenb.-Rijks) Vandepol & Bonito	*Mortierella cystojenkinii*	Soil	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Mucoromycota	*Gryganskiella fimbricystis* (W. Gams) Vandepol & Bonito	*Mortierella fimbricystis*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Gymnascella citrina* (Massee & E.S. Salmon) G.F. Orr, G.R. Ghosh & K. Roy	*Arachniotus citrinus* Massee & E.S. Salmon	Soil	Arctic: Franz Joseph Land;	Antarctica: McMurdo Station, Ross Iland, Marble Point, Deception Iland, Antarctic Peninsula	C,F	Cul	Morph	AA	Bergero et al., 1999	Sun et al., 1978; Onofri, 1999	Fadillah et al., 2021
Basidiomycota	*Gymnopilus penetrans* (Fr.) Murrill	-	Soil	Arctic: Norway, Hardangervidda, Finland	-	F	Cul	M	S	Borchhardt et al., 2019	-	Holec et al., 2022
Ascomycota	*Gyromitra infula* (Schaeff.) Quél.	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Halenospora varia* (Anastasiou) E.B.G. Jones	*Zalerion varium*	Soil, wood bait in sea water	Arctic: Canada/ Alaska	Antarctica: Terra Nova Bay	F	eDNA	M	E,S	Timling et al., 2014	Grasso et al., 1997 (cited by the British Antarctic Survey: (https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	Mensy et al., 2021

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Ascomycota	*Hamigera fusca* S.W. Peterson, Jurjević, Bills, Stchigel, Guarro & F.E. Vega	-	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Harposporium harposporiferum* (Samuels) Spatafora & Kepler	*Harposporium anguillulae* Lohde	Soil with plants, moss	-	Antarctica: Signy Iland, Factory Cove, Marble Knolls, Jane Peak, Moraine Valley, Galindez Iland, Lahille Iland, Cuverville Iland, Lynch Iland, Deception Iland, Marguerite Bay	F	Cul	Morph	N,NEP	-	Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Harposporium helicoides* Drechsler	-	Soil with Deschampsia antarctica	-	Antarctica: Graham Coast, Cape Tuxen	F	Cul	Morph	NEP	-	Gray and Smith, 1984	-
Ascomycota	*Harposporium lilliputanum* S.M. Dixon	-	Soil, moss	-	Antarctica: Signy Iland, Charlotte Bay	F	Cul	Morph	N,NEP	-	Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Harposporium oxycoracum* Drechsler	-	Moss, peat	-	Antarctica: Signy Iland, Jane Peak, Galindez Iland	F	Cul	Morph	N	-	Gray et al., 1982; Gray and Smith, 1984	-
Basidiomycota	*Hebeloma alpinum* (J. Favre) Bruchet	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010	-	Debaud et al., 1981
Basidiomycota	*Hebeloma cavipes* Huijsman	*Hebeloma lutense*	Soil	Arctic: Canada/ Alaska, Svalbard	-	F,C	eDNA	M	Ec	Timling et al., 2014; Frossard et al., 2021	-	-
Basidiomycota	*Hebeloma crustuliniforme* (Bull.) Quél.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec,PF	Geml et al., 2012	-	Thormann and Rice, 2007
Basidiomycota	*Hebeloma helodes* J. Favre	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Hebeloma hiemale* Bres.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Hebeloma incarnatulum* A.H. Sm.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Hebeloma leucosarx* P.D. Orton	*Hebeloma velutipes*	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Hebeloma mesophaeum* (Pers.) Quél.	-	Soil	Arctic: Svalbard, Russia, Yakutia	-	F,C	eDNA	M	Ec	Geml et al., 2012; Miyamoto et al., 2022	-	-
Basidiomycota	*Hebeloma pseudofragilipes* Beker, Vesterh. & U. Eberh.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Ascomycota	*Helicoon reticulatum* Linder	*Helicoon? reticulatum*	Plants, soil+plants	-	Antarctica: Signy Iland	C,F	Cul	Morph	n.i.	-	Bailey and Wynn-Williams, 1982	-
Basidiomycota	*Heliocybe sulcata* (Berk.) Redhead & Ginns	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	S	Lydolph et al., 2005	-	Kähkönen, 2017
Ascomycota	*Helminthosporium anomalum* J.C. Gilman & E.V. Abbott	-	Air	-	Antarctica: continental and peninsula, McMurdo Station, Ross Iland	F	Cul	Morph	PP	-	Sun et al., 1978	Shoemaker, 1998
Ascomycota	*Helvella pseudolacunosa* Q. Zhao & K.D. Hyde	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Hemimycena gracilis* (Quél.) Singer	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Holec, 2009
Ascomycota	*Herpotrichia diffusa* (Cooke) Ellis & Everh.	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP	Lydolph et al., 2005	-	-
Ascomycota	*Herpotrichia pinetorum* (Fuckel) G. Winter	*Herpotrichia juniperi* (Sacc.) Petr.	Lichens, soil, leafs, roots	Arctic: Svalbard, Finland, Canada/ Alaska	Antarctica: Dronnin Maud Land; Deception Iland, South Shetland Ilands, King George Island	F,C,I	eDNA	M	PP	Bjorbækmo et al., 2010; Timling et al., 2014; Zhang et al., 2015a,b; Poosakkannu et al., 2017; Hoshino et al., 2019; Frossard et al., 2021	Kochkina et al., 2014; Rosa et al., 2020	-
Basidiomycota	*Heterobasidion parviporum* Niemelä & Korhonen	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Heterophoma poolensis* (Taubenh.) Qian Chen & L. Cai	*Phoma poolensis* Taubenh.	Peat	Arctic: White Sea area, WSBS	-	C	Cul	M	PP,PF	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Holwaya mucida* (Schulzer) Korf & Abawi	-	Soil, driftwood, cryoconite	Arctic: Iceland, Svalbard	Antarctica: Ross Sea region, Antarctic Peninsula	F,C	eDNA,Cul	M	S,IF,W	Blanchette et al., 2016; Borze cka et al., 2022	Arenz et al., 2011; Arenz and Blanchette, 2011 (ITS identification 96.7%)	-
Ascomycota	*Humicola fuscoatra* Traaen	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	MF,PF	Grum-Grzhimaylo et al., 2016	-	Joshi et al., 2002
Ascomycota	*Humicola marvinii* M.E. Palm & Weinst.	-	Soil	-	Antarctica: Signy Iland, Jane Col	n.i.	Cul	Morph	S,PA?,PsF	-	Weinstein et al., 1997; Weinstein et al., 2000	-

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Ascomycota	*Humicolopsis cephalosporioides* Cabral & S. Marchand	-	Coal mine spoil, soil	Arctic: Magadan	-	C	Cul	M	S,EcA	Iluchin et al., 2022b	-	Mestre and Fontenla, 2021
Basidiomycota	*Humidicutis auratocephala* (Ellis) Vizzini & Ercole	*Hygrophorus auratocephalus* (Ellis) Murrill	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	W?	Bellemain et al., 2013	-	-
Ascomycota	*Hyalodendriella betulae* Crous, in Crous, Braun, Schubert & Groenewald	-	Soil, snow, peat	Arctic: Greenland, Magadan, Alaska	-	C,F	Cul,eDNA	M	PA,IF	Semenova et al., 2015; Perini et al., 2019; Iluchin et al., 2022b	-	Crous et al., 2007a
Ascomycota	*Hyalopeziza nectrioidea* (Rehm) Raschle	-	Soil	Arctic: Svalbard	-	C	eDNA	M	S,PA	Frossard et al., 2021	-	Quijada and Beltran-Tejera, 2019
Ascomycota	*Hyaloscypha bicolor* (Hambl. & Sigler) Vohník, Fehrer & Réblová	*Meliniomyces bicolor*	Soil	Arctic: Finland, Siberia, Alaska, Toolik Lake	-	C,I	eDNA	M	PA, Ec	Poosakkannu et al., 2017; Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	-
Ascomycota	*Hyaloscypha finlandica* (C.J.K. Wang & H.E. Wilcox) Vohník, Fehrer & Réblová	*Cadophora finlandica* (C.J.K. Wang & H.E. Wilcox) T.C. Harr. & McNew	Plant roots, soil, peat	Arctic: Svalbard, Canada/Alaska, Toolik Lake, Franz Josef Land, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Siberia	-	F,C	eDNA,Cul	M	Ec,S	Bjorbækmo et al., 2010; Timling et al., 2014; Semenova et al., 2015; Dunleavy and Mack, 2021; Miyamoto et al., 2022; Nikitin and Semenov, 2022	-	Mrnka et al., 2020
Ascomycota	*Hyaloscypha hepaticicola* (Grelet & Croz.) Baral, Huhtinen & J.R. De Sloover	*Rhizoscyphus ericae* (D.J. Read) W.Y. Zhuang & Korf, *Pezoloma ericae* (D.J. Read) Baral; *Hymenoscyphus ericae* (D.J. Read) Korf & Kernan; *Hyaloscypha hepaticola*	Soil, sand, peat, plants, leafs, roots, mosses, coal mine spoil	Arctic: Canada/ Alaska, Toolik Lakem Svalbard, Norway, Hardangervidda, Northern Fennoscandia, Finland, Western Siberia	Antarctica: Ross Sea region, Bird Iland, King George Iland, Signy Iland, Adelaide Iland, Livingstone Iland	F,C,I	eDNA,Cul	M	Er,PF	Timling et al., 2014; Zhang et al., 2015a; Poosakkannu et al., 2017; Santalahti et al., 2018; Yakushev et al., 2019; Juottonen eta l., 2020; Dunleavy and Mack, 2021; Iluchin et al., 2022a,b	Chambers et al., 1999; Upson et al., 2007; Bridge et al., 2008b; Arenz et al., 2011 (ITS identification 98.4%)	Asemaninejad et al., 2018
Ascomycota	*Hyaloscypha variabilis* (Hambl. & Sigler) Vohník, Fehrer & Réblová	*Meliniomyces variabilis* Hambl. & Sigler	Peat, soil, roots	Arctic: Canada/ Alaska, Toolik Lake	-	C,F	eDNA	M	PF,E,Er	Timling et al., 2014; Dunleavy and Mack, 2021	-	Asemaninejad et al., 2018
Ascomycota	*Hyaloscypha vraolstadiae* (Hambl. & Sigler) Vohník, Fehrer & Réblová	*Meliniomyces vraolstadiae*	Peat	Arctic: Canada/ Alaska	-	F	eDNA	M	PA	Timling et al., 2014; Semenova et al., 2015		Fehrer et al., 2019

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Basidiomycota	*Hydnellum aurantiacum* (Batsch) P. Karst.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Hydnellum caeruleum* (Hornem.) P. Karst.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Hydnellum gracilipes* (P. Karst.) P. Karst.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Ascomycota	*Hymenoscyphus caudatus* (P. Karst.) Dennis	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA,E	Zhang and Yao, 2015	-	-
Ascomycota	*Hymenoscyphus chloophilus* Spooner	-	Plants	-	Antarctica: South Georgia	n.i.	n.i.	Morph	PA	-	Smith, 1994	-
Ascomycota	*Hymenoscyphus tetracladius* Abdullah, Descals & J. Webster	*Articulospora tetracladia* Ingold	Soil, roots, cryoconite	Arctic: Canada/ Alaska, Toolik Lake, Finland, Svalbard	-	F,C,I	eDNA,Cul	M	S,W,IF	Timling et al., 2014; Poosakkannu et al., 2017; Dunleavy and Mack, 2021; Borze cka et al., 2022	-	-
Basidiomycota	*Hyphodontiella multiseptata* Å. Strid	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Bernicchia, 2000
Basidiomycota	*Hypholoma frowardii* (Speg.) Garrido	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA,S	-	Rosa et al., 2020	Nüske et al., 2002
Basidiomycota	*Hypholoma myosotis* (Fr.) M. Lange	*Pholiota myosotis* (Fr.) Singer	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S,PF	Timling et al., 2014	-	Thormann and Rice, 2007
Basidiomycota	*Hypochnicium albostramineum* (Bres.) Hallenb.	-	Conifer wood	Arctic: Finland	-	F	Cul	Morph	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Hypocrea pachybasioides* Yoshim. Doi	-	Conifer wood	Arctic: Finland	-	F	Cul	Morph	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Hypomyces chrysospermus* Tul.	*Sepedonium chrysospermum* (Bull.) Link	Soil	-	Antarctica: continental and peninsula, McMurdo Station, Ross Iland	F	Cul	Morph	MF	-	Sun et al., 1978	Dikmen et al., 2020; Tian et al., 2022
Ascomycota	*Hypomyces perniciosus* Magnus	*Mycogone perniciosa*	Peat	Arctic: Alaska	-	F	eDNA	M	MF,PF	Semenova et al., 2015	-	-
Basidiomycota	*Incrustoporia chrysella* (Niemelä) Zmitr.	*Skeletocutis chrysella*	Soil	-	Antarctica: Warren Cave	F	eDNA	M	n.i.	-	Connel and Staudigel, 2013	-

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Ascomycota	*Ilyonectria radicicola* (Gerlach & L. Nilsson) P. Chaverri & Salgado	-	Peat	Arctic: Alaska	-	F	eDNA	M	PP,PF	Semenova et al., 2015		Farh et al., 2018
Ascomycota	*Ilyonectria robusta* (A.A. Hildebr.) A. Cabral & Crous	-	Driftwood, dead plants (Salix sp.)	Arctic: Iceland	Antarctica: East Ongul Island	C	eDNA,Cul	M	S,PP	Blanchette et al., 2016	Hirose et al., 2013; Tsui, 2019	Martínez-Diz et al., 2018
Ascomycota	*Immersiella caudata* (Sacc.) A.N. Mill. & Huhndorf	-	Soil, leafs, roots	Arctic: Finland	-	I	eDNA	M	S,PA	Poosakkannu et al., 2017	-	-
Ascomycota	*Infundichalara microchona* (W. Gams) Réblová & W. Gams	*Chalara microchona* W. Gams	Lichens, soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	S,Ec,LA	Timling et al., 2014; Zhang et al., 2015a	-	-
Basidiomycota	*Inocybe abjecta* P. Karst.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe acuta* Boud.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe arctica* E. Larss., Vauras & C.L. Cripps	-	Roots	Arctic: Norway, Svalbard, Sweden, Russia, Yakutia,	-	C	eDNA	M	Ec	Cripps et al., 2020; Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe auricoma* (Batsch) Sacc.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe borealis* M. Lange	-	Roots, soil	Arctic: Russia, Yakutia, Finland, Greenland, Svalbard, Sweden, North America	-	C	eDNA	M	Ec	Kokkonen and Vauras, 2012; Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe catalaunica* Singer	*Inocybe leiocephala*	Soil	Arctic: Alaska, Russia, Yakutia	-	F,C	eDNA	M	Ec,PF	Semenova et al., 2016; Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe chondroderma* D.E. Stuntz ex Matheny, Norvell & E.C. Giles	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe cincinnata* (Fr.) Quél.	*Inocybe cincinnata* var. *major* (S. Petersen) Kuyper	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe dulcamara* (Pers.) P. Kumm.	-	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014	-	-

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Basidiomycota	*Inocybe egenula* J. Favre	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe exilis* (Kuyper) Jacobsson & E. Larss.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe fuscidula* Velen.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe fuscidula* var. *fuscidula* Velen.*	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe geophylla* P. Kumm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe glabrescens* Velen.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe griseolilacina* J.E. Lange	*Inocybe* cf. *griseolilacina*	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe hirculus* Vauras	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec,PF	Geml et al., 2012		Thormann and Rice, 2009
Basidiomycota	*Inocybe inodora* Velen.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe lacera* (Fr.) P. Kumm.	-	Soil	Arctic: Finland	-	I	eDNA	M	Ec	Poosakkannu et al., 2017	-	-
Basidiomycota	*Inocybe mixtilis* (Britzelm.) Sacc.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe nematoloma* Joss.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe nitidiuscula* (Britzelm.) Lapl.	-	Soil	Arctic: Norway; Canada/Alaska	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010; Timling et al., 2014	-	-
Basidiomycota	*Inocybe obscurobadia* (J. Favre) Grund & D.E. Stuntz	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe olympiana* A.H. Sm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe ochroalba* Bruyl.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe oreina* J. Favre	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-

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Basidiomycota	*Inocybe posterula* (Britzelm.) Sacc.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe pruinosa* R. Heim	*Inocybe* cf. *pruinosa*	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe rufuloides* Bon	-	Soil	Arctic: Svalbard	-	n.i.	eDNA	M	Ec	Frossard et al., 2021	-	-
Basidiomycota	*Inocybe sindonia* (Fr.) P. Karst.	-	Soil	Arctic: Svalbard	-	n.i.	eDNA	M	Ec	Frossard et al., 2021	-	-
Basidiomycota	*Inocybe subporospora* Kuyper	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Inocybe whitei* (Berk. & Broome) Sacc.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Inocybe xanthomelas* Boursier & Kühner	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Irpex hydnoides* Y.W. Lim & H.S. Jung	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S,PP	-	Rosa et al., 2020	Nnagadesi and Arya, 2015
Basidiomycota	*Irpex lacteus* (Fr.) Fr.	-	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PP,En	-	Connel and Staudigel, 2013	-
Basidiomycota	*Jaapia argillacea* Bres.	-	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Jackrogersella multiformis* (Fr.) L. Wendt, Kuhnert & M. Stadler	*Annulohypoxylon multiforme*	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Jugulospora antarctica* (Stchigel & Guarro) Y. Marín & Stchigel	*Apiosordaria antarctica* Stchigel & Guarro	Soil, Bird colonies	-	Antarctica: King George Iland	F	Cul	Morph	BA	-	Stchigel et al., 2003, Nikitin, 2021 (in Russian) = Nikitin, 2023	-
Ascomycota	*Juxtiphoma eupyrena* (Sacc.) Valenz.-Lopez, Crous, Stchigel, Guarro & Cano	*Phoma eupyrena* Sacc.	Cryophylic alpine meadow, permafrost sediments and soil, littoral sand, coal mine spoil	Arctic: White Sea area, Polar Urals, Siberia, Magadan	Antarctica: McMurdo Dry Valleys	F,D	eDNA,Cul	M,Morph	E	Kirtsidely et al., 2010 (in Russian); Bellemain et al., 2013; Bubnova, 2017; Iliushin et al., 2022b	Kochkina et al., 2012	Sarma et al., 2018
Ascomycota	*Knufia peltigerae* (Fuckel) Réblová & Unter.	*Capronia peltigerae* (Fuckel) D. Hawksw.	Lichens, soil	Arctic: Svalbard	-	F,C	eDNA	M	LA	Zhang et al., 2015a; Frossard et al., 2021	-	-

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Ascomycota	*Knufia marmoricola* Onofri & Zucconi	-	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA	M	EL	-	Selbmann et al., 2021	-
Ascomycota	*Knufia petricola* (Wollenz. & de Hoog) Gorbushina & Gueidan	-	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA	M	EL	-	Selbmann et al., 2021	-
Basidiomycota	*Kuehneromyces mutabilis* (Schaeff.) Singer & A.H. Sm.	-	Soil	Arctic: Norway, Hardangervidda	-	F	Cul	M	S,PF	Borchhardt et al., 2019	-	-
Basidiomycota	*Laccaria laccata* (Scop.) Cooke	*Laccaria* cf. *laccata* (Scop.) Cooke	Soil, roots	Arctic: Canada/ Alaska, Toolik Lake, Russia, Yakutia	-	F,C	eDNA	M	Ec,PF	Timling et al., 2014, Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	Thormann and Rice, 2007
Basidiomycota	*Laccaria pumila* Fayod	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Gelm et al., 2012	-	-
Ascomycota	*Lachnum carneolum* (Sacc.) Rehm	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	n.i.	Miyamoto et al., 2022	-	-
Ascomycota	*Lachnum enzenspergerianum* Henn.	*Dasyscyphus* cf. *enzenspergerianus*	Tussock litter, dead leaves	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985	-
Ascomycota	*Lachnum hyalopus* (Cooke & Massee) Spooner	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	n.i.	Lydolph et al., 2005	-	-
Ascomycota	*Lachnum pygmaeum* (Fr.) Bres.	-	Soil, leafs, roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Lachnum virgineum* (Batsch) P. Karst.	-	Roots, lake water	Arctic: Finland, Svalbard	-	I,F	eDNA	M	S,W	Zhang et al., 2015b; Poosakkannu et al., 2017	-	-
Basidiomycota	*Lactarius aquizonatus* Kytöv.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius deliciosus* (L.) Gray	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius dryadophilus* Kühner	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Gelm et al., 2012	-	-
Basidiomycota	*Lactarius glyciosmus* (Fr.) Fr.	-	Soil, roots	Arctic: Svalbard, Russia, Yakutia, Canada/ Alaska, Toolik Lake	-	F,C	eDNA	M	Ec	Gelm et al., 2012; Timling et al., 2014, Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	Barge et al., 2016
Basidiomycota	*Lactarius lanceolatus* O.K. Mill. & Laursen	-	Roots, soil	Arctic: Svalbard, Russia, Yakutia	-	C,F	eDNA	M	Ec	Gelm et al., 2012; Miyamoto et al., 2022	-	-

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Basidiomycota	*Lactarius lilacinus* Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius musteus* Fr.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	Villarreal-Ruiz, 2012
Basidiomycota	*Lactarius nanus* J. Favre	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius porniniae* Rolland	*Lactarius porninsis*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius rufus* (Scop.) Fr.	-	Soil	Arctic: Finland, Russia, Yakutia	-	F,C	eDNA	M	Ec,PF	Santalahti et al., 2018; Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius torminosus* (Schaeff.) Pers.	-	Roots, soil	Arctic: Svalbard, Russia, Yakutia	-	C,F	eDNA	M	Ec	Gelm et al., 2012; Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius subcircellatus* Kühner	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius trivialis* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius uvidus* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Lactarius vietus* (Fr.) Fr.	-	Roots	Arctic: Russia, Yakutia, Alaska, Toolik Lake	-	C	eDNA	M	Ec,PF	Dunleavy and Mack, 2021; Miyamoto etal., 2022	-	Hagara, 2014
Ascomycota	*Laetinaevia colobanthi* Gamundí & Spinedi	-	Plant tissues	-	Antarctica: Danko Coast, Antarctic Peninsula	n.i.	n.i.	n.i.	PA	-	Onofri, 1999	-
Ascomycota	*Lasionectriopsis pteridii* (W. Gams & J.C. Frankland) Lechat & P.-A. Moreau	*Acremonium pteridii* W. Gams & J.C. Frankland	Permafrost soil	Arctic: Kolyma	-	n.i.	Cul	Morph	n.i.	Ozerskaya et al., 2008	-	-
Ascomycota	*Lecanicillium evansii* Zare & W. Gams	-	Peat, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF,S	Grum-Grzhimaylo et al., 2016, 2018	-	-
Ascomycota	*Lecanicillium fungicola* (Preuss) Zare & W. Gams	-	Soil	Arctic: Franz Joseph Land	Antarctica	F	Cul	M	MF	Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian)	Berendsen et al, 2010; Gea et al., 2014
Ascomycota	*Lecanicillium fusisporum* (W. Gams) Zare & W. Gams	-	Soil	Arctic: Svalbard	-	C	eDNA	M	W,AA	Frossard et al., 2021	-	Huang et al., 2021; Xu et al., 2022

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Ascomycota	*Lecanicillium psalliotae* (Treschew) Zare & W. Gams	*Verticillium psalliotae* Treschew	Soil, mosses	Arctic: Franz Joseph Land	Antarctica: Victoria Land; Adelie Cove, Kohler Head, Terra Nova Bay	C,F	Cul	Morph	PA,S,EP,PF,PtF	Bergero et al., 1999	Tosi et al., 2002	Bridge et al., 2005
Basidiomycota	*Leccinum holopus* (Rostk.) Watling	-	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec,PF	Dunleavy and Mack, 2021	-	-
Basidiomycota	*Leccinum scabrum* (Bull.) Gray	*Leccinum rotundifoliae*	Soil, roots	Arctic: Svalbard, Finland, Russia, Yakutia, Alaska, Toolik Lake	-	C,I,F	eDNA	M	Ec	Gelm et al., 2012; Poosakkannu et al., 2017; Dunleavy and Mack, 2021; Miyamoto et al., 2022	-	-
Basidiomycota	*Leccinum schistophilum* Bon	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Leccinum variicolor* Watling	-	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021	-	-
Basidiomycota	*Leccinum versipelle* (Fr.) Snell	-	Soil	Arctic: Finland	-	I	eDNA	M	Ec	Poosakkannu et al., 2017	-	-
Ascomycota	*Lectera colletotrichoides* (J.E. Chilton) P.F. Cannon	*Volutella colletotrichoides* J.E. Chilton	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PP	-	Connel and Staudigel, 2013	Cannon et al., 2012
Basidiomycota	*Lentinus brumalis* (Pers.) Zmitr.	*Polyporus brumalis*	Driftwood	Arctic: Iceland	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Basidiomycota	*Lenzites betulinus* (L.) Fr.	-	Peat	Arctic: West Siberia	-	C	Cul	M	PF	Yakushev et al., 2019	-	-
Ascomycota	*Leohumicola minima* (de Hoog & Grinb.) Seifert & Hambl.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	LA,HR,Er	Timling et al., 2014	-	Hambleton et al., 2005; Nguyen and Seifert, 2008; Adeoyo et al., 2019
Ascomycota	*Leptodontidium irregulare* (de Hoog) de Hoog	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	S	Lydolph et al., 2005	-	Hernandez-Restrepo et al., 2017
Ascomycota	*Leptodontidium trabinellum* (P. Karst.) Baral, Platas & R. Galán	*Leptodontidium elatius*	Roots, wood, conifer wood	Arctic: Alaska, Toolik Lake, Finland	Antarctica: King George Iland, Deception Iland	C,F	eDNA,Cul	M	S,PA	Kaitera et al., 2019; Dunleavy and Mack, 2021	Held and Blanchette, 2017	Hernandez-Restrepo et al., 2017
Ascomycota	*Leptosphaeria doliolum* (Pers.) Ces. & De Not.	-	Plant (living)	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985	-
Ascomycota	*Leptosphaeria eustoma* (Fr.) Sacc.	-	Dead leaves, living plants	-	Antarctica: Macquarie Ilands, South Georgia	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985; Smith, 1994	-

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Ascomycota	*Leptosphaeria maculans* Ces. & De Not.	-	Tundra soils, permafrost soil	Arctic: Polar Urals, Siberia	-	n.i.	Cul,eDNA	M	PP	Lydolph et al., 2005; Kirtsidely et al., 2010 (in Russian)	-	-
Ascomycota	*Leptosphaeria pedicularis* (Fuckel) Gruyter, Aveskamp & Verkley	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA,E	Zhang and Yao, 2015	-	-
Ascomycota	*Leptosphaeria sclerotioides* (Preuss ex Sacc.) Gruyter, Aveskamp & Verkley	*Phoma sclerotioides* Preuss ex Sacc.	Plant tissues, permafrost soil, soil, lake water, dead plants (Salix sp.)	Arctic: Svalbard, Siberia, Canada/ Alaska	Antarctica: East Ongul Island, Deception Island	F,C	eDNA,Cul	M	PA,E	Bellemain et al., 2013; Timling et al., 2014; Zhang et al., 2015b; Zhang and Yao, 2015; Frossard et al., 2021	Hirose et al., 2013; Rosa et al., 2020	-
Ascomycota	*Leptosphaerulina trifolii* (Rostr.) Petr.	-	Soil	-	Antarctica: Ross Sea region	F	eDNA	M	PP	-	Arenz et al., 2006	Booth and Pirozynski, 1967
Ascomycota	*Letendraea helminthicola* (Berk. & Broome) Weese	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	MF	-	Rosa et al., 2020	Akulov, 2015
Basidiomycota	*Leucocybe connata* (Schumach.) Vizzini, P. Alvarado, G. Moreno & Consiglio	*Lyophyllum connatum* (Schumach.) Singer	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Smith et al., 2017; Smith, 2012
Ascomycota	*Leuconeurospora capsici* (J.F.H. Beyma) Malloch, Sigler & Hambl.	-	Coal mine spoil	Arctic: Svalbard	-	C	Cul	M	AA	Iluchin et al., 2022a	-	Malloch et al., 2016
Ascomycota	*Leuconeurospora polypaeciloides* Malloch, Sigler & Hambl.	-	Soil	-	Antarctica: Schirmacher Oasis	F	Cul	Morph	AA	-	Nikitin, 2018 (in Russian)	Malloch et al., 2016
Ascomycota	*Lichenoconium usneae* (Anzi) D. Hawksw.	-	Lichens	-	Antarctica: Bunger Oasis, Figurnoe Lake	n.i.	n.i.	n.i.	LF	-	Olech and Alstrup, 1996	Lawrey et al., 2011
Ascomycota	*Lichenoconium xanthoriae* M.S. Christ.	*Lichenoconium* cf. *xanthonae*	Lichens	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	LF	-	Möller and Dreyfuss, 1996	-
Mucoromycota	*Lichtheimia corymbifera* (Cohn) Vuill.	*Absidia corymbifera* (Cohn) Sacc. & Trotter	Contaminated yeast preparation	-	Antarctica: Dry Valleys, Victoria Land	n.i.	n.i.	n.i.	S,OHP	-	Sugiyama et al., 1967 (Part 1)	Dolatabadi et al., 2014
Basidiomycota	*Limnoperdon incarnatum* G.A. Escobar	-	Soil	Arctic: Siberia	-	n.i.	eDNA	M	W	Lydolph et al., 2005	-	Webster et al., 1993; Baerlocher et al., 2008

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Mucoromycota	*Linnemannia zychae* (Linnem.) Vandepol & Bonito	*Mortierella zychae*	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Mucoromycota	*Linnemannia sclerotiella* (Milko) Vandepol & Bonito	*Mortierella sclerotiella*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Lophiostoma compressum* (Pers.) Ces. & De Not.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Andrease et al., 2021
Ascomycota	*Lophiotrema rubi* (Fuckel) Y. Zhang ter, C.L. Schoch & K.D. Hyde	*Massarina rubi* (Fuckel) Sacc.	Moss	-	Antarctica: King George Iland	C	Cul	M	PA	-	Yu et al., 2014	Frari et al., 2019
Ascomycota	*Lophium arboricola* (Buczacki) Madrid & Gené	*Zalerion arboricola*	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Lophodermium actinothyrium* (Fuckel) Sacc.	-	Leafs	Arctic: Finland	-	I	eDNA	M	E,S	Poosakkannu et al., 2017	-	-
Ascomycota	*Lophodermium caricinum* (Roberge ex Desm.) Duby	*Leptostroma henningsii* Allesch.	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	E,S	Elvebakk and Prestrud, 1996	-	-
Ascomycota	*Loramyces macrosporus* Ingold & B. Chapm.	-	Soil, leafs, roots	Arctic: Finland	-	I	eDNA	M	PA	Poosakkannu et al., 2017	-	-
Ascomycota	*Loratospora aestuarii* Kohlm. & Volkm.-Kohlm.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Newell and Porter, 2000
Ascomycota	*Lulwoana uniseptata* (Nakagiri) Kohlm., Volkm.-Kohlm., J. Campb., Spatafora & Gräfenhan	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	E,En,W	Timling et al., 2014	-	Gonçalves et al., 2021; Torta et al., 2014
Ascomycota	*Luteonectria nematophila* (Nirenberg & Hagedorn) Sand.-Den. & L. Lombard	*Fusarium nematophilum*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	E	-	Rosa et al., 2020	Qin et al., 2022

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Basidiomycota	*Macrotyphula phacorrhiza* (Reichard) Olariaga, Huhtinen, Læssøe, J.H. Petersen & K. Hansen	*Typhula phacorrhiza*	Plants (living)	Arctic: Svalbard, Russia, Iceland	-	n.i.	n.i.	n.i.	PP	Hoshino et al., 2019	-	-
Ascomycota	*Malbranchea cinnamomea* (Lib.) Oorschot & de Hoog	*Malbranchea pulchella* var. *sulfurea* (Miehe) Cooney & R. Emers.	Soil	-	Antarctica: N. Victoria Land, Mt. Melbourne	F	Cul	Morph	S	-	Broady et al., 1987	Hüttner et al., 2017
Ascomycota	*Malbranchea pulchella* Sacc. & Penz.	-	Soil?	Arctic	-	n.i.	Cul	n.i.	S	Ozerskaya et al., 2009	-	Banerjee et al., 1994
Basidiomycota	*Mallocybe fulvipes* (Kühner) Matheny & Esteve-Rav.	*Inocybe fulvipes* Kühner	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	Cathy et al., 2010
Basidiomycota	*Mallocybe fuscomarginata* (Kühner) Matheny & Esteve-Rav.	*Inocybe fuscomarginata*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Mallocybe leucoblema* (Kühner) Matheny & Esteve-Rav.	*Inocybe leucoblema* Kühner	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	Cathy et al., 2010
Basidiomycota	*Mallocybe leucoloma* (Kühner) Matheny & Esteve-Rav.	*Inocybe leucoloma* Kühner	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	Cathy et al., 2010
Basidiomycota	*Mallocybe malenconii* (R. Heim) Matheny & Esteve-Rav.	*Inocybe malenconii* R. Heim	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014	-	-
Basidiomycota	*Mallocybe terrigena* (Fr.) Matheny, Vizzini & Esteve-Rav.	*Inocybe terrigena*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Mammaria echinobotryoides* Ces.	-	Soil	-	Antarctica: Antarctic Peninsula	F	Cul	Morph	PP	-	Kochkina et al., 2019	Kowalik, 2013
Ascomycota	*Marquandomyces marquandii* (Massee) Samson, Houbraken & Luangsa-ard	*Paecilomyces marquandii* (Massee) S. Hughes	Soil	Arctic: White Sea area, WSBS	Antarctica	D,F	Cul	Morph	OHP	Bubnova and Velikanov, 2004 (in Russian)	Nikitin, 2018 (in Russian)	Kidd et al., 2023

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Ascomycota	*Massarina igniaria* (C. Booth) Aptroot	*Periconia igniaria* E.W. Mason & M.B. Ellis	Soil	-	Antarctica	F	Cul	M	E,PP	-	Nikitin, 2018 (in Russian)	Kolomiets et al., 2008; D'Souza et al., 2019
Basidiomycota	*Melampsora epitea* Thüm.	*Melampsora lariciepitea*	Plant tissues, soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	PA,E	Timling et al., 2014; Zhang and Yao, 2015	-	-
Basidiomycota	*Melampsora lini* (Ehrenb.) Thüm.	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP	Lydolph et al., 2005	-	Lawrence et al., 2007
Ascomycota	*Melanodiplodia tianschanica* Wanas., Gafforov & K.D. Hyde	-	Coal mine spoil	Arctic: Svalbard	-	C	Cul	M	n.i.	Iluchin et al., 2022a	-	-
Ascomycota	*Memnoniella dichroa* (Grove) L. Lombard & Crous	*Stachybotrys dichrous* Grove	Peat, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016, 2018	-	Minter, 2020
Ascomycota	*Meristemomyces frigidus* Isola & Onofri	-	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA	M	EL	-	Selbmann et al., 2021	-
Ascomycota	*Metacordyceps chlamydosporia* (H.C. Evans) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora	*Pochonia chlamydosporia* (Goddard) Zare & W. Gams; *Verticillium chlamydosporium* Goddard; *Diheterospora chlamydosporia* (Goddard) G.L. Barron & Onions	Tundra soils, air, soil	Arctic: Polar Urals, Kara Sea, Amderma, Kolba, Dikson, Barents Sea, Shoyna	Antarctica: Antarctic Peninsula, South Shetland Iland	F	eDNA,Cul	M,Morph	S	Kirtsidely et al., 2010, 2011 (in Russian)	Caretta and Piontelli, 1977	-
Ascomycota	*Metapochonia bulbillosa* (W. Gams & Malla) Kepler, S.A. Rehner & Humber	*Pochonia bulbillosa* (W. Gams & Malla) Zare & W. Gams; *Verticillium bulbillosum* W. Gams & Malla	Peat, antropogenic substrates, soil, lake water	Arctic: Svalbard, White Sea area, WSBS, Novaya Zemlya, Franz Joseph Land	-	C,F	eDNA,Cul	M,Morph	S,PF,W,EP	Bergero et al., 1999; Zhang et al., 2015b; Grum-Grzhimaylo et al., 2016, 2018; Kirtsidely et al., 2016; Nikitin et al., 2021; Nikitin and Semenov, 2022	-	Asemaninejad et al., 2017
Ascomycota	*Metapochonia goniodes* (Drechsler) Kepler, S.A. Rehner & Humber	*Acrostalagmus goniodes* Drechsler	Soil, plants	-	Antarctica: South Orkney Ilands, Lynch Iland	F	Cul	Morph	NEP	-	Gray and Smith, 1984	-

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Ascomycota	*Metapochonia suchlasporia* (W. Gams & Dackman) Kepler, S.A. Rehner & Humber	*Pochonia suchlasporia* var. *catenata* (W. Gams & Dackman) Zare & W. Gams; *Verticillium suchlasporium* W. Gams & Dackman	Permafrost sediments, driftwood	Arctic: Greenland	Antarctica: McMurdo Dry Valleys	F,C	Cul	Morph,M	S	Blanchette et al., 2016	Gilichinsky et al., 2007	-
Ascomycota	*Metarhizium anisopliae* (Metschn.) Sorokīn	-	Soil	-	Antarctica: Macquarie Iland	C	Cul	Morph	S,PF	-	Kerry and Weste, 1985	-
Ascomycota	*Metarhizium viride* (Segretain, Fromentin, Destombes, Brygoo & Dodin ex Samson) Kepler, S.A. Rehner & Humber	-	Antropogenic substrates, soil	Arctic: Kara Sea region (Yamal)	Antarctica: Macquarie Iland	n.i.	Cul	Morph	AP	Kirtsideli et al., 2016 (in Russian)	Roddam and Rath, 1997	Schmidt et al., 2017
Mucoromycota	*Mucor pyriformis* Leers*	-	Soil	-	Antarctica: Windmill Ilands	C	Cul	Morph	S,PF	-	Azmi and Seppelt, 1998	-
Ascomycota	*Microascus brevicaulis* S.P. Abbott	*Scopulariopsis brevicaulis* Bainier	Soil, permafrost soil, air, bird remains	Arctic: Polar Urals, Siberia	Antarctica: Ross Sea region, King George Iland, Newfoundland	F,C	eDNA,Cul	Morph,M	K,PF,S	Kirtsidely et al., 2010 (in Russian)	Czarnecki and Bialasiewicz, 1987; Mercantini et al., 1989	-
Ascomycota	*Microascus cinereus* Curzi	-	Soil	-	Antarctica	F	Cul	M	OHP	-	Nikitin, 2018 (in Russian)	Tullio et al., 2010
Ascomycota	*Microascus cirrosus* Curzi	-	Animal seals	-	Antarctica: Primavera Cape	F	Cul	Morph,M	AA	-	Devoto et al., 2022	-
Basidiomycota	*Microbotryum pustulatum* (DC.) R. Bauer & Oberw.	-	Lake water	Arctic: Svalbard	-	F	eDNA,Cul	M	W,PP	Zhang et al., 2015b	-	Kemler et al., 2009
Basidiomycota	*Microbotryum silenes-acaulis* M. Lutz, Piątek, Kemler & Chleb.	*Microbotryum silences-acaulis*	Lake water	Arctic: Svalbard	-	F	eDNA,Cul	M	W,PP	Zhang et al., 2015b	-	Bueker et al., 2016
Ascomycota	*Microdochium bolleyi* (R. Sprague) de Hoog & Herm.-Nijh.	-	Soil	-	Antarctica: Ross Sea region	F	eDNA	M	E,PP	-	Arenz et al., 2006	Zhang et al., 2008
Ascomycota	*Microdochium lycopodinum* (Jaklitsch, Siepe & Voglmayr) Hern.-Restr. & Crous	*Monographella lycopodina*	Moss, peat	Arctic: Alaska	Antarctica: King George Iland, Deception Iland	C,F	Cul,eDNA	M	E	Semenova et al., 2015	de Carvalho et al., 2020; Rosa et al., 2020	-

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Ascomycota	*Microdochium nivale* (Fr.) Samuels & I.C. Hallett	-	Permafrost soil, dark ice with algae, lake water	Arctic: Greenland, Siberia, Alaska	Antarctica: King George Island	F,I	eDNA,Cul	M	IF,PP,W,E	Bellemain et al., 2013; Hoshino et al., 2019; Perini et al., 2019	Gonc alves et al., 2012	Tronsmo et al., 2001;
Ascomycota	*Microdochium phragmitis* Syd. & P. Syd.	-	Leafs, lake water	Arctic: Finland	Antarctica: King George Island	I	eDNA,Cul	M	E,W	Poosakkannu et al., 2017	Gonc alves et al., 2012; de Carvalho et al., 2020	-
Ascomycota	*Microdochium tainanense* (Ts. Watan.) de Hoog & Herm.-Nijh.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	Hernández-Restrepo et al., 2016
Ascomycota	*Microsphaeropsis olivacea* (Bonord.) Höhn.	-	Soil, coal mine spoil	Arctic: Magadan	Antarctica	F,C	Cul	M	OHP,E,W	Iluchin et al., 2022b	Nikitin, 2018 (in Russian)	Keusgen et al., 1996; Guarro et al., 1999; Hormazabal et al., 2005
Ascomycota	*Microsporum canis* E. Bodin ex Guég.	-	Animal seals	-	Antarctica: Primavera Cape	F	Cul	Morph,M	AA	-	Devoto et al., 2022	-
Ascomycota	*Microsporum gypseum* (E. Bodin) Guiart & Grigoraki	-	Soil	-	Antarctica: Ross Sea region, Newfoundland	n.i.	Cul	Morph	K	-	Mercantini et al., 1989	-
Ascomycota	*Mniaecia jungermanniae* (Fr.) Boud.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Pressel and Duckett, 2006
Ascomycota	*Mollisia cinerea* (Batsch) P. Karst.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	PP	Miyamoto et al., 2022	-	Boberg et al., 2011
Ascomycota	*Mollisia palustris* (P. Karst.) P. Karst.	-	Plants, soil	Arctic: subartic region	-	n.i.	Cul	Morph	PF,S	Latter and Heal, 1971	-	Filippova, 2015
Ascomycota	*Monascella botryosa* Guarro & Arx	-	Mosses, lichens	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	PA,LA	-	Möller and Dreyfuss, 1996	-
Ascomycota	*Monascus albidulus* Zhong Q. Li & F. Guo	-	Wood	-	Antarctica: Laurie Island, in the South Orkney Islands	C	Cul	Morph,M	PP	-	Gaiser et al., 2021	http://www.indexfungorum.org/Names/NamesRecord.asp?RecordID=487847
Ascomycota	*Monilinia fructicola* (G. Winter) Honey	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP	Lydolph et al., 2005	-	e Miccolis et al., 2022
Ascomycota	*Monodictys arctica* M.J. Day & Currah	-	Lichens, plant tissues, soil, lake water, roots	Arctic: Svalbard, Canada, Alaska	-	F,C	eDNA	M	W,E,LA	Day et al., 2006; Timling et al., 2014; Zhang et al., 2015a,b; Zhang and Yao, 2015	-	-

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Ascomycota	*Monodictys austrina* Tubaki	-	Soil, algae	-	Antarctica: McMurdo Station, Mac Robertson Land, Vestfold Hills, Iland Livingstone	F,C	Cul	Morph	S	-	Tubaki and Asano, 1965; Kerry, 1990b; Kostadinova et al., 2009	-
Ascomycota	*Monodictys castaneae* (Wallr.) S. Hughes	-	Wood	-	Antarctica: Ross Sea region	F	Cul	M	E	-	Arenz et al., 2006 (ITS identification 93.9)	Bezerra et al., 2012
Ascomycota	*Monodictys glauca* (Cooke & Harkn.) S. Hughes	-	Permafrost sediments	Arctic	-	F	Cul	Morph	PA	Ivanushkina et al., 2005	-	https://www.sci.muni.cz/ccm/houby/htmlh/T540.HTM
Ascomycota	*Monodictys levis* (Wiltshire) S. Hughes	-	Antropogenic substrates	Arctic: Kara Sea region (Yamal)	-	n.i.	Cul	Morph	S,PF	Kirtsideli et al., 2016 (in Russian)	-	-
Ascomycota	*Monodictys paradoxa* (Corda) S. Hughes	-	Antropogenic substrates, plants+birds fecas	Arctic: Kara Sea region (Yamal), Izvestiy TSIK Iaslands	-	F	Cul	Morph	PP	Kirtsideli et al., 2014, 2016 (in Russian)	-	Cannon, 2009
Ascomycota	*Montagnula chromolaenicola* Mapook & K.D. Hyde	-	Permafrost soil	-	Antarctica: South Shetland Ilands, Deception (Whalers Bay)	F	Cul	M	PHAOF	-	de Silva et al., 2022	-
Mucoromycota	*Mortierella alliacea* Linnem.	-	Soil	Arctic: Finland	-	F	eDNA	M	S	Santalahti et al., 2018	-	-
Mucoromycota	*Mortierella alpina* Peyrone	-	Soil, antropogenic substrates, plants, lichens, birds feces, driftwood, wood, coal mine spoil, conifer wood, lake water, permafrost soil	Arctic: Greenland, White Sea area, WSBS, Apatiti, Novaya Zemlya, Franz Joseph Land, Izvestiy TSIK Iaslands, Fersman Iland, Zenith Cape of Heiss Iland, Magadan, High Arctic, Svalbard, Finland, Canada/Alaska, subarctic region, Siberia	Antarctica: Signy Iland, Mars Oasis, Antarctic Peninsula, Deception Iland, King George Island	F,C,D,I	eDNA,Cul	M,Morph	S,PA,PF,PsF	Bergero et al., 1999; Bubnova and Velikanov, 2004 (in Russian); Lydolph et al., 2005; Kurek et al., 2007; Kirtsideli et al, 2014, 2016 (in Russian); Timling et al., 2014; Blanchette et al., 2016; Tsuji et al., 2016; Poosakkannu et al., 2017; Nikitin, 2018 (in Russian); Kaitera et al., 2019; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Nikitin et al., 2021; Iluchin et al., 2022a,b; Nikitin and Semenov, 2022; Tsuji et al., 2022	Latter and Heal, 1971; Bailey and Wynn-Williams, 1982; Onofri, 1999; Arenz and Blanchette, 2011; Gonc alves et al., 2012, 2015; Held and Blanchette, 2017; Rosa et al., 2020	Rosa et al., 2019

