# ARCTIG AND ALPINE MYCOLOGY





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## АРКТИЧЕСКАЯ И АЛЬПИЙСКАЯ МИКОЛОГИЯ

### 5

Труды пятого Международного симпозиума по Аркто-Альпийской микологии (Лабытнанги, Россия, 15-27 августа 1996)



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## ARCTIC AND ALPINE MYCOLOGY

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Proceedings of the Fifth International Symposium on Arcto-Alpine Mycology (Labytnangi, Russia, August 15-27, 1996)



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The papers by the participants of the Fifth International Symposium on Arcto-Alpine Mycology are presented in this book. They consider a wide range of questions concerning biological diversity of fungi and myxomycetes in the ecosystems of high latitudes and altitudes. A number of papers are devoted to fungal ecology, evolution of alpine and high latitudinal mycobiotas, and their existence under the influence of anthropogenic factors.

The book is for mycologists and ecologists studying ecosystems of the Arctic, Sub-Arctic and highlands, and the problems of their conservation and rational use.

В книге представлены материалы докладов участников V Международного симпозиума по Аркто-Альпийской микологии. В работах рассмотрен широкий круг вопросов, касающихся биологического разнообразия грибов и миксомицетов в экосистемах высоких широт и высокогорий. Ряд материалов посвящен вопросам экологии грибов, эволюции высокогорной и высокоширотной биот грибов, влиянию на них антропогенных факторов.

Книга адресована микологам и экологам, занимающихся изучением экосистем Арктики, Субарктики и высокогорий, а также проблемами их охраны и рационального использования.

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8

The first Symposium on Arcto-Alpine Mycology took place in 1980 in the USA where the scientists interested in the study of fungal biodiversity and ecology of the arctic and alpine ecosystems met for the first time. It was followed by the Symposia in Switzerland, Norway (Spitsbergen), France (the Alps) and Russia (the Polar Urals). There are some rules of an ISAM organization: scientific discussions and field work are combined; the number of participants is limited up to 25 people, a Symposium lasts a fortnight; it is conducted every four years. The organizing and conducting of a Symposium is entrusted to its President who is elected by the participants' direct vote. The President is responsible for the publication of the abstracts before the session and the Symposium proceedings afterwards.

The programme of the Russian Symposium was geared to the solution of three general sets of problems. One was to sum up the results of the study of arctic and alpine fungi that had been carried out for four years after ISAM 4. The second was the biodiversity of fungi, ecological and geographical patterns of their distribution, their role in the arctic and alpine ecosystems and their protection. The third concerned field excursions to the Polar Urals and the arctic regions of Yamal Peninsula, five of which took place during the Symposium.

The Organizing Committee of the Symposium consisted of Dr. H. Knudsen (Botanical Museum, University of Copenhagen, Denmark), Prof. Dr. O.K. Miller (Virginia Polytechnic Institute and State University, USA), Academician V.N. Bol'shakov (director of the Institute of Plant and Animal Ecology, Russia), Dr. Ye.P. Romanov (learned Secretary of the Ural Division of the Russian Academy of Sciences), and Prof. Dr. Ye.A. Pamyatnykh (Vice-Dean of the Ural State University, Russia). Special thanks must be given for the tireless efforts of its Secretary, Irina Goldberg, who also helped me with the work on this volume. I am deeply indebted to Yevghenya Romanova for her briliant translations at the Symposium and linguistic edition of the Proceedings. I should personally wish to thank my co-editor, Henning Knudsen, for all his efforts and support during the Symposium and the production of this volume.

The Organizing Committee is most grateful for the support of the Administration of Yamal-Nenets autonomous district and its governor, Yury Neyolov, and the Chairman of local Committee for Nature and Natural Resourses Protection Valery M. Shishmaryov.

There is no doubt that the fifth Symposium contributed to the increased interest of Russian mycologists and ecologists in the arctic and alpine mycobiotas research. The series of these unique scientific meetings doesn't stop at that. ISAM 6 is to be held in the year 2000 in Greenland — in one of the most beautiful and mysterious parts of the earth. I wish its President, Torbjoern Borgen, a great success in preparing and conducting of this important scientific forum.

President of ISAM 5,

Prof. Dr.,

p. Mexo V.A. Mukhin

#### The Fifth International Symposium on Arcto-Alpine Mycology, Labytnangi, Russia, August 15-27, 1996

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The participants were arriving on August 12-14 and were accommodated at the biological station of the Yekaterinburg Institute of Plant and Animal Ecology, where the Symposium was to be held. At the same time the Botanical Institute of St. Petersburg was conducting the VIth Field Meeting for Young Mycologists there, and some sicentists took part in both events.

August 15. It was the opening day of the Symposium. The first meeting began in the afternoon. The participants were greeted by the President of ISAM 5, Victor Mukhin (Institute of Plant and Animal Ecology, Yekaterinburg, Russia), and the Chairman of the Committee for Nature and Natural Resourses Protection of Yamal-Nenets autonomous district, Valery Shishmaryov (Salekhard, Russia) who spoke about social and ecological problems of the region (see  $\rho$ . 15). The Director of the biological station, Victor Shtro (Labytnangi, Russia), welcomed his guests.

After that the official sitting grew into a scientific session. The first lecture was delivered by Henning Knudsen (Botanical Museum, Copenhagen, Denmark) on the results of studies of fungi in Greenland. He also took an opportunity to greet one of the participants, Professor Morten Lange, who could celebrate his fiftieth jubilee as a still active arctic mycologist, since he started this career in Greenland in 1946.

Then Dr. Stepan Shiyatov of the Institute of Plant and Animal Ecology (Yekaterinburg, Russia) reported about research in the field of climatic forecasting according to changes in the developmental schedule of different timber species in a certain geographical area.

During a short break a collective photo of the participants was taken , and Mr-s Mukhin and Knudsen were interviewed by the local cable TV reporters.

The second part of the session was opened by Andrzej Chlebicki (The Insitute of Botany, Wrocław, Poland). The main subject of his lecture was dryadicolous microfungi of the Circumpolar Area. Comprehensive data on that material were presented by the speaker.

The report made by Igor V. Karatygin (Botanical Institute, St. Petersburg) was dedicated to the results and prospects of mycological investigations in the Russian Arctic. The first session was decorated with the posters by the young scientists, Olga Morozova and Yelizaveta Fomina (St. Petersburg), and Olga Lazareva (Yaroslavl).

In the evening the first party was held. The conference-hall was converted into a banquet house. Traditions of different nations reigned in the hall. That was a very uniting moment.

August 16. The bus took the mycologists to the environs of the Kharbey river. The place was typical forest-tundra. The scientists had been collecting for four hours. Apart from their scientific specimens they picked widely known mushrooms and toadstools, because the day of August 17 had been assigned for the exhibition of popular mushrooms for the residents of Labytnangi.

In the evening the first Yamal-96 collection was being identified.

**August 17**. The day was rainy. In spite of that some participants went by boat along the Ob river to Gornoknyazevsk village. While they were collecting, the people from St. Petersburg prepared the promised exhibition, which was opened at 12 o'oclock. At 5 p.m. all the social and field events were finished, and a couple of hours later a scientific session began.

Olga Ye. Marfenina of Moscow State University (Russia) was the first to take the floor. She spoke about the distribution of soil microfungi in the arctic and alpine areas and its dependence upon the elevation above sea level and the level of pollution