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Mucoromycota	*Mortierella amoeboidea* W. Gams	-	Soil, roots, lake water	Arctic: Canada, Svalbard	Antarctica: Ilands near the Antarctic Peninsula, Deception Island	F	eDNA,Cul	M	S,W	Zhang et al., 2015b; Botnen et al., 2020; Tsuji et al., 2022	Held and Blanchette, 2017; Gomes et al., 2018	-
Mucoromycota	*Mortierella antarctica* Linnem.	-	Soil, mosses, lake sediments, antropogenic	Arctic: Alaska, Canada/Alaska	Antarctica: Ross Sea region, King George Iland, Ilands near the Antarctic Peninsula, Victoria Land, Gondwana Lake, Adelie Cove, Tinker Glacier, Cape Satsrugi, Kay Iland, Harrow Peaks, King George Island, Deception Island	C,F	eDNA,Cul	M	S,PA,PsF	Timling et al., 2014; Semenova et al., 2016; Tsuji et al., 2022	Frate and Caretta, 1990; Zucconi et al., 1996; Onofri, 1999; Tosi et al., 2002; Ding et al., 2016; Gomes et al., 2018; Ogaki et al., 2020a,b; Rosa et al., 2020; Nikitin, 2021 (in Russian) = Nikitin, 2023	Rosa et al., 2019
Mucoromycota	*Mortierella elongata* Linnem.	-	Soil, mosses, lake sediments	Arctic: Svalbard, White Sea area, WSBS, Novaya Zemlya, Canada	Antarctica: Signy Iland, Larsemann Hills oasis, King George Island	D,C	Cul	M,Morph	S,PF,E	Osono et al., 2012; Grum-Grzhimaylo et al., 2016, 2018; Tsuji et al., 2016; Nikitin et al., 2021	Weinstein et al., 2000; Marfenine et al., 2016	-
Mucoromycota	*Mortierella elongatula* W. Gams & Domsch	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Mucoromycota	*Mortierella exigua* Linnem.	-	Soil	Arctic: Franz Joseph Land, Fersman Iland, Zenith Cape of Heiss Iland	Antarctica: Deception Iland, South Shetland Ilands	C,F	Cul,eDNA	Morph,M	S,PF,PsF	Bergero et al., 1999; Nikitin and Semenov, 2022	Rosa et al., 2020	-
Mucoromycota	*Mortierella gamsii* Milko	-	Soil, peat, plant tissues, permafrost soil, mosses, lichens, litter, plants, moss	Arctic: Siberia	Antarctica: Windmill Ilands, Ilands near the Antarctic Peninsula, Macquarie Iland, King George Iland, Deception Island	C,F	eDNA,Cul	Morph,M	S,PA,LA,E	Bellemain et al., 2013	Kerry and Weste, 1985; Kerry, 1990a; Möller and Dreyfuss, 1996; Azmi and Seppelt, 1998; Onofri, 1999; Bridge and Denton, 2007; Ding et al., 2016; de Carvalho et al., 2020; Rosa et al., 2020	-
Mucoromycota	*Mortierella globalpina* W. Gams & Veenb.-Rijks	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Mucoromycota	*Mortierella horticola* Linnem.	-	Soil	Arctic: Svalbard	-	n.i.	Cul	M	S,PF	Tsuji et al., 2016	-	-

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Mucoromycota	*Mortierella humicola* Oudem.	-	Soil, plants	Arctic: subarctic region	Antarctica: Signy Iland	n.i.	Cul	Morph	S,PF	Latter and Heal, 1971	https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#RIMI	-
Mucoromycota	*Mortierella hyalina* (Harz) W. Gams	-	Soil, plants, roots	Arctic: Franz Joseph Land, Svalbard	Antarctica: Jenny Iland, Continental (?), Deception Island	C,F	eDNA,Cul	Morph,M	S,PF,PtF	Bergero et al., 1999; Botnen et al., 2020	Rosa et al., 2020; https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#RIMI	-
Mucoromycota	*Mortierella lignicola* (G.W. Martin) W. Gams & R. Moreau	-	Antropogenic substrates, lake sediments	Arctic: White Sea area, WSBS; Izvestiy TSIK Ilands	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016; Kirtsideli et al., 2016 (in Russian)	-	-
Mucoromycota	*Mortierella macrocystis* W. Gams	-	Soil	Arctic: Finland	-	I	eDNA	M	S,PF	Poosakkannu et al., 2017	-	-
Mucoromycota	*Mortierella minutissima* Tiegh.	-	Soil, moss, driftwood	Arctic: Greenland, Iceland, Svalbard, Novaya Zemlya, Franz Joseph Land, Canada	Antarctica: Signy Iland, Windmill Ilands, Deception Island	C,F,D	Cul,eDNA	Morph,M	S,PF,PsF	Bergero et al., 1999; Kurek et al., 2007; Osono et al., 2012; Blanchette et al., 2016; Nikitin et al., 2021	Bailey and Wynn-Williams, 1982; McRae and Seppelt, 1999; Rosa et al., 2020	-
Mucoromycota	*Mortierella parvispora* Linnem.	-	Soil, moss, wood, conifer wood	Arctic: Svalbard, Franz Joseph Land, Finland, Subarctic region	Antarctica: Ilands near the Arctic Peninsula, King George Iland, Signy Iland, Rothera Point, Adelaide Iland, Deception Iland	C,F,I	eDNA,Cul	Morph,M	S,PA,PF,PtF	Bergero et al., 1999; Osono et al., 2012; Poosakkannu et al., 2017; Kaitera et al., 2019; Iluchin et al., 2022a	Latter and Heal, 1971; Bailey and Wynn-Williams, 1982; Onofri, 1999; Hughes et al, 2003; Yu et al., 2014; Held and Blanchette, 2017; Gomes et al., 2018; Rosa et al., 2020	-
Mucoromycota	*Mortierella polygonia* W. Gams & Veenb.-Rijks	-	Soil	Arctic: Svalbard	-	n.i.	Cul	M	S	Tsuji et al., 2016	-	-
Mucoromycota	*Mortierella pulchella* Linnem.	-	Roots, conifer wood	Arctic: Svalbard, Finland	-	F	eDNA,Cul	M	S,PA,PF	Kaitera et al., 2019; Botnen et al., 2020	-	-
Mucoromycota	*Mortierella pusilla* Oudem.	-	Soil, tundra soils	Arctic: Polar Urals	Antarctica: continental	n.i.	Cul	n.i.	S	Kirtsidely et al., 2010 (in Russian)	Greenfield, 1981 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/flistm.html#Mm)	-

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Mucoromycota	*Mortierella turficola* Y. Ling	-	Soil, plants	Arctic: subarctic region	Antarctica: Signy Iland, Deception Island	C,F	Cul,eDNA	Morph,M	S,PF	Thormann and Rice, 2007	Bailey and Wynn-Williams, 1982; Rosa et al., 2020	-
Mucoromycota	*Mucor circinelloides* Tiegh.	*Mucor jansseni* Lendn.	Cryophylic alpine meadow, antropogenic substrates, soil, moss, air	Arctic: White Sea area, WSBS, Polar Urals, Kara sea region (Yamal)	Antarctica: Larsemann Hills oasis New Harbor, Taylor Valley	C,F	Cul	Morph	S	Kirtsideli et al., 2010, 2016 (in Russian); Grum-Grzhimaylo et al., 2018	Sun et al., 1978; Marfenina et al., 2016	-
Mucoromycota	*Mucor flavus* Bainier	-	Bird feathers, antropogenic substrates, soil	Arctic: Svalbard, Taymyr	Antarctica	n.i.	Cul	M,Morph	S,BA	Singh et al., 2015; Kirtsideli et al., 2016 (in Russian)	Onofri, 1999	-
Mucoromycota	*Mucor hiemalis* Wehmer	-	Tundra soils, cryophylic alpine meadow, soil, mosses, antropogenic substrates, plants, peat, plants+birds fecas, driftwood, moss, coal mine spoil	Arctic: Greenland, Iceland, Norway, Hardangervidda, Svalbard, White Sea area, WSBS, Novaya Zemlya, Barents Sea coast, Polar Urals, Izvestiy TSIK Ilands, Taymyr, Severnaya Zemlya, Franz Josef Land, Fersman Iland, Hooker Iland near the Tikhaya Bay, Magadan, Canada, subarctic region	Antarctica: Ross Sea region, Antarctic Peninsula, Mac Robertson Land, Macquarie Iland, Cape Burks, Russkaya Station	F,C,D	eDNA,Cul	Morph,M	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsidely et al., 2010, 2014, 2016 (in Russian); Singh et al., 2012; Osono et al., 2012; Blanchette et al., 2016; Tsuji et al., 2016; Lapteva et al., 2017 (in Russian); Bubnova and Konovalova, 2018 (in Russian); Grum-Grzhimaylo et al., 2018; Borchhardt et al., 2019; Nikitin et al., 2021; Iluchin et al., 2022a,b; Nikitin and Semenov, 2022; Tsiji et al., 2022	Latter and Heal, 1971; Hurst et al., 1983; Fletcher et al., 1985; Kerry and Weste, 1985 (inBOOK); Arenz et al., 2011; Arenz and Blanchette, 2011; Marfenine et al., 2016; Nikitin, 2018 (in Russian)	-
Mucoromycota	*Mucor mucedo* Fresen.	-	Soil, plants	-	Antarctica: McMurdo, Macquarie Iland	C ?	Cul	Morph	S,PF	-	Tubaki and Asano, 1965; Kerry and Weste, 1985	-
Mucoromycota	*Mucor piriformis* A. Fisch.	-	Soil, moss	-	Antarctica: Windmill Ilands	C	Cul	Morph	S,PF	-	Azmi and Seppelt, 1998	-
Mucoromycota	*Mucor plumbeus* Bonord.	-	Permafrost sediments, antropogenic substrates, plants+birds fecas	Arctic: Franz Joseph Land, Izvestiy TSIK Iaslands	Antarctica: Mac Robertson Land	F	Cul	Morph	S,PF	Ivanushkina et al., 2005; Kirtsideli et al., 2014, 2016 (in Russian); Nikitin et al., 2021	Fletcher et al., 1985	-

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Mucoromycota	*Mucor racemosus* Fresen.	-	Tundra soil, antropogenic substrates, driftwood, soil	Arctic: Greenland, White Sea area, WSBS, Polar Urals, Izvestiy TSIK Ilands, Franz Joseph Land, Severnaya Zemlya	-	C,D	Cul	M,Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsidely et al., 2010, 2016 (in Russian); Blanchette et al., 2016; Grum-Grzhimaylo et al., 2018	-	-
Basidiomycota	*Multiclavula corynoides* (Peck) R.H. Petersen	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-
Ascomycota	*Muscodor fengyangensis* Chu L. Zhang*	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	En	-	Rosa et al., 2020	-
Basidiomycota	*Mycena amicta* (Fr.) Quél.	-	Roots	Arctic: Finland, Russia, Yakutia	-	I,C	eDNA	M	S	Poosakkannu et al., 2017; Miyamoto et al., 2022	-	-
Basidiomycota	*Mycena cinerella* (P. Karst.) P. Karst.	-	Roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Basidiomycota	*Mycena citrinomarginata* Gillet	-	Leafs, roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Basidiomycota	*Mycena filopes* (Bull.) P. Kumm.	-	Roots	Arctic: Svalbard	-	F	eDNA	M	S,PF	Lorberau et al., 2017	-	Thormann and Rice, 2007
Basidiomycota	*Mycena galericulata* (Scop.) Gray	-	Roots	Arctic: Svalbard	-	F	eDNA	M	S	Botnen et al., 2020	-	-
Basidiomycota	*Mycena galopus* (Pers.) P. Kumm.	-	Soil	Arctic: Finland	-	I	eDNA,Cul	M, Morph	S	Poosakkannu et al., 2017	-	-
Basidiomycota	*Mycena leptocephala* (Pers.) Gillet	-	Roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Basidiomycota	*Mycena maurella* Robich	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-
Basidiomycota	*Mycena metata* (Fr.) P. Kumm.	-	Roots	Arctic: Russia, Yakutia, Norway	-	C	eDNA	M	S,PF	Miyamoto et al., 2022	-	https://mycena.no/metata.htm; Thormann and Rice, 2007
Basidiomycota	*Mycena plumbea* P. Karst.	-	Roots	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Basidiomycota	*Mycena rebaudengoi* Robich	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-
Basidiomycota	*Mycena simia* Kühner	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-

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Basidiomycota	*Mycetinis scorodonius* (Fr.) A.W. Wilson & Desjardin	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	S	Miyamoto et al., 2022	-	https://www.mushroomexpert.com/mycetinis_scorodonius.html
Ascomycota	*Mycoarthris corallina* Marvanová & P.J. Fisher	*Mycoarthris corallinus*	Plant tissues, soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	PA	Timling et al., 2014; Zhang and Yao, 2015	-	-
Ascomycota	*Mycosphaerella salicicola* (Fuckel) Johanson ex Oudem.	*Septoria salicicola* (Fr.) Sacc.	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	PP	Elvebakk and Prestrud, 1996	-	https://bladmineerders.nl/parasites/fungi/dikarya/ascomycota/pezizomycotina/dothideomycetes/dothideomycetidae/mycosphaerellales/mycosphaerellaceae/mycosphaerella/mycosphaerella-salicicola/
Ascomycota	*Mycosphaerella tassiana* (De Not.) Johanson	*Davidiella tassiana* (De Not.) Crous & U. Braun	Plants, driftwood, lake water, ice core	Arctic: Iceland, Svalbard	Antarctica: Macquarie Iland, King George Island, Deception Iland, South Shetland Ilands, Vostok Station	C,F	eDNA,Cul	Morph,M	S,PP,W,I	Knowlton et al., 2013; Zhang et al., 2015b; Blanchette et al., 2016; Frossard et al., 2021	Kerry and Weste, 1985; Gonc alves et al., 2012; Rosa et al., 2020; Abyzov, 1993 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Mycosymbioces mycenophila* J.L. Frank	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA	Zhang and Yao, 2015	-	-
Ascomycota	*Mycothermus thermophilus* (Cooney & R. Emers.) X. Wei Wang, Houbraken & D.O. Natvig	*Scytalidium thermophilum* (Cooney & R. Emers.) Austwick	Bird dung	-	Antarctica: Ross Sea region, Victoria Land	C	Cul	Morph	S,BA,TF	-	Frate and Caretta, 1990	Basotra et al., 2016
Ascomycota	*Myrmecridium flexuosum* (de Hoog) Arzanlou, W. Gams & Crous	-	Soil	Arctic: Svalbard	-	C	eDNA	M	n.i.	Frossard et al., 2021	-	-
Ascomycota	*Myrmecridium schulzeri* (Sacc.) Arzanlou, W. Gams & Crous	-	Permafrost soil, antropogenic substrates	Arctic: Siberia, Franz Joseph Land	-	F	eDNA,Cul	M,Morph	S,W	Bellemain et al., 2013; Kirtsideli et al., 2016 (in Russian)	-	Gnanesh et al., 2021; Rezakhani et al., 2019

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Ascomycota	*Myxotrichum cancellatum* W. Phillips	-	Lake sediments	-	Antarctica: Antarctic Peninsula	F	Cul	M	PA,E?	-	Ogaki et al., 2020a	-
Basidiomycota	*Naucoria luteolofibrillosa* (Kühner) Kühner & Romagn.*	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Naucoria tantilla* J. Favre	*Alnicola tantilla* (J. Favre) Gulden	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Ascomycota	*Nectria inventa* Pethybr.	-	Dust	-	Antarctica: Edmonson Point	C	Cul	Morph	K	-	Mercantini et al., 1993	-
Ascomycota	*Nectria peziza* (Tode) Fr.	*Hydropisphaera peziza* (Tode) Dumort.	Soil, soil+penguin influence	-	Antarctica: Windmill Ilands	C	Cul	Morph	PA	-	Azmi and Seppelt, 1998	-
Ascomycota	*Nectria ramulariae* (Wollenw.) E. Müll.	*Neonectria ramulariae*	Driftwood	Arctic: Svalbard	-	C	eDNA	M	S	Frossard et al., 2021	-	-
Basidiomycota	*Neoantrodia serialis* (Fr.) Audet	*Antrodia serialis* (Fr.) Donk	Driftwood	Arctic: Greenland, Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Neoascochyta paspali* (P.R. Johnst.) Qian Chen & L. Cai	*Phoma* cf. *paspali*	Lake water, living leaves of Angiosperms	-	Antarctica: King George Iland, Deception Iland	I,F	Cul,eDNA	M	E,W	-	Gonc alves et al., 2012; Rosa et al., 2020; Lucini et al., 2022	-
Ascomycota	*Neobulgaria koningiana* Unter. & Réblová	*Phialophora alba* J.F.H. Beyma	Soil, mosses, lichens, lake sediments (antropogenic inf)	Arctic: Novaya Zemlya, Franz Joseph Land	Antarctica: Dronnin Maud Land, Ilands near the Antarctic Peninsula, East, King Georg Island	C,F	eDNA,Cul	Morph,M	PA,LA,PF,S,MsF	Bergero et al., 1999; Nikitin et al., 2021	Kochkina et al., 2014; Möller and Dreyfuss, 1996; Kochkina et al., 2019; Ogaki et al., 2020b	-
Ascomycota	*Neobulgaria pura* (Pers.) Petr.	-	Soil, conifer wood	Arctic: Canada/ Alaska, Finland	-	F	eDNA,Cul	M	S,PA	Timling et al., 2014; Kaitera et al., 2019	-	-
Ascomycota	*Neocucurbitaria keratinophila* (Verkley, C. Ferrer & Gené) Valenz.-Lopez, Stchigel, Guarro & Cano	*Pyrenochaeta keratinophila*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	K,OHP,AP,PP	-	Rosa et al., 2020	-
Ascomycota	*Neodevriesia capensis* (Crous) Crous	*Teratosphaeria capensis* Crous	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Dietzel et al., 2019
Ascomycota	*Neodevriesia queenslandica* (Crous, R.G. Shivas & McTaggart) Crous	*Devriesia queenslandica* Crous, R.G. Shivas & McTaggart	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PA,W,AA	Timling et al., 2014	-	Lee et al., 2022

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Ascomycota	*Neofusicoccum parvum* (Pennycook & Samuels) Crous, Slippers & A.J.L. Phillips	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Neonectria lugdunensis* (Sacc. & Therry) L. Lombard & Crous	-	Soil	Arctic: Svalbard	-	C	Cul	M	W,S	Iluchin et al., 2022a	-	Seena et al., 2020; Jain et al., 2019
Ascomycota	*Neoscytalidium dimidiatum* (Penz.) Crous & Slippers	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	OHP,PP,PF	Grum-Grzhimaylo et al., 2016	-	Bunyaratavej et al., 2016; Ray et al., 2010
Ascomycota	*Neosetophoma samarorum* (Desm.) Gruyter, Aveskamp & Verkley	-	Feathers	Arctic: Canada	-	F	Cul	M	K,BA	Robicheau et al., 2019	-	-
Ascomycota	*Niesslia exosporioides* (Desm.) G. Winter	-	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985	-
Ascomycota	*Niesslia nordinii* (Bourch.) W. Gams & Stielow	*Monocillium nordinii* (Bourch.) W. Gams	Soil	Arctic: Franz Joseph Land, Fersman Iland	Antarctica	F	Cul	M	PA,PF	Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian)	Tsuneda and Hiratsuka, 1980; Thormann et al., 2004
Ascomycota	*Nigrospora oryzae* (Berk. & Broome) Petch	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Ochrocladosporium elatum* (Harz) Crous & U. Braun	*Cladosporium elatum* (Harz) Nannf.	Permafrost soil, microbial mat	-	Antarctica: McMurdo Dry Valleys, Taylor Valley, Lake Hoare	C	Cul	Morph,M	E	-	Baublis et al., 1991	Rocha et al., 2020
Ascomycota	*Ochrocladosporium frigidarii* Crous & U. Braun	-	Coal mine spoil	Arctic: Magadan	-	C	Cul	M	AI,W	Iluchin et al., 2022b	-	Garzoli et al., 2018
Ascomycota	*Oedocephalum nicotianae* Oudem.	-	Soil	-	Antarctica	F	Cul	M	n.i.	-	Nikitin, 2018 (in Russian)	-
Ascomycota	*Oidiodendron ambiguum* Peyronel & Malan	-	Peat, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016, 2018	-	-
Ascomycota	*Oidiodendron cereale* (Thüm.) G.L. Barron	*Stephanosporium cerealis* (Thüm.) H.J. Swart	Tundra soils, cryophylic alpine meadow, soil, plants	Arctic: Polar Urals, Finland	Antarctica: Signy Iland	C,F,I	Cul	Morph	S,PF	Kirtsidely et al., 2010 (in Russian); Poosakkannu et al., 2017	Latter and Heal, 1971; Bailey and Wynn-Williams, 1982	Thormann and Rice, 2007

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Ascomycota	*Oidiodendron chlamydosporicum* Morrall	-	Soil	Arctic: Svalbard, Finland	-	C,I	eDNA	M	S,PF	Poosakkannu et al., 2017; Frossard et al., 2021	-	-
Ascomycota	*Oidiodendron echinulatum* G.L. Barron	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	Thormann and Rice, 2007
Ascomycota	*Oidiodendron flavum* Svilv.	-	Soil	Arctic: White Sea area, WSBS	-	D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian)	-	-
Ascomycota	*Oidiodendron griseum* Robak	-	Peat, lake sediments, soil, coal mine spoil	Arctic: Svalbard, White Sea area, WSBS, Izvestiy TSIK Ilands	-	F,C	Cul	Morph	S,PF	Kirtsideli et al, 2014 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Iluchin et al., 2022a	-	Thormann and Rice, 2007
Ascomycota	*Oidiodendron majus* G.L. Barron	*Oidiodendron maius* var. *citrinum* (G.L. Barron) A.V. Rice & Currah	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,Er,PF	Grum-Grzhimaylo et al., 2016	-	Thormann and Rice, 2007
Ascomycota	*Oidiodendron periconioides* Morrall	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	Thormann and Rice, 2007
Ascomycota	*Oidiodendron setiferum* Essl.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA	-	Rosa et al., 2020	Kwaśna et al., 2005
Ascomycota	*Oidiodendron tenuissimum* (Peck) S. Hughes	*Oidiodendron tennuissimum*	Soil	Arctic: White Sea area, WSBS	-	D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian)	-	Thormann and Rice, 2007
Ascomycota	*Oidiodendron truncatum* G.L. Barron	-	Soil	Arctic: White Sea area, WSBS	Antarctica: King George Iland, Deception Iland	D,F	Cul,eDNA	M,Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian)	Ding et al., 2016; Rosa et al., 2020	Thormann and Rice, 2007
Ascomycota	*Oleoguttula mirabilis* Selbmann & de Hoog	-	Lichens, plant tissues, rocks, dark ice	Arctic: Greenland, Svalbard	Antarctica: James Ross Island, Victoria Land	F,C	eDNA,Cul	M	LA,PA,EL	Zhang et al., 2015a; Zhang and Yao, 2015; Perini et al., 2019	Laichmanová, 2020; Selbmann et al., 2021	-
Basidiomycota	*Oligoporus dissectus* (Cooke) Huckfeldt & Olaf Schmidt	*Postia dissecta*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Ombrophila janthina* (Fr.) Sacc.	*Ombrophila violacea*	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PA	Timling et al., 2014	-	Matocec et al., 2005

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Ascomycota	*Ophiocordyceps sinensis* (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora	-	Soil	-	Antarctica	F	Cul	M	EP	-	Nikitin, 2018 (in Russian)	Wang and Yao, 2011
Ascomycota	*Ophiosphaerella agrostidis* Dern., M.P.S. Câmara, N.R. O'Neill, Berkum & M.E. Palm	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PP	Bellemain et al., 2013	-	Kaminski et al., 2019
Ascomycota	*Ophiostoma canum* (Münch) Syd. & P. Syd.	-	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Ophiostoma karelicum* Linnak., Z.W. de Beer & M.J. Wingf.	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Ophiostoma tetropii* Math.-Käärik	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Orbilia brochopaga* (Drechsler) Baral, E. Weber, Bin Liu & Z.F. Yu	*Dactylaria gracilis* Dudd.	Mosses	-	Antarctica: Sighy Iland, Marble Knolls, Galindez Iland, Lynch Iland, South Orkney Ilands	F,C	Cul	Morph	N,NP	-	Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Orbilia ellipsospora* (Preuss) Bin Liu, E. Weber & Baral	*Dactylella ellipsospora* (Preuss) Grove; *Monacrosporium ellipsosporum* (Preuss) R.C. Cooke & C.H. Dickinson	Soil, plants, moss	-	Antarctica: Andree Iland, Charlotte Bay, Signy Iland, Marguerite Bay, Marble Knolls, Galindez Iland	F	Cul	Morph	N,NP	-	Gray et al., 1982; Gray and Smith, 1984	-
Ascomycota	*Orbilia lysipaga* (Drechsler) Bin Liu, Baral & E. Weber	*Monacrosporium lysipagum* (Drechsler) Subram.	Moss, soil	-	Antarctica: Signy Iland, Lynch Iland	F	Cul	Morph	N	-	Gray et al., 1982	-
Ascomycota	*Otidea leporina* (Batsch) Fuckel	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Ovadendron sulphureo-ochraceum* (J.F.H. Beyma) Sigler & J.W. Carmich.	-	Soil, lichens	Arctic: Franz Joseph Land	Antarctica: King George Iland, Continetal	C	Cul	Morph	LA,PtF	Bergero et al., 1999	Möller and Dreyfuss, 1996	-
Ascomycota	*Paecilomyces antarcticus* Bridge, M.S. Clark & D.A. Pearce	-	Invertebrate animals (springtail)	-	Antarctica: Rothera Point, Adelaide Iland	n.i.	n.i.	n.i.	S,AP,AA	-	Bridge et al., 2005	Song et al., 2017

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Ascomycota	*Paecilomyces clavisporus* Hammill	-	Soil with penguin guano, soil	-	Antarctica: MacRobertson Land	F	Cul	Morph	S	-	Fletcher et al., 1985	-
Ascomycota	*Paecilomyces divaricatus* (Thom) Samson, Houbraken & Frisvad	-	Driftwood	Arctic: Greenland	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Paecilomyces fulvus* Stolk & Samson	*Byssochlamys fulva* Olliver & G. Sm.	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	S	Bellemain et al., 2013	-	-
Ascomycota	*Paecilomyces niveus* Stolk & Samson	*Byssochlamys nivea*	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,PP	Zhang et al., 2015b	-	Biango-Daniels et al., 2019
Ascomycota	*Paecilomyces variotii* Bainier	-	Cryophylic alpine meadow, mosses, soil	Arctic: Svalbard, Polar Urals	Antarctica: Ilands near the Antarctic Peninsula, East	F	Cul	Morph	S,PA,PF	Ivanushkina et al., 2005; Kirtsidely et al., 2010 (in Russian); Kochkina et al., 2011 (in Russian); Iluchin et al., 2022a	Möller and Dreyfuss, 1996; Kochkina et al., 2019	-
Basidiomycota	*Panellus stipticus* (Bull.) P. Karst.	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	S	Lydolph et al., 2005	-	-
Ascomycota	*Paraboeremia putaminum* (Speg.) Qian Chen & L. Cai	*Phoma putaminum* Speg.	Soil	Arctic: White Sea area, WSBS	-	D	Cul	Morph	E	Bubnova and Velikanov, 2004 (in Russian)	-	He et al., 2020
Ascomycota	*Paraconiothyrium brasiliense* Verkley	-	Soil, roots	Arctic: Finland	-	I	eDNA	M	E	Poosakkannu et al., 2017	-	-
Ascomycota	*Paraconiothyrium fuckelii* (Sacc.) Verkley & Gruyter	*Coniothyrium fuckelii*	Lichens	Arctic: Svalbard	-	F	eDNA	M	LA,S	Zhang et al., 2015a	-	-
Ascomycota	*Paradendryphiella arenariae* (Nicot) Woudenb. & Crous	-	Littoral soil	Arctic: Barents Sea coast	-	F	Cul	Morph	PA,E,W	Bubnova and Konovalova, 2018 (in Russian)	-	Liu et al., 2017; Furtado et al., 2019
Ascomycota	*Paradendryphiella salina* (G.K. Sutherl.) Woudenb. & Crous	*Dendryphiella salina* (G.K. Sutherl.) Pugh & Nicot; *Scolecobasidium salinum* (G.K. Sutherl.) M.B. Ellis	Moss, soil, littoral sand	Arctic: White Sea area, WSBS, Barents Sea coast	Antarctica: Victoria Land, Carezza Lake, Baker Rocks, Marble Point, Ross Sea region, Adelie Cove, Harrow Peaks, Terra Nova Bay, Ongul Iland, McMurdo Sound, Mac Robertson Land, Vestfold Hills, Cape Evans, East Ongul Island	C,F,D	Cul	M,Morph	S,PA	Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Grum-Grzhimaylo et al., 2018	Tubaki and Asano, 1965; Sun et al., 1978; Zucconi et al., 1996; Fenice et al., 1997; Frate and Caretta, 1990; Kerry, 1990b; Tosi et al., 2002; Tsui, 2019	-

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Ascomycota	*Paraleptosphaeria rumicis* (Quaedvl., Verkley & Crous) Voglmayr	*Acicuseptoria rumicis* Quaedvl., Verkley & Crous	Soil	Arctic: Svalbard	-	C	eDNA	M	PP	Frossard et al., 2021	-	Spitzer et al., 2022
Ascomycota	*Paramyrothecium roridum* (Tode) L. Lombard & Crous	*Myrothecium roridum* Tode	Soil	Arctic: Svalbard	-	F,C	Cul	Morph,M	PP	Singh et al., 2012	-	
Ascomycota	*Paraphaeosphaeria minitans* (W.A. Campb.) Verkley, Göker & Stielow	*Coniothyrium minitans* W.A. Campb.	Soil	Arctic: White Sea area, WSBS	-	D	Cul	Morph	MF	Bubnova and Velikanov, 2004 (in Russian)	-	Nicot et al., 2019
Ascomycota	*Paraphaeosphaeria sporulosa* (W. Gams & Domsch) Verkley, Göker & Stielow	-	Roots	Arctic: Finland	-	I	eDNA	M	E	Poosakkannu et al., 2017	-	-
Ascomycota	*Paraphoma fimeti* (Brunaud) Gruyter, Aveskamp & Verkley	*Phoma fimeti*	Soil, lake water	-	Antarctica: East, Antarctic Peninsula, King George Island	F,I	Cul	Morph,M	S?,W	-	Gonc alves et al., 2012; Nikitin, 2018 (in Russian); Kochkina et al., 2019	-
Ascomycota	*Parengyodontium album* (Limber) C.C. Tsang, J.F.W. Chan, W.M. Pong, J.H.K. Chen, A.H.Y. Ngan, M. Cheung, C.K.C. Lai, D.N.C. Tsang, S.K.P. Lau & P.C.Y. Woo	*Engyodontium album* (Limber) de Hoog; *Tritirachium album* Limber	Permafrost soil, frozen sediments, peat, lake sediments, soil, cryoconite, lake water	Arctic: Svalbard, White Sea area, WSBS, Kolyma, Franz Joseph Land	Antarctica: McMurdo Dry Valleys, Victoria Land, Continental and peninsula Antarctica, Browning Peninsula, Windmill Islands	F,C	eDNA,Cul	Morph,M	PF,IF,W	Bergero et al., 1999; Ivanushkina et al., 2005; Zhang et al., 2015b; Grum-Grzhimaylo et al., 2016, 2018; Borze cka et al., 2022	Onofri, 1999; Gilichinsky et al., 2007; Zucconi et al., 2012; Pudasaini et al., 2017	-
Ascomycota	*Patinella hyalophaea* Sacc.	-	Soil, coal mine spoil , lake sediments, wood, cryoconite	Arctic: Svalbard	Antarctica: King George Iland, Deception Iland	C,F	Cul	M	PF,S,W,IF	Borze cka et al., 2022; Iluchin et al., 2022a	Held and Blanchette, 2017; Ogaki et al., 2020b	-
Ascomycota	*Penicillium adametzii* K.W. Zaleski	-	Air, soil	-	Antarctica: McMurdo Sound, Continental and peninsula Antarctica, Lake Bonney, Taylor Valley	F,C	Cul	Morph	S,PF	-	Tubaki and Asano, 1965; Sun et al., 1978	-
Ascomycota	*Penicillium allii-sativi* Frisvad, Houbraken & Samson	-	Soil	-	Antarctica: Ellsworth Mountains	F	Cul	M	S	-	Godinho et al., 2015	-
Ascomycota	*Penicillium amphipolaria* Visagie, Malloch & Seifert	-	Soil	Arctic: subarctic East Canada, Quebec	Antarctica: McMurdo Dry Valleys	n.i.	Cul	Morph	S	Visagie et al., 2016	Visagie et al., 2016	-

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Ascomycota	*Penicillium angulare* S.W. Peterson, E.M. Bayer & Wicklow	-	Peat	Arctic: Alaska	-	F	eDNA	M	S	Semenova et al., 2015	-	-
Ascomycota	*Penicillium antarcticum* A.D. Hocking & C.F. McRae	-	Soil near Fulmar nests, soil, animal seals, birds nest, feathers	Arctic: Canada	Antarctica: Windmill Ilands, Wilkes Land, Schirmacher Oasis, Primavera Cape	F	Cul	Morph,M	S,AA,BA,E,W,PsF	Robicheau et al., 2019	McRae et al., 1999; Singh et al., 2006; Nikitin, 2021 (in Russian) = Nikitin, 2023; Devoto et al., 2022	Shiono et al., 2014; Park et al., 2015; Rosa et al., 2019
Ascomycota	*Penicillium arcticum**	-	Ice, water	Arctic: Svalbard	-	I	Cul	Morph	S	Gunde-Cimerman et al., 2003	-	-
Ascomycota	*Penicillium astrolabium* R. Serra & S.W. Peterson	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Penicillium atramentosum* Thom	-	Littoral soil	Arctic: Barents Sea coast	-	F	Cul	Morph	S	Bubnova and Konovalova, 2018 (in Russian)	-	-
Ascomycota	*Penicillium aurantiacobrunneum* Houbraken, Frisvad & Samson	*Penicillium auratiacobrunneum*	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Penicillium aurantiogriseum* Dierckx	*Penicillium puberulum* Bainier; *Penicillium viridicatum* Westling; *Penicillium cyclopium* Westling; *Penicillium verrucosum* var. *cyclopium*	Cryopeg, permafrost and tundra soils, anchient sediments, permafrost sediments, antropogenic substrates, air, ice core, fellfield vegetation, birds fecal, soil with recreational plant community, peat, soil, littoral sand, moss, litter, plants, coal mine spoil,birds nest	Arctic: Svalbard, Kolyma, Novaya Zemlya, Polar Urals, White Sea, WSBS, Sonsnovetz Iland, Barents Sea, Kolguyev Iland, Beliy nos, Shoyna, Novaya Zemlya, Kara Sea, Yamal, Vaygach Iland, Amderma, Kolba, Dikson, Izvestiy TSIK Ilands, Arctic Ocean, Vize Iland, Franz Joseph Land, Apatiti, Hooker Iland near the Tikhaya Bay, Fersman Iland, Zenith Cape of Heiss Iland, Melekhov Cape of Alexandra Land, Taymyr, Severnaya Zemlya	Antarctica: McMurdo Dry Valleys, Dronnin Maud Land, Macquarie Iland, South Georgia, Enderby Land, Mac-Robertson, Land, Signy Iland, Coronation Iland, Ross Sea, Windmill Ilands, Vestfold Hills, Mawson, Vostok Station, NewfoundLand, Larsemann Hills oasis	F,C,D	Cul	Morph	S,BA,PF	Kirtsidely, 1999; Bubnova and Velikanov, 2004 (in Russian); Gilichinsky et al., 2005; Ivanushkina et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008, 2009; Stakhov et al., 2008; Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Kochkina et al., 2011 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Nikitin et al., 2021; Iluchin et al., 2022a; Nikitin an Semenov, 2022	Fletcher et al., 1985; Kerry and Weste, 1985; Kerry, 1990a,b; McRae et al., 1999; Onofri, 1999; Corte et al., 2000; Gilichinsky et al., 2007; Kochkina et al., 2012, 2014; Marfenina et al., 2016; Nikitin, 2018 (in Russian); Rosa et al., 2020	-
Ascomycota	*Penicillium bialowiezense* K.W. Zaleski	-	Dark ice with algae	Arctic: Greenland	-	n.i.	Cul	M	IF	Perini et al., 2019	-	-

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Ascomycota	*Penicillium biourgeianum* K.W. Zaleski*	-	Driftwood	Arctic: Iceland	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Penicillium brasilianum* Bat.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Penicillium brevicompactum* Dierckx	-	Permafrost and tundra soils, permafrost sediments, mosses, ice, antropogenic substrate, air, litter, plants, peat, soil, conifer wood	Arctic: Finland, White Sea area, WSBS, Apatiti, Barents Sea coast, Polar Urals, Svalbard, Kara Sea region (Yamal), Komi, Izvestiy TSIK Ilands, Franz Joseph Land, Taymyr, Severnaya Zemlya	Antarctica: McMurdo Dry Valleys, Marcobertson Land, Ilands near the Antarctic Peninsula, Macquarie Iland, South Georgia, King George Iland, Enderby Land, Cabo Primavera, Signy Iland, Mount Melbourne, Victoria Land, Ellsworth Mountains	F,C,D	Cul	Morph,M	S,PA,PF	Kirtsidely, 1999; Gunde-Cimerman et al., 2003; Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Kirtsidely et al., 2010, 2016 (in Russian); Grum-Grzhimaylo et al., 2016; Lapteva et al., 2017 (in Russian); Bubnova and Konovalova, 2018 (in Russian); Kaitera et al., 2019	Fletcher et al., 1985; Kerry and Weste, 1985; Kerry, 1990a; Chalmers et al., 1996; Möller and Dreyfuss, 1996; McRae et al., 1999 (cyt. Barker, 1977); Onofri, 1999; Tosi et al., 2002; Gilichinsky et al., 2007; Kochkina et al., 2012, 2014; Godinho et al., 2015	-
Ascomycota	*Penicillium brocae* S.W. Peterson, Jeann. Pérez, F.E. Vega & Infante	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Penicillium camemberti* Thom	*Penicillium biforme*	Tundra soils, air, antropogenic substrates, food, coal mine spoil, rocks	Arctic: Polar Urals, Franz Joseph Land, Taymyr, Magadan	Antarctica: Arctowski Station, King George Iland, South Shetlands Islands	C	Cul	Morph,M	S,EL	Kirtsidely, 1999 (in Russian); Kirtsidely et al., 2010, 2016 (in Russian); Iliushin et al., 2022b	Czarnecki and Bialasiewicz, 1987	-
Ascomycota	*Penicillium canescens* Sopp	*Penicillium kapuscinskii* K.W. Zaleski	Tundra soils, antropogenic substrates, soil, air, plants+birds fecas, peat, driftwood, coal mine spoil	Arctic: Greenland, Svalbard, Siberia, Polar Urals, White Sea, WSBS, Sonsnovetz Iland, Kara Sea, Kolba, Izvestiy TSIK Ilands, Novaya Zemlya, Franz Joseph Land, Taymyr, Komi, Magadan	Antarctica: East Ongul Iland, Continental and peninsula Antarctica, Lake Vand, Wright Valley, McMurdo quarry and Station, Ross Iland, Victoria Valley	F,C,D	Cul	Morph,M	S,PF	Kirtsidely, 1999; Bubnova and Velikanov, 2004 (in Russian); Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Blanchette et al., 2016; Lapteva et al., 2017 (in Russian); Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Nikitin et al., 2021; Iluchin et al., 2022a,b	Tubaki and Asano, 1965; Sun et al., 1978	-
Ascomycota	*Penicillium cairnsense* Houbraken, Frisvad & Samson	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-

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Ascomycota	*Penicillium catenatum* D.B. Scott	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Penicillium chermesinum* Biourge	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016, 2018	-	-
Ascomycota	*Penicillium chrysogenum* Thom	*Penicillium notatum* Westling	Tundra soils, permafrost sediments, soil, soil+bird influence, frozen sediments, ice, air, microbial mat, water, fruit, food, peat, rocks, littoral sand, moss, regoliths, coal mine spoil, snow, lake sediments (antroponenic inf), lake water, feathers, ice core, algae	Arctic: Canada, Greenland, White Sea, WSBS, Novaya Zemlya, Sonsnovetz Iland, Barents Sea, Shoyna, Norway, Svalbard, Finland, Siberia, Kara Sea, Vaygach Iland, Kolba, Dikson, Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land, Polar Urals, Siberia	Antarctica: McMurdo Dry Valleys, Windmill Ilands, Dronnin Maud Land, Antarctic Peninsula, King George Iland, Ilands near the Antarctic Peninsula, South Georgia, Signy Iland, Ross Sea, Tarn Flat, Inexpressible Iland, King Gondwana, Windmill Ilands, Victoria Land, Marie Byrd Land, Vostok Station, McMudro Station, Ross Iland, Heald Iland, Wright Valley, New Harbor, Taylor Valley, Lake Vanda, Heritage Range, Larsemann Hills oasis, Russkaya Station, Ellsworth Mountains, Deception Iland, lakes in the Larsemann Hills, Vestfold Hills and the McMurdo Dry Valleys	F,C,D	eDNA,Cul	Morph,M	S,BA,PF,IF,EL, W,PHAOF,PtF	Kirtsidely, 1999 (in Russian); Gunde-Cimerman et al., 2003; Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Lydolph et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008; Kirtsidely et al., 2010, 2011 (in Russian); Kochkina et al., 2011 (in Russian); Singh et al., 2012; Bellemain et al., 2013; Knowlton et al., 2013; Zhang et al., 2015b; Blanchette et al., 2016; Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Perini et al., 2019; Robicheau et al., 2019; Yakushev et al., 2019; Kochkina et al., 2021; Nikitin et al., 2021; Iluchin et al., 2022a; Nikitin and Semenov, 2022	Caretta and Piontelli, 1977; Sun et al., 1978; Czarnecki and Bialasiewicz, 1987; Baublis et al., 1991; Chalmers et al., 1996; Azmi and Seppelt, 1998; McRae et al., 1999 (cyt. Rudolph, 1970; L. Smith, 1994); Corte et a., 2000; Brunati et al., 2009; Kochkina et al., 2012, 2014; Zucconi et al., 2012; Godinho et al., 2015; Abneuf et al., 2016; Ding et al., 2016; Marfenina et al., 2016; Gonçalves et al., 2017; Gomes et al., 2018; Alves et al., 2019; de Menezes et al., 2019; Ogaki et al., 2020b; de Silva et al., 2022	Rosa et al., 2019
Ascomycota	*Penicillium citreonigrum* Dierckx	*Penicillium citreoviride* Biourge	Soil, peat, air, conifer wood	Arctic: Svalbard, Finland, White Sea area, WSBS	Antarctica: East, Antarctic Peninsula, continental, Lake Bonney, Taylor Valley	F,C	Cul	Morph,M	S,PA,PF	Zhang et al., 2015b; Grum-Grzhimaylo et al., 2016; Kaitera et al., 2019	Sun et al., 1978; Kochkina et al., 2019	-

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Ascomycota	*Penicillium citrinum* Thom	*Penicillium steckii* K.M. Zalessky	Permafrost sediments, soil, antropogenic substrates, air, soil with recreational plant community, rocks, driftwood, lake sediments, littoral soil, coal mine spoil	Artcica: Greenland, White Sea area, WSBS, Barents Sea coast, Siberia, Kara Sea region (Yamal), Izvestiy TSIK Ilands, Franz Joseph Land, Taymyr, Severnaya Zemlya, Magadan	Antarctica: McMurdo Dry Valleys, King George Iland, Signy Iland, Skua lake, Robertskollen, western Dronning Maud Land, NewfoundLand, Antarctic Peninsula, South Georgia Iland, Heritage Range, Deception Island	F,C,D	eDNA,Cul	Morph,M	S,BA,PF	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Bellemain et al., 2013; Kirtsideli et al., 2014, 2016 (in Russian); Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016; Bubnova and Konovalova, 2018 (in Russian); Iluchin et al., 2022b	Ryan et al., 1989; Chalmers et al., 1996; Corte et al., 2000; Kochkina et al., 2012; Ding et al., 2016; Gonçalves et al., 2017; Rosa et al., 2020	-
Ascomycota	*Penicillium coffeae* S.W. Peterson, F.E. Vega, Posada & Nagai	-	Rocks, soil	-	Antarctica: Heritage Range	F	Cul,eDNA	M	S	-	Gonçalves et al., 2017; Rosa et al., 2020	-
Ascomycota	*Penicillium commune* Thom	-	Permafrost sediments, bird feathers, ice, soil	Arctic: Svalbard, Novaya Zemlya;	Antarctica: McMurdo Dry Valleys; Windmill Ilands, Wilkes Land, Cabo Primavera, Rothera Point Adelaide Iland	F	Cul	Morph,M	S,BA,K,PF	Kirtsidely, 1999; Gunde-Cimerman et al., 2003; Singh et al., 2015; Nikitin et al., 2021; Iluchin et al., 2022a	McRae and Seppelt, 1999; McRae et al., 1999; Hughes et al., 2007; Kochkina et al., 2012; Litova et al., 2014	-
Ascomycota	*Penicillium coprophilum* (Berk. & M.A. Curtis) Seifert & Samson	-	Soil	-	Antarctica: Dronnin Maud Land	F	Cul	Morph	S	-	Kochkina et al., 2014	-
Ascomycota	*Penicillium corylophilum* Dierckx	-	Soil, plants, peat, birds nest, ice core	Arctic: Greenland, White Sea area, WSBS	Antarctica: East, Windmill Ilands, McMudro quarry and Station,Lake Vanda, Wright Valley, Ross Iland, Ongul Iland, Cape Evans, Wilkes Land, Continental and peninsula Antarctica, Victoria Valley, Macquarie Iland, Russkaya Station	F,C	Cul	Morph,M	S,BA,PF,I	Knowlton et al., 2013; Grum-Grzhimaylo et al., 2016	Tubaki and Asano, 1965; Sun et al., 1978; Kerry and Weste, 1985; McRae and Seppelt, 1999; McRae et al., 1999; Marfenina et al., 2016; Kochkina et al., 2019	-

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Ascomy-cota	*Penicillium decum-bens* Thom	-	Tundra soils, cryo-phylic alpine meadow, ice, antropogenic substrates, plants, soil, feathers	Arctic:Canada, White Sea area, WSBS, Apatiti, Polar Urals, Svalbard, Kara Sea region (Yamal), Izvestiy TSIK Ilands, Franz Joseph Land, Severnaya Zemlya	Antarctica: Macquarie Iland	F,C,D	Cul	Morph	S,PF,BA	Gunde-Cimermanet al., 2003; Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Kirtsidely et al., 2010, 2016 (in Russian); Grum-Grzhimaylo et al., 2018; Robicheau et al., 2019; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	Kerry and Weste, 1985; Kerry et al., 1990a	-
Ascomy-cota	*Penicillium dierck-xii* Biourge	*Penicillium charle-sii* G. Sm.; *Penicil-lium fellutanum*	Soil, peat	Arctic: White Sea area, WSBS, Apatiti, Kara Sea region (Ya-mal), Izvestiy TSIK Ilands, Franz Joseph Land, Severnaya Zemlya	Antarctica: Ongul Iland, McMurdo Station, Ross Iland, Victoria Land, Marie Byrd Land, Cape Evans	C,F	Cul	Morph,M	S,PF	Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al., 2016 (in Russian); Ko-rneykova et al., 2020 (in Russian) = Korneykova et al., 2022	Tubaki and Asano, 1965; McRae et al., 1999 (cyt. Rudolph, 1970)	-
Ascomy-cota	*Penicillium dipodo-myicola* (FrisvaD,Filt. & Wicklow) Frisvad	-	Coal mine spoil	Arctic: Magadan	-	C	Cul	M	S	Iluchin et al., 2022b	-	-
Ascomy-cota	*Penicillium dipodo-myus* (FrisvaD,Filt. & Wicklow) Banke, Frisvad & S. Rosend.	-	Antropogenic substrates	Arctic: Severnaya Zemlya	-	n.i.	Cul	Morph	S	Kirtsideli et al., 2016 (in Russian)	-	-
Ascomy-cota	*Penicillium echinula-tum* Raper & Thom ex Fassat.	-	Soil, ice, wood, littoral soil	Arctic: Svalbard, Barents Sea coast	Antarctica: Ross Sea region, South Georgia, MacRobertson Land	F	eDNA,Cul	M,Morph	S	Gunde-Cimerman et al., 2003; Bubnova and Konovalova, 2018 (in Russian)	McRae et al., 1999 (cyt. Heatwole et al., 1989); Arenz et al., 2006	-
Ascomy-cota	*Penicillium expansum* Link	-	Tundra soils, permafrost and frozen sediments, soil, soil+birds influence, antropogenic substrates, air, wooden huts, wood, peat, moss, stones with algae, regoliths, cryo-conite, algae	Arctic:Svarbard, White Sea area, WSBS, Polar Urals, Taymyr, Severnaya Zemlya, Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: McMurdo Dry Valleys, Windmill Ilands, East, Kerguelen Iland, South Georgia, MacRobertson, Land, Wilkes Land, Cabo Primavera, Cape Evans Ross Iland, Terra Nova, Larsemann Hills oasis, Russkaya Station	F,C,D	Cul	Morph,M	S,PF,IF,W	Bubnova and Velikanov, 2004 (in Russian); Kurek et al., 2007; Kirtsidely et al., 2010, 2016 (in Rus-sian); Grum-Grzhimaylo et al., 2016; Borze cka et al., 2022; Nikitin and Semenov, 2022	Azmi and Seppelt, 1998; McRae et al., 1999 (cyt. Barker, 1977); Duncan et al., 2006; Duncan, 2007; Kochkina et al., 2012, 2019; Zucconi et al., 2012; Marfenina et al., 2016; Nikitin, 2018 (in Russian)	-
Ascomy-cota	*Penicillium fusispo-rum* L. Wang	-	Snow	Arctic: Greenland	-	n.i.	Cul	M	IF	Perini et al., 2019	-	-

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Ascomycota	*Penicillium glabrum* (Wehmer) Westling	*Penicillium frequentans* Westling	Permafrost and tundra soils, permafrost and frozen sediments, mosses, ice, antropogenic substrates, air, plants+birds fecas, plants, peat, soil, littoral sand, coal mine spoil, conifer wood, lake sediments (antropogenic inf)	Arctic: Finland, Kolyma, Polar Urals, Siberia, Barents Sea, White Sea area, WSBS, Kolguyev Iland, Shoyna, Novaya Zemlya, Svalbard, Franz Joseph Land, Kara Sea, Vaygach Iland, Marre-Sale, Ust'-Kara, Amderma, Kolba, Dikson, Izvestiy TSIK Iaslands, Taymyr, Severnaya Zemlya, Magadan, subarctic region	Antarctica: McMurdo Dry Valleys, Ilands near the Antarctic Peninsula, Macquarie Iland, King George Iland, Victoria Land, Marie Byrd Land, Dronning Maud Land, Robertskollen, Macquarie Iland, Larsemann Hills oasis, Russkaya Station	F,C,D	eDNA,Cul	Morph,M	S,BA,PA,PF	Kirtsidely, 1999 (in Russian); Gunde-Cimerman et al., 2003; Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Ozerskaya et al., 2008; Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Kochkina et al., 2011 (in Russian); Bellemain et al., 2013; Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian); Kaitera et al., 2019; Iluchin et al., 2022a,b	Latter and Heal, 1971; Kerry and Weste, 1985; Ryan et al., 1989; McRae et al., 1999 (cyt. Rudolph, 1970); Möller and Dreyfuss, 1996; Kochkina et al., 2012; Zucconi et al., 2012; Marfenina et al., 2016; Ogaki et al., 2020b	-
Ascomycota	*Penicillium glandicola* (Oudem.) Seifert & Samson	-	Ice core, soil	-	Antarctica: Macquarie Iland, South Georgia, Vostok Station, Russkaya Station	F	Cul	Morph	S	-	Marfenina et al., 2016; Abyzov, 1993 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Penicillium glaucoalbidum* (Desm.) Houbraken & Samson	*Thysanophora penicillioides*	Conifer wood, permafrost soil	Arctic: Finland, Kolyma	-	F	Cul	M,Morph	S,PA	Ozerskaya et al., 2008; Kaitera et al., 2019	-	-
Ascomycota	*Penicillium granulatum* Bainier	-	Permafrost soil, permafrost sediments, plants, ancient seeds	Arctic: Kolyma	Antarctica: McMurdo Dry Valleys, Macquarie Iland	F	Cul	Morph	S	Ozerskaya et al., 2008; Stakhov et al., 2008	Kerry and Weste, 1985; Kochkina et al., 2012	-
Ascomycota	*Penicillium griseofulvum* Dierckx	-	Cryopeg, soil, driftwood, peat, lake sediments	Arctic: Greenland, White Sea area, WSBS, Kolyma	Antarctica: Dronnin Maud Land	F,C	Cul	Morph,M	S,PF	Ozerskaya et al., 2008; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018	Kochkina et al., 2014; Nikitin, 2018 (in Russian)	-
Ascomycota	*Penicillium groenlandense**	-	Ice, water	Arctic: Svalbard	-	n.i.	Cul	Morph	S	Gunde-Cimerman et al., 2003	-	-

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Ascomycota	*Penicillium herquei* Bainier & Sartory	*Penicillium herqei; Penicillium herque; Penicillium herqueri*	Tundra soils, antropogenic substrates, soil	Arctic: Svalbard, White Sea area, WSBS, Polar Urals, Kara sea region (Yamal), Franz Joseph Land, Taymyr, Severnaya Zemlya	-	D,C	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2010, 2016 (in Russian); Iluchin et al., 2022a	-	-
Ascomycota	*Penicillium hirsutum* Dierckx	-	Soil	Arctic: White Sea area, WSBS	-	D	Cul	Morph	S	Bubnova and Velikanov, 2004 (in Russian)	-	-
Ascomycota	*Penicillium hordei* Stolk	-	Air	-	Antarctica: Signy Iland	n.i.	n.i.	n.i.	S	-	Chalmers et al., 1996	-
Ascomycota	*Penicillium implicatum* Biourge	-	Permafrost sediments, antropogenic substrates, peat, soil	Arctic: White Sea area, WSBS, Severnaya Zemlya, Komi, Taymyr	Antarctica: McMurdo Dry Valleys, Russkaya Station	F,C	Cul	Morph	S,PF	Kirtsidely, 1999; Grum-Grzhimaylo et al., 2016; Kirtsideli et al., 2016 (in Russian); Lapteva et al., 2017 (in Russian)	Kochkina et al., 2012; Marfenina et al., 2016	-
Ascomycota	*Penicillium italicum* Wehmer	-	Soil, coal mine spoil	Arctic: Magadan	Antarctica: Iland Livingstone	C	Cul	Morph	S	Iluchin et al., 2022b	Kostadinova et al., 2009	-
Ascomycota	*Penicillium jamesonlandense* Frisvad & Overy	-	Lake sediments	-	Antarctica: Antarctic Peninsula	F	Cul	M	S	-	Ogaki et al., 2020a	-
Ascomycota	*Penicillium janczewskii* K.W. Zaleski	-	Peat, soil, moss, coal mine spoil	Arctic: White Sea area, WSBS, Novaya Zemlya, Magadan	Antarctica: Larsemann Hills oasis, Russkaya Station	C,D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Grum-Grzhimaylo et al., 2016; Nikitin, 2018 (in Russian); Nikitin et al., 2021; Iluchin et al., 2022b	Marfenina et al., 2016	-
Ascomycota	*Penicillium jensenii* K.W. Zaleski	-	Permafrost sediments, glacier sand, soil, plants, coal mine spoil	Arctic: Svalbard, Magadan	Antarctica: McMurdo Dry Valleys, Casey Station, Taylor Valley, Lake Hoare, Ross Sea region	F,C	Cul	Morph	S,PF	Iluchin et al., 2022a,b	Kerry, 1990a; Baublis et al., 1991; Corte et al., 2000; Kochkina et al., 2012	-

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Ascomycota	*Penicillium lanosum* Westling	-	Tundra soils, cryophylic alpine meadow, ice, ice core, lichens, peat, antropogenic substrates, lanosum, driftwood, soil, coal mine spoil	Arctic: Iceland, White Sea area, WSBS, Polar Urals, Izvestiy TSIK Iaslands, Barents Sea, Kolguyev Iland, Beliy nos, Varandey, Novaya Zemlya, Svalbard, Kara Sea, Marre-Sale, Ust'-Kara, Amderma, Dikson, Arctic Ocean, Franz Josef Land, Vize Iland, Magadan	Antarctica: Vostok Station	F,C,D	Cul	Morph,M	S,PF	Kirtsideli, 1999 (in Russian); Gunde-Cimerman et al., 2003; Bubnova and Velikanov, 2004 (in Russian); Kurek et al., 2007; Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Blanchette et al., 2016; Iluchin et al., 2022a,b	Abyzov, 1993 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Penicillium lividum* Westling	-	Soil, stones with algae	Arctic: Norway, Hardangervidda	Antarctica: Larsemann Hills oasis, Russkaya Station	F	Cul	M,Morph	S	Borchhardt et al., 2019	Marfenina et al., 2016	-
Ascomycota	*Penicillium maclennaniae* H.Y. Yip	-	Soil	Arctic: Magadan	-	C	Cul	M	S	Iluchin et al., 2022b	-	-
Ascomycota	*Penicillium melinii* Thom	-	Sea water, soil, plants, sediments	Arctic: White Sea area, WSBS, Apatiti, subarctic region	Antarctica: Ross Sea region	D,F	Cul	Morph,M	S,PF	Bubnova and Velikanov, 2004 (in Russian); Ozerskaya et al., 2009; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	Latter and Heal, 1971; Möller and Dreyfuss, 1996; Corte et al., 2000	-
Ascomycota	*Penicillium miczynskii* K.W. Zaleski	*Penicillium soppii* K.W. Zaleski	Permafrost sediments, mosses, regoliths, soil, conifer wood	Arctic: Canada, Norway, Finland, Apatiti	Antarctica: McMurdo Dry Valleys, Larsemann Hills oasis, Russkaya Station	F,D,C	Cul	Morph,M	S,PA,PF	Kirtsidely, 1999; Ozerskaya et al., 2009; Bjorbækmo et al., 2010; Osono et al., 2012; Kaitera et al., 2019; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	Baublis et al., 1991; Corte et al., 2000; Kochkina et al., 2012; Marfenina et al., 2016	-
Ascomycota	*Penicillium montanense* M. Chr. & Backus	-	Sediments, soil	Arctic: White Sea area, WSBS	Antarctica: Skua Lake, Russkaya Station	C,F	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2018	Corte et al., 2000; Marfenina et al., 2016	-
Ascomycota	*Penicillium multicolor* Grig.-Man. & Porad.	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	-

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Ascomycota	*Penicillium nalgiovense* Laxa	-	Ice, antropogenic substrates, soil, peat	Arctic: Svalbard, Apatiti, Severnaya Zemlya, White Sea area, WSBS	-	C,F	Cul	Morph	S,PF	Gunde-Cimerman et al., 2003; Houbraken et al., 2012; Grum-Grzhimaylo et al., 2016; Kirtsideli et al., 2016 (in Russian); Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	-	-
Ascomycota	*Penicillium nordicum* Dragoni & Cantoni ex C. Ramírez	-	Ice, water	Arctic: Svalbard	-	n.i.	Cul	Morph	S	Gunde-Cimerman et al., 2003	-	-
Ascomycota	*Penicillium ochrochloron* Biourge	-	Coal mine spoil	Arctic: Svalbard	-	C	Cul	Morph	S	Iluchin et al., 2022a	-	-
Ascomycota	*Penicillium olsonii* Bainier & Sartory	-	Permafrost sediments, ice	Arctic: Svalbard	Antarctica: McMurdo Dry Valleys	F	Cul	Morph	S	Gunde-Cimerman et al., 2003	Kochkina et al., 2012	-
Ascomycota	*Penicillium oxalicum* Currie & Thom	-	Soil, antropogenic substrates, coal mine spoil	Arctic: White Sea area, WSBS, Kara Sea region (Yamal), Severnaya Zemlya, Magadan	Antarctica: King George Iland, Warren Cave on Mt. Erebus	D,C	Cul	Morph	S	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2016 (in Russian); Iluchin et al., 2022b	Connel and Staudigel, 2013; Ding et al., 2016	-
Ascomycota	*Penicillium palitans* Westling	-	Soil, soil+penguen influence, frozen sediments, ice	Arctic: Svalbard	Antarctica: Windmill Ilands, Wilkes Land, MacRobertson Land, McMurdo Dry Valleys	C,F	Cul	Morph,M	S	Gunde-Cimerman et al., 2003	Azmi and Seppelt, 1998; McRae et al., 1999; Zucconi et al., 2012	-
Ascomycota	*Penicillium paneum* Frisvad	-	Lake water	Arctic: Svalbard	Antarctica: King George Iland	I,F	Cul,eDNA	M	S,W,PA	Zhang et al., 2015b	Gonc alves et al., 2012	-
Ascomycota	*Penicillium paradoxum* (Fennell & Raper) Samson, Houbraken, Visagie & Frisvad	*Aspergillus paradoxus* Fennell & Raper	Permafrost soil, Mummified penguin	-	Antarctica: McMurdo Dry Valleys, S. Victoria Land	C	Cul	Morph	S,BA	-	Baublis et al., 1991	-
Ascomycota	*Penicillium paxilli* Bainier	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Penicillium pimiteouiense* S.W. Peterson	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Penicillium polonicum* K.W. Zaleski	-	Ice, soil	Arctic: Svalbard	Antarctica: Deception Iland, South Shetland Ilands	C,F	Cul,eDNA	Morph,M	S	Gunde-Cimerman et al., 2003; Frossard et al., 2021	Rosa et al., 2020	-

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Ascomycota	*Penicillium purpurescens* (Sopp) Biourge	*Penicillium purpurascens*	Soil, peat, lake sediments	Arctic: White Sea area, WSBS, Western Siberia	Antarctica: Newfoundland	C	Cul	M,Morph	S,PF	Grum-Grzhimaylo et al., 2016; Yakushev et al., 2019	Corte and Gestro Coppo, 1998 (cited by the British Antarctic Survey site: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Penicillium raistrickii* G. Sm.	-	Tundra soils, soil	Arctic: White Sea area, WSBS, Polar Urals	-	D	Cul	Morph	S	Bubnova and Velikanov, 2004 (in Russian); Kirtsidely et al., 2010 (in Russian)	-	-
Ascomycota	*Penicillium restrictum* J.C. Gilman & E.V. Abbott	-	Permafrost sediments, soil, plants, peat	Arctic: White Sea area, WSBS	Antarctica: East, ? Signy Iland, Macquarie Iland	F,C	Cul	Morph	S,PF	Ivanushkina et al., 2005; Grum-Grzhimaylo et al., 2016, 2018	Kerry and Weste, 1985; Kochkina et al., 2019	-
Ascomycota	*Penicillium rolfsii* Thom	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Penicillium roqueforti* Thom	-	Ice, antropogenic substrates, air, wooden huts, ice core, wood, driftwood, soil	Arctic: Greenland, White Sea, WSBS, Sonsnovetz Iland, Svalbard, Taymyr, Severnaya Zemlya	Antarctica: Signy Iland, Cabo Primavera, Vostok Station, Cape Evans Ross Iland, Nimrod, Ellsworth Mountains	C,D,I	Cul	Morph,M	S	Gunde-Cimerman et al., 2003; Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2011, 2016 (in Russian); Blanchette et al., 2016; Chalmers et al., 1996	Duncan et al., 2006; Duncan, 2007; Godinho et al., 2015	-
Ascomycota	*Penicillium roseopurpureum* Dierckx	-	Peat, lake sediments, soil	Arctic: White Sea area, WSBS	Antarctica: Skua Lake, Cape Burks	C,D,F	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Grum-Grzhimaylo et al., 2016, 2018	Corte et al., 2000; Nikitin, 2018 (in Russian)	-
Ascomycota	*Penicillium rubens* Biourge	-	Soil, rocks	-	Antarctica: Ilands near the Antarctic Peninsula, Heritage Range, South Shetland Ilands, King George (Arctowski), Ellsworth Mountains	F	Cul	M	S,PHAOF	-	Godinho et al., 2015; Gonçalves et al., 2017; Gomes et al., 2018; de Silva et al., 2022	-
Ascomycota	*Penicillium sacculum* E. Dale	*Eladia saccula* (E. Dale) G. Sm.	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	S	Bellemain et al., 2013	-	-
Ascomycota	*Penicillium samsonianum* L. Wang, Frisvad & Houbraken	-	Soil, coal mine spoil	Arctic: Svalbard	-	C	Cul	M	S	Iluchin et al., 2022a	-	-
Ascomycota	*Penicillium sclerotiorum* J.F.H. Beyma	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	-

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Ascomycota	*Penicillium simplicissimum* (Oudem.) Thom	*Penicillium janthinellum* Biourge	Lichens, mosses, ice core, air, soil, stones with algae, littoral soil, permafrost soil, cryophylic alpine meadow, antropogenic substrates, coal mine spoil	Arctic: Svalbard, Apatiti, Novaya Zemlya, Barents Sea, Beliy nos, Varandey, Kara Sea, Ust'-Kara, Amderma, Arctic Ocean, Franz Josef Land, Kolyma, Polar Urals, Taymyr	Antarctica: Ilands near the Antarctic Peninsula, Macquarie Iland, King George Iland, Larsemann Hills oasis, Russkaya Station, Vostok Station, Windmill Ilands	C,F	Cul	Morph,M	S,PA,PF	Kirtsidely, 1999 (in Russian); Ozerskaya et al., 2008; Kirtsideli et al., 2010, 2011, 2016 (in Russian); Bubnova and Konovalova, 2018 (in Russian); Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Nikitin et al., 2021; Iluchin et al., 2022a	Möller and Dreyfuss, 1996; Vishniac, 1996 (cyt. Bunt, 1965); McRae and Seppelt, 1999; McRae et al., 1999 (cyt. Ellis-Evans, 1985); Marfenina et al., 2016; Nikitin, 2018 (in Russian)	-
Ascomycota	*Penicillium solitum* Westling	*Penicillium crustosum* Thom; *Penicillium solitum* var. *solitum* Westling	Soil, ice, microbial mat in lake water, antropogenic substrates, lake sediments, peat, soil, coal mine spoil, birds nest, lake sediments (antroponenic infl)	Arctic: Greenland, Svalbard, White Sea area, WSBS, Magadan	Antarctica: Dronnin Maud Land, Windmill Ilands, Wilkes Land, King George Iland, Ross Iland, McMurdo, Cape Evans, Continental Antarctica; Terra Nova, Cape Burks, Russkaya Station, King George Island, lakes in the Larsemann Hills, Vestfold Hills and the McMurdo Dry Valleys	F,C,D	Cul	Morph,M	S,BA,PF,IF	Gunde-Cimerman et al., 2003; Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Grum-Grzhimaylo et al., 2016; Perini et al., 2019; Iluchin et al., 2022b	Tubaki and Asano, 1965; McRae et al., 1999; McRae and Seppelt, 1999; Onofri, 1999; Dunkan, 2007; Brunati et al., 2009; Kochkina et al., 2014; Ding et al., 2016; Marfenina et al., 2016; Nikitin, 2018 (in Russian); de Menezes et al., 2019; Ogaki et al., 2020b	-
Ascomycota	*Penicillium spinulosum* Thom	-	Tundra soils, cryophylic alpine meadow, permafrost soil, air, plants, peat, lake sediments, soil, coal mine spoil	Arctic: Apatiti, Polar Urals, White Sea, Sonsnovetz Iland, Barents Sea,WSBS, Varandey, Izvestiy TSIK Iaslands, Kara Sea, Marre-Sale, Magadan, subarctic region, Alaska	Antarctica: McMurdo Dry Valleys, Signy Iland, MacRobertson Land, Windmill Ilands, Taylor Valley, Lake Hoare, Enderby Land	C,F	Cul,eDNA	Morph,M	S,PF	Kirtsidely et al., 2010, 2011, 2014; Semenova et al., 2015; Grum-Grzhimaylo et al., 2016; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Iliushin et al., 2022b	Latter and Heal, 1971; Fletcher et al., 1985; Baublis et al., 1991; Chalmers et al., 1996; McRae et al., 1999 (cyt. Barker, 1977); Corte et al., 2000	-
Ascomycota	*Penicillium sumatraense* Svilv.*	-	Cryoconite	Arctic: Svalbard	Antarctica: Deception Iland, South Shetland Ilands	F	Cul,eDNA	M	S,IF,W	Borze cka et al., 2022	Rosa et al., 2020	-
Ascomycota	*Penicillium svalbardense* Frisvad, Sonjak & Gunde-Cim.	-	Ice, water	Arctic: Svalbard	-	n.i.	Cul	Morph	S	Gunde-Cimerman et al., 2003	-	-
Ascomycota	*Penicillium swiecickii* K.W. Zaleski	-	Soil, driftwood, coal mine spoil	Arctic: Greenland, Svalbard	Antarctica: Ross Sea region	F,C	eDNA,Cul	M	S	Blanchette et al., 2016; Iluchin et al., 2022a	Arenz et al., 2011	-

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Ascomy-cota	*Penicillium tardochrysogenum* Frisvad, Houbraken & Samson	-	Soil, permafrost soil, rocks	-	Antarctica: Ilands near the Antarctic Penin-sula, South Shetland Ilands, Livingston, Dry Valley	F	Cul	M	S,PHAOF,PsF	-	Houbraken et al., 2012; Gomes et al., 2018; Alves et al., 2019; Nikitin, 2021 (in Russian) = Nikitin, 2023; de Silva et al., 2022	Rosa et al., 2019
Ascomy-cota	*Penicillium thomii* Maire	-	Soil, plants, peat, lake sediments, littoral soil	Arctic: Izvestiy TSIK Iaslands, subarctic region, White Sea area, WSBS, Barents Sea coast	-	F,C,D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al, 2014 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Bubnova and Konovalova, 2018 (in Russian)	-	-
Ascomy-cota	*Penicillium thymicola* Frisvad & Samson	-	Cryopeg water	Arctic: Kolyma	-	n.i.	Cul	n.i.	S,W	Kochkina et al., 2021	-	-
Ascomy-cota	*Penicillium turba-tum* Westling	-	Dead plants (Salix sp.)	-	Antarctica: East Ongul Island	C	Cul	M	PA	-	Hirose et al., 2013	-
Ascomy-cota	*Penicillium vanluykii* Frisvad, Houbraken & Samson	-	Soil	-	Antarctica: Shetland del Sur	n.i.	n.i.	n.i.	S	-	Houbraken et al., 2012	-
Ascomy-cota	*Penicillium veluti-num* J.F.H. Beyma	-	Pond mud, soil, coal mine spoil, cryoconite	Arctic: Svalbard, White Sea area, WSBS, Magadan	Antarctica: continental	D,C,F	Cul	Morph,M	S,IF,W	Bubnova and Velikanov, 2004 (in Russian); Borze cka et al., 2022; Iluchin et al., 2022b	Corte and Gestro, 1994 (cited by the British Antarctic Survey site: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomy-cota	*Penicillium verruco-sum* Dierckx	-	Cryopeg, permafrost soil, anchient sediments, peat, stones with algae, coal mine spoil, lake water	Arctic: Svalbard, White Sea area, WSBS, Novaya Zem-lya, Kolyma, Franz Josef Land, Fersman Iland, Hooker Iland near the Tikhaya Bay	Antarctica: McMurdo Dry Valleys, Larsemann Hills oasis, Russkaya Station, King George Island	F,C,I	Cul	Morph,M	S,PF,W	Gilichinsky et al., 2005; Ivanushkina et al., 2005; Ozerskaya et al., 2008; Kochkina et al., 2011 (in Russian); Grum-Grzhi-maylo et al., 2016; Nikitin et al., 2021; Iluchin et al., 2022a; Nikitin and Semenov, 2022	Gilichinsky et al., 2007; Gonc alves et al., 2012; Marfenina et al., 2016	-

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Ascomycota	*Penicillium vinaceum* J.C. Gilman & E.V. Abbott	-	Soil, peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Penicillium vulpinum* (Cooke & Massee) Seifert & Samson	-	Air, soil	Arctic: White Sea area, WSBS, Barents Sea, Varandey	Antarctica: Russkaya Station	D,F,I	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2011 (in Russian)	Marfenina et al., 2016	-
Ascomycota	*Penicillium waksmanii* K.W. Zaleski	-	Permafrost sediments, antropogenic substrates, peat, soil, stones with algae, coal mine spoil	Arctic: Svalbard, White Sea area, WSBS, Novaya Zemlya, Kara sea region (Yamal), Komi, Severnaya Zemlya, Kolyma	Antarctica: McMurdo Dry Valleys, Signy Iland, Skua Lake, Inexpressible Iland, Gondwana, Antarctic Peninsula, South Georgia Iland, Larsemann Hills oasis, Russkaya Station	F,C,D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al., 2016 (in Russian); Lapteva et al., 2017 (in Russian); Kochkina et al., 2021; Nikitin et al., 2021; Iluchin et al., 2022a	Vishniac, 1996 (cyt. Pugh and Allsopp, 1982); McRae et a., 1999 (cyt. L. Smith, 1994); Corte et al., 2000; Kochkina et al., 2012; Marfenina et al., 2016	-
Basidiomycota	*Peniophora albobadia* (Schwein.) Boidin	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Basidiomycota	*Peniophora cinerea* (Pers.) Cooke	-	Feathers	Arctic: Canada	-	F	Cul	M	BA	Robicheau et al., 2019	-	-
Basidiomycota	*Peniophora laxitexta* C.E. Gómez	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA	-	Rosa et al., 2020	http://www.indexfungorum.org/Names/NamesRecord.asp?RecordID=319314
Basidiomycota	*Peniophora lycii* (Pers.) Höhn. & Litsch.	-	Soil	-	Antarctica: Browning Peninsula, Windmill Islads	F	Cul	M	PA	-	Pudasaini et al., 2017	https://www.naturespot.org.uk/species/peniophora-lycii
Basidiomycota	*Peniophora piceae* (Pers.) J. Erikss.	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	M	PF,PA	Grum-Grzhimaylo et al., 2016	-	Lambevska et al., 2013
Ascomycota	*Periconia byssoides* Pers.	-	Lake sediments (antropogenic inf), soil	-	Antarctica: King George Iland, Deception Iland	F	Cul,eDNA	M	W,AA	-	Ogaki et al., 2020b; Rosa et al., 2020	Yamada et al., 2004
Ascomycota	*Periconiella mucunae* M.B. Ellis	-	Wood	-	Antarctica: Laurie Island, in the South Orkney Islands	C	Cul	Morph,M	PP	-	Gaiser et al., 2021	Wearn et al., 2012
Ascomycota	*Peroneutypa scoparia* (Schwein.) Carmarán & A.I. Romero	*Eutypella scoparia* (Schwein.) Ellis & Everh.	Soil	Arctic: Franz Joseph Land	Antarctica: Deception Iland, South Shetland Ilands	C,F	Cul,eDNA	Morph,M	E,S	Bergero et al., 1999	Rosa et al., 2020	de Errasti et al., 2014

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Ascomycota	*Pestalotiopsis trachycarpicola* Yan M. Zhang & K.D. Hyde*	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	Araujo et al., 2023; Fan et al., 2021
Ascomycota	*Peyronellaea calorpreferens* (Boerema, Gruyter & Noordel.) Aveskamp, Gruyter & Verkley	-	Soil	-	Antarctica	F	Cul	M	E	-	Nikitin, 2018 (in Russian)	Deng et al., 2011
Ascomycota	*Pezicula brunnea* (Sigler) P.R. Johnst.	*Cryptosporiopsis brunnea* Sigler	Soil	Arctic: Svalbard	-	C	eDNA	M	PA,Er	Frossard et al., 2021	-	Sigler et al., 2005
Ascomycota	*Pezicula radicicola* (Kowalski & Bartnik) P.R. Johnst.	*Cryptosporiopsis radicicola*	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010	-	-
Ascomycota	*Phacidiopycnis washingtonensis* C.L. Xiao & J.D. Rogers	-	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Phaeosphaeria culmorum* (Auersw.) Leuchtm.	-	Leafs, soil	Arctic: Finland	-	I	eDNA	M	PA,S	Poosakkannu et al., 2017	-	-
Ascomycota	*Phaeosphaeria dennisiana* Leuchtm.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	-
Ascomycota	*Phaeosphaeria eustoma* (Fuckel) L. Holm	*Leptosphaeria eustoma* (Fuckel) Pass.	Mosses, lichens, plants	-	Antarctica: Ilands near the Antarctic Peninsula, South Georgia, King George Iland	C	Cul	Morph	PA,LA	-	Kerry and Weste, 1985; Möller and Dreyfuss, 1996	-
Ascomycota	*Phaeosphaeria herpotrichoides* (De Not.) L. Holm	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	AI	Bellemain et al., 2013	-	Santiago et al., 2012
Ascomycota	*Phaeosphaeria juncophila* Leuchtm.	-	Plant tissues, lake water	Arctic: Svalbard	-	F	eDNA	M	PA,W	Zhang et al., 2015b; Zhang and Yao, 2015	-	-
Ascomycota	*Phaeosphaeria microscopica* (P. Karst.) O.E. Erikss.	-	Mosses, lichens	-	Antarctica: King George Iland	C	Cul	Morph	PA,LA	-	Möller and Dreyfuss, 1996	-
Ascomycota	*Phaeosphaeria podocarpi* Crous & A.R. Wood	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PA	-	Rosa et al., 2020	Crous et al., 2014
Ascomycota	*Phaeosphaeria pontiformis* (Fuckel) Leuchtm.	-	Soil	Arctic: Canada/Alaska	-	F	eDNA	M	E	Timling et al., 2014	-	Paulovska et al., 2017

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Ascomycota	*Phaeosphaeria silenes-acaulis* (De Not.) L. Holm	-	Leafs	Arctic: Finland	-	I	eDNA	M	PA,S	Poosakkannu et al., 2017	-	-
Ascomycota	*Phaeosphaeria triglochinicola* (Curr.) Leuchtm.	-	Lichens, plant tissues, soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	PA,LA,E	Timling et al., 2014; Zhang et al., 2015a; Zhang and Yao, 2015	-	-
Ascomycota	*Phaeosporobolus usneae* D. Hawksw. & Hafellner	*Phaeosporus usneae* D. Hawksw. et Hafellner.	Lichens	-	Antarctica: Bunger Oasis	n.i.	n.i.	n.i.	LF	-	Olech and Alstrup, 1996	Flakus and Kukwa, 2012
Basidiomycota	*Phanerochaete cumulodentata* (Nikol.) Parmasto	-	Cryoconite	Arctic: Svalbard	-	F	Cul	M	S,IF,W	Borze cka et al., 2022	-	Gilbertson and Lombard, 1976
Basidiomycota	*Phanerochaete sordida* (P. Karst.) J. Erikss. & Ryvarden	-	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Basidiomycota	*Phanerochaete velutina* (DC.) P. Karst.	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PA,S	Lydolph et al., 2005	-	Zafiu et al., 2021
Basidiomycota	*Phanerodontia chrysosporium* (Burds.) Hjortstam & Ryvarden	*Sporotrichum pruinosum* J.C. Gilman & E.V. Abbott	Permafrost sediments	Arctic	-	F	Cul	Morph	S	Ivanushkina et al., 2005	-	Miao et al., 2021
Ascomycota	*Phialemoniopsis curvata* (W. Gams & W.B. Cooke) Perdomo, Dania García, Gené, Cano & Guarro	*Phialemonium curvatum*	Penguin feathers	-	Antarctica: King George Iland	F	Cul	Morph,M	BA,OHP	-	Devoto et al., 2022	Alvarez Martinez et al., 2021
Ascomycota	*Phialemonium inflatum* (Burnside) Dania García, Perdomo, Gené, Cano & Guarro	*Paecilomyces inflatus* (Burnside) J.W. Carmich.	Antropogenic substrates, soil	Arctic: White Sea area, WSBS, Kara Sea region (Yamal), Severnaya Zemlya	-	D	Cul	Morph	E,PS	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2016 (in Russian)	-	Zhou et al., 2018; Sword et al., 2017
Ascomycota	*Phialemonium obovatum* W. Gams & McGinnis	-	Antropogenic substrates	Arctic: Kara Sea region (Yamal)	-	n.i.	Cul	Morph	AP,PHOF	Kirtsideli et al., 2016 (in Russian)	-	Smith et al., 2000; McGinnis et al., 1986
Ascomycota	*Phialocephala dimorphospora* W.B. Kendr.	-	Driftwood, coal mine spoil	Arctic: Siberia, Iceland, Magadan	-	C	Cul	M	S,PF	Blanchette et al., 2016; Iluchin et al., 2022b	-	-
Ascomycota	*Phialocephala europaea* Grünig & T.N. Sieber	-	Soil, peat	Arctic: Canada/ Alaska, White Sea area, WSBS	-	F,C	eDNA,Cul	M,Morph	PF	Timling et al., 2014; Grum-Grzhimaylo et al., 2016	-	-

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Ascomycota	*Phialocephala flargerbergii**	-	Lichens	Arctic: Svalbard	-	F	eDNA	M	n.i.	Zhang et al., 2015a	-	-
Ascomycota	*Phialocephala fortinii* C.J.K. Wang & H.E. Wilcox	-	Soil, Cephaloziella varians, moss, roots, dead plants (Salix sp.), permafrost soil	Arctic: Svalbard, Magadan, Russia, Siberia, Yakutia, Canada/Alaska, Toolik Lake	Antarctica: Adelaide Iland, Antarctic Peninsula, Rothera Point, East Ongul Station	F,C	eDNA,Cul	M	PA,Ec,PF,S	Lydolph et al., 2005; Bjorbækmo et al., 2010; Timling et al., 2014; Dunleavy and Mack, 2021; Frossard et al., 2021; Iluchin et al., 2022b; Miyamoto et al., 2022	Jumpponen et al., 2003; Hirose et al., 2013; Tsui, 2019	-
Ascomycota	*Phialocephala lagerbergii* (Melin & Nannf.) Grünig & T.N. Sieber	*Phialophora lagerbergii* (Melin & Nannf.) Conant; *Cadophora lagerbergii* Melin. & Nannf.	Permafrost soil, sandy soil, driftwood, lake sediments, dead plants (Salix sp.)	Arctic: Svalbard, White Sea area, WSBS, Siberia, Novaya Zemlya, Franz Joseph Land, Izvestiy TSIK Iaslands, Fersman Iland, Melekhov Cape of Alexandra Land, Magadan	Antarctica: McMurdo Dry Valleys and dump, Winter Quarters Bay, Ross Iland, S. Victoria Land, Continental and peninsula Antarctica, East Ongul Station	C,F	Cul	Morph,M	S,PF,PtF	Bergero et al., 1999; Kirtsideli et al, 2014 (in Russian); Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Nikitin et al., 2021; Iliushin et al., 2022b; Nikitin and Semenov, 2022	Sun et al., 1978; Baublis et al., 1991; Onofri, 1999; Hirose et al., 2013	-
Ascomycota	*Phialocephala virens* A.L. Siegfr. & Seifert	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Phialophora atrovirens* (J.F.H. Beyma) Schol-Schwarz	-	Tundra soils	Arctic: Polar Urals	-	n.i.	Cul	Morph	S	Kirtsidely et al., 2010 (in Russian)	-	-
Ascomycota	*Phialophora cinerescens* (Wollenw.) J.F.H. Beyma	-	Soil, antropogenic substrates, littoral sand	Arctic: White Sea area, Barents Sea coast, Franz Joseph Land	-	C,D,F	Cul	Morph	S,PtF	Bergero et al., 1999; Kirtsideli et al., 2016 (in Russian); Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian)	-	-
Ascomycota	*Phialophora cyclaminis* J.F.H. Beyma	-	Soil, antropogenic substrates	Arctic: Franz Joseph Land	-	C	Cul	Morph	S,MsF	Bergero et al., 1999; Kirtsideli et al., 2016 (in Russian)	-	-
Ascomycota	*Phialophora dancoi* Cabello	*Phialophora dancoii* Cabello	Rhizosphere	-	Antarctica: Danko Coast	n.i.	Cul	Morph	S	-	Vishniac, 1996 (cyt. Cabello, 1989); Onofri, 1999	Zhang et al., 2022
Ascomycota	*Phialophora geniculata* Emden	-	Soil	Arctic: Finland	-	I	eDNA	M	S	Poosakkannu et al., 2017	-	-
Ascomycota	*Phialophora verrucosa* Medlar	-	Permafrost soil, driftwood, peat	Arctic: White Sea area, WSBS, Siberia	Antarctica: McMurdo Dry Valleys	C	Cul	Morph,M	S,PF	Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018	Baublis et al., 1991	-

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Ascomycota	*Phillipsia domingensis* (Berk.) Berk. ex Denison	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	S,PA	Bellemain et al., 2013	-	https://www.mushroomexpert.com/phillipsia_domingensis.html
Basidiomycota	*Phlebia radiata* Fr.	-	Conifer wood	Arctic: Finland	-	C	Cul	M	S,PA	Kaitera et al., 2019	-	-
Basidiomycota	*Phlebia subserialis* (Bourdot & Galzin) Donk	-	Driftwood	Arctic: Siberia	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Basidiomycota	*Phlebiopsis gigantea* (Fr.) Jülich	-	Peat, lake sediments, conifer wood	Arctic: Finland, White Sea area, WSBS	-	C	Cul	M	S,PF,PA	Grum-Grzhimaylo et al., 2016; Kaitera et al., 2019	-	-
Basidiomycota	*Pholiota baeosperma* Singer	-	Lake sediments (antropogenic inf)	-	Antarctica: King George Iland	F	Cul	M	S	-	Ogaki et al., 2020b	Romano et al., 2019
Ascomycota	*Phoma delphinii* (Rabenh.) Cooke*	-	Soil	Arctic: Franz Joseph Land, Fersman Iland	-	F	Cul	M	n.i.	Nikitin and Semenov, 2022	-	-
Ascomycota	*Phoma herbarum* Westend.	-	Soil, soil+birds influence, plant tissues, feathers, bird dung, permafrost soil, moss, antropogenic substrates, skeleton remains, driftwood, wood, stones with algae, ornithogenic soil, coal mine spoil, glacier, lake water, fossil seeds	Arctic: Canada, Greenland, Iceland, Siberia, Svalbard, Izvestiy TSIK Ilands, Novaya Zemlya, Franz Joseph Lands, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Melekhov Cape of Alexandra Land, Taymyr, Severnaya Zemlya, Magadan	Antarctica: Ross Sea region, Crater Cirque, Antarctic Peninsula, Windmill Ilands, Dronnin Maud Land, Vilgelm II Land, East, Casey, Schirmacher Oasis, MacRobertson, Land, Victoria Land, Gondwana Lake, Prior Iland, Bruce Point, Adelie Cove, Tinker Glacier, Snowy Point, Edmonson Point, Cape Irizar, Camp Icare, Starr Nunatak, Cape Reynolds, Inexpressible Iland, Cape Satsrugi, Kay Iland, Harrow Peaks, Mac Robertson Land, Vestfold Hills, Mawson, Deception Iland, Larsemann Hills oasis, Russkaya Station, Beaufort Iland, King George Island, Syowa Station	F,C,D,I	eDNA,Cul	M,Morph	S,BA,AA, PA,E,W	Stakhov et al., 2008; Bellemain et al., 2013; Bubnova et al., 2014; Zhang and Yao, 2015; Blanchette et al., 2016; Kirtsideli et al., 2016 (in Russian); Nikitin et al., 2021; Iluchin et al., 2022a,b; Nikitin and Semenov, 2022; Tsiji et al., 2022	Fletcher et al., 1985; Frate and Caretta, 1990; Kerry, 1990a,b; Zucconi et al., 1996; Azmi and Seppelt, 1998; McRae and Seppelt, 1999; Onofri, 1999; Onofri et al., 2000; Tosi et al., 2002, 2005; Hughes et al., 2003; Arenz et al., 2006; Arenz and Blanchette, 2011; Gonc alves et al., 2012; Alias et al., 2013; Kochkina et al., 2014, 2019; Marfenina et al., 2016; Held and Blanchette, 2017; Pudasaini et al., 2017; Nikitin, 2018 (in Russian)	-

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Ascomycota	*Phoma hibernica* Grimes, M. O'Connor & Cummins	-	Soil, air	-	Antarctica: McMurdo Station, Ross Iland, Brown Peninsula	F	Cul	Morph	OHP,S	-	Sun et al., 1978	Bakerspigel et al., 1969; Gulati et al., 2022
Ascomycota	*Phoma jolyana* Piroz. & Morgan-Jones	-	Permafrost soil	Arctic: Kolyma	-	n.i.	Cul	Morph	PP	Ozerskaya et al., 2008		Iqbal and Chohan, 1984
Ascomycota	*Phoma leveillei* Boerema & G.J. Bollen	-	Permafrost anchient sediments, soil	-	Antarctica: McMurdo Dry Valleys	F	Cul	Morph	PA	-	Gilichinsky et al., 2007; Nikitin, 2018 (in Russian)	https://www.dsmz.de/collection/catalogue/details/culture/DSM-27590
Ascomycota	*Phoma rabiei* (Pass.) Khune ex Gruyter	*Ascochyta rabiei*	Cryoconite hole	Arctic: Svalbard	-	F	Cul	M	PP	Edwards et al., 2013	-	Valetti et al., 2021
Ascomycota	*Phoma sepalorum* Lind	-	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	n.i.	Elvebakk and Prestrud, 1996	-	-
Ascomycota	*Phoma violacea* (Bertel) Eveleigh		Soil	-	Antarctica	F	Cul	Morph	S,PA	-	Nikitin, 2018 (in Russian)	Kwaśniewska-Sip et al., 2018
Ascomycota	*Phomatodes nebulosa* (Pers.) Qian Chen & L. Cai	*Phoma nebulosa* (Pers.) Mont.	Permafrost soil, fossil seads	Arctic: Kolyma	Antarctica: Vestfold Hills, Mawson Base	F	Cul	Morph	S,PA	Ozerskaya et al., 2008; Stakhov et al., 2008	Line, 1988	Wijesinghe et al., 2021
Basidiomycota	*Piloderma bicolor* (Peck) Jülich	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Piloderma olivaceum* (Parmasto) Hjortstam	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Piloderma sphaerosporum* Jülich	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec,S	Santalahti et al., 2018	Line, 1988	Mäkipää et al., 2017
Ascomycota	*Pinaceicola pini* (Crous & de Hoog) Crous, M. Shen & Y. Zhang ter	*Fusicladium pini* Crous & de Hoog	Soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	n.i.	Grum-Grzhimaylo et al., 2018	-	-
Mucoromycota	*Pirella circinans* Bainier	-	Cadavers of the beetle Hydromedion sparsutum	-	Antarctica: Bird Iland, South Georgia	n.i.	Cul	Morph,M	C,S,AA	-	Bridge et al., 2008a,b	-
Mucoromycota	*Planticonsortium tenue* (Greenall) C. Walker & D. Redecker	*Glomus tenue* (Greenall) I.R. Hall	Plants (mycorrhiza)	-	Antarctica: South Georgia, Grytviken	F	Cul	Morph	E	-	Christie and Nicholson, 1983	-

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Ascomycota	*Plectosphaerella cucumerina* (Lindf.) W. Gams	-	Littoral soil	Arctic: Svalbard, Barents Sea coast	-	F,C	Cul,eDNA	Morph,M	PP	Bubnova and Konovalova, 2018 (in Russian); Frossard et al., 2021	-	Pétriacq et al., 2016
Ascomycota	*Plenodomus hendersoniae* (Fuckel) Gruyter, Aveskamp & Verkley	*Leptosphaeria hendersoniae* (Fuckel) L. Holm	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Aiello et al., 2020
Ascomycota	*Pleospora ambigua* (Berl. & Bres.) Wehm.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	-
Ascomycota	*Pleospora graminearum* Wehm.	-	Plants, soil	Arctic: White Sea area, WSBS	Antarctica: Macquarie Iland	C	Cul	Morph	S	Grum-Grzhimaylo et al., 2018	Kerry and Weste, 1985	-
Ascomycota	*Pleospora lutea* Wehm.	-	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	PP	-	Kerry and Weste, 1985	-
Ascomycota	*Pleotrichocladium opacum* (Corda) Hern.-Restr., R.F. Castañeda & Gené	*Trichocladium opacum* (Corda) S. Hughes	Lichens, soil, peat	Arctic: Svalbard, Finland, Alaska	Antarctica: Ilands near the Antarctic Peninsula/ King George Iland	C,I,F	eDNA,Cul	Morph,M	S,LA,PF	Semenova et al., 2017; Poosakkannu et al., 2017; Frossard et al., 2021	Möller and Dreyfuss, 1996	-
Ascomycota	*Pleuroascus nicholsonii* Massee & E.S. Salmon	-	Penguin feathers	-	Antarctica: King George Iland	F	Cul	Morph,M	BA	-	Devoto et al., 2022	-
Ascomycota	*Pleurostoma repens* (R.W. Davidson) Réblová & Jaklitsch	*Pleurostomophora repens* (R.W. Davidson) L. Mostert, W. Gams & Crous	Antropogenic substrates	Arctic: Kara Sea region (Yamal)	Antarctica: Victoria Land	n.i.	Cul	Morph,M	PP	Kirtsideli et al., 2016 (in Russian)	-	Sadallah et al., 2022
Basidiomycota	*Pluteus nanus* (Pers.) P. Kumm.	-	Soil	Arctic: Svalbard	-	C	eDNA	M	S	Frossard et al., 2021	-	-
Basidiomycota	*Pluteus xylophilus* (Speg.) Singer	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	S	Bellemain et al., 2013	-	-
Mucoromycota	*Podila clonocystis* (W. Gams) Vandepol & Bonito	*Mortierella clonocystis*	Soil	Arctic: Canada	-	F	Cul	M	S	Tsuji et al., 2022	-	-
Mucoromycota	*Podila humilis* (Linnem. ex W. Gams) Vandepol & Bonito	*Mortierella humilis*	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,S	Zhang et al., 2015b	-	-
Ascomycota	*Polyscytalum fecundissimum* Riess	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF,S,PP	Grum-Grzhimaylo et al., 2016	-	Minter, 2007
Ascomycota	*Polysporina subfuscescens* (Nyl.) K. Knudsen & Kocourk.	-	Soil	Arctic: Svalbard	-	C	eDNA	M	LF	Frossard et al., 2021	-	Knudsen and Kocourkova, 2008

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Basidiomycota	*Porodaedalea pini* (Brot.) Murrill	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Preussia africana* Arenal, Platas & Peláez	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	E,LA	Bellemain et al., 2013	-	Seddouk et al., 2022; Zhang et al., 2012
Ascomycota	*Preussia flanaganii* Boylan	-	Soil	Arctic: Svalbard	Antarctica: Ilands near the Antarctic Peninsula	C	eDNA,Cul	M	S	Frossard et al., 2021	Gomes et al., 2018	Boylan, 1968
Ascomycota	*Preussia octomera* (Auersw.) Kruys	-	Glacier	Arctic: Canada	-	F	Cul	M	CF,IF	Tsuji et al., 2022	-	Lytvynenko et al., 2022
Ascomycota	*Preussia polymorpha* Asgari & Zare	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	S	Bellemain et al., 2013	-	Abbasi and Aliabadi, 2013
Ascomycota	*Protoventuria alpina* (Sacc.) M.E. Barr	*Venturia alpina* Sacc. = *Protoventuria alpina* (Sacc.) M.E. Barr, or *Venturia alpina* Niessl = *Gibbera niesslii* (Sacc.) E. Müll.	Plant tissues, plants+birds fecas, peat	Arctic: Izvestiy TSIK Iaslands, Svalbard	-	F	eDNA,Cul	M	PA,E	Kirtsideli et al, 2014 (in Russian); Zhang and Yao, 2015	-	-
Basidiomycota	*Psathyrella dunensis* Kits van Wav.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Hausknecht and Krisai, 1987
Basidiomycota	*Psathyrella rostellata* Örstadius	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	Vašutová, 2008
Ascomycota	*Pseudallescheria boydii* (Shear) McGinnis, A.A. Padhye & Ajello	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	OHP,AA	-	Rosa et al., 2020	Chen et a., 2022; Sorres et al., 2022
Ascomycota	*Pseudeurotium bakeri* C. Booth	-	Soil	Arctic: Svalbard	Antarctica: Antarctic Peninsula, Eats Antarctica	F	eDNA	M	S	Zhang et al., 2015b	Arenz and Blanchette, 2011; Kochkina et al., 2014	-
Ascomycota	*Pseudeurotium desertorum* Mouch.	-	Wood, soil, air	-	Antarctica: Ross Sea region, Antarctic Peninsula, Cape Evans, Hut Point	F	Cul	M	S	-	Arenz et al., 2006 (ITS identification 95.1); Duncan et al., 2010; Arenz and Blanchette, 2011	-
Ascomycota	*Pseudeurotium hygrophilum* (Sogonov, W. Gams, Summerb. & Schroers) Minnis & D.L. Lindner	*Teberdinia hygrophila* Sogonov, W. Gams, Summerb. & Schroers	Soil, peat, littoral sand, cryoconite, lake sediments, antropogenic	Arctic: Svalbard, White Sea area, WSBS, Barents Sea coast	Antarctica: Ross Sea region, Antarctic Peninsula, King George Island, Deception Island	F,C,D	eDNA,Cul	M,Morph	S,IF,W	Bubnova, 2017; Grum-Grzhimaylo et al., 2016, 2018; Bubnova and Konovalova, 2018 (in Russian); Borze cka et al., 2022	Arenz and Blanchette, 2011; Kochkina et al., 2019; Ogaki et al., 2020a,b; Rosa et al., 2020	-

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Ascomycota	*Pseudocamarosporium africanum* (Damm, Verkley & Crous) Crous	-	Snow	-	Antarctica: Antarctic Peninsula	C	Cul	M	IF,PP	-	de Menezes et al., 2019	-
Ascomycota	*Pseudocercospora eucommiae* Y.L. Guo & X.J. Liu	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	-
Ascomycota	*Pseudocladosporium proteae* (Viljoen & Crous) Crous	Cladophialophora proteae	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA	M	EL,PP	-	Selbmann et al., 2021	Crous et al., 2008
Ascomycota	*Pseudocosmospora vilior* (Starbäck) C.S. Herrera & P. Chaverri	*Cosmospora vilior* (Starbäck) Rossman & Samuels	Wood, lake water	-	Antarctica: Ross Sea region, King George Island	F,I	Cul	M	MF,W	-	Arenz et al., 2006; Gonc alves et al., 2012	Herrera et al., 2013
Ascomycota	*Pseudogymnoascus appendiculatus* A.V. Rice & Currah	-	Soil, leafs, roots, lake sediments	Arctic: Finland	Antarctica: Antarctic Peninsula, Ilands near the Antarctic Peninsula, Deception Island	F,I	eDNA,Cul	M	S,PF	Poosakkannu et al., 2017	Gomes et al., 2018; Ogaki et al., 2020a; Rosa et al., 2020	-
Ascomycota	*Pseudogymnoascus destructans* (Blehert & Gargas) Minnis & D.L. Lindner	-	Soil, snow, lake sediments, antropogenic	-	Antarctica: Ilands near the Antarctic Peninsula, Antarctic Peninsula, King George Island	C,F	Cul	M	AP,S,PsF	-	Gomes et al., 2018; de Menezes et al., 2019; Ogaki et al., 2020a,b	Reynolds et al., 2015; Rosa et al., 2019

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Ascomycota	*Pseudogymnoascus pannorum* (Link) Minnis & D.L. Lindner	*Geomyces pannorum* (Link) Sigler & J.W. Carmich.; *Geomyces vulgaris* Traaen; *Chrysosporium pannorum* (Link) S. Hughes; *Chrysosporium verrucosum* Tubaki; *Geomycea vulgare*	Cryopeg, permafrost and tundra soils, cryophylic alpine meadow, wood, permafrost sediments, mosses, lichens, sand, antropogenic substrates, air, deposit and micro-bial mat, plants, plants+birds fecas, birds dung, moss, mud, litter, penguin dung, feathers, roots, peat, driftwood, lake sediments and water, littoral sand, animal seals, coal mine spoil, glacier, fossil seeds, algae	Arctic: Canada, Iceland, Kolyma, Arctic Ocean, Franz Joseph Land, Svalbard, Finland, White Sea, WSBS, Sonsnovetz Iland, Barents Sea, Shoyna, Novaya Zemlya, Kara Sea region, Komi, Yamal, Amderma, Dikson, Taymyr, Izvestiy TSIK Ilands, Magadan	Antarctica: Ross Sea region, Antarctic Peninsula, McMurdo Dry Valleys, Windmill Ilands, Dronnin Maud Land, Vilgelm II Land, Oates Land, Islads near the Antarctic Peninsula, Signy Iland, East, South Georgia, Macquarie Iland, Signy Iland, King George Iland, Casey, MacRobertson, Land, W. Ongul Iland, Gondwana Lake, Cape Irizar, Starr Nunatak, Cape Reynolds, Kay Iland, Kohler Head, Harrow Peaks, Victoria Land, Kay Iland, Carezza Lake, Giardino, Campo Icaro, Crater Cirque, Edmonson Point, Mac Robertson Land, Vestfold Hills, Mawson, Cabo Primavera, Taylor Valley, Lake Hoare, Iland Livingstone, Primavera Cape, lakes in the Larsemann Hills, Vestfold Hills and the McMurdo Dry Valleys	F,C,D,I	eDNA,Cul	Morph,M	S,K,BA,PA,LA ,PF,PtF	Bergero et al., 1999; Kirtsidely, 1999 (in Russian); Bubnova and Velikanov, 2004 (in Russian); Gilichinsky et al., 2005; Ivanushkina et al., 2005; Kurek et al., 2007; Ozerskaya et al., 2008; Stakhov et al., 2008; Osono et al., 2012; Singh et al., 2012; Kochkina et al., 2011 (in Russian), 2012; Blanchette et al., 2016; Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al., 2010, 2011, 2014, 2016 (in Russian); Bubnova, 2017; Lapteva et al., 2017 (in Russian); Poosakkannu et al., 2017; Bubnova and Konovalova, 2018 (in Russian); Robicheau et al., 2019; Kochkina et al., 2021; Nikitin et al., 2021; Iluchin et al., 2022a,b; Nikitin and Semenov, 2022; Tsuji et al., 2022	Tubaki, 1961; Tubaki and Asano, 1965; Latter and Heal, 1971; Sun et al., 1978; Bailey and Wynn-Williams, 1982; Hurst et al., 1983; Fletcher et al., 1985; Kerry and Weste, 1985; Czarnecki and Bialasiewicz, 1987; Ryan et al., 1989; Frate and Caretta, 1990; Kerry, 1990a,b; Baublis et al., 1991; Mercantini et al., 1993; Chalmers et al., 1996; Möller and Dreyfuss, 1996; Vishniac, 1996 (cyt. Pugh and Allsopp, 1982; Corte and Daglio, 1963); Zucconi et al., 1996; Fenice et al., 1997; Azmi and Seppelt, 1998; McRae and Seppelt, 1999; Onofri, 1999; Onofri et al., 2000; Weinstein et al., 2000; Tosi et al., 2002, 2005; Hughes et al., 2003; Arenz et al., 2006, 2011; Brunati et al., 2009; Kostadinova et al., 2009; Blanchette et al., 2010; Arenz and Blanchette, 2011; Gonc alves et al., 2012; Kochkina et al., 2014, 2019; Ding et al., 2016; Hirose et al., 2016; Pudasaini et al., 2017; Gomes et al., 2018; Nikitin, 2021 (in Russian) = Nikitin, 2023; Devoto et al., 2022	-

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Ascomycota	*Pseudogymnoascus roseus* Raillo	*Pseudogymnoascus vinaceus* Raillo	Soil, roots, littoral sand, coal mine spoil, lake sediments	Arctic: Svalbard, Finland, White Sea area, Sonsnovetz Iland, Barents Sea, Shoyna, Novaya Zemlya, Magadan, Polar Ural	Antarctica: Antarctic Peninsula, Deception Island	C,D,I	eDNA,Cul	M,Morph	S,PF	Ozerskaya et al., 2009; Kirtsideli et al., 2010, 2011 (in Russian); Poosakkannu et al., 2017; Bubnova, 2017; Frossard et al., 2021; Nikitin et al., 2021; Iluchin et al., 2022a,b	Ding et al., 2016; Kochkina et al., 2019; Ogaki et al., 2020a,b; Rosa et al., 2020; Onofri et al., 2005 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Pseudogymnoascus verrucosus* A.V. Rice & Currah	-	Soil, snow, lake sediments, antropogenic	-	Antarctica: Ilands near the Antarctic Peninsula, Antarctic Peninsula, King George Island	C	Cul	M	S,PF,IF	-	Gomes et al., 2018; de Menezes et al., 2019; Ogaki et al., 2020a,b	-
Ascomycota	*Pseudohelicoon gigantisporum* (Goh & K.D. Hyde) Y.Z. Lu & J.K. Liu	*Helicoon gigantisporum* Goh & K.D. Hyde	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	W,PA	Timling et al., 2014	-	Goh and Hyde, 1996; Orłowska et al., 2004
Basidiomycota	*Pseudohydnum gelatinosum* (Scop.) P. Karst.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Zhou et al., 2022
Ascomycota	*Pseudomassaria sepincoliformis* (De Not.) Arx	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S,PA	Timling et al., 2014	-	Jaklitsch and Voglmayr, 2012
Ascomycota	*Pseudomassariosphaeria grandispora* (Sacc.) Phukhams., Ariyaw. & K.D. Hyde	*Massariosphaeria grandispora* (Sacc.) Leuchtm.	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	W,S	Timling et al., 2014	-	Magaña-Dueñas et al., 2020; Jones et al., 2020
Ascomycota	*Pseudopassalora gouriqua* Crous	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Crous et al., 2011
Ascomycota	*Pseudopithomyces chartarum* (Berk. & M.A. Curtis) Jun F. Li, Ariyaw. & K.D. Hyde	*Leptosphaerulina chartarum*	Peat	Arctic: Alasca	-	F	eDNA	M	PP,S,AP	Semenova et al., 2015	-	Perelló et al., 2017; Sidhu et al., 2021
Ascomycota	*Pseudoplectania nigrella* (Pers.) Fuckel	-	Soil, leafs	Arctic: Northern Fennoscandia, Finland	-	F,I	eDNA	M	S,PA	Poosakkannu et al., 2017; Juottenen et al., 2020	-	-
Basidiomycota	*Pseudosperma bulbosissimum* (Kühner) Matheny & Esteve-Rav.	*Inocybe bulbosissima* (Kühner) Bon	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-

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Basidiomycota	*Pseudosperma flavellum* (P. Karst.) Matheny & Esteve-Rav.	*Inocybe flavella* P. Karst.	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Geml et al., 2012	-	-
Basidiomycota	*Pseudosperma rimosum* (Bull.) Matheny & Esteve-Rav.	*Inocybe rimosa* (Bull.) P. Kumm.; *Inocybe fastigiata*	Soil	Arctic: Norway, Svalbard, Canada/ Alaska	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010; Gelm et al., 2012; Timling et al., 2014	-	Bandini and Oertel, 2020
Basidiomycota	*Pseudosperma sororium* (Kauffman) Matheny & Esteve-Rav.	*Inocybe sororia* Kauffman	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	Bandini and Oertel, 2020
Basidiomycota	*Pseudotomentella tristis* (P. Karst.) M.J. Larsen	*Pseudotomentella umbrina*	Soil, roots	Arctic: Canada/ Alaska, Finland, Russia, Yakutia	-	F,C,I	eDNA	M	Ec	Timling et al., 2014; Poosakkannu et al., 2017; Miyamoto et al., 2022	-	-
Ascomycota	*Pseudotorula heterospora* Subram.	-	Permafrost soil (Microbial mat on ice and mummified penguin?)	-	Antarctica: McMurdo Dry Valleys	C	Cul	Morph	BA	-	Baublis et al., 1991	-
Ascomycota	*Psilocistella deschampsiae* Gamundí & Spinedi	-	Plant tissues	-	Antarctica: Danko Coast	n.i.	n.i.	n.i.	PA	-	Onofri, 1999	-
Basidiomycota	*Psychromyces glacialis* L. Perini & Zalar	-	Ice, cryoconite	Arctic: Greenland, Svalbard	-	C	Cul	M	IF	Perini et al., 2021	-	-
Ascomycota	*Psychronectria hyperantarctica* (D. Hawksw.) J. Pawłowska, Istel, Wrzosek & D. Hawksw.	*Thyronectria antarctica* var. *hyperantarctica*	Mosses	-	Antarctica	n.i.	eDNA	n.i.	PP	-	Hawksworth, 1973; Hoshino et al., 2019	-
Ascomycota	*Psychrophila antarctica* M.M. Wang & Xing Z. Liu	-	Soil	-	Antarctica: Great Wall Station	C	Cul	M	n.i.	-	Wang et al., 2015	-
Ascomycota	*Pulvinula convexella* (P. Karst.) Pfister	*Pulvinula constellatio* (Berk. & Broome) Boud.	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Uzun and Kaya, 2019
Basidiomycota	*Punctularia strigosozonata* (Schwein.) P.H.B. Talbot	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-

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Ascomycota	*Purpureocillium lavendulum* Perdomo, Dania García, Gené, Cano & Guarro 2013	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	AP,N,EP	-	Rosa et al., 2020	Bao et al., 2022; Liu et al., 2019
Ascomycota	*Purpureocillium lilacinum* (Thom) Luangsa-ard, Houbraken, Hywel-Jones & Samson	*Paecilomyces lilacinus* (Thom) Samson; *Penicillium lilacinum* Thom	Permafrost soil, feathers	Arctic: Canada, Novaya Zemlya, Siberia, Franz Josef Land, Fersman Iland, Melekhov Cape of Alexandra Land	Antarctica: Pendulum cove	F,I	eDNA,Cul	M, Morph	BA,K,OHP	Bellemain et al., 2013; Robicheau et al., 2019; Nikitin et al., 2021; Nikitin and Semenov, 2022	Vishniac, 1996 (cyt. Caretta and Piontelli, 1977); Gonçalves et al., 2015	Kidd et al., 2023
Ascomycota	*Pyrenopeziza revincta* (P. Karst.) Gremmen	cf. *Pyrenopeziza revincta*	Wood	Arctic: Canada	-	n.i.	Cul	M	S	Jurgens et al., 2009	-	Yadav, 1966
Ascomycota	*Pyrenophora chaetomioides* Speg.	*Pyrenophora* cf. *chaetomioides*	Living leaves of Angiosperms	-	Antarctica: King George Iland	F	Cul	M	E	-	Lucini et al., 2022	-
Ascomycota	*Rachicladosporium antarcticum* Egidi & Onofri	-	Rock	-	Antarctica: Antarctic Peninsula, James Ross Island, Victoria Land	C	Cul,eDNA	M	EL	-	Coleine et al., 2017; Laichmanová, 2020; Selbmann et al., 2021	-
Ascomycota	*Rachicladosporium inconspicuum* de Hoog & Stielow	-	Leafs	Arctic: Finland	-	I	eDNA	M	E	Poosakkannu et al., 2017	-	-
Ascomycota	*Rachicladosporium mcmurdoi* Selbmann & Onofri	-	Rocks, sandstones	-	Antarctica: Victoria Land	F	eDNA	M	EL	-	Selbmann et al., 2021	-
Ascomycota	*Rachicladosporium monterosanum* Isola & Zucconi	*Rachicladosporium monterosium* Isola & Zucconi	Lichens, plant tissues	Arctic: Svalbard	-	F	eDNA	M	E,LA,PA	Zhang et al., 2015a; Zhang and Yao, 2015	-	-
Ascomycota	*Radulidium subulatum* (de Hoog) Arzanlou, W. Gams & Crous	*Ramichloridium subulatum* de Hoog	Soil	Arctic: Franz Joseph Land	-	C	Cul	Morph	E,PtF	Bergero et al., 1999	-	Salimi et al., 2019
Ascomycota	*Ramularia pratensis* Sacc.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Wilson, 1986
Ascomycota	*Recurvomyces mirabilis* Selbmann & de Hoog	-	Sandstone	-	Antarctica: Battleship Promontory Southern Victoria Land	F	Cul	M	EL	-	Selbmann et al., 2008, 2021	Ruibal et al., 2011

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Ascomycota	*Remotididymella destructiva* (Plowr.) Valenz.-Lopez, Cano, Crous, Guarro & Stchigel	*Phoma destructive* Plowr.	Permafrost soil	Arctic: Kolyma	-	n.i.	Cul	Morph	PP	Ozerskaya et al., 2008	-	Sultana and Hossain., 2021
Basidiomycota	*Resinicium bicolor* (Alb. & Schwein.) Parmasto	-	Peat, conifer wood	Arctic: Finland, White Sea area, WSBS	Antarctica: Warren Cave	C,F	Cul,eDNA	M	S,PA	Grum-Grzhimaylo et al., 2016; Kaitera et al., 2019	Connel and Staudigel, 2013	Nakasone, 2007
Ascomycota	*Rhexocercosporidium carotae* (Årsvoll) U. Braun	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP	Lydolph et al., 2005	-	Kastelein, 2007
Ascomycota	*Rhinocladiella aquaspersa* (Borelli) Schell, McGinnis & Borelli	*Acrotheca aquaspersa* Borelli	Antropogenic substrates	Arctic: Izvestiy TSIK Ilands	-	n.i.	Cul	Morph	OHP	Kirtsideli et al., 2016 (in Russian)	-	Badali et al., 2010
Ascomycota	*Rhinocladiella atrovirens* Nannf.	-	Permafrost sediments, driftwood	Arctic: Greenland	-	F,C	Cul	Morph,M	S	Ivanushkina et al., 2005; Blanchette et al., 2016	-	-
Ascomycota	*Rhinotrichum lanosum* (Cooke) Cooke	-	Soil	-	Antarctica: Signy Iland	C,F	Cul	Morph	S	-	Bailey and Wynn-Williams, 1982	Bohacz and Korniłłowicz-Kowalska, 2019
Basidiomycota	*Rhizoctonia solani* J.G. Kühn	*Thanatephorus cucumeris*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	
Basidiomycota	*Rhizomarasmius epidryas* (Kühner ex A. Ronikier) A. Ronikier & Ronikier	*Marasmius* cf. *epidryas* Kühner ex A. Ronikier; *Marasmius epidryas*	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S,PA	Timling et al., 2014	-	Ronikier and Ronikier, 2011
Glomeromycota	*Rhizophagus antarcticus* (Cabello) C. Walker	*Glomus antarcticum*	Plants roots (mycorrhiza)	-	Antarctica: Antarctic Western Peninsula	n.i.	n.i.	n.i.	En	-	Cabello et al., 1994	Cabello etal., 1994
Basidiomycota	*Rhizopogon evadens* A.H. Sm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Rhizopogon graveolens* (Vittad.) Tul. & C. Tul.	*Rhizopogon graveolens* f. *pomaceus*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Rhizopogon laricinus* Y. Miyamoto & T.C. Maximov	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Mucoromycota	*Rhizopus arrhizus* A. Fisch.	*Rhizopus oryzae* Went & Prins. Geerl.; *Rhizopus nodosus*	Frozen sediments and soils, air	Arctic: Chukchi Peninsula, Taymyr, Yakutia	Antarctica: McMurdo Dry Valleys; Ross Iland, Victoria Land, Continental and peninsula Antarctica, New Harbor, Taylor Valley	F	Cul	M,Morph	S	Marfenina et al., 2014 (in Russian)	Sun et al., 1978; Zucconi et al., 2012	-
Mucoromycota	*Rhizopus stolonifer* (Ehrenb.) Vuill.	*Rhizopus nigricans* Ehrenb.	Soil, soil + penguen influence, algae, air, antropogenic substrates, moss, food	Arctic: White Sea area, WSBS; Novaya Zemlya, Kara Sea region (Yamal), Taymyr	Antarctica: Windmill Ilands, Cabo Primavera, Arctowski Station, King George Iland, Larsemann Hills oasis, Iland Livingstone	C,D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2016 (in Russian); Nikitin et al., 2021	Czarnecki and Bialasiewicz, 1987; Azmi and Seppelt, 1998; Kostadinova et al., 2009; Marfenina et al., 2016	-
Ascomycota	*Rhizosphaera kalkhoffii* Bubák	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Rhizosphaera macrospora* Gourb. & M. Morelet	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA	Zhang and Yao, 2015	-	-
Ascomycota	*Rhodesiopsis gelatinosa* B. Sutton & R. Campb.	-	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985; Kerry, 1990a	-
Ascomycota	*Rhytisma acerinum* (Pers.) Fr.	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP	Lydolph et al., 2005	-	Weber and Webster, 2002
Basidiomycota	*Russula aeruginea* Lindblad ex Fr.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Russula atrorubens* Quél.	-	Soil	Arctic: Finland	-	F	eDNA	M	Ec	Santalahti et al., 2018	-	-
Basidiomycota	*Russula betularum* Hora	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Russula brevipes* Peck	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Gelm et al., 2012	-	-
Basidiomycota	*Russula chloroides* (Krombh.) Bres.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula decolorans* (Fr.) Fr.	-	Soil, roots	Arctic: Finland, Alaska, Toolik Lake	-	F,C	eDNA	M	Ec	Santalahti et al., 2018; Dunleavy and Mack, 2021	-	-
Basidiomycota	*Russula delica* Fr.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010		
Basidiomycota	*Russula emetica* (Schaeff.) Pers.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Russula gracillima* Jul. Schäff.	-	Soil	Arctic: Finland	-	I	eDNA	M	Ec	Poosakkannu et al., 2017	-	-
Basidiomycota	*Russula laccata* Huijsman	-	Roots	Arctic: Svalbard	-	F	eDNA	M	Ec	Lorberau et al., 2017	-	-
Basidiomycota	*Russula nana* Killerm.	-	Soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA	M	Ec	Gelm et al., 2012; Timling et al., 2014	-	-
Basidiomycota	*Russula nuoljae* Kühner	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula olivobrunnea* Ruots. & Vauras	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula pascua* (F.H. Møller & Jul. Schäff.) Kühner	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Gelm et al., 2012	-	-
Basidiomycota	*Russula persicina* Krombh.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Russula pubescens* A. Blytt	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula renidens* Ruots., Sarnari & Vauras	-	Roots	Arctic: Svalbard, Russia, Yakutia	-	C,F	eDNA	M	Ec	Lorberau et al., 2017; Miyamoto et al., 2022	-	-
Basidiomycota	*Russula rhodopus* Zvára	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula risigallina* (Batsch) Sacc.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula robertii* J. Blum	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula saliceticola* (Singer) Kühner ex Knudsen & T. Borgen	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Russula sanguinea* Fr.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula subrubens* (J.E. Lange) Bon	*Russula chamiteae*	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021	-	-
Basidiomycota	*Russula suecica* Ruots. & Vauras	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula versicolor* Jul. Schäff.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Russula vinosa* Lindblad	*Russula* cf. *vinosa* Lindblad	Soil, roots	Arctic: Canada/ Alaska, Toolik Lake, Finland	-	F,C	eDNA	M	Ec	Timling et al., 2014; Santalahti et al., 2018; Dunleavy and Mack, 2021	-	-
Basidiomycota	*Russula vinososordida* Ruots. & Vauras	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Russula xerampelina* (Schaeff.) Fr.	-	Soil	Arctic: Svalbard	-	F	eDNA	M	Ec	Gelm et al., 2012	-	-
Ascomycota	*Sagenomella humicola* (Onions & G.L. Barron) W. Gams	*Paecilomyces humicola* Onions & G.L. Barron	Tundra soils, sandy soil	Arctic: Polar Urals, Izvestiy TSIK Ilands	-	F	Cul	Morph	n.i.	Kirtsidely et al., 2010, 2014 (in Russian)	-	-
Ascomycota	*Salinomyces thailandicus* (Crous & K.D. Hyde) Czachura & Piątek	*Hortaea thailandica*	Rocks, sandstones	-	Antarctica: Victoria Land	F	Cul	M	EL,PP	-	Selbmann et al., 2021	Crous et al., 2009
Ascomycota	*Sarea difformis* (Fr.) Fr.	-	Wood	-	Antarctica: Ross Sea region	F	Cul	M	PA	-	Arenz et al., 2006	McMullin, 2018
Ascomycota	*Sarocladium dejongiae* L. Lombard	-	Lake sediments (antropogenic inf)	-	Antarctica: King George Iland	F	Cul	M	n.i.	-	Ogaki et al., 2020b	-
Ascomycota	*Sarocladium implicatum* (J.C. Gilman & E.V. Abbott) A. Giraldo, Gené & Guarro	*Acremonium implicatum* (J.C. Gilman & E.V. Abbott) W. Gams	Soil	Arctic: White Sea area, WSBS	Antarctica: King George Iland; Warren Cave on Mt. Erebus	C,F	Cul,eDNA	M, Morph	S	Grum-Grzhimaylo et al., 2018	Connel and Staudigel, 2013; Ding et al., 2016	-
Ascomycota	*Sarocladium kiliense* (Grütz) Summerb.	*Acremonium kiliense* Grütz	Soil, plants, soil with recreational plant community	Arctic: Novaya Zemlya, Franz Joseph Land, Izvestiy TSIK Iaslands, Fersman Iland	Antarctica: Macquarie Iland, Ellsworth Mountains	C,F	Cul	Morph,M	S,PF	Bergero et al., 1999; Kirtsideli et al, 2014 (in Russian); Nikitin et al., 2021; Nikitin and Semenov, 2022	Kerry and Weste, 1985 (inBOOK); Godinho et al., 2015; Nikitin, 2018 (in Russian)	-

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Ascomycota	*Sarocladium strictum* (W. Gams) Summerb.	*Acremonium strictum* W. Gams; *Cephalosporium acremonium*	Tundra soils, cryophylic alpine meadow, soil, moss, melt water, intestinal tract of larvae of Eretmoptera murphyi, plants, peat, lichens, antropogenic substrates, air, permafrost soil, antropogenic substrates, littoral sand	Arctic: Polar Urals, Novaya Zemlya, Franz Josef Land, White Sea area, WSBS, Izvestiy TSIK Iaslands, Barents Sea, Kolguyev Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: Ross Sea Region, Kay Iland, Oates Land, Taylor Valley, Lake Hoare, Mac Robertson Land, Vestfold Hills, Mawson, Signy Iland, Factory Cove, Macquarie Iland, McMurdo Dry Valleys, Laurie Island, in the South Orkney Islands	C,F,D	Cul	Morph,M	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsidely et al., 2010, 2011, 2014, 2016 (in Russian); Bubnova, 2017; Nikitin et al., 2021; Nikitin and Semenov, 2022	Kerry and Weste, 1985; Frate and Caretta, 1990; Kerry, 1990b; Baublis et al., 1991; Zucconi et al., 1996; Bridge and Denton, 2007; Kochkina et al., 2014; Gaiser et al., 2021	-
Ascomycota	*Sarocladium terricola* (J.H. Mill., Giddens & A.A. Foster) A. Giraldo, Gené & Guarro	*Acremonium terricola* (J.H. Mill., Giddens & A.A. Foster) W. Gams	Plants	-	Antarctica: South Georgia, Macquarie Iland	n.i.	Cul	Morph	S	-	Hurst et al., 1983; Kerry and Weste, 1985	-
Basidiomycota	*Schizophyllum commune* Fr.	-	Soil, lake water	Arctic: Svalbard	Antarctica: King George Iland, South Shetland Ilands	F	Cul,eDNA	M	S,OHP,W	Zhang et al., 2015b	Krishnan et a., 2016	Chowdhary et al., 2013
Ascomycota	*Schizothecium carpinicola* (Mouch.) L. Cai	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	PA	Bellemain et al., 2013	-	Cai et al., 2005
Ascomycota	*Schizothyrioma stilbocarpae* Spooner	-	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	PP	-	Kerry and Weste, 1985	-
Ascomycota	*Sclerococcum dobrowolskii* (Olech & Alstrup) Ertz & Diederich	*Dactylospora dobrowolskii* Olech & Alstrup	Lichens	-	Antarctica: Bunger Oasis, East Antarctica	n.i.	n.i.	n.i.	LF	-	Olech and Alstrup, 1996	Zhurbenko, 2022
Ascomycota	*Sclerotinia borealis* Bubák & Vleugel	*Myriosclerotinia borealis* (Bubák & Vleugel) L.M. Kohn	Bird colonies, plants	Arctic: Canada, Sweden, Svalbard, Finland, Russia, Siberia, Cola Peninsula, Alaska	Antarctica	n.i.	Cul	n.i.	PP,PsF	Groves and Bowerman, 1955; Tkachenko, 2013; Hoshino et al., 2019	Nikitin, 2021 (in Russian) = Nikitin, 2023	Mardanov et al., 2014
Ascomycota	*Sclerotinia sclerotiorum* (Lib.) de Bary	-	Soil with antropogenic contamination	-	Antarctica: Windmill Ilands, King George Iland	C	Cul	Morph	PP	-	Azmi and Seppelt, 1998	Purdy, 1979

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Ascomycota	*Scopulariopsis brumptii* Salv.-Duval	-	Antropogenic substrates, lake sediments, soil, littoral soil	Arctic: White Sea area, WSBS, Barents Sea coast, Kara Sea region (Yamal), Izvestiy TSIK Ilands, Franz Joseph Land, Taymyr	-	C,F	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al., 2016 (in Russian); Bubnova and Konovalova, 2018 (in Russian)	-	-
Ascomycota	*Scopulariopsis candida* Vuill.	-	Soil?	Arctic	-	n.i.	Cul	n.i.	S	Ozerskaya et al., 2009	-	-
Ascomycota	*Scutellinia heteroscu lpturata* Kullman & Raitv.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	S	Timling et al., 2014	-	Schumacher, 1993;
Ascomycota	*Scytalidium album* L. Beyer & Klingström	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Scytalidium lignicola* Pesante	-	Antropogenic substrates	Arctic: Izvestiy TSIK Ilands, Franz Joseph Land	-		Cul	Morph	S,OHP	Kirtsideli et al., 2016 (in Russian)	-	Dickinson et al., 1983; de Medeiros et al., 2019
Basidiomycota	*Sebacina epigaea* (Berk. & Broome) Bourdot & Galzin	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	Riess et al., 2013
Basidiomycota	*Sebacina incrustans* (Pers.) Tul. & C. Tul.	-	Soil	Arctic: Norway, Canada/Alaska	-	F	eDNA	M	Ec	Bjorbækmo et al., 2010; Timling et al., 2014	-	Riess et al., 2013
Ascomycota	*Septofusidium elegantulum* (Pidopl.) W. Gams	-	Air	-	Antarctica: Signy Iland	n.i.	n.i.	n.i.	PP	-	Chalmers et al., 1996	Hettiarachchi et al., 1983
Ascomycota	*Septoria stellariae* Roberge ex Desm.	-	n.i.	Arctic: Svalbard	-	n.i.	Cul?	Morph?	PP	Elvebakk and Prestrud, 1996	-	Verkley et al., 2013
Ascomycota	*Septoriella elongata* (Wehm.) Y. Marín & Crous	-	living leaves of Angiosperms	-	Antarctica: King George Iland	F	Cul	M	E	-	Lucini et al., 2022	-
Ascomycota	*Septoriella vagans* (Niessl) Y. Marín & Crous	*Pleospora vagans* Niessl; *Phaeosphaeria vagans* (Niessl) O.E. Erikss.	Vascular plants, leafs	Arctic: Finland	Antarctica: King George Iland, Ilands near the Antarctic Peninsula, Macquarie Iland	C,I	eDNA,Cul	Morph,M	PP,PA,S	Poosakkannu et al., 2017	Kerry and Weste, 1985; Möller and Dreyfuss, 1996	-
Basidiomycota	*Serendipita vermifera* (Oberw.) P. Roberts	*Sebacina vermifera* Oberw.	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	E	Timling et al., 2014	-	Sarkar et al., 2019
Basidiomycota	*Serpula himantioides* (Fr.) P. Karst.	-	Conifer wood	Arctic: Finland	-	F	Cul	Morph	S,PA	Kaitera et al., 2019	-	

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Basidiomycota	*Serpula similis* (Berk. & Broome) Ginns	-	Roots	Arctic: Svalbard	-	F	eDNA	M	E	Botnen et al., 2020	-	de Silva et al., 2019
Ascomycota	*Similiphoma crystallifera* (Gruyter, Noordel. & Boerema) Valenz.-Lopez, Crous, Cano, Guarro & Stchigel	*Phoma crystallifera* Gruyter, Noordel. & Boerema	Permafrost sediments, fossil seeds	Arctic: Kolyma	-	F	Cul	Morph	PP	Stakhov et al., 2008	-	Razaghi et al., 2017
Ascomycota	*Simplicillium aogashimaense* Nonaka, Kaifuchi & Masuma	-	Soil	-	Antarctica	F	Cul	M	MF,E	-	Nikitin, 2018 (in Russian)	Jauregui et al., 2020
Ascomycota	*Simplicillium lamellicola* (F.E.V. Sm.) Zare & W. Gams	*Verticillium lamellicola* (F.E.V. Sm.) W. Gams	Mosses, rhizosphere	-	Antarctica: Kay Iland, Terra Nova Bay; Victoria Land, Kay Iland, Islands near Antarctic Peninsula	F	Cul	Morph,M	PA	-	Tosi et al., 2002; Gonc alves et al., 2015	-
Basidiomycota	*Sistotrema biggsiae* Hallenb.	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Sistotrema brinkmannii* (Bres.) J. Erikss.	-	Wood, peat, lake sediments, soil, conifer wood	Arctic: Finland, White Sea area, WSBS	Antarctica: Primavera Base, Warren Cave, Deception Island	C,F	Cul,eDNA	M	S,PF,PA	Grum-Grzhimaylo et al., 2016, 2018; Kaitera et al., 2019	Connel and Staudigel, 2013; Held and Blanchette, 2017	Thormann and Rice, 2007
Basidiomycota	*Sistotrema eximum* (H.S. Jacks.) Ryvarden & Solheim	-	Soil, roots	Arctic: Canada/ Alaska, Finland	-	F,I	eDNA	M	PA	Timling et al., 2014; Poosakkannu et al., 2017	-	-
Basidiomycota	*Sistotrema muscicola* (Pers.) S. Lundell	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Sistotrema luteoviride* Kotir. & K.H. Larss.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Slopeiomyces cylindrosporus* (D. Hornby, Slope, Gutter. & Sivan.) Klaubauf, M.-H. Lebrun & Crous	*Gaeumannomyces cylindrosporus* D. Hornby, Slope, Gutter. & Sivan.	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	E	Bellemain et al., 2013	-	Ampt et al., 2022; Pereira et al., 2019
Ascomycota	*Spadicoides bina* (Corda) S. Hughes	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-

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Ascomycota	*Sphaeronaemella mougeotii* (Fr.) Sacc.	*Sphaeronaema mougeotii* (Fr.) Sacc.	Permafrost sediments	Arctic	-	F	Cul	Morph	n.i.	Ivanushkina et al., 2005; Ozerskaya et al., 2009	-	-
Ascomycota	*Sphaerostilbella penicillioides* (Corda) Rossman, L. Lombard & Crous	*Sphaerostilbella aureonitens* (Tul. & C. Tul.) Seifert, Samuels & W. Gams	Cryophylic alpine meadow, Antropogenic substrates	Arctic: Polar Urals, Izvestiy TSIK Ilands, Franz Joseph Land	-	n.i.	Cul	Morph	n.i.	Kirtsidely et al., 2010, 2016 (in Russian)	-	-
Ascomycota	*Spiromastigoides gypsea* (Sigler & J.W. Carmich.) Stchigel, Rodr.-Andr. & Cano	*Malbranchea gypsea* Sigler & J.W. Carmich.	Dust	-	Antarctica: Edmonson Point	C	Cul	Morph	K	-	Mercantini et al., 1993	-
Ascomycota	*Sporormiella affinis* (Sacc., E. Bommer & M. Rousseau) S.I. Ahmed & Cain	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	CF	Timling et al., 2014	-	Doveri, 2011
Ascomycota	*Sporormiella heptamera* (Auersw.) S.I. Ahmed & Cain	-	Soil	Arctic: Finland	-	I	eDNA	M	S,CF	Poosakkannu et al., 2017	-	Doveri, 2011
Ascomycota	*Sporormiella pulchella* (E.C. Hansen) S.I. Ahmed & Cain	-	Permafrost soil	Arctic: Siberia	-	F	eDNA	M	CF	Bellemain et al., 2013	-	Doveri, 2011
Ascomycota	*Sporothrix brasiliensis* Marimon, Gené, Cano & Guarro	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	OHP,AP	-	Rosa et al., 2020	Doveri, 2011
Ascomycota	*Sporothrix inflata* de Hoog	-	Soil	-	Antarctica: King George Iland, South Shetland Ilands	n.i.	Cul	M	E,PA	-	Krishnan et a., 2016	Halmschlager and Kowalski, 2003
Ascomycota	*Sporothrix pallida* (Tubaki) Matsush.	-	Soil	-	Antarctica: King George Iland, South Shetland Ilands	n.i.	Cul	M	K,S	-	Krishnan et a., 2016	D'Alessandro et al., 2016
Ascomycota	*Sporothrix ramosissima* G. Arnaud ex de Hoog	-	Soil	-	Antarctica: MacRobertson Land	n.i.	Cul	Morph	n.i.	-	Fletcher et al., 1985	-
Ascomycota	*Sporothrix schenckii* Hektoen & C.F. Perkins 1900		Soil	-	Antarctica: King George Iland, South Shetland Ilands	n.i.	Cul	M	OHP,PF	-	Krishnan et a., 2016	Thormann and Rice, 2007

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Ascomycota	*Stachybotrys chartarum* (Ehrenb.) S. Hughes	*Stachybotrys atrus* Corda, Stachybotrys atra Corda	Permafrost sediments, Antropogenic substrates, peat	Arctic: White Sea area, WSBS, Taymyr, Severnaya Zemlya	Antarctica: continental, S. Victoria Land	F,C	Cul	Morph	S,PF	Ivanushkina et al., 2005; Grum-Grzhimaylo et al., 2016; Kirtsideli et al., 2016 (in Russian)	Onofri, 1999	Domsh et al., 2007
Ascomycota	*Stachybotrys cylindrosporus* C.N. Jensen	*Stachybotrys cylindrospora* C.N. Jensen	Tundra soils	Arctic: Polar Urals	-	n.i.	Cul	n.i.	S	Kirtsidely et al., 2010 (in Russian)	-	Domsh et al., 2007
Ascomycota	*Stachybotrys echinatus* (Rivolta) G. Sm.	-	Soil	Arctic: White Sea area, WSBS, Apatiti	-	C,F	Cul	Morph,M	S	Grum-Grzhimaylo et al., 2018; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	-	Domsh et al., 2007
Ascomycota	*Stagonospora ischaemi* (Sacc.) Sacc.	*Stagonospora ischmaemi*	Plants	-	Antarctica: Macquarie Iland	n.i.	Cul	Morph	S	-	Kerry and Weste, 1985; Kerry, 1990a	-
Ascomycota	*Stemphylium botryosum* Sacc.	-	Plants, soil	Arctic: White Sea area, WSBS	Antarctica: Mac Robertson Land, Vestfold Hills, Macquarie Iland	F,D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian)	Kerry and Weste, 1985; Kerry, 1990b	-
Ascomycota	*Stemphylium solani* G.F. Weber	-	Air	Arctic: Barents Sea, Shoyna	-	I	Cul	Morph	PP	Kirtsideli et al., 2011 (in Russian)	-	Kim et al., 2004; Mehta, 2001; Zheng et al., 2008
Ascomycota	*Stemphylium verruculosum* (O.E.R. Zimm.) Sacc.*	-	Peat	Arctic: Komi	-	n.i.	Cul	Morph	PF,PP,S	Lapteva et al., 2017 (in Russian)	-	Shinde et al., 2011; Smirnov et al., 2021
Ascomycota	*Stemphylium vesicarium* (Wallr.) E.G. Simmons	*Pleospora herbarum*	Driftwood, plants	Arctic: Iceland	Antarctica: South Georgia	C	Cul	M,Morph	S,PA	Blanchette et al., 2016	Smith, 1994	-
Ascomycota	*Stephanosporium atrum* Dal Vesco	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF	Grum-Grzhimaylo et al., 2016	-	-
Basidiomycota	*Stereum hirsutum* (Willd.) Pers.	-	Soil, wood	-	Antarctica: Ross Sea region	F	eDNA	M	PP,S	-	Arenz et al., 2011 (ITS identification 96%)	Dubin et al., 2000; Cuevas et al., 2015
Basidiomycota	*Stereum rugosum* Pers.	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Basidiomycota	*Stereum sanguinolentum* (Alb. & Schwein.) Fr.	-	Conifer wood	Arctic: Finland	Antarctica: Warren Cave on Mt. Erebus	F	Cul,eDNA	M	S,PA	Kaitera et al., 2019	Connel and Staudigel, 2013	-
Ascomycota	*Striaticonidium cinctum* (Corda) L. Lombard & Crous	*Myrothecium cinctum* (Corda) Sacc.	Antropogenic substrates	Arctic: Kara Sea region (Yamal), Franz Joseph Land, Taymyr	-	n.i.	Cul	Morph	n.i.	Kirtsideli et al., 2016 (in Russian)	-	-

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Basidiomycota	*Strobilurus tenacellus* (Pers.) Singer	-	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	M	PF,S	Grum-Grzhimaylo et al., 2016	-	Selim and Khalil, 2021
Ascomycota	*Stromatinia rapulum* (Bull.) Boud.	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	PP	Lydolph et al., 2005	-	Chachuła et al., 2018
Basidiomycota	*Suillus cavipes* (Klotzsch) A.H. Sm. & Thiers	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Suillus grevillei* (Klotzsch) Singer	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Suillus luteus* (L.) Roussel	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Suillus variegatus* (Sw.) Richon & Roze	-	Roots	Arctic: Finland, Russia, Yakutia	-	C,F	eDNA	M	Ec	Santalahti et al., 2018; Miyamoto et al., 2022	-	-
Basidiomycota	*Suillus viscidus* (L.) Roussel	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Sydowia polyspora* (Bref. & Tavel) E. Müll.	*Hormonema dematioides* Lagerb. & Melin	Wood, antropogenic substrates, air, peat, soil, conifer wood, snow, permafrost soil	Arctic: Greenland, Finland, White Sea area, WSBS, Izvestiy TSIK Ilands, Siberia	Antarctica: Signy Iland, Ross Sea region, Deception Iland	F,C	Cul,eDNA	M	S,PA,PF,IF	Lydolph et al., 2005; Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al., 2016 (in Russian); Kaitera et al., 2019; Perini et al., 2019	Chalmers et al., 1996; Arenz et al., 2006; Held and Blanchette, 2017	-
Basidiomycota	*Sympodiomycopsis kandeliae* G.Y. Liou, Y.H. Wei & F.L. Lee ex Kijporn. & Aime	-	Soil	-	Antarctica	F	Cul	M	PA	-	Nikitin, 2018 (in Russian)	Wei et al., 2011
Mucoromycota	*Syncephalastrum monosporum* R.Y. Zheng, G.Q. Chen & F.M. Hu	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Talaromyces aculeatus* (Raper & Fennell) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium aculeatum* Raper & Fennell	Lake sediments	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF,S	Grum-Grzhimaylo et al., 2016, 2018	-	-
Ascomycota	*Talaromyces atroroseus* N. Yilmaz, Frisvad, Houbraken & Samson	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-

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Ascomycota	*Talaromyces diversus* (Raper & Fennell) Samson, N. Yilmaz & Frisvad	*Penicillium diversum* Raper & Fennell	Air, peat, soil, antropogenic substrates	Arctic: White Sea area, WSBS, Kara Sea region (Yamal), Severnaya Zemlya	Antarctica: King George Iland	C,D	Cul	Morph	PF,S	Bubnova and Velikanov, 2004 (in Russian); Grum-Grzhimaylo et al., 2016; Kirtsideli et al., 2016 (in Russian)	Bialasiewicz and Czarnecki, 1999 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Talaromyces duclauxii* (Delacr.) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium duclauxii* Delacr.	Soil, lake sediments	Arctic: White Sea area, WSBS	Antarctica: continental	C	Cul	Morph	PF,S	Grum-Grzhimaylo et al., 2016	Cameron, 1971 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Talaromyces flavus* (Klöcker) Stolk & Samson	-	Soil	-	Antarctica	F	Cul	Morph	PA,S,HR,PHOF	-	Nikitin, 2018 (in Russian)	Panek, and Frąc, 2019
Ascomycota	*Talaromyces funiculosus* (Thom) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium funiculosum* Thom	Permafrost sediments, antropogenic substrates, soil, peat, antropogenic substrates, lake sediments	Arctic: Svalbard, White Sea area, WSBS, Izvestiy TSIK Ilands, Severnaya Zemlya	Antarctica: McMurdo Dry Valleys, continental	F,C	Cul	Morph,M	PF,S	Kirtsideli et al., 2014, 2016 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Iluchin et al., 2022a	Kochkina et al., 2012	-
Ascomycota	*Talaromyces islandicus* (Sopp) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium islandicum*	Soil	Arctic: Svalbard	-	C	Cul	Morph	S	Kurek et al., 2007	-	-
Ascomycota	*Talaromyces minioluteus* (Dierckx) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium minioluteum* Dierckx	Cryopeg, permafrost soil, permafrost sediments, mosses	Arctic: White Sea area, WSBS, Kolyma, Siberia	Antarctica: McMurdo Dry Valleys, Gondwana Lake, Mount Melbourne, Victoria Land	F,D	eDNA,Cul	Morph,M	PA	Bubnova and Velikanov, 2004 (in Russian); Gilichinsky et al., 2005; Ivanushkina et al., 2005; Ozerskaya et al., 2008, 2009; Kochkina et al., 2011 (in Russian); Bellemain et al., 2013	Tosi et al., 2002; Kochkina et al., 2012	-

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Ascomycota	*Talaromyces purpureogenus* Samson, N. Yilmaz, Houbraken, Spierenb., Seifert, Peterson, Varga & Frisvad	*Penicillium purpureogenum* Stoll; *Penicillium purpurogenum*	Permafrost and tundra soils, permafrost sediments, antropogenic substrate, lake water	Arctic: Svalbard, Polar Urals, Kara Sea region (Yamal), Taymyr, Severnaya Zemlya	Antarctica: McMurdo Dry Valleys	F,D	Cul,eDNA	Morph,M	S	Kirtsidely, 1999 (in Russian); Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Kirtsidely et al., 2010, 2016 (in Russian); Zhang et al., 2015b	Kochkina et al., 2012	-
Ascomycota	*Talaromyces radicus* (A.D. Hocking & Whitelaw) Samson, N. Yilmaz, Frisvad & Seifert	-	Peat	Arctic: Alaska	-	F	eDNA	M	S,PF	Semenova et al., 2015	-	-
Ascomycota	*Talaromyces ruber* (Stoll) N. Yilmaz, Houbraken, Frisvad & Samson	*Penicillium rubrum* Stoll	Antropogenic substrates, soil	Arctic: White Sea area, WSBS, Kara Sea region (Yamal)	-	D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2016 (in Russian)	-	-
Ascomycota	*Talaromyces rugulosus* (Thom) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium rugulosum* Thom; *Penicillium tardum* Thom	Permafrost and tundra soils, cryophylic alpine meadow, anchient sediments, antropogenic substrates, air, peat, birds fecas, soil, plants+feathers	Arctic: Canada, Svalbard, White Sea area, WSBS, Kolyma, Polar Urals, Izvestiy TSIK Ilands	Antarctica: McMurdo Dry Valleys, Signy Iland	F,C,D	Cul	Morph	S,PF,BA	Bubnova and Velikanov, 2004 (in Russian); Ivanushkina et al., 2005; Ozerskaya et al., 2008; Kirtsideli et al., 2010, 2014, 2016 (in Russian); Kochkina et al., 2011 (in Russian); Grum-Grzhimaylo et al., 2016; Robicheau et al., 2019; Iluchin et al., 2022a	Chalmers et al., 1996; Gilichinsky et al., 2007; Brunati et al., 2009; Litova et al., 2014	-
Ascomycota	*Talaromyces sayulitensis* Visagie, N. Yilmaz, Seifert & Samson	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Talaromyces variabilis* (Sopp) Samson, N. Yilmaz, Frisvad & Seifert	*Penicillium variabile* Sopp	Cryopeg, permafrost and tundra soils, permafrost sediments, soil, ice core, peat, lake sediments	Arctic: Greenland, White Sea area, WSBS, Kolyma, Polar Urals, Franz Josef Land, Fersman Iland, Melekhov Cape of Alexandra Land	Antarctica: McMurdo Dry Valleys, East, Antarctic Peninsula, Russkaya Station	F,C	Cul	M,Morph	S,PF	Ma et al., 1999; Ivanushkina et al., 2005; Ozerskaya et al., 2008; Kirtsidely et al., 2010 (in Russian); Kochkina et al., 2011 (in Russian); Grum-Grzhimaylo et al., 2016; Nikitin and Semenov, 2022	Kochkina et al., 2012, 2019; Marfenina et al., 2016	-
Ascomycota	*Talaromyces verruculosus* (Peyronel) Samson, N. Yilmaz, Frisvad & Seifert	-	Peat, lake sediments, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF,S	Grum-Grzhimaylo et al., 2016, 2018	-	-

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Ascomycota	*Talaromyces wortmannii* (Klöcker) C.R. Benj.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S,PF	-	Rosa et al., 2020	Thormann and Rice, 2007
Ascomycota	*Taphrina americana* Mix	-	Soil, peat	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014; Semenova et al., 2015	-	Christita et al., 2022
Ascomycota	*Taphrina carpini* (Rostr.) Johanson	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Nguyen et al., 2016
Ascomycota	*Tarzetta catinus* (Holmsk.) Korf & J.K. Rogers	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	Mrak et al., 2020
Basidiomycota	*Tausonia pullulans* (Lindner) Xin Zhan Liu, F.Y. Bai, M. Groenew. & Boekhout	*Guehomyces pullulans* (Lindner) Fell & Scorzetti	Sandy soil, antropogenic substrates, conifer wood	Arctic: Finland, Izvestiy TSIK Ilands	-	F	Cul	M	S,PA	Kirtsideli et al., 2014, 2016 (in Russian); Kaitera et al., 2019	-	Arastehfar et al., 2021
Ascomycota	*Tetracladium ellipsoideum* M.M. Wang & Xing Z. Liu	-	Ice cover	-	Antarctica: McMurdo Dry Valleys, Lake Chad	F	Cul	M	IF,PsF	-	Kudalkar, 2016	Wang et al., 2015
Ascomycota	*Tetracladium furcatum* Descals	-	Lichens, plant tissues, soil	Arctic: Svalbard, Canada/Alaska	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S,LA,PA,E	Timling et al., 2014; Zhang et al., 2015a; Zhang and Yao, 2015	Rosa et al., 2020	-
Ascomycota	*Tetracladium globosum* M.M. Wang & Xing Z. Liu	-	Lake sediments (antropogenic inf)	-	Antarctica: King George Iland	F	Cul	M	W	-	Ogaki et al., 2020b	Lim et al., 2021
Ascomycota	*Tetracladium marchalianum* De Wild.	-	Coal mine spoil	Arctic: Svalbard	Antarctica: Deception Iland, South Shetland Ilands	C,F	Cul,eDNA	M	S	Iliushin et al., 2022a	Rosa et al., 2020	-
Ascomycota	*Tetracladium maxilliforme* (Rostr.) Ingold	-	Soil, permafrost soil	Arctic: Norway, Siberia	Antarctica: Dronnin Maud Land	F	eDNA	M	S	Bjorbækmo et al., 2010; Bellemain et al., 2013	Kochkina et al., 2014	-
Basidiomycota	*Thaxterogaster comarostaphylidis* (Ammirati, Halling & Garnica) Niskanen & Liimat.	*Cortinarius comarostaphylidis*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Thaxterogaster crenulatus* (Rob. Henry ex Bidaud & Reumaux) Niskanen & Liimat.	*Cortinarius crenulatus*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Thaxterogaster herpeticus* (Fr.) Niskanen & Liimat.	*Cortinarius herpeticus*	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021	-	-
Basidiomycota	*Thaxterogaster pinophilus* (Soop) Niskanen & Liimat.	*Cortinarius pinophilus*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Thaxterogaster vibratilis* (Fr.) Niskanen & Liimat.	*Cortinarius vibratilis*	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Ascomycota	*Thelebolus balaustiformis* Bovio, Garzoli, A. Poli, Prigione & Varese	-	Snow	-	Antarctica: Antarctic Peninsula, South Shetland Islands	C	Cul	M	AA,W,IF,PsF	-	de Menezes et al., 2019; Nikitin, 2021 (in Russian) = Nikitin, 2023	Bovio et al., 2018; Rosa et al., 2019
Ascomycota	*Thelebolus caninus* (Sacc.) Jeng & J.C. Krug	-	Soil	-	Antarctica: Ross Sea region, Continental Antarctica	F	eDNA,Cul	M	CF	-	Arenz et al., 2006	-
Ascomycota	*Thelebolus ellipsoideus* Brumm. & de Hoog	-	Biomats in lakes, Bird colonies, soil, leafs	Arctic: Finland, Novaya Zemlya	Antarctica: McMurdo dry valleys Victoria Land, Vestfold Hills, Larsemann Hills	F	Cul,eDNA	M,Morph	W,BA	Poosakkannu et al., 2017; Nikitin et al., 2021	de Hoog et al., 2005; Nikitin, 2018, 2021 (in Russian) = Nikitin, 2023	Rosa et al., 2019
Ascomycota	*Thelebolus globosus* Brumm. & de Hoog	-	Lichens, biomats in lakes, soil, algobacterial mat, Bird colonies, ornithogenic soil, snow, rocks, lake sediments, antropogenic, lake water	Arctic: Greenland, Norway, Hardangervidda, Svalbard, Franz Josef Land, Fersman Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land	Antarctica: Vestfold Hills, McMurdo Dry Valley; Schirmacher Oasis, Windmill Ilands, Browning Peninsula, Beaufort Iland, South Shetlands Islands, Antarctic Peninsula, King George Island	F,C	eDNA,Cul	M,Morph	S,BA,EL,IF,W,PsF	Zhang et al., 2015a,b; Borchhardt et al., 2019; Perini et al., 2019; Nikitin and Semenov, 2022	de Hoog et al., 2005; Alias et al., 2013; Pudasaini et al., 2017; Nikitin, 2018 (in Russian); Alves et al., 2019; de Menezes et al., 2019; Ogaki et al., 2020a,b; Rosa et al., 2020; Nikitin, 2021 (in Russian) = Nikitin, 2023	Rosa et al., 2019
Ascomycota	*Thelebolus microcarpus* Stchigel, Y. Marín, Guarro & Cano	-	Glacier, soil	Arctic: Canada	-	F	Cul	M	IF	Tsuji et al., 2022	-	Crous et al., 2015

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Ascomycota	*Thelebolus microsporus* (Berk. & Broome) Kimbr.	*Thelebolus* cf. *microsporus*	Soil, soil + bird influence, feathers, bird dung, lichens, vascular plants, antropogenic substrates, moss, sandy soil, ornithogenic soil, lake water, algae	Arctic: Novaya Zemlya, Franz Joseph Land, Izvestiy TSIK Iaslands, Alger Iland, Fersman Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land, Svalbard	Antarctica: Ross Sea region, Windmill Ilands, Vilgelm II Land, Ilands near the Antarctic Peninsula, Signy Iland, Casey, King George Iland, S. Orkneys, Hope Bay, MacRobertson, Land, Edmonson Point Victoria Land, Vestfold Hills, Larsemann Hills, Taylor Valley McMurdo Land, Antarctic Peninsula, East, Mac Robertson Land, Vestfold Hills, Mawson, Enderby Land, Vegetation Iland, Dronning Maud Land, Robertskollen, Beaufort Iland, Syowa Station	F,C,I	eDNA,Cul	M,Morph	S,BA,K,PA,LA,W,PtF	Bergero et al., 1999; Singh et al., 2015; Kirtsideli et al., 2014, 2016 (in Russian); Tsuji et al., 2016; Nikitin et al., 2021; Nikitin and Semenov, 2022	Fletcher et al., 1985; Ryan et al., 1989; Frate and Caretta, 1990; Kerry, 1990a,b; Chalmers et al., 1996; Möller and Dreyfuss, 1996; Fenice et al., 1997; Azmi and Seppelt, 1998; McRae and Seppelt, 1999; Onofri, 1999; Onofri et al., 2000; Tosi et al., 2002, 2005; de Hoog et al., 2005; Arenz et al., 2006; Connel et al., 2006; Arenz and Blanchette, 2011; Gonc alves et al., 2012; Alias et al., 2013; Kochkina et al., 2014, 2019; Ding et al., 2016; Pudasaini et al., 2017; Nikitin, 2018 (in Russian), 2021 (in Russian) = Nikitin, 2023; Tsui, 2019; Devoto et al., 2022	-
Ascomycota	*Thelebolus spongiae* Bovio, Garzoli, A. Poli, Prigione & Varese	-	Soil	-	Antarctica	n.i.	Cul	n.i.	AA,W,PsF	-	Nikitin, 2021 (in Russian) = Nikitin, 2023	Bovio et al., 2018; Rosa et al., 2019
Ascomycota	*Thelebolus stercoreus* Tode	-	Soil, lake water	Arctic: Svalbard, Novaya Zemlya, Franz Joseph Land, Fersman Iland, Hooker Iland near the Tikhaya Bay, Greenland	Antarctica	F	Cul,eDNA	M	CF	Zhang et al., 2015b; Nikitin et al., 2021; Nikitin and Semenov, 2022	de Hoog et al., 2005	-
Basidiomycota	*Thelephora atra* Weinm.	*Tomentella atramentaria* Rostr.; *Tomentella atra**	Soil, roots	Arctic: Russia, Yakutia, Canada/Alaska	-	F,C	eDNA	M	Ec	Timling et al., 2014; Miyamoto et al., 2022	-	Rudawska et al., 2018
Basidiomycota	*Thelephora caryophyllea* (Schaeff.) Pers.	*Tomentella caryophyllea**	Soil, roots	Arctic: Svalbard, Russia, Yakutia, Canada/Alaska	-	F,C	eDNA	M	Ec	Geml et al., 2012; Timling et al., 2014; Miyamoto et al., 2022	-	

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Basidiomycota	*Thelephora terrestris* Ehrh. ex Fr.	-	Roots	Arctic: Alaska, Toolik Lake	-	C	eDNA	M	Ec	Dunleavy and Mack, 2021	-	Kanunfre and Zancan, 1998
Basidiomycota	*Thelephora wakefieldiae* Zmitr., Shchepin, Volobuev & Myasnikov	*Tomentella sublilacina*	Roots, soil	Arctic: Canada/ Alaska, Toolik Lake	-	C,F	eDNA	M	Ec	Timling et al., 2014; Dunleavy and Mack, 2021	-	
Ascomycota	*Thelonectria lucida* (Höhn.) P. Chaverri & Salgado	-	Littoral soil	Arctic: Barents Sea coast	-	F	Cul	Morph	S,PA	Bubnova and Konovalova, 2018 (in Russian)	-	Chaverri et al., 2011
Ascomycota	*Thermomyces lanuginosus* Tsikl.	-	Feathers, peat, soil, plants	-	Antarctica: Ross Sea region, Victoria Land, S. Victoria Land, Macquarie Iland	C	Cul	Morph	S,BA,PA,TF	-	Ellis, 1980; Frate and Caretta, 1990	-
Ascomycota	*Thermothelomyces thermophilus* (Apinis) Y. Marín, Stchigel, Guarro & Cano	*Myceliophthora thermophila* (Apinis) Oorschot	Soil, soil with algae	-	Antarctica: N. Victoria Land, Mt Melbourne, Cloyd Iland near Casey Station	F	Cul	Morph	AI,TF	-	Ellis, 1980; Broady et al., 1987	Balabanova et al., 2022
Ascomycota	*Thyronectria coryli* (Fuckel) Jaklitsch & Voglmayr	-	Conifer wood	Arctic: Finland	-	F	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomycota	*Thyronectria cucurbitula* (Tode) Jaklitsch & Voglmayr	*Zythiostroma pinastri* (P. Karst.) Höhn.	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	PF,E	Grum-Grzhimaylo et al., 2016	-	Lee et al., 2020
Ascomycota	*Tolypocladium album* (W. Gams) C.A. Quandt, Kepler & Spatafora	*Chaunopycnis alba* W. Gams	Mosses, lichens	-	Antarctica: King George Iland, South Shetlan, Deception Island	C,F	Cul,eDNA	Morph,M	PA,LA,PF,S	-	Möller and Dreyfuss, 1996; Rosa et al., 2020	-
Ascomycota	*Tolypocladium cylindrosporum* W. Gams	-	Peat, lake sediments, soil, littoral soil, lake water	Arctic: Svalbard, White Sea area, WSBS, Barents Sea coast	Antarctica: Galindez Iland, King George Iland, Subantarctica	C,F	Cul,eDNA	M,Morph	PF,W	Zhang et al., 2015b; Grum-Grzhimaylo et al., 2016, 2018; Bubnova and Konovalova, 2018 (in Russian)	Vishniac, 1996 (cyt. Lopez Lastra et al., 1991); Nikitin, 2018 (in Russian)	-
Ascomycota	*Tolypocladium geodes* W. Gams	-	Soil, peat, lake sediments	Arctic: Franz Joseph Land, White Sea area, WSBS	-	C	Cul	Morph,M	EP,PF,S,MsF	Bergero et al., 1999; Meyling et al., 2012; Grum-Grzhimaylo et al., 2016	-	-

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Ascomycota	*Tolypocladium inflatum* W. Gams	*Elaphocordyceps subsessilis* (Petch) G.H. Sung, J.M. Sung & Spatafora	Soil, peat, lake sediments, conifer wood	Arctic: Greenland, Finland, White Sea area, WSBS, Barents Sea coast, Magadan, Alaska	-	C,F	Cul,eDNA	M,Morph	EP,PF,S	Meyling et al., 2012; Semenova et al., 2015; Bubnova and Konovalova, 2018 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Kaitera et al., 2019; Iliushin et al., 2022b	-	-
Ascomycota	*Tolypocladium nubicola* Bissett	-	Mosses, peat, soil	Arctic: White Sea area, WSBS	Antarctica: Ilands near the Antarctic Peninsula, King George Iland, South Shetlan	C	Cul	Morph	S,PA,PF	Grum-Grzhimaylo et al., 2016, 2018	Möller and Dreyfuss, 1996	-
Ascomycota	*Tolypocladium ovalisporum* (C. Möller & W. Gams) C.A. Quandt, Kepler & Spatafora	*Chaunopycnis ovalispora* C. Möller & W. Gams	Lichens	-	Antarctica: Ilands near the Antarctic Peninsula	C	Cul	Morph	LA	-	Möller and Dreyfuss, 1996	-
Ascomycota	*Tolypocladium sinense* C. Lan Li	-	Soil	Arctic: Magadan	-	C	Cul	M	EP	Iliushin et al., 2022b	-	Wang et al., 2022
Ascomycota	*Tolypocladium tundrense* Bissett	-	Soil, lake sediments	Arctic: White Sea area, WSBS, Franz Joseph Land, Fersman Iland, Zenith Cape of Heiss Iland	Antarctica: Galindez Iland, King George Iland, Subantarctica	C,F	Cul	M,Morph	PF,W,AA	Grum-Grzhimaylo et al., 2016, 2018; Nikitin and Semenov, 2022	Nikitin, 2018 (in Russian)	Godinho et al., 2019
Basidiomycota	*Tomentella alnii**	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentella badia* (Link) Stalpers	-	Roots, soil	Arctic: Svalbard, Russia, Yakutia	-	C,F	eDNA	M	Ec	Gelm et al., 2012; Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentella fuscocinerea* (Pers.) Donk	-	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	Ec	Timling et al., 2014	-	-
Basidiomycota	*Tomentella lapida* (Pers.) Stalpers	-	Soil, roots	Arctic: Russia, Yakutia, Alaska	-	F,C	eDNA	M	Ec,PF	Semenova et al., 2016; Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentella lilacinogrisea* Wakef.	-	Soil, roots	Arctic: Russia, Yakutia, Canada/Alaska	-	F,C	eDNA	M	Ec	Timling et al., 2014; Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentella muricata* (Ellis & Everh.) Wakef.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentella stuposa* (Link) Stalpers	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Tomentella subclavigera* Litsch.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentella terrestris* (Berk. & Broome) M.J. Larsen	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentellopsis echinospora* (Ellis) Hjortstam	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tomentellopsis submollis* (Svrček) Hjortstam	-	Soil, roots	Arctic: Canada/ Alaska, Toolik Lake	-	F,C	eDNA	M	Ec	Timling et al., 2014; Dunleavy and Mack, 2021	-	Rosling et al., 2003
Ascomycota	*Toxicocladosporium irritans* Crous & U. Braun	-	Soil	-	Antarctica: Warren Cave	F	eDNA	M	OHP,E	-	Connel and Staudigel, 2013	Zhang et al., 2011; Bezerra, J.D., Sandoval-Denis et al., 2017
Basidiomycota	*Trametes coccinea* (Fr.) Hai J. Li & S.H. He	*Pycnoporus coccineus* (Fr.) Bondartsev & Singer	Permafrost soil, mummified penguin	-	Antarctica: McMurdo Dry Valleys, S. Victoria Land	C	Cul	Morph	BA,S,PA	-	Baublis et al., 1991; Bridge et al., 2008b	-
Basidiomycota	*Trametes cubensis* (Mont.) Sacc.	-	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PP,PA,S	-	Connel and Staudigel, 2013	https://eol.org/pages/160627
Basidiomycota	*Trametes versicolor* (L.) Lloyd	-	Cryoconite	Arctic: Svalbard	-	F	Cul	M	S,PA,IF,W	Borze cka et al., 2022	-	-
Basidiomycota	*Trametes villosa* (Sw.) Kreisel	-	Ornithogenic soil (penguins)	-	Antarctica: Henry Arctowisky station	I	Cul	M	S,PA,BA	-	Gonçalves et al., 2015	Tomé et al., 2022
Basidiomycota	*Tremella diploschistina* Millanes, M. Westb., Wedin & Diederich	-	Soil	Arctic: Finland	-	I	eDNA	M	S,LA	Poosakkannu et al., 2017	-	-
Basidiomycota	*Tremella fuciformis* Berk.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Basidiomycota	*Tremella indecorata* Sommerf.	-	Soil	-	Antarctica: Antarctic Peninsula	F	eDNA	M	S	-	Arenz and Blanchette, 2011	-
Ascomycota	*Tricellula aquatica* J. Webster	*Tricellula* cf. *aquatica* Webster	Lichens	-	Antarctica: Ilands near the Antarctic Peninsula/ King George Iland	C	Cul	Morph	LA,W	-	Möller and Dreyfuss, 1996	Koske and Duncan, 1974

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Ascomycota	*Trichocladium antarcticum* (Stchigel & Guarro) X. Wei Wang & Houbraken	*Thielavia antarctica* Stchigel & Guarro	Lichens, Bird colonies, lake sediments	-	Antarctica: King George Iland, Antarctic Peninsula	F	Cul	Morph	LA,BA	-	Stchigel et al., 2003; Ogaki et al., 2020a; Nikitin, 2021 (in Russian) = Nikitin, 2023	-
Ascomycota	*Trichocladium asperum* Harz	-	Soil, coal mine spoil	Arctic: Canada/ Alaska, Svalbard	-	F	eDNA,Cul	M	S,PP,PF	Timling et al., 2014; Iluchin et al., 2022a	-	Kirk, 1994
Ascomycota	*Trichocladium griseum* (Traaen) X. Wei Wang & Houbraken	*Humicola grisea* Traaen	Tundra soils, soil with recreational plant community, air, soil	Arctic: White Sea area, WSBS, Apatiti, Polar Urals, Izvestiy TSIK Ilands, Barents Sea, Shoyna, Franz Joseph Land, Taymyr	Antarctica: Deception Iland, South Shetland Ilands	F,D,C	Cul,eDNA	Morph,M	PP,PF	Kirtsideli, 1999 (in Russian); Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2010, 2011, 2014, 2016 (in Russian); Iluchin et al., 2022a; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	Rosa et al., 2020	-
Ascomycota	*Trichoderma asperellum* Samuels, Lieckf. & Nirenberg	-	Lake sediments, soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016, 2018		-
Ascomycota	*Trichoderma atroviride* P. Karst.	*Trichoderma atroviride*	Permafrost sediments, driftwood	Arctic: Siberia	Antarctica: McMurdo Dry Valleys	F,C	Cul	Morph,M	S	Blanchette et al., 2016	Kochkina et al., 2012	-
Ascomycota	*Trichoderma aureoviride* Rifai	-	Tundra soils, cryophylic alpine meadow, coal mine spoil	Arctic: Svalbard, Polar Urals, Magadan	-	C	Cul	Morph	S,PF	Kirtsideli et al., 2010 (in Russian); Iluchin et al., 2022a,b	-	-
Ascomycota	*Trichoderma avellaneum* (Rogerson & S.T. Carey) Jaklitsch & Voglmayr	*Hypocrea avellanea*	Peat	Arctic: Alaska	-	F	eDNA	M	S,PF	Semenova et al., 2015	-	-
Ascomycota	*Trichoderma citrinum* (Pers.) Jaklitsch, W. Gams & Voglmayr	*Trichoderma album* Preuss	Antropogenic substrates, peat	Arctic: Izvestiy TSIK Ilands, Komi	-	F	Cul	Morph	S,PF	Kirtsideli et al., 2014, 2016 (in Russian); Lapteva et al., 2017 (in Russian)	-	-
Ascomycota	*Trichoderma hamatum* (Bonord.) Bainier	-	Lake sediments, soil	Arctic: White Sea area, WSBS	-	C,D	Cul	Morph	S,PF	Bubnova and Velikanov, 2004 (in Russian); Grum-Grzhimaylo et al., 2016	-	-

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Ascomycota	*Trichoderma harzianum* Rifai	-	Permafrost sediments, soil, air, plants, littoral sand, moss, stones with aglae, regoliths, peat, lake sediments	Arctic: White Sea area, WSBS, Barents Sea coast	Antarctica: McMurdo Dry Valleys, Windmill Ilands, East, continental and peninsula Antarctica, Don Juan Pond, Wright Valley, McMurdo Station, Ross Region, Dronning Maud Land, Robertskollen, Macquarie Iland, Larsemann Hills oasis, Russkaya Station	F,C,D	Cul	Morph	S,BA,PF	Bubnova and Velikanov, 2004 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Bubnova and Konovalova, 2018 (in Russian)	Sun et al., 1978; Kerry and Weste, 1985; Ryan et al., 1989; Azmi and Seppelt, 1998; Kochkina et al., 2012, 2019; Marfenina et al., 2016	-
Ascomycota	*Trichoderma koningii* Oudem.	*Hypocrea koningii*	Antropogenic substrates, soil, peat, lake water	Arctic: Svalbard, White Sea area, WSBS, Apatiti, Franz Joseph Land, Taymyr, Alaska	Antarctica: Cabo Primavera, Rothera Point Adelaide Iland	C,D,F	Cul,eDNA	Morph,M	S,PF,W	Bubnova and Velikanov, 2004 (in Russian); Semenova et al., 2015; Zhang et al., 2015b; Kirtsideli et al., 2016 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	Hughes et al., 2007	-
Ascomycota	*Trichoderma koningiopsis* Samuels, Carm. Suárez & H.C. Evans	-	n.i.	Arctic: Svalbard	-	C	Cul	M	S	Iluchin et al., 2022a	-	-
Ascomycota	*Trichoderma lixii* (Pat.) P. Chaverri	*Hypocrea lixii* Pat.	Soil	-	Antarctica: Antarctic Peninsula	F	eDNA	M	S	-	Arenz and Blanchette, 2011	-
Ascomycota	*Trichoderma longibrachiatum* Rifai	*Trichoderma* cf. *longibrachiatum*	Permafrost sediments, soil, lake water	Arctic: Kolyma	Antarctica: continental, Islands near Antarctic Peninsula	F,I	Cul	Morph,M	S,W	Ivanushkina et al., 2005	Gonc alves et al., 2012, 2015; Samuels et al 1998 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-
Ascomycota	*Trichoderma parapiluliferum* (B.S. Lu, Druzhin. & Samuels) Jaklitsch & Voglmayr	-	Soil	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S	Grum-Grzhimaylo et al., 2018	-	-
Ascomycota	*Trichoderma paraviridescens* Jaklitsch, Samuels & Voglmayr	*Hypocrea viridescens*	Conifer wood	Arctic: Finland	-	F	Cul	Morph	S,PA	Kaitera et al., 2019	-	-

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Ascomycota	*Trichoderma piluliferum* J. Webster & Rifai	-	Peat	Arctic: White Sea area, WSBS	-	C	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016	-	-
Ascomycota	*Trichoderma polysporum* (Link) Rifai	-	Mosses, peat, lake sediments, soil, littoral soil, coal mine spoil, lake sediments	Arctic: Canada, Svalbard, White Sea area, WSBS, Barents Sea coast	Antarctica: Antarctic Peninsula	D,C,F	Cul	Morph,M	S,PF	Osono et al., 2012; Bubnova and Konovalova, 2018 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Iluchin et al., 2022a	Ogaki et al., 2020a	-
Ascomycota	*Trichoderma pseudokoningii* Rifai	-	Soil + bird influence	-	Antarctica: Windmill Ilands	C	Cul	Morph	S,PF	-	Azmi and Seppelt, 1998	-
Ascomycota	*Trichoderma psychrophilum* Jaklitsch	*Hypocrea psychrophila* E. Müll., Aebi & J. Webster	Bird colonies	-	Antarctica	n.i.	Cul	n.i.	S	-	Nikitin, 2021 (in Russian) = Nikitin, 2023	-
Ascomycota	*Trichoderma viride* Pers.	*Trichoderma lignorum* (Tode) Harz	Tundra soils, cryophylic alpine meadow, antropogenic substrates, soil, moss, peat, lake sediments, littoral soil, coal mine spoil	Arctic: Polar Urals, White Sea, WSBS, Sonsnovetz Iland, Barents Sea coast, Izvestiy TSIK Ilands, Franz Joseph Land, Taymyr, Komi, Severnaya Zemlya, Magadan, subarctic region	Antarctica: Livingstone Iland, Windmill Ilands, Ellsworth Base, Mac Robertson Land, Vestfold Hills, Mawson	F,C,D	Cul	Morph	S,PF	Latter and Heal, 1971; Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2010, 2011, 2014, 2016 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Lapteva et al., 2017 (in Russian); Bubnova and Konovalova, 2018 (in Russian); Iluchin et al., 2022a,b	Kerry, 1990b; McRae and Seppelt, 1999	-
Basidiomycota	*Tricholoma albobrunneum* (Pers.) P. Kumm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tricholoma bonii* Basso & Candusso	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tricholoma boreosulphurescens* Mort. Chr. & Heilm.-Claus.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tricholoma bryogenum* Mort. Chr., Heilm.-Claus. & Vauras	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-
Basidiomycota	*Tricholoma equestre* (L.) P. Kumm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidio-mycota	*Tricholoma focale* (Fr.) Ricken	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec,PF	Miyamoto et al., 2022	-	Thormann and Rice, 2007
Basidio-mycota	*Tricholoma sapona-ceum* (Fr.) P. Kumm.	-	Soil, roots	Arctic: Svalbard, Russia, Yakutia	-	C	eDNA	M	Ec	Frossard et al., 2021; Miyamoto et al., 2022	-	Cullings and Courty, 2009
Basidio-mycota	*Tricholoma virga-tum* (Fr.) P. Kumm.	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec,PF	Miyamoto et al., 2022	-	Thormann and Rice, 2007
Ascomy-cota	*Trichophyton mentagrophytes* (C.P. Robin) Sabour.	-	Dust	-	Antarctica: Edmonson Point	C	Cul	Morph	K	-	Mercantini et al., 1993	-
Ascomy-cota	*Trichophyton terrestre* Durie & D. Frey	-	Soil	-	Antarctica: Ross Sea region, South Shetland Iland	n.i.	Cul	Morph	K	-	Mercantini et al., 1989; Vishniac, 1996 (cyt. Pugh and Allsopp, 1982)	-
Ascomy-cota	*Trichosporiella cerebriformis* (G.A. de Vries & Kleine-Natrop) W. Gams	-	Tundra soils, cryophylic alpine meadow, soil	Arctic: Polar Urals	Antarctica: Antarctic Peninsula	F	Cul	Morph	S	Kirtsideli et al., 2010 (in Russian)	Kochkina et al., 2019	-
Ascomy-cota	*Trichothecium cro-tocinigenum* (Schol-Schwarz) Summerb., Seifert & Schroers	*Acremonium crotocinigenum* (Schol-Schwarz) W. Gams	Soil + bird influence	-	Antarctica: Windmill Ilands	C	Cul	Morph	MF	-	Azmi and Seppelt, 1998	Pacioni and Leonardi, 2016
Ascomy-cota	*Trichothecium roseum* (Pers.) Link	-	Antropogenic substrates	Arctic: Izvestiy TSIK Ilands	-	n.i.	Cul	Morph	MF,PP	Kirtsideli et al., 2016 (in Russian)	-	Pacioni and Leonardi, 2016; Hamid et al., 2014
Ascomy-cota	*Tricladium angula-tum* Ingold	-	Lichens	Arctic: Svalbard	-	F	eDNA	M	W,LA	Zhang et al., 2015a	-	Canhoto and Graça, 1999
Ascomy-cota	*Tricladium obe-sum* Marvanová	-	Coal mine spoil	Arctic: Magadan	-	C	Cul	M	W	Iluchin et al., 2022b	-	Baschien et al., 2013
Ascomy-cota	*Tricladium splen-dens* Ingold	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	W	Lydolph et al., 2005	-	Field and Webster, 1983
Basidio-mycota	*Tulasnella vio-lea* (Quél.) Bourdot & Galzin	-	Conifer wood	Arctic: Finland	-	C	Cul	M	S,PA	Kaitera et al., 2019	-	-
Ascomy-cota	*Tumularia aquatica* (Ingold) Descals & Marvanová	-	Soil	-	Antarctica: Dronnin Maud Land	F	eDNA	M	W	-	Kochkina et al., 2014	Read et al., 1991
Basidio-mycota	*Tylospora asteropho-ra* (Bonord.) Donk	-	Roots	Arctic: Russia, Yakutia	-	C	eDNA	M	Ec	Miyamoto et al., 2022	-	-

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Basidiomycota	*Typhula variabilis* Riess	-	Soil	Arctic: Canada/ Alaska, Svalbard, Russia, Iceland	-	F	eDNA	M	PP	Timling et al., 2014; Hoshino et al., 2019	-	Ikeda et al., 2017
Ascomycota	*Tyrannosorus hystrioides* (Dugan, R.G. Roberts & Hanlin) Crous, M. Shen & Y. Zhang	*Cladophialophora hachijoensis* (Matsush.) U. Braun & Feiler; *Venturia hystrioides* (Dugan, R.G. Roberts & Hanlin) Crous & U. Braun	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PA	Timling et al., 2014	-	Shen et al., 2020
Mucoromycota	*Umbelopsis angularis* W. Gams & M. Sugiy.	-	Leafs	Arctic: Finland	-	I	eDNA	M	S,PF	Poosakkannu et al., 2017	-	Thormann and Rice, 2007
Mucoromycota	*Umbelopsis dimorpha* Mahoney & W. Gams	-	Soil	Arctic: Svalbard	-	C	eDNA	M	S	Frossard et al., 2021	-	-
Mucoromycota	*Umbelopsis isabellina* (Oudem.) W. Gams	*Mortierella isabellina* Oud.; *Umbelopsis isabelline*	Cryophylic alpine meadow, peat, soil, littoral sand, conifer wood	Arctic: Finland, White Sea area, WSBS, Apatiti, Polar Urals, Izvestiy TSIK Ilands	-	F,C,D	Cul	Morph,M	S,PA,PF	Kirtsideli et al., 2010, 2014 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Kaitera et al., 2019; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	-	-
Mucoromycota	*Umbelopsis longicollis* (Dixon-Stew.) Y.N. Wang, X.Y. Liu & R.Y. Zheng	-	Lake sediments, soil	Arctic: White Sea area, WSBS, Apatiti	-	C,F	Cul	Morph	S,PF	Grum-Grzhimaylo et al., 2016; Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022	-	-
Mucoromycota	*Umbelopsis ramanniana* (Möller) W. Gams	*Mortierella ramanniana* (Möller) Linnem.	Tundra soils, mosses, antropogenic substrates, soil, peat, plants+birds fecas, lake water	Arctic: Svalbard, White Sea area, WSBS, Polar Urals, Izvestiy TSIK Ilands, Novaya Zemlya, Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Melekhov Cape of Alexandra Land, Canada	Antarctica	D,F,C	eDNA,Cul	Morph,M	S,PF,W	Bubnova and Velikanov, 2004 (in Russian); Kirtsideli et al., 2010, 2014 (in Russian); Osono et al., 2012; Zhang et al., 2015b; Grum-Grzhimaylo et al., 2016, 2018; Kirtsideli et al., 2014, 2016; Nikitin et al., 2021; Nikitin and Semenov, 2022	Greenfield, 1981 (cited by the British Antarctic Survey: https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#Use)	-

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Mucoromycota	*Umbelopsis vinacea* (Dixon-Stew.) Arx	-	Tundra soils, cryophylic alpine meadow, peat, soil	Arctic: Svalbard, White Sea area, WSBS, Polar Urals	-	C	Cul	Morph	S,PF	Kirtsideli et al., 2010 (in Russian); Grum-Grzhimaylo et al., 2016, 2018; Iluchin et al., 2022a	-	-
Ascomycota	*Varicosporium delicatum* S.H. Iqbal	-	Driftwood	Arctic: Greenland	-	C	Cul	M	S	Blanchette et al., 2016	-	-
Ascomycota	*Varicosporium elodeae* W. Kegel	-	Plant tissues, cryoconite holes	Arctic: Svalbard	-	F	eDNA	M	PA,E	Edwards et al., 2013; Zhang and Yao, 2015	-	-
Ascomycota	*Venturia atriseda* Rehm	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA,E	Zhang and Yao, 2015	-	-
Ascomycota	*Venturia ditricha* (Fr.) P. Karst.	-	Soil	Arctic: Finland	-	I	eDNA	M	E,PP	Poosakkannu et al., 2017	-	-
Ascomycota	*Venturia minuta* M.E. Barr	-	Plant tissues	Arctic: Svalbard	-	n.i.	eDNA	M	PA,E	Zhang and Yao, 2015	-	-
Ascomycota	*Venturia polygonivivipari* Arx	-	Bird feathers, soil	Arctic: Svalbard, Canada/Alaska	-	F	eDNA,Cul	M,Morph	BA	Timling et al., 2014; Singh et al., 2015	-	-
Ascomycota	*Verrucoconiothyrium nitidae* (Crous & Denman) Crous	*Coniothyrium nitidae* Crous & Denman	Soil	Arctic: Canada/ Alaska	-	F	eDNA	M	PP	Timling et al., 2014	-	Gonçalves et al., 2019
Ascomycota	*Verticillium bjoernoeyanum** Crous & Rämä	-	Sand grains attached to driftwood	Arctic: Svalbard	-	n.i.	Cul	M,Morph	n.i.	Crous et al., 2022	-	-
Ascomycota	*Verticillium coccosporum* (Drechsler) W. Gams	*Spicaria coccospora* Drechsler	Soil	-	Antarctica: Deception Iland, Marguerite Bay, South Georgia, King Edward Cove	C	Cul	Morph	NEP	-	Gray and Smith, 1984	Zhang et al., 1996; Glockling and Shimazu, 1997
Ascomycota	*Verticillium dahliae* Kleb.	-	Littoral soil, soil	Arctic: Barents Sea coast	Antarctica: Warren Cave on Mt. Erebus	F	Cul,eDNA	Morph,M	PP	Bubnova and Konovalova, 2018 (in Russian)	Connel and Staudigel, 2013	Compendium
Ascomycota	*Verticillium insectorum* (Petch) W. Gams	-	Lake water	Arctic: Svalbard	-	F	eDNA	M	W,N	Zhang et al., 2015b	-	Shengyang and Qixin, 1987
Ascomycota	*Volucrispora graminea* Ingold, P.J. McDougall & Dann	*Ypsilina graminea* (Ingold, P.J. McDougall & Dann) Descals, J. Webster & Marvanová	Vascular plants, lichens, moss, soil	Arctic: Canada/ Alaska, Svalbard	Antarctica: Ilands near the Antarctic Peninsula/ King George Iland, South Shetland Ilands, Macquarie Iland, Deception Islands	C,F	eDNA,Cul	Morph,M	PP,PA,S,W,LA	Timling et al., 2014; Frossard et al., 2021	Kerry and Weste, 1985; Möller and Dreyfuss, 1996; Rosa et al., 2020	-

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Ascomycota	*Volutellonectria consors* (Ellis & Everh.) J. Luo, X.M. Zhang & W.Y. Zhuang	*Volutella consors*	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	PP	-	Rosa et al., 2020	
Ascomycota	*Wardomyces anomalus* F.T. Brooks & Hansf.	-	Permafrost anchient sediments	-	Antarctica: McMurdo Dry Valleys	F	Cul	n.i.	S	-	Gilichinsky et al., 2007	Domsh et al., 2007
Ascomycota	*Wardomyces humicola* Hennebert & G.L. Barron	-	Antropogenic substrates	Arctic: Taymyr	-	n.i.	Cul	Morph	S,W	Kirtsideli et al., 2016 (in Russian)		Domsh et al., 2007
Ascomycota	*Wardomyces inflatus* (Marchal) Hennebert	-	Soli	Arctic: Svalbard	Antarctica: King George Iland, South Shetland Ilands	C	Cul	M,Morph	S	Iluchin et al., 2022a	Krishnan et a., 2016	Fracchia et al., 1998
Ascomycota	*Wardomyces ovalis* W. Gams	-	Pleurophyllum hookeri, littoral soil	Arctic: Barents Sea coast	Antarctica: Macquarie Iland	F	Cul	Morph	n.i.	Bubnova and Konovalova, 2018 (in Russian)	https://legacy.bas.ac.uk/bas_research/data/access/fungi/Speciespublic2.html#RIMI	-
Ascomycota	*Westerdykella dispersa* (Clum) Cejp & Milko	-	Permafrost soil	Arctic: Siberia	-	n.i.	eDNA	M	W,OHP	Lydolph et al., 2005	-	Xu et al., 2017; Sue et al., 2014
Ascomycota	*Wilcoxina rehmii* Chin S. Yang & Korf	-	Soil, roots	Arctic: Canada/ Alaska, Siberia	-	F,C	eDNA	M	Ec	Timling et al., 2014; Miyamoto et al., 2022	-	Smith et al., 2005
Ascomycota	*Xenopyrenochaetopsis pratorum* (P.R. Johnst. & Boerema) Valenz.-Lopez, Crous, Stchigel, Guarro & Cano	*Pyrenochaetopsis pratorum* (P.R. Johnst. & Boerema) Gruyter, Aveskamp & Verkley	Bird feathers	Arctic: Svalbard	-	n.i.	Cul	M,Morph	BA,K	Singh et al., 2015	-	-
Ascomycota	*Xerochrysium xerophilum* (Pitt) Pitt	*Chrysosporium xerophilum* Pitt	Permafrost anchient sediments	-	Antarctica: McMurdo Dry Valleys	F	Cul	n.i.	XF	-	Gilichinsky et al., 2007	Pitt et al., 2013
Ascomycota	*Xylaria apiculata* Cooke	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Ascomycota	*Xylaria cubensis* (Mont.) Fr.	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-

Divisions of fungi	Species of fungi (modern names from the Index Fungorum)	Archaic names of species from articles, if different	Soil type(s); Substrate	Location of studies in the North pole	Location of studies in the South pole	Storage of samples	Method(s) of detection	Method(s) of identification	Role(s) and/or ecological associating**	Reference(s) of species detection and ecology in Arctic	Reference(s) of species detection and ecology in Antarctica	Additional reference(s) of species ecological features
Ascomycota	*Xylaria hypoxylon* (L.) Grev. 1824	-	Soil	-	Antarctica: Deception Iland, South Shetland Ilands	F	eDNA	M	S	-	Rosa et al., 2020	-
Basidiomycota	*Xylodon nesporii* (Bres.) Hjortstam & Ryvarden	*Hyphodontia* (cf.) *nesporii* (Bres.) J. Erikss. & Hjortstam	Permafrost soil, wood	Arctic: Siberia	-	F	eDNA	M	PA	Bellemain et al., 2013	-	Luo et al., 2022
Basidiomycota	*Xylodon rimosissimus* (Peck) Hjortstam & Ryvarden	*Hyphodontia rimosissima* (Peck) Gilb.	Soil	-	Antarctica: Warren Cave	F	eDNA	M	PA	-	Connel and Staudigel, 2013	Luo et al., 2022
Ascomycota	*Xylohypha nigrescens* (Pers.) E.W. Mason	-	Permafrost soil	Arctic: Kolyma	-	n.i.	Cul	Morph	OHP	Ozerskaya et al., 2008	-	Masclaux et al., 1995
Ascomycota	*Zymoseptoria passerinii* (Sacc.) Quaedvl. & Crous	-	Leafs, roots	Arctic: Finland	-	I	eDNA	M	PP,PA	Poosakkannu et al., 2017	-	-
	Mycelia sterilia (white; dark; dark with sclerotia)	-	Cryopeg, permafrost and tundra soils, cryophylic alpine meadow, anchient sediments, soil, soil + bird influence, bird dung, feathers, mosses, antropogenic substrates, air, peat, lake sediments, algae	Arctic: White Sea area, WSBS, Apatiti, Novaya Zemlya, Kolyma, Polar Urals, Barents Sea, Kolguyev Iland, Beliy nos, Varandey, Shoyna, Kara Sea, Vaygach Iland, Marre-Sale, Ust'-Kara, Amderma, Kolba, Dikson, Arctic Ocean, Franz Josef Land, Alger Iland, Fersman Iland, Zenith Cape of Heiss Iland, Hooker Iland near the Tikhaya Bay, Melekhov Cape of Alexandra Land, Izvestuy TSIK Ilands, Taymyr, Komi, Severnaya Zemlya, Svalbard, Canada, subarctic region	Antarctica: McMurdo Dry Valleys, Windmill Ilands, Ross sea region, Ilands near the Arctic Peninsula, Marble Point, Northern Victoria Land, Crater Cirque, Campo Icaro, Kay Iland	F,C,D	Cul	Morph,M	S,E,K,LA,PA,PF	Zabawski, 1982; Bergero et al., 1999; Kirtsidely, 1999 (in Russian); Bubnova and Velikanov, 2004 (in Russian); Kurek et al., 2007; Ozerskaya et al., 2008; Stakhov et al., 2008; Kirtsidely et al., 2010, 2011, 2016 (in Russian); Kochkina et al., 2011 (in Russian); Singh et al., 2012; Osono et al., 2012; Grum-Grzhimaylo et al., 2016, 2018; Bubnova, 2017; Lapteva et al., 2017 (in Russian); Bubnova and Konovalova, 2018 (in Russian); Korneykova et al., 2020 (in Russian) = Korneykova et al., 2022; Nikitin et al., 2021; Nikitin and Semenov, 2022	Christie and Nicholson, 1983; Fletcher et al., 1985; Mercantini et al., 1989, 1993; Frate and Caretta, 1990; Kerry, 1990a,b; Möller and Dreyfuss, 1996; Zucconi et al., 1996; Fenice et al., 1997; Azmi and Seppelt, 1998; Tosi et al., 2002; Duncan, 2007; Gilichnsky et al., 2007; Kochkina et al., 2012, 2019; Abneuf et al., 2016	-

https://www.sciencedirect.com/science/article/pii/S1749461324000277#appsec1

Supplem. Table 1E. Abbreviation of ecological features of the fungi from the lists of the Supplem Tables 1A-D.

AA - animal associated fungi, except birds and insects
Al - algae associated fungi
AP - animal pathogenic
BA - birds associated fungi
CF - coprophilous fungi
E - endophytic
Ec - ectomycorrhizal
EcA - ectomycorrhiza associated fungi
EL - endolithic fungi
En - endomycorrhizal
EP - enthomopathogens
Er - ericoid mycorrhizal
FA - fungi associated fungi
HR - heat-resistant fungi
HF - halophilic fungi
HtF - halotolerant fungi
IF - ice and snow fungi
K - keratinolytic/keratinophilic
LA - lichen associated fungi
LF - lichenicolous fungi
MF - mycoparasitic fungi
MsF - mesophilic
N - nematophagous
NEP - endoparasitic nematophagous
NP - predatory nematophagous
OHP - opportunistic human pathogenic
PA - plant associated fungi
PF - peatlands fung
PHAOF - potential human or animal opportunistic fungi
PHOF - potential human opportunistic fungi
PP - plant pathogenic fungi
PS - plant symbionts
PsF - psychrophilic fungi
PtF - psychrotolerant fungi
S - saprotrophic fungi
TF - thermophilic fungi
TtF - thermotolerant fungi
W - whater fungi (fresh and/or marine)
XF - xerophilic fungi

Supplemental Table 4

Fungi from the polar regions pointed as opportunistic or potential opportunistic human and / or animal species.

Name of species	Number of references		Substrate of detection
	Arctic	Antarctica	
Arachnomyces kanei	1	0	Ancient permafrost soil
Aspergillus conicus	2	0	Ice
Aspergillus fischeri	**1**	**2**	Soil, permafrost soil
Aspergillus fumigatus	**6**	**10**	Permafrost soil, guano, soil, moss, animal seals, penguins
Aspergillus hiratsukae	0	1	Permafrost soil
Aspergillus sydowii	**9**	**9**	Permafrost soil, anchient sediments, permafrost sediments, soil, glacier sand, Ice core, air, stones with algae, cryoconite
Aspergillus terreus	**1**	**2**	Soil, coal mine spoil
Byssochlamys spectabilis	0	2	Rocks, soil
Chaetomium globosum	**8**	**4**	Permafrost and tundra soils, cryophylic alpine meadow, anchient sediments, lichens, antropogenic substrates, peat, coal mine spoil, cryoconite
Cladophialophora arxii	1	0	Soil
Coniochaeta hoffmannii	**2**	**3**	Moss, pond mud, soil, driftwood, wood, lake sediments
Coniochaeta mutabilis	2	0	Soil, permafrost soil
Cryptendoxyla hypophloia	0	1	Soil
Curvularia lunata	0	2	Soil
Cyphellophora laciniata	0	1	Soil
Cyphellophora pluriseptata	0	1	Soil
Cyphellophora pluriseptata	0	1	Soil
Exophiala castellanii	0	1	Soil
Exophiala dermatitidis	0	1	Soil
Exophiala jeanselmei	1	0	Sandy soil
Exophiala moniliae	1	0	Peat

Exophiala spinifera	0	1	Soil, wood
Exophiala tremulae	**1**	**1**	Soil
Lichtheimia corymbifera	0	1	Contaminated yeast preparation
Marquandomyces marquandii	**1**	**1**	Soil
Microascus cinereus	0	1	Soil
Microsphaeropsis olivacea	**1**	**1**	Soil, coal mine spoil
Montagnula chromolaenicola	0	1	Permafrost soil
Neocucurbitaria keratinophila	0	1	Soil
Neoscytalidium dimidiatum	1	0	Peat
Penicillium chrysogenum	**24**	**22**	Tundra soils, permafrost sediments, soil+bird influence, frozen sediments, ice, air, microbial mat, water, fruit, food, peat, rocks, littoral sand, moss, regoliths, coal mine spoil, snow, lake sediments (with antroponenic influence), lake water, feathers, ice core, algae
Penicillium rubens	0	4	Rocks, soil
Penicillium tardochrysogenum	0	5	Soil, permafrost soil, rocks
Phialemoniopsis curvata	0	1	Penguin feathers
Phialemonium obovatum	1	0	Antropogenic substrates
Phoma hibernica	0	1	Soil, air
Pseudallescheria boydii	0	1	Soil
Purpureocillium lilacinum	**4**	**2**	Permafrost soil, feathers
Rhinocladiella aquaspersa	1	0	Antropogenic substrates
Schizophyllum commune	**1**	**1**	Soil, lake water
Scytalidium lignicola	1	0	Antropogenic substrates
Sporothrix brasiliensis	0	1	Soil
Sporothrix schenckii	0	1	Soil
Talaromyces flavus	0	1	Soil
Toxicocladosporium irritans	0	1	Soil
Westerdykella dispersa	1	0	Permafrost soil
Xylohypha nigrescens	1	0	Permafrost soil

CHAPTER 6

Occurrence of *Psychrophilomyces antarcticus* in the Arctic

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Published in Fungal Ecology, https://doi.org/10.1016/j.funeco.2024.101408

The fungus *Psychrophilomyces antarcticus* M.M. Wang & Xing Z. Liu, previously known only from the Qinghai-Tibet Plateau and Antarctica, was isolated in the Arctic from sediments on the littoral of the Kara Sea (Shokalsky Island) and represented by strains VKM F-5025 / CBS 151455 and VKM F-5026 / CBS 151456[4]. The macro- and micro-morphology of the isolate was studied and partial sequences of the DNA regions ITS, LSU, TEF1, and ß-TUB were determined, as well as the optimal values for temperature, pH and salinity. Slight differences between our two isolates and previously known strains of *P. antarcticus* were found in morphology (colony color and shape, size of phialides and spores) and physiological traits (optimal growth temperature, range of acceptable temperature and pH values for growth, colony odor, and degree of mucosity under extreme conditions). However, the high similarity in the sequenced DNA fragments from 97 to 100 % indicates that these slight morphological and physiological variations of the studied strains of *P. antarcticus* are intraspecific variation. Our study demonstrates that *P. antarcticus* is a cold-adapted poly-extreme tolerant species that occurs and can function in extremely cold areas, such as high alpine, Antarctic, and Arctic regions.

Key words
Psychrophilomyces antarcticus, poly-extreme tolerant fungi, psychrotolerant, acidotolerant, halotolerant, Arctic, Antarctica, Qinghai-Tibet Plateau.

4 VKM F-5025, VKM F-5026 – official strains numbers in the All-Russian Collection of Microorganisms; CBS 151455, CBS 151456 – official strains numbers in the Westerdijk Institute Collection (WI-KNAW Collections) of Microorganisms.

Introduction

Earth has environmentally harsh and extremely cold areas, such as high alpine and polar regions, that are nearly inhabitable for life. High mountain and Polar regions share some comparable climate characteristics, including low temperature, intense ultraviolet radiation, and frequently limited nutrient availability in their substrates (Tsuji and Hoshino, 2019; Selbmann et al., 2021; Zhang et al., 2020). Nevertheless, some organisms manage to inhabit such unfriendly environments. To survive or to even thrive, the organisms in these regions possess adaptations that protect them against the environment's stressful conditions. Examples of adaptations of microorganisms to cold environments include changes in the structure (fluidity) and functions of cellular membranes, unique genome structure, gene expression changes, production of cold-adapted and cold-active enzymes, antifreeze proteins that protect microorganisms from these adverse conditions (Dasila et al., 2022; Yusof et al., 2021). In the review by Yusof et al. (2021), the results of studies on the adaptive mechanisms of the Antarctic yeast fungus *Glaciozyma antarctica* are collected and described in detail. The researchers also highlight the significant potential role of cold-resistant bacteria and fungi in biotechnology and their important role in cold ecosystems (Dasila et al., 2022; Yusof et al., 2021).

Fungi are among the most abundant groups in high alpine and Polar regions due to their adaptive flexibility (Coleine et al., 2022). The adaptability of fungi enables them to perform their functions as decomposers, symbionts, parasites, and predators even in such extreme ecosystems, allowing for their important contribution to carbon, nitrogen, and other nutrient cycles. In recent years, several studies have identified the uniqueness and similarity of fungal communities in geographically distant yet similar regions of the planet (Noffsinger et al., 2020). These investigations are important for understanding the roles of ecological selection and fungal dispersal in shaping fungal communities in such widely separated extreme habitats (Cox et al., 2016). However, despite these investigations no conclusions can be drawn about similarity of fungal alpine and polar regions communities because of limited research and a lack of data (Cox et al., 2016). The situation is further complicated by the fact that permafrost zones are shrinking due to global warming and, as a result, the number of microorganisms adapted to cold conditions is decreasing (Tsuji et al., 2022; Wang et al., 2015). Additionally, data is severely limited on the stress tolerance of fungi found in extreme environments, which hinders understanding of the extent to which these fungi actively function and are involved in global biogeochemical processes, as well as how their activity will change in response to global climate change (Coleine et al., 2022; Harrison et al., 2013; Noffsinger et al., 2020).

Several recent studies show the presence of similar fungal species in the Arctic and Antarctic (Cox et al., 2016; Iliushin, 2020), as well as in high mountain regions and Antarctica

(Wang et al., 2015). However, we have not seen any mention of fungal species found in a high mountain region as well as both polar regions. In 2011, three fungal species belonging to the genus *Psychrophila* were first isolated from samples taken from glaciers in the Qinghai-Tibet Plateau highlands and from Antarctic soil samples (Wang et al., 2015). However, the study used the invalid name *Psychrophila*, but it is validated here with a new generic name *Psychrophilomyces* (see below the section "Taxonomy"). The genus *Psychrophilomyces* was described with the type species *Psychrophilomyces antarcticus*. To date, *P. antarcticus* has only been described in the aforementioned study by Wang et al. (2015) and has not yet been found in any other region. *Psychrophilomyces* species are psychrotolerant[5] characterized as fungi that prefer cold environments and are well adapted to habitats with low temperatures. Wang et al. (2015) provided a comprehensive description of the morphological features of *P. antarcticus*, as well as gene sequences for ITS, LSU, ß-TUB, and TEF1 genes.

In 2015, we discovered two strains that resembled *P. antarcticus* in samples of littoral sediments from the Arctic Shokalsky Island. Through a combination of morphological and molecular analysis, as well as a study of their physiological characteristics, we determined that these Arctic isolates shared similarities with the Tibetian and Antarctic *P. antarcticus* isolates. This marks the first time *P. antarcticus* has been detected in the Arctic, and we provide the details of the identification process in this study. Recognizing the lack of information regarding fungi with the ability to tolerate extreme conditions (Coleine et al., 2022; Harrison et al., 2013), we also examined the growth rate of these strains under different temperatures, salinity levels, and pH values. These factors were selected based on the isolation of the strains from the littoral zone of the Kara Sea, situated in the Arctic region. Our objective was to ascertain the temperature range and optimal growth conditions for the strains, as well as their preferred salinity, considering their origin from sea sediments. Additionally, we conducted tests to evaluate their growth rate under varying pH levels, as this factor is recognized as one of the important limiting factors for fungal development (Ali et al., 2017; Jiang et al., 2022; Sharma et al., 2016).

Material and methods

Study area and sampling

Sediment samples of the littoral zone of the Shokalsky Island coast in the Arctic were collected with permission from the management of the state nature reserve "Gydanskiy". This flat area of the island measures approximately 20 x 30 km and is located in the Kara Sea. It is covered with tundra vegetation, as well as numerous swamps, lakes, and streams

5 Psychrotolerant species – fungi that can grow close to 0°C, with optimum growth temperatures of >15°C and maximum growth temperatures of >20°C (Coleine et al., 2022).

(Kalyakin et al. 2000). The average air temperature in July and August is around +5°C, and the frost-free period does not exceed 70 days. The island is located at the exit of the Ob Bay, and its Western coast is significantly influenced by river discharge, resulting in the transport of large amounts of terrigenous materials and the desalination of marine waters (Galimov et al. 2006; Zatsepin et al. 2010).

In August 2015, 23 sediment samples were collected from the mid-littoral zone at four locations on Shokalsky Island, near the mouths of the streams. Two isolates of *Psychrophilomyces antarcticus* were obtained from one of the seven samples of sandy sediments collected on the middle littoral zone of the island's western coast, north of the mouth of the Pereprava River (72°55′37.5″N 74°17′32.3″E, Fig. 1). Initially, the top 2 mm of soil were removed with a sterile knife, and 2 cm^3 of sediments were collected by a sterile syringe inserting it vertically to the sediment. The material was then placed in a sterile craft paper bag, dried, and stored at 6°C and further cultured on a nutrient medium for 2.5 months.

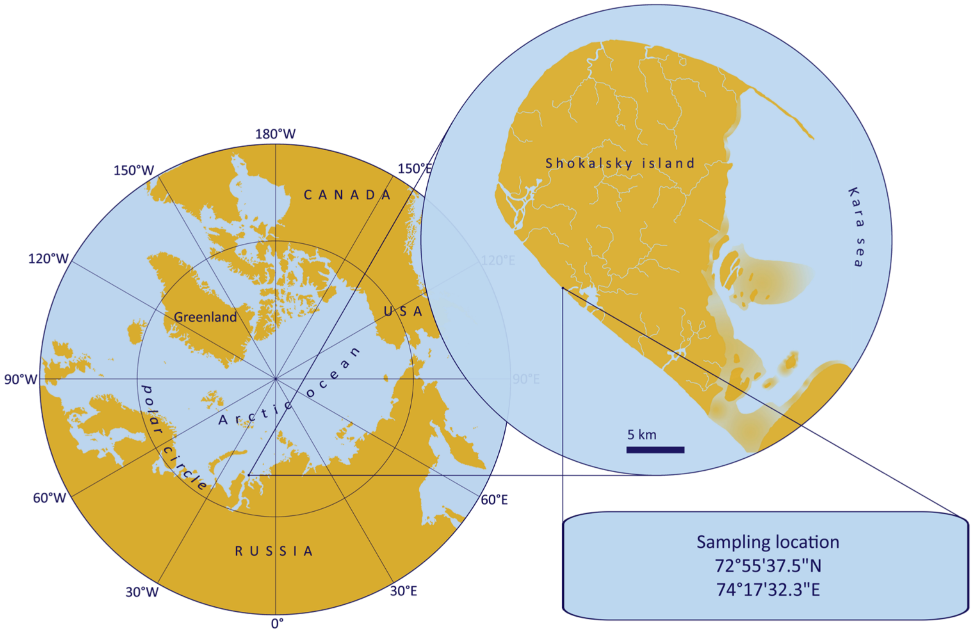

Fig. 1. Sampling point on Shokalsky Island from which two strains of *P. antarcticus* were isolated.

6

Detection of the *Psychrophilomyces antarcticus* strains

Cultivation of samples

For plating, 1 g of the sample was taken and evenly distributed among five Petri dishes containing Malt Extract Agar medium (distilled water, Malt Extract to a total sugar content of 0.2%, aquarium marine salt 35‰ (Red Sea Salt, moderate alkalinity), gentamicin (Microgen) - 160 mg / L, lincomycin (Microgen) - 600 mg / L). The seeded dishes were incubated at +4 °C for two months, after which all grown colonies were isolated into pure cultures for subsequent identification.

Identification of fungi

The sorting and initial identification of fungal isolates were conducted based on morphological and cultural characteristics. Molecular methods were then used to determine the taxonomic affiliation of the cultures, which was difficult to determine based on morphology alone.

Morphological observations

Primary identification of strains, later assigned to the species *P. antarcticus*, was conducted using an Olympus cx 23 microscope after the culture slides were prepared by transferring a portion of the colony from the medium onto a glass slide. For further accurate identification, slide cultures were prepared as follows: a drop of PDA medium was placed on a sterile glass slide, a fungal culture was inoculated onto it, covered with a cover slip, and then placed in a sterile Petri dish. Each fungus was inoculated in eight replicates. Petri dishes with cultures on slides were wrapped with Parafilm and incubated at 10°C for 4 weeks. Subsequently, sporulation was studied and photographed by using Zeiss and Leica microscopes at magnifications of x63 and x100, respectively.

DNA extraction, PCR amplification and sequence analysis

Total genomic DNA (gDNA) was extracted from the mycelium of both strains using the chloroform/isopropanol method (Karakousis et al., 2006; Grum-Grzhimaylo et al., 2016). The primers ITS-1f and ITS-4r (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 and LR7 (Vilgalys and Gonzalez, 1990) were used for amplification of part of the nuclear large large subunit nrDNA gene (LSU); EF1-728F and EF1-986R (Carbone and Kohn, 1999) were used to amplify partial translation elongation factor 1-α gene (TEF1), and Bt-2a and Bt-2b (Glass and Donaldson, 1995) were used to amplify partial β-tubulin gene (β-TUB). PCR mixes (Promega Corp., Madison, Wisconsin) contained 0.5 µL 25 mM $MgCl_2$, 5 µL 5x PCR GoTaq buffer (Promega), 1 µL 10 mM dNTP, 1 µL 10 mM of each primer, 0.1 µL GoTaq G2 polymerase (Promega) and 2 µL gDNA, and filled with MQ-water to 25 µL. The amplification program included an initial step of 94 C for 5 min, then 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 using the PCR clean-up Gel extraction kit (Macherrey-Nagel) following the instruction manual. The purified PCR products were sent for Sanger sequencing to Eurofins Genomics (EU). Sequences were compared with the data from GenBank using BLAST similarity searches.

Phylogentic analysis

In total, we used 13 strains (11 of *Psychrophilomyces*) to reconstruct the phylogeny and confirm identification of our two strains (Supplem. material 1). We used four loci, LSU, ITS, TEF1, β-TUB) for each strain, except *P. lagodekhiensis* CBS122314 (this strain had only LSU and ITS available). Individual gene matrices were aligned with MAFFT (v7.505) with an automatic alignment strategy, and trimmed with Trimal (v.1.5.rev0) with -nogaps flag to generate gapless alignments. PhyKIT (v. 1.20.0) was used to concatenate the four alignments but retaining partition information for each gene. We then used IQ-TREE (v.2.2.0.3) to test the DNA substitution model for each partition and generate a maximum likelihood tree with SH-aLRT and ultrafast bootstrap supports (-m TEST --alrt 1000 -B 1000), with *Tetracladium globosum*_HAILUO215 as outgroup. Aesthetics were added with Adobe Illustrator CC 2018.

Submitting to collections

Both strains were deposited in the All-Russian collection of microorganisms (VKM) and in the Westerdijk Institute Collection (WI-KNAW Collections) of Microorganisms. Newly generated sequences were deposited in GenBank (Table 1).

Table 1. GenBank Accession Numbers of our *P. antarcticus* strains

Strain No		Accession Numbers of the gene's regions			
VKM	WI-KNAW	ITS	LSU	TEF1	β-TUB
VKM F-5025	CBS 151455	PP390063	PP390068	PP935172	PP722763
VKM F-5026	CBS 151456	PP390064	PP390069	PP935173	PP722764

Exploring *Psychrophilomyces antarcticus* tolerance to extreme environmental factors

Growth at different temperature

Both fungal strains were inoculated by transferring a 1x1 mm piece into the beginning of a race tube or the center of a Petri dish with PDA medium, with 3 – 6 repetitions for different temperature values (Supplem. material 2A), and incubated for 35 days at the following temperature values: -2.0, -0.5, 0, +5, +10, +15, +16.5, +18, +20, +22.5, +25 °C.

Specimens were incubated in standard incubators within a temperature range of +5 to +25 °C. To guarantee a controlled temperature of 0 °C, we used a floating basket inside a styrofoam box containing ice. Placing the box in a +4 °C room allowed the ice to last for two weeks. To develop subzero incubator boxes, we prepared a sodium chloride (NaCl) solution to produce ice and water, based on desired temperatures (Supplem. 1B). This approach aimed to target the freezing point, density, specific heat, and dynamic viscosity of the sodium chloride and water coolant mixture (source: https://www.engineeringtoolbox.com/sodium-chloride-water-d_1187.html). The incubator boxes containing ice and water were similarly prepared to the zero incubator and maintained at a temperature of +4 °C. To maintain the appropriate temperature in the hand made incubators, we replaced the ice every two days.

Growth at different salinity and temperature

Both fungal strains were inoculated by transferring a 1x1 mm piece into the center of Petri dishes containing MEA medium (15 g malt extract [Millipore (Canada)], 15 g agar per liter of distilled water) with 0 %, 1.2 % and 3.4 % of NaCl, six repetitions for each salinity. Three replicates of each strain on different salinity media were incubated at 6, 15, 18 and 20 °C for 35 days.

Growth at different pH

To conduct a growth experiment at different pH values, media based on phosphate buffer were prepared as follows (per 1 L): 0.2 M buffer – 500 mL, malt extract – 15 g, agar – 15 g, distilled water – 500 mL. Stock solutions were prepared for buffer preparation (Supplem. material 2C), which were then combined in different proportions to obtain a buffer with the desired pH value (Supplem. material 2D). Both fungal strains were inoculated by transferring a 1x1 mm piece onto the center of Petri dishes containing media with four repetitions for each pH values, and incubated for 35 days.

Colony measurement and processing the results

The radius of each colony was measured in two directions from the inoculum, and their average length was calculated. Then, the average values of colony diameters or radii of all replicates were calculated and graphs with standard deviation were created in Excel.

Results

Phylogenetic and morphological observation

As part of our study of the littoral sediments in Shokalsky Island, we isolated strains VKM F-5025 / CBS 151455 (further designated by No 1) and VKM F-5026 / CBS 151456 (further designated by No 2). BLAST analysis of the partial ITS, LSU, TEF1 and β-TUB genes sequences showed high similarity between our two isolates, as well as between our isolates and all known *Psychrophilomyces antarcticus* strains (Supplem. material 3). Phylogenetic analysis resolves all four species of *Psychrophilomyces* and places our two strains firmly (86.6/81 SH-aLRT/ultrafast bootstrap support) within the *P. antarcticus* species clade (Fig. 2).

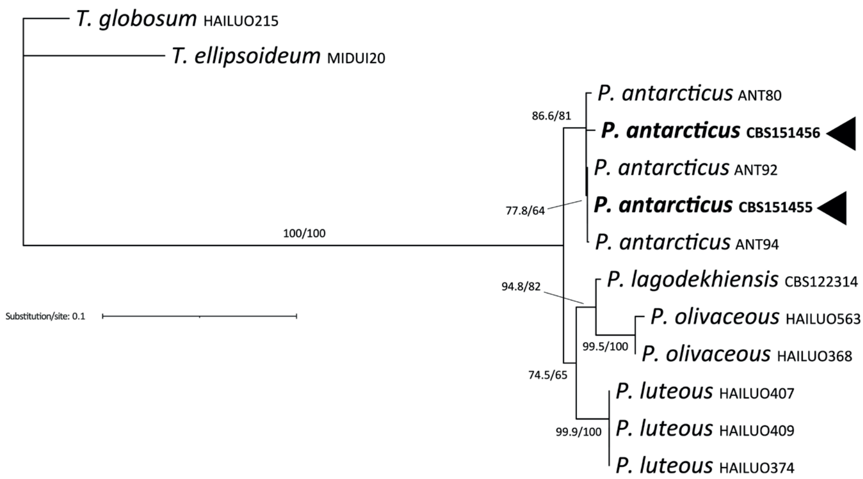

Fig. 2. Phylogenetic placement of *P. antarcticus* based on combined LSU+ITS+TEF1+BTUB dataset. Maximum likelihood phylogeny was reconstructed using IQ-TREE with automatic best substitution model selection for each partition. SH-aLRT and ultrafast bootstrap supports are indicated at corresponding nodes.

Morphological description of strain 1.

Colonies on PDA at 10 °C attained 14 mm diam after 5 wk, OGT 20 °C, eurypsychrophile; colonies rose-cream white, aerial mycelium were less abundant or sparse on the surface of the colony (Fig. 3). The reverse is white. Conidiophores were sometimes short, or much differentiated, conidiogenesis phialidic, phialides short, hyaline, flask-shaped, single or in groups, 5.1–8.0 × 2.5–4.5 µm, apically tapering into a broad funnel, bottleneck-like constriction; the collarette was 2.1–4 µm, wedge-shaped, widely flaring; vegetative hyphae hyaline, sometimes agglomerate to bundles or swollen to irregular shapes, 2-4 µm. Conidia were in the heads, hyaline, 1-celled, smooth, mostly globose, 2.0–2.2 µm diam.

Morphological description of strain 2.

Colonies on PDA at 10 °C attained 14 mm diam after 5 wk, OGT 22.5 °C, eurypsychrophile; colonies were creamish, aerial mycelium was practically absent; if present, it was in the form of a small tuft in the center of the colony (Fig. 4). The reverse is yellowish only in the center while closer to the edges it is lighter. Conidiophores were sometimes short, or much differentiated, conidiogenesis phialidic, phialides short, hyaline, flask-shaped, mostly single, 5.1–8.0 × 2.5–4.5 µm, apically tapering into a broad funnel, bottleneck-like constriction; the collarette was 2.1–4 µm, wedge-shaped, widely flaring; vegetative hyphae hyaline was sometimes agglomerate to bundles or swollen to irregular shapes, 2 – 4 µm. Conidia in the heads, 1-celled, smooth, mostly globose, 2.0–2.2 µm diam.

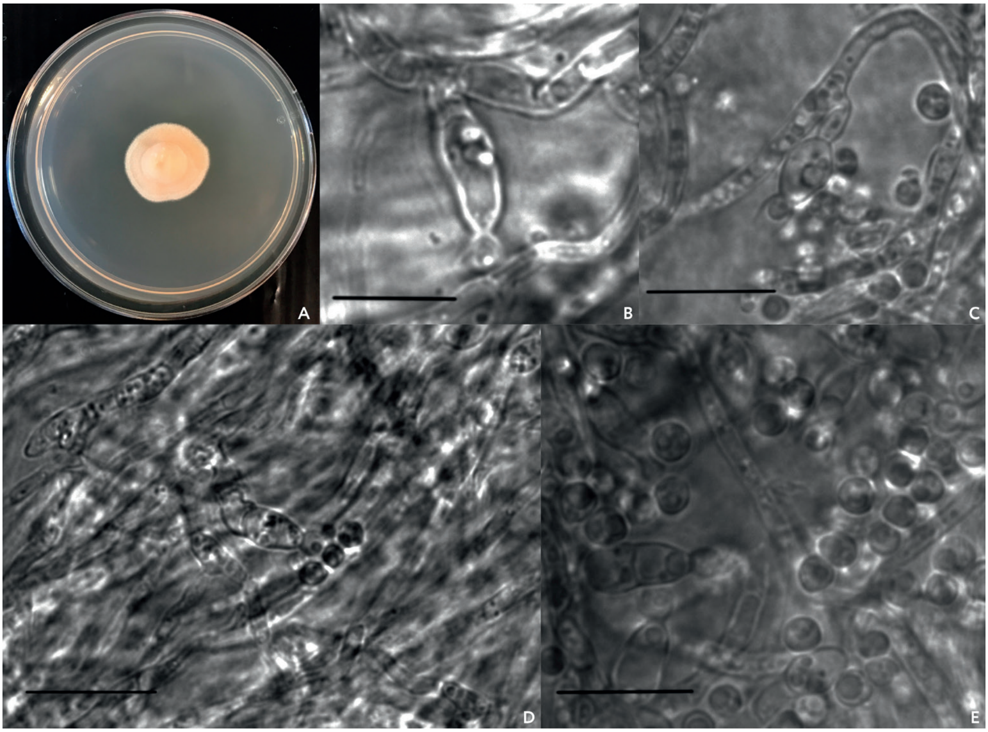

Fig. 3. *Psychrophilomyces antarcticus* (from strain 1) A. Colony morphology at 10 °C after 35 days; B – E. mycelium, conidiophores, conidiogenous cells and conidia. — Scale bars = 10 µm.

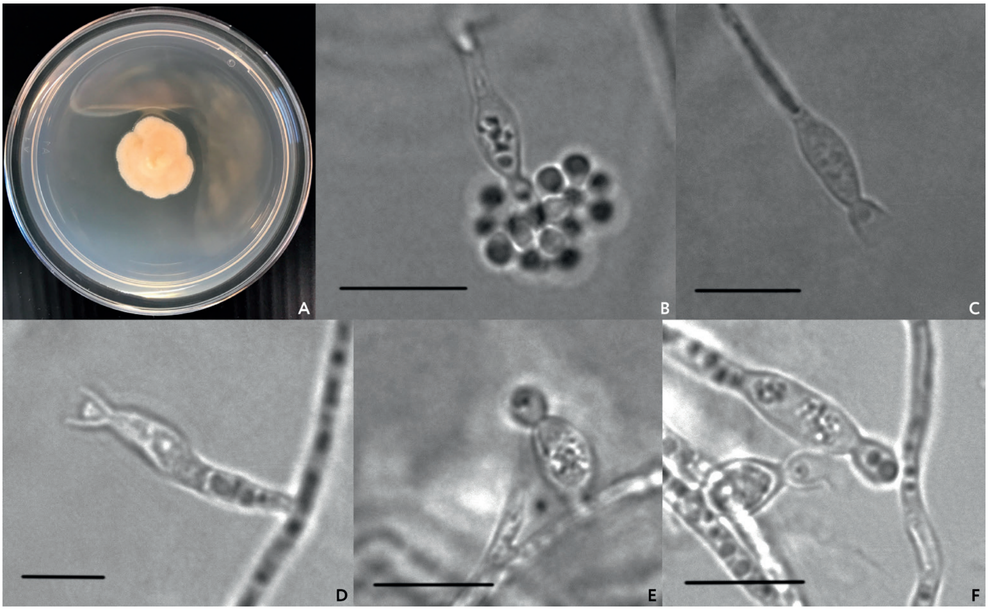

Fig. 4. *Psychrophilomyces antarcticus* (from strain 2) A. Colony morphology at 10 °C after 35 days; B – E. mycelium, conidiophores, conidiogenous cells and conidia. — Scale bars = 10 μm.

Growth at different temperature

As a result of measuring the linear growth rate of strains 1 and 2 at different temperatures (from -2.5 to 25 °C), optimal growth temperatures (OGT) were identified: 20 °C for strain 1 and 22.5 °C for strain 2 (Fig. 5; Supplem. material 4). Both strains showed the ability to grow at subzero temperatures; at 25 °C, strain 1 practically stopped growing, and strain 2 grew slowly.

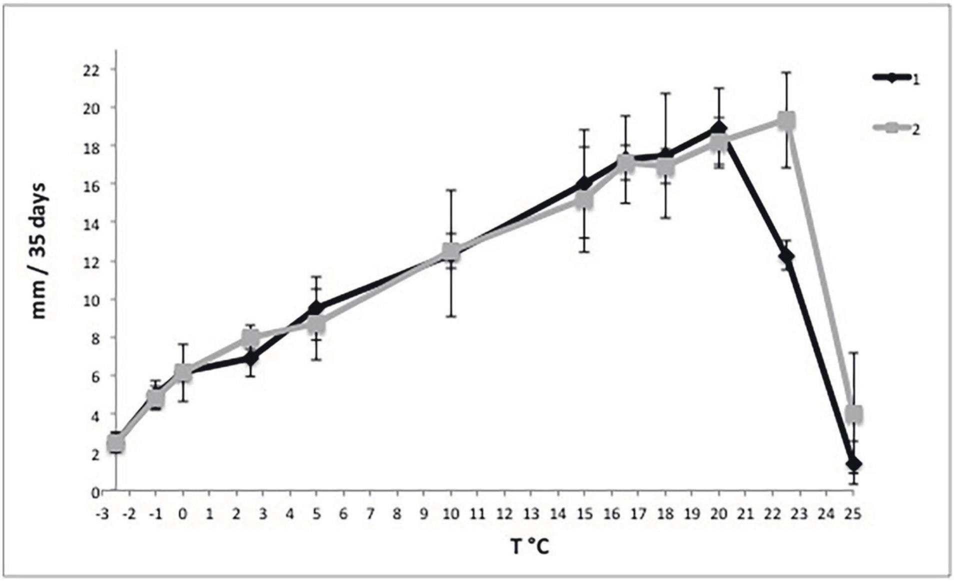

Fig. 5. Linear growth rate of strains 1 and 2 at different temperatures (diameter in mm/35 days).

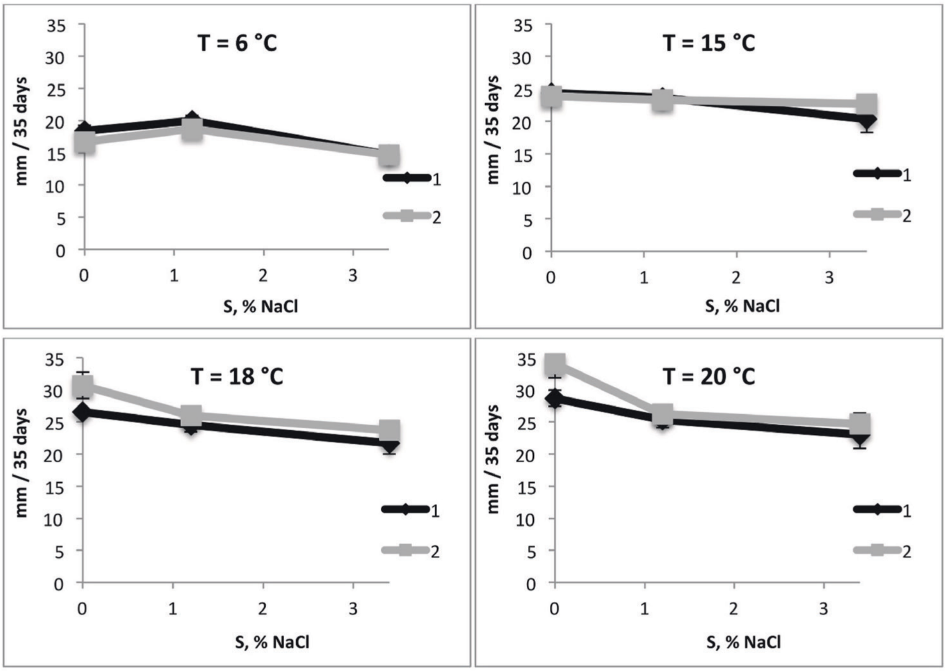

Fig. 6. Linear growth rate of strains 1 and 2 at different temperatures and salinities (diametr); T – temperature, S – salinity.

Growth at different temperature

The linear growth rate of strains 1 and 2 slightly decreased with increasing salinity from 0 to 3.4% NaCl at temperatures of 15, 18, and 20°C. At a temperature of 6°C, the maximum growth rates of both strains were observed at a salinity of 1.2% NaCl (Fig. 6; Supplem. material 5). It was also noted that at temperatures of 15, 18, and 20°C and in the absence of NaCl in the medium, colonies grew dry, whereas with increasing salinity, colonies became slimy, aerial mycelium disappeared, and more hyphae agglomerated to bundles were detected upon microscopic examination. Sporulation was present at all salinity levels at temperatures of 15, 18, and 20°C. At a temperature of 6°C, colonies were slimy at all salinity levels, with abundant aerial hyphae, and sporulation was nearly absent. It was also observed that in the presence of NaCl in the medium, colonies remained small longer during the first 10-14 days, but by day 35, when measurements were taken, they nearly caught up in growth rate to colonies growing at zero salinity.

Growth at different pH

The study of the linear growth rate of strains 1 and 2 at pH values of 5, 6, 7, 8, and 9 revealed a deceleration of growth rate from pH 5 to 7 and complete cessation of growth at pH 8 for strain 1. Strain 2 exhibited a similar trend, but retained the ability to grow even at high pH values (Fig. 7). Colonies of the strains became more compact, more submerged in the substrate, lost aerial mycelium, and exhibited changes in color as pH increased (Supplem. material 6).

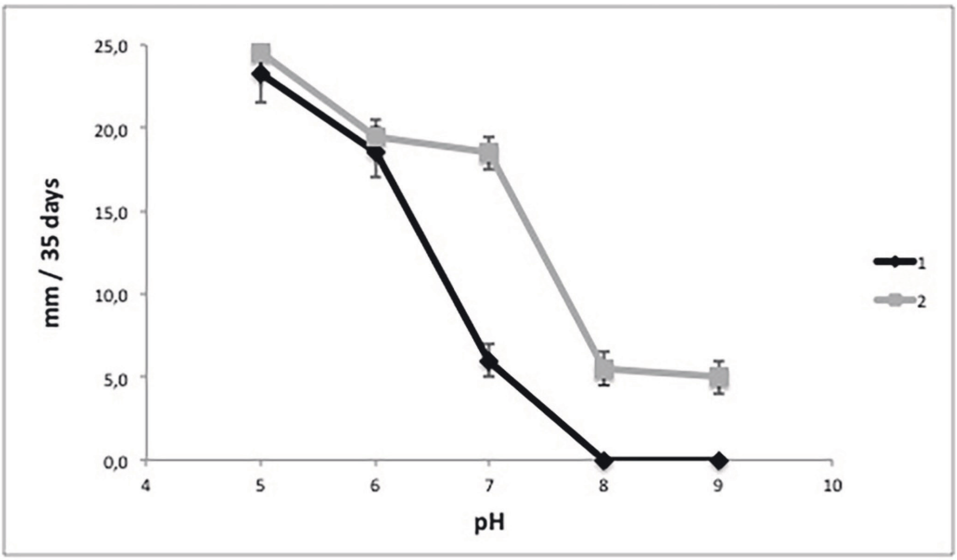

Fig. 7. Linear growth rate of strains 1 and 2 at different pH values (diameter).

Taxonomy

Psychrophilomyces O.A. Grum-Grzhim. *nom. nov.* Mycobank MB 856658
Replaced synonym: *Psychrophila* M.M. Wang & Xing Z. Liu, Persoonia 34: 105. 2014.
Non *Psychrophila* (DC.) Bercht. & J.Presl, Prir. Rostlin Aneb. Rostl. 1: 79. 1823.
Description and illustration: Wang et al. (2015)
Type species: *Psychrophilomyces antarcticus* (=*Psychrophila antarctica* M.M. Wang & Xing Z. Liu)

Psychrophilomyces antarcticus (M.M. Wang & Xing Z. Liu) O.A. Grum-Grzhim. *comb. nov.* Mycobank MB 856660
Basionym: *Psychrophila antarctica* M.M. Wang & Xing Z. Liu, Persoonia 34: 106. 2014.
Type: Antarctic, Great Wall Station, S62°12′ W58°57′, from soil, Jan. 2011, T. Zhang (dried culture HMAS244374 holotype, living culture ex-type CGMCC315133 (ANT92)).

Psychrophilomyces lagodekhiensis (Unter., Réblová & Bills) O.A. Grum-Grzhim. *comb. nov.* Mycobank MB 856661
Basionym: *Psychrophila lagodekhiensis* Unter., Réblová & Bills, Mycologia 111: 1020. 2019.
Type: Georgia, Lagodekhi, from the rhizosphere of *Hedera helix* at 645 m, 4 Feb 2007, G.F. Bills (dried culture on MLA UAMH 12042 holotype, living culture ex-type CBS 122314).

Psychrophilomyces luteous (M.M. Wang & Xing Z. Liu) O.A. Grum-Grzhim. *comb. nov.* Mycobank MB 856663
Basionym: *Psychrophila lutea* M.M. Wang & Xing Z. Liu, Persoonia 34: 106. 2014.
Type: China, Sichuan, Hailuogou Glacier, N29°33′ E101°58′, from soil, 20 Apr. 2011, M. Wang (dried culture HMAS244372 holotype, living culture ex-type CGMCC315134 = HAILUO409).

Psychrophilomyces olivaceous (M.M. Wang & Xing Z. Liu) O.A. Grum-Grzhim. *comb. nov.* Mycobank MB 856664
Basionym: *Psychrophila olivacea* M.M. Wang & Xing Z. Liu, Persoonia 34: 107. 2014.
Type: China, Sichuan, Hailuogou Glacier, N29°33′ E101°58′, from soil, 20 Apr. 2011, M. Wang (dried culture HMAS244375 holotype, living culture ex-type CGMCC315135 = HAILUO368).

Discussion

Interest in studying and comparing fungal communities in extremely cold habitats, such as high altitude and polar regions, is constantly increasing for several reasons. Firstly, the mycobiota of these territories is understudied due to their inaccessibility (Bridge and

Spooner, 2012). Some studies show that fungi can play an important ecological role in cold regions as decomposers, symbionts, and parasites (Barbosa et al., 2017; da Silva et al., 2022; Makhalanyane et al., 2016; Robicheau et al., 2019; Tsuji and Hoshino 2019; etc.). However, due to the limited amount of mycological research, it is difficult to assess the contribution of fungi in high altitude and polar regions to global biospheric processes (da Silva et al., 2019). Secondly, cold-adapted fungi may have unique biochemical and physiological characteristics and may be applied in biotechnology, for instance, as cold-active enzymes, materials for new drugs, biosurfactants, as well as in molecular biology, food industry, beverage production, detergents, etc. (Tsuji et al., 2022; Sarsan et al., 2024). Therefore, the importance of cold-adapted fungi for both the biosphere and human use are evident. Another reason for the increasing interest in these fungi is related to the discovery of identical species known only in such remote places as high altitude and polar regions of the Earth, which is interesting from the perspective of the evolution, adaptation, distribution, and dispersal of these fungi (Wang et al., 2015; Cox et al., 2016). And finally, with global warming, the activity of cold-adapted and mesophilic fungi is changing, affecting the intensity of greenhouse gas emissions and other global processes (Dunleavy and Mack, 2021; Semenova et al., 2015; Wild et al., 2014). Therefore, studying the diversity of fungi in extremely cold habitats is important for a better understanding of the effect of global warming, which appears to lead to a reduction in fungal species diversity and loss of psychrophilic species, as shown in a recent study by Tsuji et al. (2022).

Mycoflora composition of Walker Glacier in the Canadian High Arctic was studied recently by Tsiju et al. (2022). They demonstrated the presence of unique ice-dependent mycobiota on this glacier, with strains that were unable to compete or survive in the glacial environment because of warming. The accelerating retreat of Arctic glaciers due to global warming is leading to habitat loss and may ultimately result in the extinction of these cold-adapted fungi. In other areas along the margins of the Little Ice Age in Canada and Greenland, the most high-latitude coastal region of the Arctic, there is recent evidence of complete loss of certain types of ecosystems and widespread ice depletion (Vincent and Mueller, 2019). Thus, psychrophilic fungal taxa of high-mountain and polar regions are gradually losing their habitat, underscoring the importance of local biodiversity research. Conservation efforts should include genomic research and cryopreservation of samples of Arctic ecological microbiomes, as well as the further isolation of fungal strains from these habitats for cultivation and analysis (Tsuji et al., 2022).

Cold-adapted enzymes have many unique characteristics due to their thermolabile nature and high activity at very low temperatures. Psychrophilic enzymes exhibit higher and faster activity than mesophilic or thermophilic enzymes, even at low enzyme concentrations under optimal conditions, making them more efficient and cost-effective (Sarsan et al. 2024). All of these reasons emphasize the importance of preserving and studying cold-adapted fungal species.

In 2015, Wang et al. described the genus *Psychrophilomyces* (Helotiales) containing three psychrotolerant species: *P. antarcticus* (the type species), *P. luteous*, and *P. olivaceous* while studying fungi from the Qinghai-Tibet Plateau. *P. antarcticus* was also found by these researchers in soil samples from Antarctica. Since these authors provided a detailed morphological description of the fungal species they discovered, sequences of four gene loci (ITS, LSU, β-TUB, and TEF1), and results of incubation at temperatures of 4, 10, and 20 °C, we were able to compare our Arctic strains with their data based on these parameters.

The high similarity at four gene loci, morphology, and optimal growth temperature of our Arctic fungal cultures with Antarctic and Tibetan cultures of *P. antarcticus* warrant them to be classified as this species. Since we could not find mentions of *P. antarcticus* in other regions, we provisionally consider this species to be known only in Tibet, Antarctica, and the Arctic. In terms of temperature, this fungus belongs to psychrotolerant species, so it is most active in cool conditions (10-23 °C), functions slowly at low temperatures (-2.5-5 °C), and quickly loses the ability to grow at temperatures above 25 °C. According to our growth study results at different salinity levels, *P. antarcticus* belongs to halotolerant[6] species and can grow in salty ecosystems up to at least 3.4% (w/v) NaCl. It is interesting that many well-known halotolerant species of fungi, originally discovered in saltworks, have later been found in Arctic glacier ice and other polar environments. This can be explained by the low water activity as a common critical parameter in both environments, and therefore the xerophilic nature of these species. For example, in polar glaciers, abundant marine and other halotolerant yeasts capable of growth at salinities of 5% and 10% NaCl in combination with temperatures of 4, 10, and 24°C have been found (Butinar et al., 2007). Examples of halotolerant mycelial fungi may include cosmopolitan species of the genus *Cladosporium*. For instance, *Cladosporium halotolerance*, initially isolated from hypersaline habitats, has subsequently been repeatedly found in Antarctica (Zalar et al., 2007; Gunde-Cimerman and Zalar, 2014; Grum-Grzhimaylo et al., 2024). This species can tolerate salinities up to 20% NaCl, but thrives in non-saline environments as well (Zalar et al., 2007). More examples of halotolerant fungi, known in both hypersaline and cold habitats, can be found in publications by Coleine et al. (2022), Gunde-Cimerman and Zatar (2014). We have not tested the maximum salinity that *P. antarcticus* can tolerate, but it would be interesting to conduct such a study in the future. The observed sliming of colonies during an increase in salinity, as well as at temperatures close to zero, may represent an adaptation of this fungus to extreme conditions. With respect to pH, our

6 Halotolerant fungi can grow in salt environments (1.2–2.9% NaCl) such as coastal dunes and saline deserts but that can still grow without salt (Coleine et al., 2022).

cultures are considered acidotolerant[7]. Thus, *P. antarcticus* can be classified as a polyextremotolerant[8] species at least in relation to three factors - low temperature, high salinity, and high acidity.

The obtained data partially correlate with the conditions characteristic of the ecotope from which our cultures were isolated: a cold region and a salinity of approximately 1.2% NaCl. The results of testing our cultures at different pH values correlate with the results of our experiment on other fungi from the Shokalsky Island, most of which achieve maximum growth rates at pH 5 (unpublished data). We cannot correlate with the pH of the sampling areas from which our fungi were isolated, as we do not have data on their pH. However, Shokalsky Island is predominantly covered with oligotrophic tundra lakes, with a pH ranging from 5.2 to 6.8 (https://gdanskiynp.ru/?page_id=4153). Additionally, this island is located near the mouth of the Ob River into the Kara Sea, which significantly freshens the seawater and potentially lowers its pH. These facts suggest that the sediments pH at the sampling site was likely reduced.

The two arctic strains show similarities of of 99% (a difference of 2 nucleotides) for ITS and LSU, 100% for β-TUB, and 98% for TEF1 (a difference of 6 nucleotides; Supplem. material 3B), while both cultures are 98-100% similar to *P. antarcticus* strains from Genbank (Supplem. material 3A). In terms of morphology, cultures 1 and 2 differ slightly in colony color, texture, and odor. No significant differences in sporulation were found. In terms of physiology, there are differences in the optimal temperature value and the ability to grow at high pH values (Fig. 4, 6). The phenotypic differences we described may be adaptive traits of these strains to environmental variation within the normal range of response.

It is difficult to explain how a particular species ended up in such geographically distant places from each other. Cox et al., 2016, who compared the mycoflora of Antarctica and the Arctic, suggest that microorganisms with well-developed dispersal abilities can inhabit the opposite poles of the Earth and then thrive there as a result of environmental selection. However, the organization of phialospores in slimy heads in *P. antarcticus* do not suggest effective dispersal, for example, through the wind. It is possible for fungi to be transported from one pole to another on floating materials or aquatic animals, but this dispersal mode is not possible to the high-altitude Qinghai-Tibet Plateau. Fungal spores may also be spread on the bodies of migratory birds. Such a mode of dispersion between the Qinghai-Tibet Plateau and both polar regions is hypothetically possible if there are bird species that make such migrations. Our results are consistent with Baas-Becking's statement (1934) on microbial biogeography "everything is everywhere, but the environ-

7 Acidotolerant fungi can live in acidic habitats but also able to grow under neutral or even alkaline pH (Coleine et al., 2022).

8 Polyextremotolerant species thrive under multiple extreme conditions (Coleine et al., 2022).

ment selects". However, there has been debate over the correctness of this statement for many years (Cox et al., 2016). Thus, the question of the origin or dispersal of fungi known only in different poles of the Earth and high mountain regions remains unresolved.

Summarizing our research, *Psychrophilomyces antarcticus* a polyextremotolerant species, is found in high alpine, Antarctic, and Arctic regions. Arctic strains have been deposited in two established microbial collections; thus, they can be considered preserved for further research.

Acknowledgements and Funding

The author team thanks the management of the reserve for allowing us to conduct our research; Sofia Bondarenko for collecting samples; Eric Bastiaans for creating thermostats that maintain temperatures of 0, -1, and -2.5 degrees Celsius; Francisca Reyes Marquez for assistance with sequencing; José van de Belt for assistance with microscopy; Marcelo Sandoval for help with taxonomic descriptions. This work was supported by the Wageningen University, Plant Sciences Group, Laboratory of Genetics; the Government basic research program of Moscow State University, grant number 121032500077-8; the Russian Foundation for Basic Research, project 20-04-00882a.

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6

Supplemental materials: Table 1, 3A, 3B

Here is just a part of the Supplemental materials. All the rest are available at this link: https://www.sciencedirect.com/science/article/pii/S1754504824000795#appsec1

Table 1. GenBank accession numbers of gene sequences for phylogenetic analysis.

	CBS number	other collections	LSU	ITS	TEF1	ß-TUB	
P_antarcticus_CBS151455	CBS151455	VKM F-5025	**PP390068**	**PP390063**	**PP935172**	**PP722763**	
P_antarcticus_CBS151456	CBS151456	VKM F-5026	**PP390069**	**PP390064**	**PP935173**	**PP722764**	
P_antarcticus_ANT80		ANT80	**KF768459**	**JX001628**	**KF768425**	**KF768438**	
P_antarcticus_ANT92		ANT92	**KF768452**	**JX001640**	**KF768424**	**KF768437**	
P_antarcticus_ANT94		ANT94	**KF768458**	**JX001639**	**KF768423**	**KF768436**	
P_luteous_HAILUO374		HAILUO374	**KF768456**	**JX001638**	**KF768421**	**KF768441**	
P_luteous_HAILUO407		HAILUO407	**KF768455**	**JX001615**	**KF768422**	**KF768439**	
P_luteous_HAILUO409		HAILUO409	**KF768454**	**JX001637**	**KF768420**	**KF768440**	
P_olivaceous_HAILUO368		HAILUO368	**KF768457**	**JX001618**	**KF768427**	**KF768443**	
P_olivaceous_HAILUO563		HAILUO563	**KF768453**	**JX001633**	**KF768426**	**KF768442**	
P_lagodekhiensis_CBS122314	CBS122314		**MK185695**	**MK185681**	**x**	**x**	
T_ellipsoideum_MIDUI20		MIDUI20	**KF768465**	**JX029111**	**KF768431**	**KF768444**	**outgroup**
T_globosum_HAILUO215		HAILUO215	**KF768460**	**JX029109**	**KF768433**	**KF768448**	**outgroup**

Supplemental material 3A. The similarity of Arctic strains 1 and 2 with *Psychrophilomyces antarcticus* by four genes.

	Similarity with *P. antarcticus*				***P. antarcticus***
Genes	**Strain 1**		**Strain 2**		**GenBank**
ITS	**100%**	467/467	99%	466/467	**JX001640**
	99%	437/438	99%	436/437	**JX001628**
	99%	462/464	99%	461/464	**JX001639**
	99%	428/429	**100%**	428/428	**JX001627**
LSU	**100%**	625/625	99%	779/781	**KF768459**
	100%	625/625	99%	779/781	**KF768458**
	100%	625/625	99%	779/781	**KF768452**
TEF1	**100%**	255/255	98%	249/255	**KF768423**
	100%	252/252	98%	246/252	**KF768424**
	99%	251/254	98%	249/254	**KF768425**
β-TUB	**100%**	352/352	**100%**	352/352	**KF768436**
	100%	352/352	**100%**	352/352	**KF768437**
	99%	348/352	99%	348/352	**KF768438**

Supplemental material 3B. Similarity between Arctic strains 1 and 2.

Genes	% of similarity	No of nucleotides
ITS	99%	475/477
LSU	99%	617/619
TEF1	98%	249/255
β-TUB	100%	360/360

CHAPTER 7

General Discussion

Fungi are among the best adapted organisms to live in extreme conditions, in which they, as one of the few groups of organisms, are able to perform their ecological roles as decomposers, mutualistic symbionts, and parasites (Coleine et al., 2022). Fungi exhibit both interspecies and intraspecies phenotypic plasticity, which enables them to adapt to a wide range of conditions (Alster et al., 2021). Interest in studying extremotolerant and extremophilic fungi continues to grow. For example, research on marine fungi, soda lakes, and salty lakes is actively evolving (Bubnova, 2010; Bubnova et al., 2018; Grum-Grzhimaylo et al., 2016; Guo et al., 2023; Mwirichia, 2022). Mechanisms of adaptation to high pH values of the fungus *Sodiomyces alkalinus* isolated from soda lakes have been demonstrated (Grum-Grzhimaylo et al., 2018). Black Antarctic fungi are actively studied for their adaptability to polyextremophilic cosmic conditions (Coleine et al., 2018; Selbmann et al., 2005). In this work, I have expanded our understanding of the diversity of fungi inhabiting peat bogs and polar regions. The former are characterized by extremely low pH and temperature, lack of oxygen, oligotrophy, and high humidity, while the latter are characterized by permafrost, often lack of nutrients and a short or even lack of vegetation period. In addition, a significant part of the Arctic is covered with permafrost peatlands, that is, it combines the conditions of both permafrost and peatlands. A comparison of fungal communities in the polar regions is interesting because these regions are the most distant from each other, but share the extremely cold conditions. At the same time, a significant part of the Arctic permafrost is transformed into swamps during the thawing process. Therefore, knowledge of the similarities between permafrost and boreal peat fungal communities is useful for predicting how global warming will change these communities and influence biogeochemical cycles.

Starting my research with fungi from peat bogs, I gradually expanded it to include polar regions because in the face of climate change, interconnected transformations between permafrost and peatland ecosystems can be observed. For example, rapid thawing of permafrost and warming of extensive areas are occurring under the influence of global warming. In Arctic regions rich in peat bogs, including permafrost, this leads to the peatification and heating of new areas. This activates both fungal spores preserved in the permafrost and those constantly supplied by the wind, birds, other animals and people. In peat bogs located south of permafrost, gradual drying and warming are occurring due to global warming (Robinson et al., 2023). This also leads to the activation of preserved fungal spores in peat and changes in the species composition of the most active fungi in peat bogs. These changes, in turn, affect the rate of decomposition of plant residues, the rate of peat accumulation, and the release of stored carbon. These processes influence global carbon and nitrogen biogeochemical cycles, the changes of which due to global warming are still poorly understood. Knowledge of the fungal biodiversity in permafrost and experimental studies of their ecological role are necessary for predicting changes in biogeochemical cycles due to climate change.

In addition to global warming, the expansion of peatlands is also caused by the isolation of water bodies from seas, which occurs in many Arctic regions due to postglacial land uplift. These lakes separated from the seas gradually become freshened and peatified, upon which characteristic microbial communities of peatlands are formed in them (Grum-Grzhimaylo et al., 2018). The further development of these lakes and their microbial communities under the influence of global warming will apparently lead to the formation of peatlands and corresponding microbial communities in them. In this chapter, I summarize the data obtained during my study of the diversity of mycelial fungi from northern peat bogs, isolated freshwater bodies peatifying from seas, and polar regions. I also compare the data obtained on fungal communities from different geographical regions and establish a relationship between habitat conditions and fungal species composition.

Biogeochemical Cycles

In order to grow, reproduce, and maintain their structural and functional integrity, living organisms select a limited number of chemical compounds from the environment to build organic biomolecules, forming the basic units of the cell. As cells die, they release their organic components back into the environment in the form of simple minerals, primarily due to the activity of microorganisms. Thus, every biological element undergoes a continuous cycle, known as "biogeochemical cycle", in which it alternately transitions from a mineral, non-living state to a living substance.

The cycling of matter is accompanied by a unidirectional flow of energy, as opposed to elements, energy cannot be regenerated. There is a continuous input of energy from solar radiation used in photosynthesis by photo-autotrophic organisms, but the amount of chemical substances available on Earth is replenished only by meteorites and micrometeorites. Therefore, the recycling of chemical elements is necessary to sustain life on Earth. Among the 92 naturally occurring elements, only about 30, considered biogenic, are crucial for living organisms. The four most common elements are oxygen, carbon, hydrogen, and nitrogen, which make up about 97-99% of the mass of most cells. Other elements (iron, sulfur, phosphorus, manganese, magnesium, calcium, copper, zinc, molybdenum, etc.) make up only a very small part of living matter, yet they are essential for life. Key stages of biogeochemical cycles include: 1) the formation of primary organic production from inorganic substances by autotrophic producer organisms; 2) the transfer of primary production through food chains, accompanied by the release of carbon dioxide and the production of organic waste or minerals; 3) the conversion of organic matter into a mineral form by aerobes (aerobic respiration) and anaerobes (fermentation and anaerobic respiration) upon the death of organisms; 4) the processing of elements from all trophic levels of food chains by reducers (heterotrophic microorganisms) with subsequent returns of released mineral elements into cycles (Bertrand et al. 2015).

Knowledge of the biodegradation of organic compounds requires understanding both their synthesis and pathways of decomposition. All living organisms participate in biogeochemical cycles, but microorganisms (bacteria, archaea, protozoans and fungi) play a key role in the functioning and evolution of biogeochemical cycles, due to their high abundance, vast metabolic capabilities, and adaptive potential. Therefore, they play a crucial role in the change and resilience of ecosystems.

For three billion years, all stages of biogeochemical cycles were carried out only by microorganisms. Currently, they participate in virtually all stages of cycles and are the only organisms capable of performing some of these stages (sulfate reduction, denitrification, nitrogen fixation, methane production and consumption). In their absence, all elements necessary for life would remain trapped in organic molecules of corpses and waste. Sustaining the life of plants, animals, and humans depends entirely on the activity of microbes (Bertrand et al. 2015).

Fungi are involved in the cycling of many substances (Bindschedler et al., 2016). Traditionally, fungi have been considered key players in the global biogeochemical carbon cycle due to their ability to process organic materials through saprotrophic or parasitic lifestyles. This activity typically leads to the release of CO_2 and major nutrients such as N, P, and S. However, fungi also interact with metals and other inorganic minerals and therefore participate in the biogeochemical cycling of compounds such as Fe, Ca, K, P, Mg, and so on (Bindschedler et al., 2016). Here I present only a few examples. For instance, fungi are involved in the iron cycle, as they are capable of consuming insoluble iron-containing compounds and thereby acquire an important cofactor for oxidoreductive enzymes (Nyilasi et al., 2005). Some fungi can also sequester iron in their cells, preventing its toxic effects (Howard, 1999). Fungi can absorb sulfur from both organic and inorganic sources, thus participating in the cycling of this element, which is present in amino acids cysteine and methionine (Paietta, 2004; Traynor et al., 2019). As a result of biomineralization, also carried out by fungi, calcite ($CaCO_3$) is formed, making fungi participants in the cycles of both calcium and carbon (Bindschedler et al., 2016). Mycorrhizal fungi play a crucial role in absorbing and transporting compounds containing phosphorus and nitrogen to plants (Bücking and Kafle, 2015; Madrid-Delgado et al., 2021).

Although fungi are involved in the cycling of many substances, this chapter mainly discusses the role of fungi in the carbon and nitrogen cycles, as these cycles are highly sensitive to global warming. Climate change directly affects the release of carbon-containing and nitrogen-containing substances preserved in peat and permafrost. This, in turn, influences the release of greenhouse gases into the atmosphere.

Peculiarities of the carbon and nitrogen cycles in boreal peatlands

Peatlands accumulate carbon and nitrogen and generate atmospheric greenhouse gases (Fig. 1). Multiple groups of organisms are involved in these processes, the activity of which is influenced by numerous factors (Robinson et al., 2023).

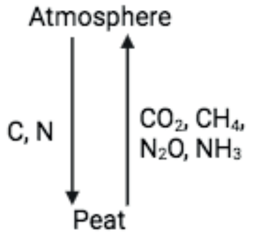

Fig. 1. Accumulation of carbon and nitrogen and generation of atmospheric greenhouse gases in peatlands.

Peatlands are estimated to have absorbed 539 Gt of carbon (C) from the atmosphere (Robinson et al., 2023). According to various estimates, in peatlands, approximately 15% of the carbon dioxide fixed in the process of photosynthesis is returned to the atmosphere through the respiration of organisms (Vasander and Kettunen, 2006). The remaining carbon is transformed into plant structures and deposited as dead plant residues (peat). The carbon entering the peatland partially exits in dissolved form. Losses of dissolved carbon from peatlands may increase due to climate warming, and increased carbon losses from peat are also influenced by more frequent wildfires. In the oxygenated surface layers of the peat, the litter initially decomposes predominantly by aerobic fungi and bacteria, leading to the release of CO_2, but over time the litter becomes gradually covered by rising water levels. In the waterlogged anaerobic part of the peat, decomposition occurs slowly mainly due to bacteria and archaea, and a large portion of the total mineralized carbon is released into the atmosphere as CH_4. The rates of exchange of CO_2 and CH_4 between peatlands and the atmosphere are highly variable. Despite peatlands generally acting as carbon sinks, they simultaneously represent the most important source of CH_4 globally. It is estimated that high-latitude northern peatlands, the majority of which are in the boreal zone, contribute 34–60% of global CH_4 emissions from wetlands. Because CH_4 is more potent in accelerating global warming than CO_2, they may have a significant impact on climate change (Vasander and Kettunen, 2006; Robinson et al., 2023).

The nitrogen cycle in peatlands strongly depends on the type of peatland receiving mineral substances (Limpens et al., 2006). In addition to the type of peatland, disturbances of the peat deposit by humans significantly affect the nitrogen cycle. Here, I will focus on undisturbed oligotrophic peatlands, as this type predominates in northern latitudes (Grum-Grzhimaylo et al., 2016). In such peatlands, the main external source of N, providing 13–80% of plant nutrient needs, is atmospheric nitrogen deposits, which enter in the form of nitrogen oxides, ammonia, and organic components (e.g. plant pollen). The presence of nitrogen compounds in the atmosphere is closely related to human activities such as fuel combustion and agriculture, thus varying depending on the distance of the peatlands from populated areas, as well as the strength and direction of the wind (Limpens et al., 2006).

The rate of nitrogen fixation correlates with the presence of moisture in peat, temperature, redox potential, pH, and mineral concentration in peat. In peatlands, atmospheric N_2 is fixed into organic compounds by cyanobacteria, symbiotic actinomycetes, and free-living bacteria. Their community is more limited in oligotrophic peatlands due to high acidity. Additionally, the metabolism of nitrogen fixers depends on the degree of moisture and the presence of symbiotic plants for nitrogen-fixing microorganisms. The highest rates of nitrogen fixation are recorded in rich lowland peats at lower latitudes compared to surface peat of subarctic bogs. Nitrogen also enters peatlands with water inflow. This nitrogen is mainly organic, peaking during snowmelt and increasing with the relative size of the catchment area.

Nitrogen losses in undisturbed peatlands mainly occur through water runoff and denitrification by microorganisms in anaerobic conditions; NH_3 volatilization is considered a minor component. However, in oligotrophic acidic peats, the presence of NO_3^- is usually very low. In these peatlands, NO_3^- may enter through nitrification NH_4^+, atmospheric deposition, or nitrogen fixation. Nitrification occurs slowly in oligotrophic peatlands due to unfavorable anaerobic, acidic, and cold conditions. Additionally, other microorganisms, *Sphagnum* and other mosses, and vascular plants can absorb NO_3^- from deposition or nitrification before it reaches anaerobic zones or microsites where denitrification occurs. As a result, denitrification in oligotrophic bogs is generally considered quantitatively insignificant.

The main reservoir of nitrogen in peatlands is in dead organic matter; a small portion is retained in living organisms. Other major reservoirs in order of magnitude include vascular plants, live moss layer, microbes, and pore water. In addition to nitrogen deposition, it has been shown that other factors such as groundwater level, metabolic activity, and species of dominating *Sphagnum* moss influence nitrogen retention in oligotrophic bogs.

Decomposition and mineralization are key processes in the nutrient cycling in terrestrial ecosystems. In oligotrophic peatlands, the accumulation of organic matter containing carbon and nitrogen is controlled by slow decomposition rates rather than high productivity. The decomposition rate of litter in peatlands is influenced by environmental conditions such as pH, redox potential, temperature, and the chemical composition of the litter itself, with decomposition primarily limited by the biologically active upper layer of peat, approximately 30-40 cm thick. Most of the nitrogen is stored in the *Sphagnum* litter, which receives nitrogen from atmospheric deposition, nitrogen fixation, and pore water.

The rate of organic matter degradation in soil is determined by both the microbial community and environmental conditions (e.g., temperature, pH, soil moisture content, etc.), which regulate the biogeochemical activity of microorganisms (Rousk and Bengtson, 2014). Aeration and hydrothermal conditions are key factors in determining microbial abundance. Nitrogen availability limits the ability of plants and microorganisms to respond to changing environmental conditions. However, increased decomposition of organic matter can release amino acids as organic nitrogen sources stored in the protein material of peat-forming plants and microbial communities, which can also impact the nitrogen cycle (Pastukhov et al., 2022). It is important to study the composition of the microbial community, their metabolic state, and enzyme activity for the degradation of organic substrates, as well as the plant-microbial feedback to regulate decomposition and organic matter formation. Understanding how microbial processes respond to higher temperatures and other environmental variables influenced by climate change is crucial (Robinson et al., 2023; Rousk and Bengtson, 2014).

Fungi are an important part of the microbial community in peatlands, influencing the intensity of the described processes (Fig. 2). It is known that fungi are important participants in nutrient cycles and can alter the rate of carbon accumulation in peatlands (Song et al., 2020). The results of recent experimental studies have shown that increasing temperature, permafrost thaw, and nitrogen addition contribute to CO_2 and N_2O emissions (Gao et al., 2022; Song et al., 2022). Fungal abundance positively correlates with soil CO_2 and N_2O emissions, suggesting that fungal communities may play a significant role in carbon and nitrogen exchange in permafrost peatlands (Song et al., 2022). Moreover, the flows of carbon and nitrogen are affected by the ratio of saprotrophic and mycorrhizal fungi, which, in turn, depends on the species composition of plants, which is drastically changing under the influence of global warming (Robinson et al., 2023). Additionally, the rate of CO_2 release is positively correlated with the abundance of fungi, bacteria, nitrogen-fixing bacteria, and denitrifying bacteria in the *Sphagnum* litter layer (Gao et al., 2022). Jiang et al. (2020) demonstrated that the intensity and total volume of CO_2 and CH_4 emissions at 15 °C at all soil depths were higher than those observed at 5 °C. Thus, increased temperature increases carbon emissions from peatlands in permafrost regions, and modeled CO_2 emissions are linked to the abundance of microorganisms involved in the carbon cycle (Jiang et al., 2020).

Pastukhov et al. (2022) showed the presence of microorganisms in each layer throughout the thickness of northern permafrost peat bogs. They also showed that the availability of amino acids for microorganisms will depend on climate change, which can impact changes in carbon and nitrogen cycles in peatlands during permafrost degradation (Pastukhov et al., 2022). Fungi dominate and are more active in the upper aerated layers of peatlands, where they initiate the decomposition of complex organic matter, while bacteria dominate in the lower anaerobic layers. Based on a six-year experiment studying the enzymatic activity of microorganisms in a permafrost peat bog, Song et al. (2021) note that fungal numbers in these ecosystems greatly increase under warming conditions. As fungi decompose a large part of lignin, further warming is likely to accelerate the indirect breakdown of lignin-related compounds by fungi, leading to increased carbon losses mediated by microbes (Song et al., 2023, 2021).

Based on data from the scientific literature, I have developed a diagram outlining the main processes resulting from global warming that impact the intensity of greenhouse gas emissions in northern regions (Fig. 2). The idea behind this diagram was inspired by a scheme presented by Allison et al. (2011) illustrating the feedback of climate change on microbial decomposition in boreal soils. I reorganized and expanded this scheme based on information about processes occurring in peatlands due to climate change from other studies (Robinson et al., 2023; Wieder et al., 2006). Besides microorganisms and plants, animals undoubtedly also influence material flows, but considering them is outside the scope of my thesis.

Based on this scheme, which is highly simplified compared to reality (Fig. 2), climate change directly and indirectly affects many processes occurring in peatlands, organism communities, and their metabolism, ultimately influencing greenhouse gas emissions rates. These processes are interdependent and provoke a feedback reaction. Global warming increases the frequency of fires, thawing of permafrost, and dries out peat, which in turn increases the risk of fires. These processes alter the area of peatlands, species composition and functioning of plant and microbial communities.

Due to global warming, the groundwater level of peat bogs is decreasing. Wiedermann et al. (2017) showed that the lowered groundwater level reduces the activity of certain enzymes and increases the decomposition of cellulose and *Sphagnum*. Based on the results of a laboratory experiment conducted with intact peat monoliths, they concluded that the groundwater level plays a dominant role in decomposition processes in peatlands (Wiedermann et al., 2017).

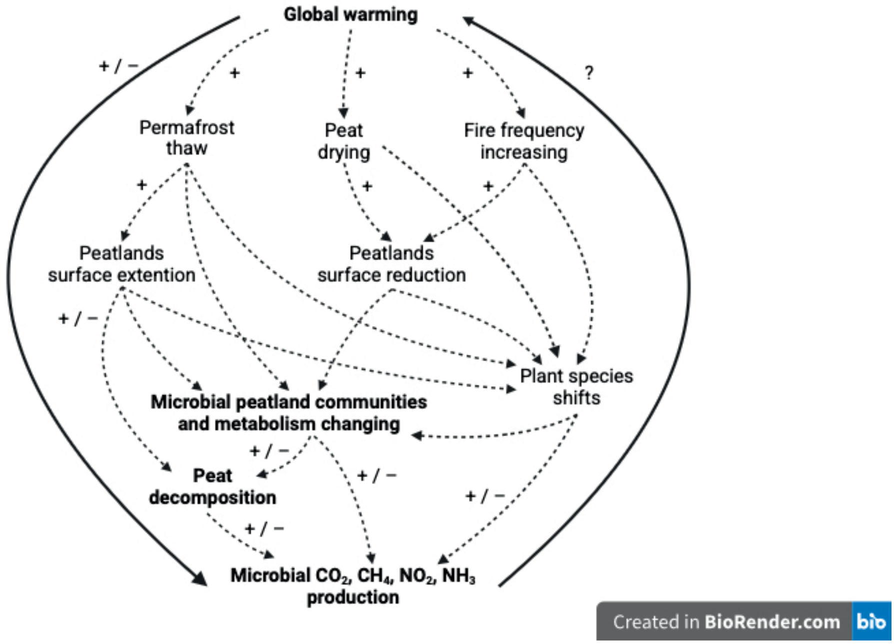

Fig. 2. How climate change affects the microbial production of greenhouse gases through the interaction of physical (e.g. peat thawing and drying, and wildfires) and biological (e.g. plant species, and microbial communities) interactions and feedback loops [Inspired by Allison et al. (2011)]. Stages in which fungi participate are indicated in bold: **microbial peatland communities** contain fungi, the species composition and metabolism of which are influenced by plant communities, temperature and the degree of moisture; fungi are key peat decomposers, therefore, changes in the activity of fungi will affect the processes of peat formation and **peat decomposition**; **microbial (including fungal) greenhouse gases (CO_2, CH_4, NO_2, NH_3) production** will change as a result of warming, as well as peatland surface, plant and microbial species, peat decomposition changing and will influence global warming.

+ – strengthening influence, – weakening influence, +/ – – strengthens and weakens, ? – direction of influence is unknown.

Changes in plant species can lead to changes in the fungal species they are associated with, as many plant species have symbiotic, parasitic, or antagonistic relationships with fungi. For instance, plants from the *Ericaceae* family found in peatlands can impact decomposers through the ericoid mycorrhizal fungi in their roots. Shrubs, which typically benefit from decreased groundwater levels, may further suppress saprothrophic fungi with peatland drying, affecting decomposition processes (Wiedermann et al., 2017).

Permafrost contains a large pool of microorganisms, including fungi (Pastukhov et al., 2022), some of which are in an inactive state and become active with increasing temperatures (Jiang et al., 2020; Gao et al., 2022). For example, it has been shown that long-term warming facilitates sustained carbon loss in permafrost due to fungi, as they effectively decompose high molecular weight compounds, and the intensity of their metabolism and functioning increases with warming (Song et al., 2023). The expansion of peatland areas due to permafrost thawing, as well as their shrinkage due to drying, also affect fungal species composition and the intensity of their metabolism (Song et al., 2020; 2021; 2023; Gao et al., 2022; Fig. 2). As fungi together with bacteria are key participants in peat formation, the listed changes result in a shift in the balance between peat accumulation and decomposition rates, which affects the volume of greenhouse gas emissions (Song et al., 2020; Jiang et al., 2020; Gao et al., 2022). Greenhouse gas emissions, in turn, impact the rate of global warming (Fig. 2).

A precise assessment of the contribution of these processes to global substance fluxes is currently lacking. Yet, based on what is currently known from the literature and the results of my thesis, I mapped the complexity of how global warming may both enhance and reduce the emissions of greenhouse gases produced by microorganisms in Figure 2. The ultimate outcome of the interplay between physical, meteorological, and biological processes depends on the ratio between the amount of thawing of permafrost peat deposits and the drying and burning of peatlands in more southern boreal regions. The expansion of peatlands due to permafrost thawing may both increase and decrease the rate of peat decomposition. This is because, on the one hand, the increase in temperature of peat and its drying will enhance the metabolism of many species of microorganisms, while on the other hand, increasing flooding of peatlands during permafrost thaw will simultaneously reduce the metabolism of many microorganisms, especially fungi. This, in turn, will have an ambiguous effect on the amount of greenhouse gases emitted by peatland microorganisms. Another ambiguity in these processes arises from the change in plant communities in peatlands as a result of permafrost thaw, as well as drying and burning of peat. As previously noted, plants are connected to fungi and other microorganisms through ecological relationships, and a change in plant species will lead to a change in the species composition of microorganisms, which will affect the intensity of greenhouse gas emissions. However, it is unknown whether this effect will be accelerating or decelerating.

When it comes to fungi in peatlands of southern and northern regions, there is a significant difference in fungal species composition (**Chapter 4**). This indicates a high likelihood that with climate change, mycobiota will also change, and therefore, fungal metabolic activity, rates of peat decomposition, and greenhouse gas emissions will change. However, again, the direction of these changes is unknown. Furthermore, when it comes to fungi and the analysis of experimental studies simulating warming, their response to temperature increase is often contradictory, or even absent (Robinson et al., 2023, Appendix A1). The response of the fungal community to groundwater lowering and drying is also ambiguous. In some cases, the biomass, abundance, and species diversity of fungi increased, while in others it decreased (Robinson et al., 2023, Appendix A2). Nevertheless, many researchers are actively working on understanding the entire cascade of events initiated by global warming (Robinson et al., 2023). Additionally, it is important to note that most studies to date have focused on northern peatlands, while microbial communities in tropical peatlands and their changes due to global warming remain largely unknown. Considering their large carbon stocks, the scale of land use changes, and the potential for rehabilitation/restoration, they may contribute significantly to changes in global substance flows (Robinson et al., 2023). Thus, the complex impact of global warming will depend on the relative strength of each described effect.

Fungal communities in peatlands and their ability to decompose *Sphagnum* mosses

At first, I was interested in studying the formation of fungal communities in peat bogs. *Sphagnum* mosses contain complex decomposable substances in their tissues and, being peat-forming plants, are known as particularly resistant to decomposition by microorganisms (Grum-Grzhimaylo et al., unpublished data). Fungi take an active part in the decomposition of *Sphagnum* mosses due to the presence of enzymes in some species that can destroy *Sphagnum* tissue (Fig. 3). Moreover, in the process of this decomposition, succession of fungal species occurs, starting from species that decompose the most complex substances, then moving on to decomposers of less complex substances. (Thormann, 2006; Grum-Grzhimaylo et al., unpublished data, see supplement).

To investigate the diversity of fungi in these habitats, samples of *Sphagnum* mosses and peat from different depths of peat deposits in seven oligotrophic bogs located in northern and temperate latitudes of Russia were collected. Samples of bottom mud from the watersheds of the studied bogs were also taken from northern peatlands. During laboratory work, these samples were inoculated on standard and selective nutrient media. The use of selective nutrient media allowed for the identification of slowly growing oligotrophic, acid-tolerant, acidophilic, and alkali-tolerant fungal species. A working collection of pure cultures of fungal mycelia was created from the isolated fungal cultures for further identification and experimental study. Some obtained cultures were deposited in public collections of microorganisms for further research. The results of studying the fungal community in the peatlands are descriptive in nature and involve qualitative comparisons, as the main goal was to identify fungal species rather than to assess their abundance.

Chapters 2 and 3 describe the communities of cultivated mycelial fungi from four arctic peat bogs located on the coast of the White Sea. These bogs were formed because of post-glacial land uplift, which resulted in small water bodies being separated from the sea, becoming freshened, peatified, and transformed into oligotrophic peat bogs (Pantyulin et al., 2011). The studied bogs vary greatly in age, ranging from bogs that separated from the White Sea several thousand years ago to a lake that is currently in the process of separating from the sea and becoming peatified. In all studied peatlands, anamorphic species of ascomycetes, mostly saprotrophic, predominate. However, significant differences are observed at the lower level of taxonomic categories. For example, the species composition of fungi in the semi-freshened water body separating from the White Sea significantly differs from the fungal complex of long-established bogs (Grum-Grzhimaylo et al., 2018). Moreover, due to their marine origin, even in long-established bogs, species characteristic of marine ecosystems were found among the typical species of peat bogs. The presence of psychrophilic and psychrotolerant fungal species in the studied peatlands demonstrates the influence of cold conditions in the Arctic region on the formation of fungal communities. The detection of entomopathogenic fungal species may be due to bogs being typical habitats for many insects to inhabit and reproduce. Additionally, species of fungi known as typical inhabitants of peatlands and decomposers of *Sphagnum* mosses were identified.

In my thesis, I also showed that peat represents a system in which selective conditions are created for the growth and functioning of a limited group of fungi. Lake bottom sediment systems are more dynamic compared to peat due to differences in organic input and susceptibility to external physico-chemical and hydrological influences. Unlike peat, marine deposits and marine species are present in sediments of the lakes.

Based on our results, in **Chapter 4**, I present a comparison of the mycobiota of northern long-established peatlands and peatlands located in the temperate zone. It should be noted that comparing results from two regions was difficult to accurately conduct due to differences in methodological approaches. Samples from northern peatlands were processed immediately after collection, while samples from temperate zone peatlands were frozen before analysis. In addition, northern peatlands were studied over four seasons, while temperate zone peat bogs were studied for only one season. Despite this, some patterns became apparent. A low species similarity was found between fungal communities in northern and temperate peatlands (1/5 common species). Most shared species in peatlands from different regions are typical inhabitants of *Sphagnum* bogs and decomposers of *Sphagnum* mosses. Psychrotolerant fungal species were predominant in northern peatlands, while thermotolerant species were more common in temperate peatlands. Many insect-associated species were also found in northern peatlands, but these are also known to be psychrotolerant. My results suggest that for fungi to thrive in peatlands, they should be able to decompose tissue of *Sphagnum* mosses. The community composition of fungi in peatland then seems to be further determined by factors such as acidity, temperature and aeration.

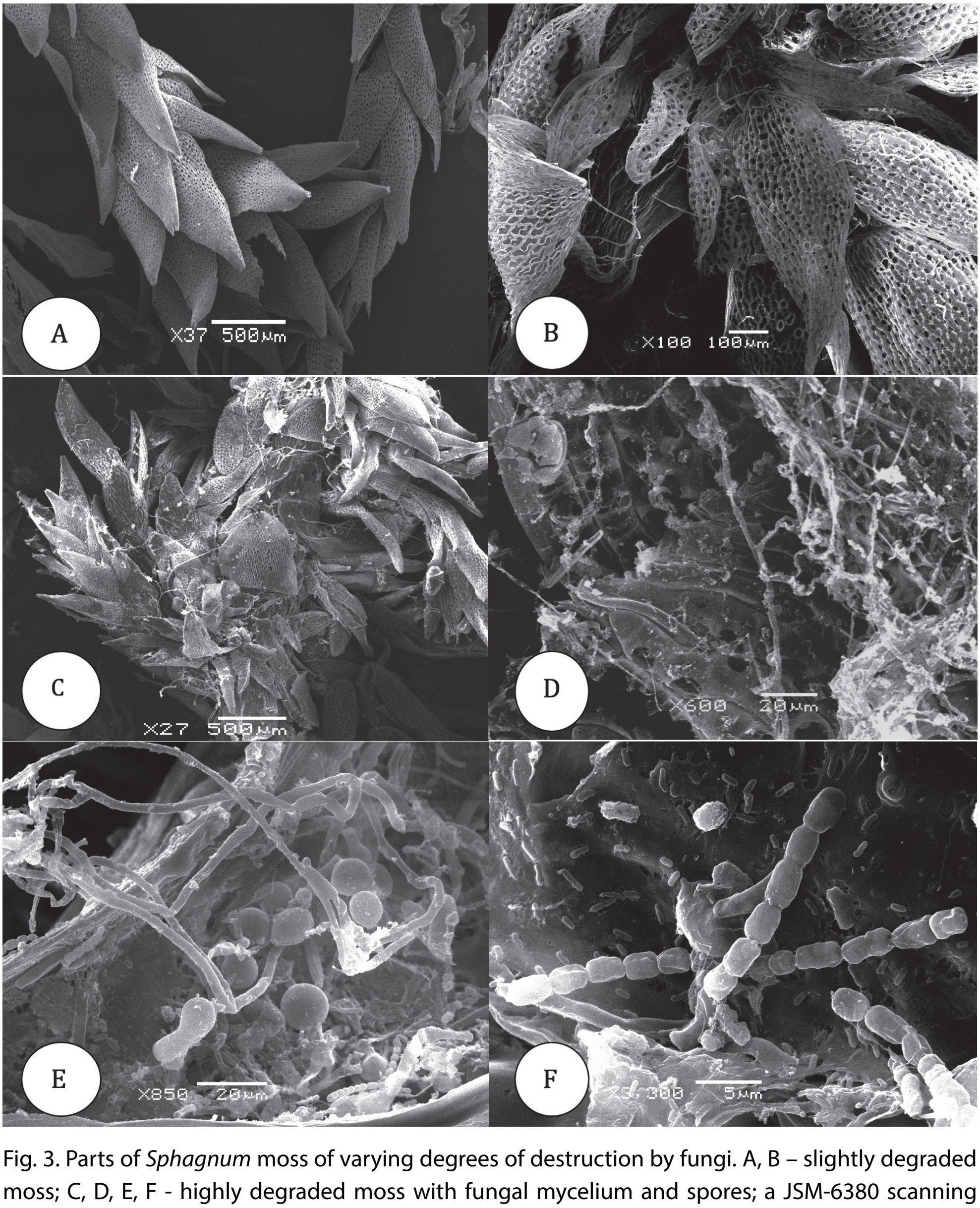

Fig. 3. Parts of *Sphagnum* moss of varying degrees of destruction by fungi. A, B – slightly degraded moss; C, D, E, F - highly degraded moss with fungal mycelium and spores; a JSM-6380 scanning electron microscope was used.

Fungi in Polar regions

In **Chapter 5**, I provide a taxonomic and ecological characterization of fungal communities in polar regions and compare these communities with each other. The uniqueness of fungal communities in the northern and southern polar regions, as well as their similarities, are defined by the predominant source of organic matter, the presence of mutualistic relationships with plants, and the degree of isolation from neighboring densely populated areas of animals and humans.

The Arctic polar region is largely covered by peatlands, and as global warming progresses, northern peatlands are losing their underlying permafrost layer. In turn, northern perennial permafrost, under suitable hydrological and temperature conditions, undergoes peat formation, which leads to an increase in peatland area (Fig. 2). These processes impact both the composition and functioning of fungi inhabiting the region. Changes in conditions may activate dormant fungal structures (spores and mycelium) preserved in permafrost. Additionally, warming leads to the loss of psychrophilic fungal species and, consequently, a decrease in their diversity (Tsuj et al., 2022). With a comprehensive list of Arctic fungi, I also analyzed several studies on the species composition of peatland fungi (Thormann and Rice, 2007; Grum-Grzhimailo et al., 2016, 2018), which indicate that about 30% of fungal species known in the Arctic are also found in peatlands. When additional studies on peatland fungi are planned, it is likely that a significantly greater number of identical fungal species will be found in the Arctic and peatlands. This fact is worth exploring in future research. It is also of interest to determine how active these fungi are in permafrost and peat, how global warming affects their metabolism, and what role they play in greenhouse gas emissions.

A significant portion of the Arctic is part of the landmasses of North America and Eurasia. This connection facilitates the free movement of terrestrial animals and people into the Arctic zone and allows plants to advance northward with warming temperatures. These factors also facilitate the dispersal of fungal spores on the fur of animals and the clothing of people, as well as the northward movement of mycorrhizal fungi along with their associated plant species.

Despite a considerably larger number of articles on Antarctic fungi compared to Arctic fungi, the fungal diversity at the South Pole has been found to be lower. On one hand, this can be attributed to the continent's rocky nature, colder and drier climate, and lack of organic matter. Antarctica features a thin layer of soil and peat, with the primary sources of organic matter being bird colonies and pinniped haul-out sites. In such locations, fungal diversity is mainly constrained by the composition of bird and mammal feces and other remains. On the other hand, Antarctica is an isolated continent, resulting in a greater number of presumed endemic fungal species. Additionally, the isolation hinders the movement of fungi from other continents, contributing to the lower species diversity and a higher number of endemics.

As research progresses, a pattern emerges: the number of species shared between the two poles increases with the number of studied articles. This also applies to species initially considered endemic to Antarctica but later found in the Arctic. This is expected when these regions are (still) under-sampled, urging me to continue my sampling efforts in the future and hopefully inspires others to do so as well. Although I have scarcely analyzed studies on fungi in high-altitude regions, I suspect that many species will also be shared with polar regions. An example of such a species is *Psychrophilomyces antarcticus*, described in **Chapter 6**, which is found in Antarctica, high-altitude regions, and the Arctic. The relatively high similarity of fungal communities in such distant regions is likely explained by similar climatic conditions and the dispersal of fungal spores by migratory birds, animals, and humans.

As described in **Chapter 5**, the use of varying methodologies by different researchers for the investigation and comparison of fungal communities in polar regions has proven to be a significant challenge. This variability complicates data (meta) analyses and the application of currently available statistical methods (see also below on this point). In my opinion, a crucial task for future research on fungal diversity is the development of a standardized protocol. This protocol should encompass sample collection and quantity, storage methods, composition of growth media, sample inoculation and fungal culture identification methods, as well as the analysis of eDNA and RNA.

To summarize the points discussed in this subsection, the following conclusions can be drawn: 1) the species composition of fungi in polar regions is largely determined by substrate quality; 2) the differences in fungal communities between cold regions will decrease as research into fungal diversity increases; 3) as the study of fungi in cold regions expands, the number of endemic species will decrease; 4) as shown on the maps in **Chapter 5**, there is a shortage of research in the Arctic and Antarctica due to their inaccessibility and harsh conditions, and it is safe to assume that this problem similarly affects the study of high-altitude regions; 5) the establishment of a unified sample processing protocol would be highly beneficial for studying fungal diversity and analyzing results.

The application of statistical methods for partial evaluating the obtained results and future research

As mentioned above, in the process of conducting this study, I did not apply statistical methods to assess fungal communities in the studied biotopes and mainly described the species composition of fungi that could be identified from the samples in a qualitative way. Most of my analyses are descriptive and comparisons are qualitative. An example may illustrate this. In **Chapter 6**, I describe the finding of a species previously only known from Antarctica, in the Arctic. The conclusion of this chapter is based on a single isolate, which is sufficient to show its occurrence. This type of biogeographical questions about habitat of species can thus be answered based on absence-presence data, which do not require statistical tests *per se*. Analyzing the literature data to write the review **Chapter 5**, I found that researchers used different methods for discovering fungi, for example, they selected different substrates and in different quantities, stored them differently, and used different plating methods for fungal detection. Due to all those differences, statistical analysis of the results seemed inappropriate as the outcome of such tests may be confounded by these methodology differences.

The primary goal of my research presented in this thesis was to compile lists of identified fungal species in boreal peatlands and polar regions. I included even those species that were encountered only once. When applying statistical methods, these species might become unaccounted for, as is often the case during statistical analyses of metabarcoding results when we remove from the overall species list those OTUs (operational taxonomic units) that occur as singletons. With such an approach, we could potentially overlook species such as *Psychrophilomyces antarcticus*, which was identified for the first time in the Arctic (**Chapter 6**). However, many studies over the past several decades have emphasized the importance of utilizing statistical methods. For instance, the renowned mycologist Walter Gams (1992) justifies their significance and discusses the value of comparative similarity coefficients and diversity indices, analyzing their optimal applications for specific mycological tasks (W. Gams, 1992). Contemporary mycological studies almost invariably include statistical analyses.

Considering the above, in my future research it will be very useful to add statistical evaluation methods. For example, cluster analysis (one of the most common multivariate techniques) will allow for the grouping of different peatlands and their components according to a hierarchical principle based on variables such as the presence or absence or abundance of species (Schmit and Lodge, 2005). Ordination methods are also well suited for assessing the degree of species similarity in fungal communities between peat bogs, representing a set of methods based on assessing the degree of similarity between sample areas. Ordination allows arranging descriptions of fungal communities along certain axes based on species composition data, which enables tracking existing relationships between ecological factors and mycobiota composition. Additionally, ordination methods can represent the results of mycobiota classification and evaluate the relationships of the identified groups with environmental factors, for example, in this study - in relation to distance from the sea, depth and pH of samples, and climate zone. For reliable statistical results, a sufficient number of samples is required, as well as an equal number from each peat bog and its elements (peat, subaqueous deposits, various types of peat, soils, and littoral soils). In the literature on the application of statistical methods for the study of fungi by classical approaches it is recommended collecting approximately 30 samples of the substrate being investigated (Schmit and Lodge, 2005). However, the authors assert that studies with a sufficient sample size for reliable statistical analysis are virtually absent for various reasons.

Chapter 2 of this thesis describes fungal communities in peat and subaqueous deposits of four peat bogs. Since statistical analysis was not planned before the start of this work, the number of samples varied depending on the depth of the peat deposit and the lake of each peat bog. Peat was sampled annually for three years, while the bottom sediment samples were collected only once (Table 1). Thus, we had from 9 to 22 peat samples and from 4 to 7 bottom sediments samples in each peatland, which is very small for statistical processing. Despite the uneven input data, I applied possible statistical evaluation methods for the results presented in **Chapter 2**. The program PAST (Paleontological Statistics, Version 4.11) was used for statistical analysis.

Table 1. The total number of peat and sediment samples collected from four peatlands.

Habitat	P1	P2	P3	P4	S1	S2	S3_1	S3_2	S4
Nu of samples	22	21	19	9	6	6	4	6	7

P1 – peat of peatland A, P2 peat of peatland B, P3 peat of peatland C, P4 peat of peatland D, S1 – bottom silt of lake peatland A, S2 – bottom silt of lake peatland B, S3_1 – bottom silt of lake 1 of peatland C, S3_2 – bottom silt peatland lakes C, S4 – bottom silt of peatland lake D (Chapter 2, Fig 1).

Table 2 presents the results of the assessment of alpha diversity of fungi in peat and sediment studied in the investigated peatlands. According to the values of these indices, the fungal communities obtained are relatively balanced, and single dominant species are absent.

Table 2. Alpha diversity indices for the peat and sediments peatlands studied.

	Peat and silt of the investigated peatlands								
Indices	**P1**	**P2**	**P3**	**P4**	**S1**	**S2**	**S3_1**	**S3_2**	**S4**
Taxa_S	50	33	41	51	41	21	21	46	21
Individuals	84	64	63	73	66	31	30	58	34
Dominance_D	0,02639	0,02877	0,01895	0,01218	0,04615	0,05376	0,04368	0,009074	0,1212
Simpson_1-D	0,9736	0,9712	0,9811	0,9878	0,9538	0,9462	0,9563	0,9909	0,8788
Shannon_H	4,799	3,716	4,292	4,686	4,452	4,211	4,143	4,869	4,185
Evenness_e H	0,6077	0,7618	0,7787	0,835	0,5898	0,7704	0,8066	0,995	0,5921
Brillouin	2,98	2,722	2,865	3,07	2,714	2,155	2,177	2,949	1,977
Menhinick	5,455	4,125	5,166	5,969	5,047	3,772	3,834	6,04	3,601
Margalef	11,06	7,694	9,655	11,65	9,547	5,824	5,88	11,08	5,672
Equitability_J	1,227	1,063	1,156	1,192	1,199	1,383	1,361	1,272	1,375
Fisher_alpha	52,02	27,38	50,91	75,11	46,22	28,6	31,09	102,9	23,41
Berger-Parker	0,1071	0,07813	0,07937	0,05479	0,197	0,2258	0,2	0,06897	0,3529
Chao-1	233	51,83	82,33	166,6	122,4	44,23	44,2	107,9	70,05
iChao-1	309,5	60,4	100,9	228,6	154,8	51,97	51,93	116,8	99,62
ACE	199,9	53,95	93,87	129,8	145,4	87,49	78,1	130,8	111
Squares	129,8	49,65	79,07	109,3	129,8	54,18	51,87	112,8	91,8

P1 – peat of peatland A, P2 peat of peatland B, P3 peat of peatland C, P4 peat of peatland D, S1 – bottom silt of lake peatland A, S2 – bottom silt of lake peatland B, S3_1 – bottom silt of lake 1 of peatland C, S3_2 – bottom silt peatland lakes C, S4 – bottom silt of peatland lake D (Chapter 2, Fig 1).

Rarefaction curves constructed for peat and bottom deposits of four peatlands are presented in Figure 4. Rarefaction evaluates how species richness depends on sample size, and this evaluation is reconstructed from the number of species in subsamples of varying size from the original sample. This analysis shows that the lines do not plateau yet, and hence, that species richness is much higher than based on our samples. The maximum species richness is estimated in the peat of peatland 1 (P1), and the minimum - in the bottom mud of lakes 2, 3(1) and 4 (S2, S3_1, S4; Fig 2). Partially, this result correlates with the number of samples analyzed. However, in the case of bottom deposits S3_2 and peat P4, this correlation is disrupted, and individual rarefaction analysis shows almost the same level of estimation for different numbers of analyzed samples. Overall, the results of this analysis indicate that more samples need to be collected for a comprehensive identification of fungal species.

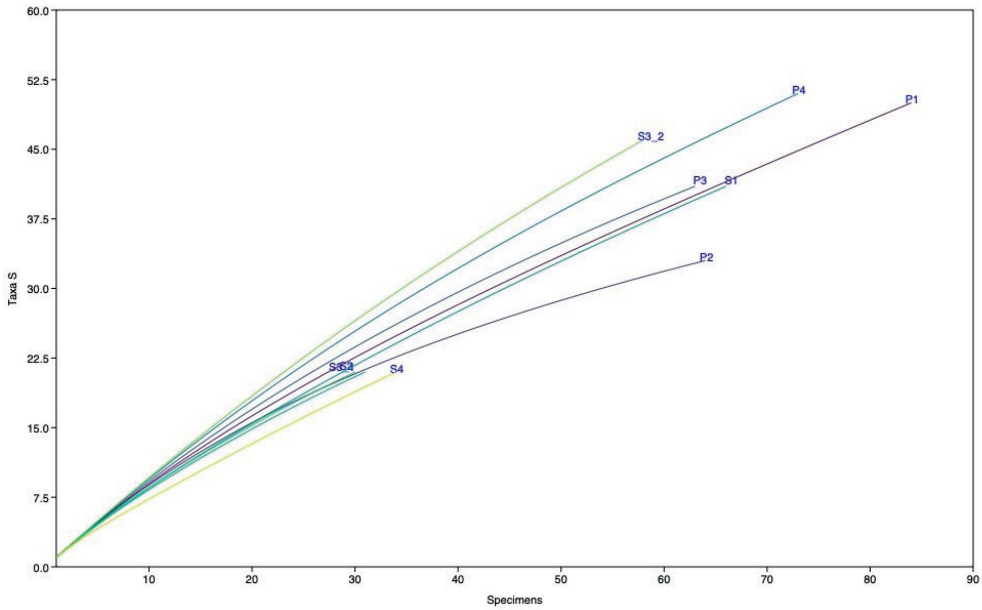

Fig. 4. Individual rarefaction curves for peat and sediment samples collected from four peatlands. P1 – peat of peatland A, P2 peat of peatland B, P3 peat of peatland C, P4 peat of peatland D, S1 – bottom silt of lake peatland A, S2 – bottom silt of lake peatland B, S3_1 – bottom silt of lake 1 of peatland C, S3_2 – bottom silt peatland lakes C, S4 – bottom silt of peatland lake D (Chapter 2, Fig 1).

Non-metric multidimensional scaling (NMDS) reveals the differentiation of peat and sediment in four peat bogs based on the abundance of collected fungal species (Fig. 5, 6). The fungal community of the peat in the youngest peat bog, in the process of separating from the White Sea, shows the greatest differences from the fungal communities of peat in bogs that have long been separated from the sea and already formed (Fig. 5). This demonstrates the difference in ecological conditions of the peat bog separating from the sea compared to others, possibly related to differences in plant species composition, higher pH values, and the presence of seawater inflow.

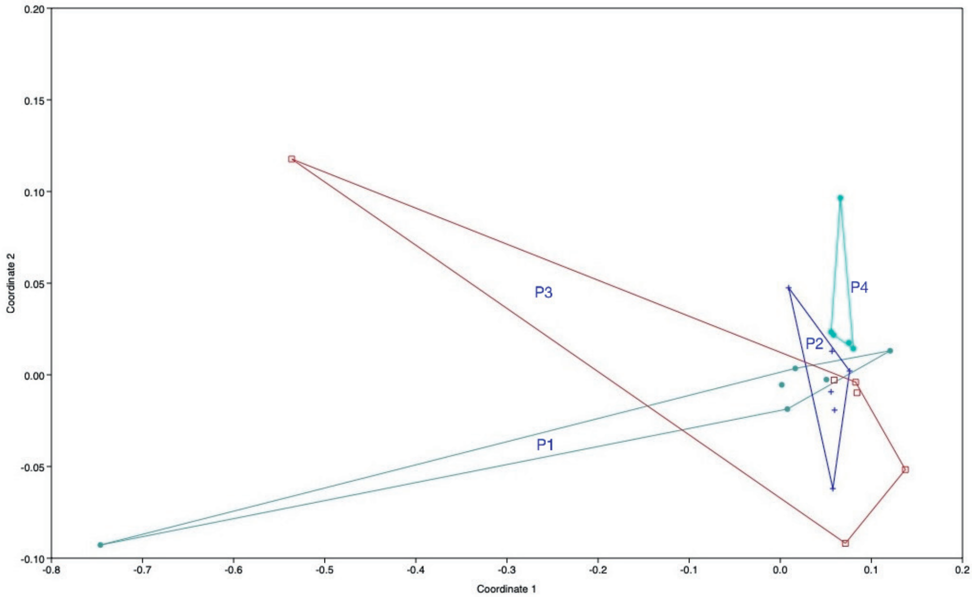

Fig. 5. NMDS ordination diagram for fungal communities of peat from four peatlands. P1 – peat of peatland A, P2 peat of peatland B, P3 peat of peatland C, P4 peat of peatland D (Chapter 2, Fig 1).

For the fungal communities in the bottom sediments of the studied peatlands, NMDS did not show a clear correlation (Fig. 6). This could be due to insufficient sample size and our assumptions about the ecological characteristics of the lake bottom sediments in these peatlands as described in **Chapter 2**.

Based on the results of the statistical analysis presented here, it is necessary to carefully plan future research to correctly analyze them using statistical methods. At a minimum, a sufficient number of samples (~30) should be selected from each studied biotope, with the same number of samples from each (Schmit and Lodge, 2005). For example, to study the mycobiota of the living and dying parts of *Sphagnum* mosses, it would be optimal to select samples from 15 *Sphagnum* hummocks on each peat bog. Additionally, it is useful to measure as many additional factors as possible to trace the relationship between fungal species community and these factors. When studying northern peat bogs of marine origin, these factors may include pH values, salinity, temperature, plant species composition, and altitude.

In addition to NMDS for comparing the fungal species composition of different biotopes, other ordination methods (PCA, PCoA, CA, DCA, etc.) may be suitable. For future statistical analysis of results, different conditions for sample cultivation can be applied, such as varying pH, salinity, and temperature values, while ensuring an adequate number of replicates (Petri dishes) during sample plating.

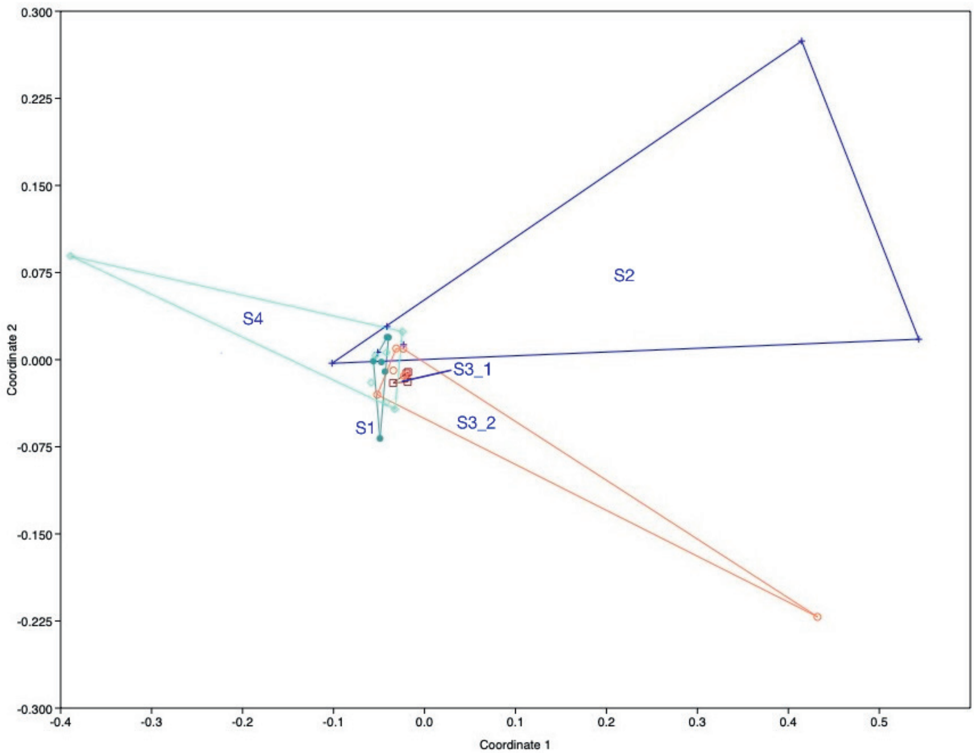

Fig. 6. NMDS ordination diagram for fungal communities of bottom sediments from four peatlands. S1 – bottom sediments of lake peatland A, S2 – bottom sediments of lake peatland B, S3_1 – bottom sediments of lake 1 of peatland C, S3_2 – bottom sediments peatland lakes C, S4 – bottom sediments of peatland lake D (Chapter 2, Fig 1).

Nevertheless, in conclusion I want to note that the statistical analysis conducted based on my data with a limited sample size supports my conclusions in **Chapter 2** regarding the similarities and differences in the mycobiota of the analyzed peatlands.

Main conclusions

In conclusion of my dissertation, I summarize the main outcomes of my PhD-research for the research questions 1 to 5 as outlined in my general introduction (**Chapter 1**).

- The fungal species composition of *Sphagnum* bogs along the White Sea coast is determined by the conditions of these ecosystems and the type of substrate examined

(**Chapters 2-3**). Saprotrophic fungi, which decompose organic matter, predominate in the investigated peatlands. In peatlands, they participate in plant degradation and peat formation, as they possess enzymes that decompose tissues of *Sphagnum* mosses (**Chapter 7**).

- The marine origin of the studied peatlands also influences their mycobiota, as evidenced by the presence of typical marine species in peatlands that have long been separated from the sea. Additionally, there is an increase in the number of marine species in peatlands that still have a connection to the sea or have recently become separated from it (**Chapter 3**).
- Regional climatic conditions influence the species composition of fungal communities in *Sphagnum* bogs (**Chapter 4**).
- Communities of fungi in polar regions approximately overlap by 20% at the species level (**Chapter 5**). Common species of fungi are also known for the Arctic, Antarctica, and high mountain regions (**Chapter 6**). More work is needed to identify the factors determining geographical distribution ranges of fungi. Terrestrial mycelial fungal communities in polar regions, as identified through cultivation methods and eDNA analysis, comprise over a thousand species. However, it remains unclear which of these species are functional under these polyextreme conditions. A comprehensive approach is necessary for further identification of fungi and assessment of their current activity. A similar situation is observed with fungi in boreal peatlands (**Chapters 2–5**).
- Fungi are the primary decomposers in the aerated layers in northern peatlands dominated by *Sphagnum* mosses (**Chapters 2-4**). Furthermore, a significant number of fungi have been identified across all studied substrate types in extreme polar regions (**Chapters 4-5**). This indicates the substantial role of fungi in the nutrient cycling of the investigated habitats and, consequently, their contribution to the global nutrient cycle, including greenhouse gas emissions into the atmosphere. Metabolism of fungi also changes under the influence of global warming. This affects the intensity of greenhouse gas emissions from thawing permafrost and drying peat, as well as the rate of deposition of organic matter in the peat formation process. However, in addition to fungi, the functioning of many other organisms and climatic zones also influences these processes. A comprehensive predictive model that considers all the nuances affecting the intensity of greenhouse gas emissions in the process of global warming does not yet exist (**Chapter 7**), but I have mapped the various factor necessary to make predictions on these emissions.

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Supplemental materials 1

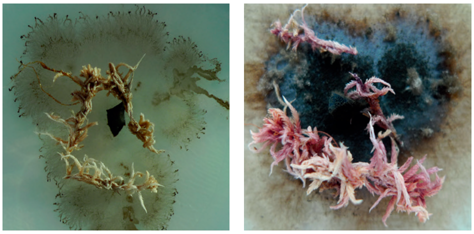
We conducted an experimental study to determine the ability of more than 200 fungal cultures to decompose *Sphagnum* spp. Part of the strains belong to 30 identified species. Other strains were identified to genus or higher taxonomic levels or were unidentified (Table 1). All these strains were isolated from investigated northern peatlands located near the White Sea. For this experiment the fungi were inoculated on water-agar medium, placed around sterilized *Sphagnum* spp. branches taken from the same peatlands, and incubated for six months at 20 °C. The resulting Petri dishes were photographed directly and under a binocular microscope (Fig. 3, 4).

The tested fungi can be divided into three groups (Table 1):
Group 1) well-growing on water agar, not decomposing *Sphagnum* spp. (Fig. 1);
Group 2) well-growing across the entire surface of the Petri dish, including on *Sphagnum* spp. tissues (the biggest group; Fig. 2);
Group 3) growing only on *Sphagnum* spp. and decomposing it (the smallest group; Fig. 3).

Table 1. List of fungi tested for ability to decompose *Sphagnum* spp.

Group 1	Group 2		Group 3
Acsomycota	***Ascomycota***		***Basidiomycota***
Alternaria spp.	*Acremonium* spp.	*Talaromyces funiculosus*	*Basidiomycota* spp.
Ascomycota spp.	*Ascomycota* spp.	*Teberdinia hygrophila*	*Clavulinaceae* sp.
Cadophora luteo-olivaceae	*Aspergillus tubingensis*	*Tolypocladium cylindrosporum*	*Phlebiopsis gigantea* 3
Cladosporium cladosporioides	*Botryotinia* sp.	*Tolypocladium geodes*	*Polyporus* sp.
Cladosporium herbarum	*Cadophora fastigiata*	*Tolypocladium inflatum*	*Sistotrema brinkmannii*
Cladosporium langeronii	*Cadophora luteo-olivaceae*	*Tolypocladium* spp.	*Sistotrema* sp.
Cladosporium sp	*Cadophora malorum*	*Trichoderma polysporum*	***Mucoromycota***
Crocicreas sp.	*Cadophora* sp.	*Trichoderma* sp.	*Mortierella elongata*
Dothideales sp.	*Chaetosphaeria* sp.	*Trichoderma viride*	**Unidentified fungi**
Eurothium sp.	*Cladosporium cladosporioides*	***Basidiomycota***	Sterile mycelium
Helotiales spp.	*Cladosporium* spp.	*Antrodia* sp.	
Penicillium spinulosum	*Coniochaeta* spp.	*Basidiomycota* sp.	
Phoma poolensis	*Crocicreas* sp.	*Clavulinaceae* sp.	
Pochonia bulbillosa	*Dothideomycetes* spp.	*Cylindrobasidium laeve*	
Sydowia polyspora	*Eurotium* spp.	*Neolentinus* sp.	
Teberdinia hygrophila	*Gloeophyllum separium*	*Peniophora* sp.	
Volutella sp.	Gnomoniaceae spp.	*Phellinus* sp.	
Basidiomycota	*Helotiales* spp.	*Phlebiopsis gigantea* 2	
Amylostereum areolatum	*Lachnum* sp.	*Pholiota* sp.	
Antrodia sp.	*Leotiomycetes* spp.	*Piptoporus betulinus*	
Antrodia xantha	*Massarinaceae* sp.	*Pleosporales* sp.	
Basidiomycota sp.	*Mollisia* spp.	*Polyporales* sp.	
Peniophora spp.	*Nectriaceae* spp.	*Resinicium bicolor*	
Phlebiopsis gigantea 1	*Paradendryphiella salina*	*Sistotrema brinkmannii*	
Resinicium sp.	*Penicillium* sp.	*Sistotrema* spp.	
Mucoromycota	*Penicillium thomii*	*Stereum / Xylobolus* sp.	
Mucor hiemalis	*Penicillium variabile*	*Strobilurus tenacellus*	
Unidentified fungi	*Pezizomycotina* spp.	**Unidentified fungi**	
Fungus sp.	*Phoma poolensis*	*Fungus* spp.	
	Plectosphaerella spp.	Sterile mycelium	
	Pleosporales spp.		

Here, I present photos of only some examples from this experiment (Fig. 1, 2, 3).



Sydowia polyspora *Cladosporium langeronii*

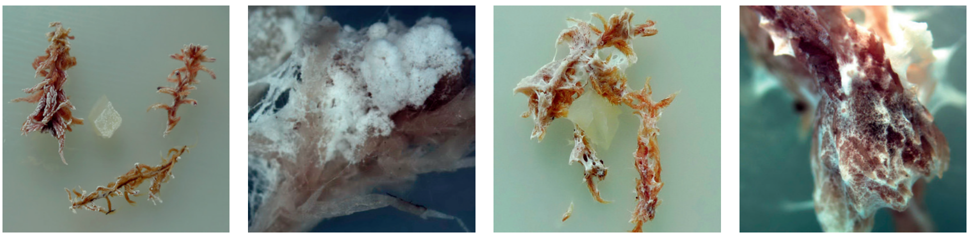
Fig. 1. Examples of fungi from group 1: well-growing on water agar, not decomposing *Sphagnum* spp.

Helotiales sp. *Stereum* sp. *Penicillium thomii* *Ascomycota* sp.

Fig. 2. Examples of fungi from group 2: well-growing across the entire surface of the Petri dish, including on *Sphagnum* spp. tissues.

A B A B

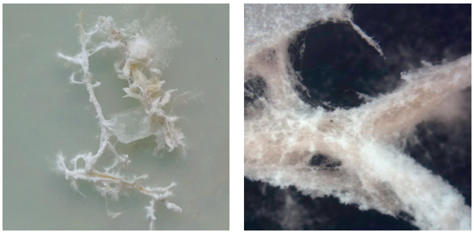
Sistotrema brinkmannii *Polyporus* sp.



A B A B

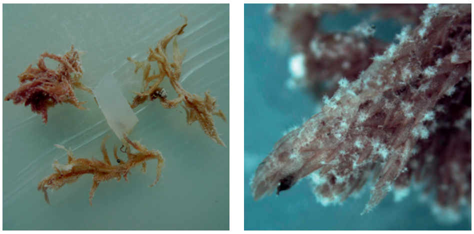
Mortierella elongata Sterile mycelium

Fig. 3. Fungi growing only on *Sphagnum* spp. and decomposing it. A – direct photography; B –binocular microscope photography.



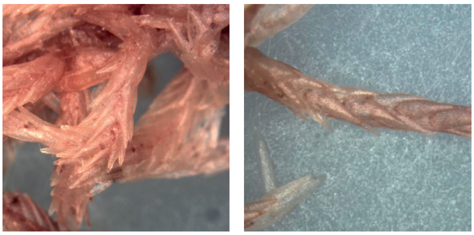
A B

Phlebiopsis gigantea, strain 3



A B

Phlebiopsis gigantea, strain 2



B B

Phlebiopsis gigantea, strain 1

Fig. 4. Three strains of *Phlebiopsis gigantea* growing differently on *Sphagnum* tissues. A – direct photography; B –binocular microscope photography.

It is interesting that in some cases, different strains of the same species ended up in different groups in terms of their ability to decompose *Sphagnum*. For example, three strains of the species *Phlebiopsis gigantea* were categorized into three different groups (Table 1, Fig. 7). A similar situation is observed with the species *Cladosporium cladosporioides*, *Cadophora luteo-olivaceae*, *Phoma poolensis*, *Sistotrema brinkmannii*, *Teberdinia hygrophila* (Table 1). Further research is needed to clarify these trends. However, it can be summarized that the majority of tested fungal strains can grow on *Sphagnum* tissues and degrade them with varying intensity. Additionally, many of the tested fungal species can grow in extreme conditions typical of oligotrophic peatlands. For example, *Sistotrema brinkmannii* and *Phlebiopsis gigantean* are known as acidophiles; *Cadophora luteo-olivaceae* and *Phoma poolensis* are acidotolerant (Grum-Grzhimaylo, unpublished data); *Mortierella elongate*, *Tolypocladium* spp. are psychrotolerant (Grum-Grzhimaylo et al., 2016); *Talaromyces funiculosus* and *Trichoderma viride* are capable of growing in hypoxic conditions (Grum-Grzhimaylo, unpublished data; *Cladosporium cladosporioides*, *Phoma poolensis*, *Talaromyces funiculosis*, *Penicillium spinulosum*, *Tolypocladium cylindrosporum* grow in a medium with 5% tannic acid (Grum-Grzhimaylo, unpublished data); *Penicillium spinulosum*, *Talaromyces funiculosis*, *Stereum* sp., *Antrodia* sp., *Phlebiopsis gigantea*, *Mortierella elongata* and *Phoma poolensis* grow well on lignin-enriched medium (Grum-Grzhimaylo, unpublished data). Presumably, the afore mentioned fungal species capable of growing in the extreme conditions typical of oligotrophic peatlands are active in these ecosystems.

Appendices

Summary

Estimates suggest that more than 40-50% of the area of the northern hemisphere of our planet is covered by *Sphagnum* bogs, which act as a reservoir for storing planetary carbon stocks in peat, with polar and high mountain regions underlain by permafrost. In the boreal zone, permafrost also underlies some of the peatlands. Both the cold polar and high mountain regions, as well as the acidic flooded *Sphagnum* bogs, represent poly-extreme conditions for existence. However, even in these ecotopes, actively functioning microorganisms (bacteria, archaea, protists, and fungi) are known. In this work, I focused on studying the mycelial fungi of boreal peatlands, the Arctic, and Antarctica.

In peatlands, fungi mainly play an important role as decomposers of recalcitrant tissues of *Sphagnum* mosses, initiating this process. Fungi break down the most complex phenolic components into simpler ones, making them available to bacterial enzymes. Being mostly aerobic organisms, fungi are predominantly active in the upper aerated layers of peat, while in deeper peat deposits, the main role of decomposers shifts to anaerobic prokaryotic organisms. With global warming, the thawing of permafrost is occurring, resulting in the expansion of the area of boreal peatlands. This process is accompanied by the loss of thriving fungal species in permafrost and the activation of species that are preserved in frozen substrate as spores. At the same time, the upper layers of boreal peatlands are heating up and drying out, enhancing the activity of resident fungi. These transformations affect the intensity of global biogeochemical cycles, and therefore, the rate of peat accumulation and greenhouse gas emissions. Currently, the description of fungal communities in peatlands and permafrost soils is lacking. Furthermore, the issue with current understanding of fungal communities in permafrost and peat is that it is unknown which of the detected fungi are active and which are present as spores. Without information on the species composition of fungi in these locations and the extent of their activity, it is impossible to predict changes in the functioning of fungal communities and substance cycling under the impact of global warming.

The objectives of my dissertation were to describe the diversity of fungi in *Sphagnum* bogs located in the Arctic region on the coast of the White Sea, compare the obtained fungal communities with the fungal community of three *Sphagnum* bogs in the temperate zone, and analyze the existing literature on terrestrial mycelial fungi in the Arctic and Antarctica.

To expand the information on the species composition of fungi in boreal peat bogs, in **Chapter 2**, I present the results of the study of peat deposits and bottom sediments of five near-coastal peatlands. These peatlands are located at different elevations relative to sea level, and they were formed at different times after the retreat of the sea due to post-

glacial land uplift from the White Sea. In this study, I used culture methods to identify fungi, so it is not possible to determine whether they are active or preserved as spores. In this chapter, I present a list of identified fungal species, a comparative characterization of the fungal communities of *Sphagnum* mosses and peat at different depths, as well as the studied peatlands. Marine fungal species were found in bottom sediments, while they were absent in peat deposits. The highest number of fungi and their diversity were found in the surface aerated layers of peatland, such as living and dying parts of *Sphagnum*, as well as at the maximum depth of the peat deposit (in the underlying rock), which can be explained by the leaching of fungal spores and their accumulation in waterproof underlying substrate.

The object of study in **Chapter 3** was the brackish lake Kislo-Sladkoe, which is currently in the process of becoming isolated from the White Sea and gradually becoming peatified. In this work, as in the previous chapter, culture methods were used to identify fungi. The result of this study was the discovery of mosaicism in the fungal community in this ecosystem. I collected samples from different components of this lake, such as bottom mud from different depths, littoral deposits from the shore where periodic influx of seawater occurs, *Sphagnum* from the opposite shore where a freshwater stream flows into the lake and peatification has begun, as well as soil from the costal forest. These samples differed in pH and salinity values, and corresponding differences in fungal species composition were found.

In **Chapter 4**, I present a brief comparison of fungal communities of three boreal and three temperate *Sphagnum* peatlands. Culture methods were used in both regions, however, the methods of storing samples differed, which could have influenced the results. Nevertheless, extremely low similarity was noted in the fungal communities of northern and temperate peatlands at the species level. Strong differences in fungal communities are presumably explained by the climatic differences between these regions, as well as by different methodological approaches.

Chapter 5 provides a review dedicated to the description of terrestrial mycelial fungi of the Arctic and Antarctic regions. As a result of this research, I compiled a list of known fungi in polar regions, provided maps of their occurrences, analyzed the substrates of fungal discovery, compared methodological approaches, and attempted to determine the presence of endemic fungal species in the Arctic and Antarctic. I found that nearly 1300 species of mycelial fungi are known in polar regions, isolated from various substrates. In the Arctic, fungal species diversity is higher than in Antarctica, with approximately 20% of fungal species overlapping between the two regions. Different studies used different methods for collecting and storing specimens, fungal discovery, and identification. Therefore, it is very difficult to analyze results obtained using such diverse methods.

Nevertheless, I showed that endemic species may be more prevalent in Antarctica compared to the Arctic. However, with increasing research in polar and high-altitude regions, a growing similarity in fungal species composition in these regions is being observed. The question of the presence of endemic fungal species in polar regions remains debatable.

Chapter 6 focuses on two isolates of the fungus species *Psychrophilomyces antarctius*, discovered in Antarctica and the Tibetan Plateau in 2015, and described as a new fungal species. We isolated it from samples of littoral deposits of Shokalsky Island (Kara Sea, Arctic), identified it based on morphology and four sequences of conservative genes, and conducted experimental work to determine the optimal values of temperature, pH, and salinity for growth of this fungus. We demonstrated that this fungus belongs to the species *P. antarctius* with the highest similarities in morphology, physiology, and DNA sequences. Thus, I discovered another fungal species shared between polar and high-altitude regions, confirming my hypothesis that with increasing research in these regions, differences in fungal communities are diminishing.

In **Chapter 7**, I discuss all the material of this thesis, as well as provide and discuss statistical processing. In main conclusions, I summarize the main questions of this thesis and possible future research directions. Additionally, I present unpublished results of an experiment showing the ability of over 200 tested fungal cultures from peatlands to decompose *Sphagnum* mosses. I found that fungi can be divided into three groups: those growing only on *Sphagnum* and actively decomposing its tissues, those growing on and around *Sphagnum*, and those growing around *Sphagnum* but not decomposing it.

Acknowledgements

Considering the lengthy and winding path of my thesis journey, it's not possible to keep this chapter brief, as many people have been involved in various ways throughout this process.

First and foremost, I want to express my heartfelt gratitude to my supervisors, Prof. Dr. **Bas Zwaan**, Prof. Dr. **Duur Aanen**, and Dr. Ir. **Fons Debets**.

Fons, in the distant year of 2010, you responded to my interest in coming to work for a year in a group of geneticists at WUR. Despite my catastrophically terrible English at that time, you showed incredible patience in trying to understand me and always spoke to me in the clearest terms possible. I felt ashamed and pained to see the sparkle in your eyes diminish as you struggled to grasp what I was trying to say. Once you even said, "I have no idea what you mean. "What a nightmare! But despite that, you regularly checked in every few days to ask how my work was progressing, how I was settling in the Netherlands, and so on. Over the years, we continued our collaboration during which you always supported my ideas (even if they were unrealistic) and made time to discuss my work at any moment. Thank you, Fons, for your kindness, trust, genuine involvement in my projects, and endless support! It was super cool to meet you with colleagues in Moscow, where you bravely came in 2012!

I am very grateful to you, **Duur**, for taking an interest in my research topic and becoming my supervisor! Always friendly, you meticulously reviewed the drafts of my publications, found time to discuss my research, and supported me with recommendations and smiles. I am very happy that we became co-authors of articles together, and I really hope to continue our collaboration!

Thank you so much, **Bas**, for approving the completion of my thesis in your wonderful laboratory and for always supporting me! Your recommendations for my thesis were incredibly helpful. Throughout all these years, I have been amazed at how sensitively and skillfully you lead the group, and how humanely and amicably you treat your mentees, including myself. Every day, coming to Radix and the laboratory, I felt happy simply because I work here!

Dear my brother **Alex**! I find it incredible that we once both enrolled in the Biology Faculty at Moscow University, then, without any prior agreement, chose the Department of Mycology and Algology and ended up with our scientific advisor, Dr. Elena Bilanenko. And later, thanks to the trust of Fons, Prof. Dr. Rolf Hoekstra and other colleagues in genetics, we both came here to work at WUR. Side by side, we have traveled our long, yet both

similar and different scientific path. Your help in mastering skills in the molecular laboratory, analyzing gene sequences, conducting phylogenetic analyses, and understanding English have been invaluable! Not to mention how great it has always been to get energized by your jokes at the start of the workday! Курочка по зёрнышку клюёт :) Thank you for your kindness and for the time you devoted to helping me! It was great living and working in Wageningen, communicating with you and your family!

Dear my fellow student **Nastya Sivolapova**. Thank you for your help and support during my very first visit to Wageningen! You found accommodation for me, greeted me, showed me around the city, and it was wonderful to be here with you! Even now, when I ride my bike past the windows of the room you lived in, I remember your green and lilac curtains. I really miss them, just like their kind owner!

I am very grateful to **Erik Bastiaans**. From the very beginning, you became a good friend, and I fondly recall the time when we lived together in the same apartment with you and Alex. Those were fun and beer-filled days! Thank you for your support, help, and kindness throughout all these years.

I cannot forget the wonderful technicians **Marÿke Slakhorst** and **Bertha Koopmanschap**, who helped me a lot and patiently with my laboratory work, always tried to talk to me and provide support! It is very painful that Bertha is no longer with us, but her bright spirit will forever remain in my memory.

I am also very grateful to **Witske Nijenhuis**, who helped me resolve all formal matters while always being so friendly and welcoming! It's always a pleasure to see you again! And of course, to all the other wonderful colleagues from those 2010-2011 years: **Merijn, Martijn, Bart, Jianhua**, thank you for the company, for the great parties, conversations, and smiles!

I also want to sincerely thank the colleagues with whom we became acquainted later.

Dear **Marjan**, your kindness, warmth, and help in resolving all formal matters are invaluable – thank you very much!

Dear **Gabriella**, we work with completely different subjects, but you always find time to talk to me, support me, smile, and wave at me. Your genuine interest in my life has been an incredible source of support for me all these years! Dear **Francisca**, thank you for your assistance in my uncomplicated but time-consuming molecular inquiries! You are so kind and attentive, and you always made time for my work. I am very grateful to José for his help with microscopy, and to **José, Corrie, Frank, Jordy, Bart** and all the other lab users

for your assistance with ordering reagents, primers, sending sequences, and being ready to answer questions about laboratory work. Thank you, dear **Sijmen** and **Saskia**, for your many years of friendship and hospitality! Dear **Hilje**, the idea of creating a Christmas choir of geneticists was such a great one! Those two rehearsals and our small, but warm performance were a real breath of fresh air during a challenging time for me. Thank you and all the participants of our little choir! Thank you, **Hans**, for allowing us to rent your cozy apartment during our some visits; it was wonderful to stay there! Dear **Anna**, it was great to communicate with you at work too! A huge thank you to all the members of the genetics group at Wageningen University; it has been fantastic to work and communicate with you all these years! I would love to mention each of you by name, but that might make this chapter too long. I mentally embrace and thank you all!

Thanks to our friends **Kristina** and **Jacob, Lena** and **Dima, Vika** and **Sasha**, and your daughters for the communication and companionship. I wish us all peaceful skies above and hope to keep in touch with you!

Certainly, a big thank you to all my colleagues, friends, and classmates at Moscow State University, especially to the director of the White Sea Biological Station, Prof. Dr. **Alexander Tzetlin**, my first scientific mentor Dr. **Elena Bilanenko**, my dear friends and colleagues Dr. **Anna Zhadan** and Dr. **Ekaterina Bubnova**, all my teachers and colleagues at the Biological Faculty, and all the staff at our wonderful biological station and your families, for the knowledge, help, support, kindness, and simply for being in my life! Thank you very much, dear Dr. **Galina Belyakova**, for telling me about the international program that brought me to WUR.

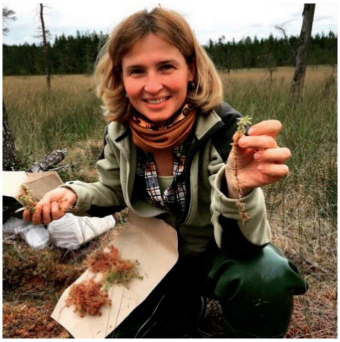
Dear my friend **Valya**! We've been friends for so many years, supporting each other and hanging out – in Moscow, at the White Sea, in Vologda, and even here in the Netherlands, where we somehow both ended up. It's incredible! You supported me at the defense of my first dissertation in Moscow back in 2013, and now you're supporting me here. Thank you for being by my side!

I am grateful to my relatives – my dad **Alexey**, my brothers with their wives: **Alexey** and **Anna, Denis** and **Sasha, Vasya** and **Dasha**, for their support in everything! A special thanks to you, dear **тётя Таня**, for everything you give to me and my daughter just because, and for always being on our side!

I am also very grateful to my esteemed opponents Prof. Dr. **Liesje Mommer**, Prof. Dr. **Pedro Crous**, Dr. **Emilia Hannula**, Dr. **Anne van Diepeningen**, agreeing to delve into my work, analyze and evaluate it.

I sincerely thank the **wonderful country Netherlands**, where my daughter and I have been fortunate to spend this time! Thank you for the natural, healthy cycling lifestyle, sports everywhere, the spring explosion of colors, the clear system of rules, cleanliness and order in the streets, the care given to every piece of land, the tolerance and friendliness of the people around us, and the wonderful school where my daughter felt happy for three years! We have fallen deeply in love with this country of mists and flowers, and we hope to come here regularly!

About the author



My thesis seems too long already, so I will keep this chapter very brief 😊
I was born in Moscow on March 25, 1980. After completing my basic education and music school, I graduated from two vocational colleges: a music college and a pedagogical college. Then, I enrolled in the Biology Department at Lomonosov Moscow State University, where I chose peatland fungi as my research subject. I continued to explore this topic during my graduate studies. While in graduate school, I spent a year on an internship at Wageningen University in a genetics group. Since then, our pleasant collaboration has continued. In 2013, I defended my dissertation in Moscow, and now I am defending my second one in Wageningen. Most of my research has been conducted around the White Sea Biological Station, where I have been every summer and sometimes part of the winter for the past 26 years.
In addition to my scientific work, I teach a lot—I worked in music and general education schools for 10 years, and for over 15 years, I have been teaching biology to high school graduates and students at MSU. Furthermore, for the past five years, I have been part of the development team for the unified state exam in biology for school graduates in Russia. Over the last two years, I have been studying psychology and have already started practicing this new field with clients.
I love all these areas of my work and combine them. However, music has gradually become more of a hobby for me. By the way, I spent a full 20 years of my life singing in various academic choirs. During my tours with choirs, I visited the USA, China, Ireland, Italy, Hungary, Austria, Serbia, Bulgaria, and many cities in Russia. Choral singing is truly my weakness. I am also absolutely passionate about field research and laboratory work! So, in a way, this can also be considered one of my favourite hobbies.
I also love both the North, with its peat bogs and lichens, and the warm sea with soft white sand and palm trees along the shore. I dream of visiting Antarctica. I enjoy driving cars and motorboats, summer and winter diving, especially for the purpose of collecting biological materials for research and teaching. I have a wonderful daughter who has been participating in my field trips since she was born. Once, while we were at a peat bog, she lost her footing, ended up completely in the water, and lost her boots in the peat. Since then, she has hated my peat bogs, but as a bonus, she happily eats the ripe berries there—cloudberries, blueberries, and sour cranberries! 😊
I am very happy that I have managed to complete this thesis, and now I am ready for the next stages of my life.

List of publications

This thesis:

- (Chapter 2) **O.A Grum-Grzhimaylo**, A.J.M. Debets, and E.N. Bilanenko. The diversity of microfungi in peatlands originated from the White Sea // Mycologia, 2016 DOI: 10.3852/14-346
- (Chapter 3) **O.A. Grum-Grzhimaylo**, A.J.M. Debets, and E.N. Bilanenko. Mosaic structure of the fungal community in the Kislo-Sladkoe Lake that is detaching from the White Sea // Polar Biology, 2018 DOI: 10.1007/s00300-018-2347-9
- (Chapter 4) E.N. Bilanenko and **O.A. Grum-Grzhimaylo**. The comparative analysis of the cultured micromycetes in oligotrophic peatlands of natural biosphere reservations located in the northern and central parts of Russia // Nature Conservation Research. Заповедная наука. Саранск: 2016. 1(2): 90-95.
- (Chapter 5) **O.A. Grum-Grzhimaylo**, A.A.Shurigina, A.J.M.Debets and D.K. Aanen. Biogeography and Uniqueness of filamentous terrestrial Fungi in the Polar Regions // Fungal Biology Reviews, Volume 49, 2024, 100382, https://doi.org/10.1016/j.fbr.2024.100382
- (Chapter 6) **O.A. Grum-Grzhimaylo**, E.N. Bubnova, A.A. Grum-Grzhimaylo, A.J.M.Debets and D.K. Aanen. Occurrence of *Psychrophilomyces antarcticus* in the Arctic // Fungal Ecology, Volume 74, April 2025, 101408, https://doi.org/10.1016/j.funeco.2024.101408

Other publications:

- O.V. Ezhova, **O.A. Grum-Grzhimaylo**, J.A. Kokurkina, I.A. Ekimova, M.M. Gantsevich, V.V. Malakhov. The interaction of marine fungi and acorn worms (Hemichordata, Enteropneusta), Doklady Biological Sciences, DOI: 10.1134/S0012496624600568 *(in print)*
- E.A. Ianutsevich, O.A. Danilova, **O.A. Grum-Grzhimaylo**, V.M. Tereshina. Membrane lipids and osmolytes in the response of the acidophilic basidiomycete *Phlebiopsis gigantea* to heat, cold and osmotic shocks // Int. J. Mol. Sci. 2024, 25, 3380. https://doi.org/10.3390/ ijms25063380
- E.A. Ianutsevich, O.A. Danilova, **O.A. Grum-Grzhimaylo** and V.M. Tereshina. The Role of Osmolytes and Membrane Lipids in the Adaptation of Acidophilic Fungi // Microorganisms MDPI, 2023 DOI: https://doi.org/10.3390/ microorganisms11071733
- E.A. Ianutsevich, O.A. Danilova, **O.A. Grum-Grzhimaylo**, N.V. Groza, and V.M. Tereshina. Adaptation of the Acidophilic Fungus *Sistotrema brinkmannii* to the pH Factor // Microbiology, 2023 DOI: 10.1134/S0026261723600210
- E.N. Bubnova, **O.A. Grum-Grzhimaylo**, V.V. Kozlovsky. Composition and structure of the community of mycelial fungi in the bottom sediments of the White Sea // Moscow University Biological Sciences Bulletin, 2020 DOI: 10.3103/S0096392520030037

- **O.A. Grum-Grzhimaylo**, E.N. Bilanenko, E.N. Bubnova, M.L. Georgieva. Current Trends in the Exploration of Fungi of Northern Peat Bogs in Connection with Climate Change and the Thawing of Perennial and Permafrost // RFBR Sciences Bulletin, 020 DOI: 10.22204/2410-4639-2020-106-02-101-114 *(in Russian)*
- E.N. Bubnova, M.L. Georgieva, **O.A. Grum-Grzhimaylo**. Methods for isolation and enumeration of fungi developing in marine sediments // Microbiology, 2018 DOI: 10.1134/S0026261718060061
- E.N. Bubnova, **O.A. Grum-Grzhimaylo**, O.P. Konovalova, O.E. Marfenina. Fifty Years of Mycological Studies at the White Sea Biological Station of Moscow State University: Challenges, Results, and Outlook // Moscow University biological sciences bulletin, 2014 DOI: 10.3103/S0096392514010039
- **O.A. Grum-Grzhimaylo**, E.N. Bilanenko .The micromycete complexes of bogs at the Kandalaksha Bay of the White Sea // Micologia i phytopatologia. V. 46, № 5. 2012. P. 297–305. *(in Russian)*
- **O.A. Grum-Grzhimaylo**, E.N. Bilanenko. Microfungi as a component of bogs ecosystems *(a review)* // Micologia i phytopatologia. V. 44, № 6. 2010. P. 485-496. *(in Russian)*

Training and Education Statement of the Graduate School for Production Ecology and Conservation

With the training and education activities listed below the PhD candidate has complied with the requirements set by the C.T. De Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 30 ECTS (=22 weeks of activities)

Review / project proposal (4.5 ECTS)

Biogeography and Uniqueness of filamentous terrestrial Fungi in the Polar Regions

Postgraduate courses (9.6 ECTS)

- Introduction to R and R Studio; PE&RC (2024)
- Tidy data transformation and visualization with R; PE&RC (2024)
- Adobe Illustrator: Scientific Artwork & Infographics; PE&RC (2024)
- Basic Statistics; PE&RC (2024)
- Advanced Statistics course Design of Experiments; PE&RC (2023)
- Linear Models; PE&RC (2024)
- Mixed Linear Models; PE&RC (2024)
- Generalized Linear Model; PE&RC (2024)
- Untroduction to LateX workshop; PE&RC (2023)
- Soil Biology Lab Skills Course For Assessing Soil Functions; PE&RC (2024)

Invited review of journal manuscripts (2 ECTS)

- PlosOne, Fungal ecology topic (2016)
- Scientific Reports, Fungal ecology topic (2020)

Competence, Skills and Career-oriented activities (4 ECTS)

- Scientific Writing; WUR (2024)
- Writing Grant Proposals; WUR (2024)

Scientific Integrity/Ethics in science activities (0.6 ECTS)

- Scientific Integrity; WUR (2024)

PE&RC Retreat, PE&RC Day, and other PE&RC events (0.9 ECTS)

- PE&RC Day, 26 October (2023)
- PE&RC retreat last years' weekend (2024)
- PhD Last stretch and writing propositions (2023)

National scientific meetings, local seminars, and discussion groups (6 ECTS)

- All-Russian Conference (Congress): 4th Russian Microbiological Congress XI, Tomsk, Russia (2023)
- International Scientific and Practical Conference "Marine Research and Education" MARESEDU, Moscow, Russia (2022)
- All-Russian Conference: Fifth Congress of Mycologists of Russia, Moscow, Russia (2022)
- All-Russian conference with international participation: "Franz Josef Land: 150 years of exploration", Arkhangelsk, Russia (2023)

International symposia, workshops and conferences (10 ECTS)

- Netherlands Annual Ecology Meeting, NERN, Lunteren, Netherlands (2024)
- KNVM meeting, Utrecht, Netherlands (2023)
- International conference, dedicated to the 85th anniversary of the Pertzov White Sea Biological Station, WSBS, Russia (2023)
- All-Russian Conference with international participation: XIV All-Russian Conference with international participation "Problems of studying, rational use and protection of natural resources of the White Sea", Saint-Petersburg, Russia (2022)
- International Conference: Marine Biology, Geology, Oceanology: Interdisciplinary Research at Marine Stations 80th anniversary of the Nikolai Pertsov White Sea Biological Station, Moscow, Russia (2018)
- All-Russian Conference with international participation Mycology and Algology in Russia. XX - XXI centuries: Change of Paradigms, dedicated to the 100th anniversary of the Department of Mycology and Algology, Moscow, Russia (2018)
- 13-th International Conference on Salt Lake Research, Ulan-Ude, Russia (2017)

Societally relevant exposure (1 ECTS)

- Magazine interview (in Russian): "7 questions to mycologist Olga Grum-Grzhimaylo" https://expert.ru/russian_reporter/2014/40/7-voprosov-olge-grum-grzhimajlo-mikologu/ (2014)

Lecturing/Supervision of practicals/tutorials (6 ECTS)

- Lichenology, practical field course, 24 days every summer (2012-2024)
- Small workshop on mycology and algology, 16 days (2009)

BSc/MSc thesis supervision (5 ECTS)

- Xenia Moroz, BSc thesis: Bacteria and fungi associated with the White Sea sponge *Halisarca dujardinii*
- Iuliia Kokurkina, BSc thesis: Fungi associated with the hemichordate enteropneustans *Saccoglossus mereschkowskii* (Wagner, 1885) from the White Sea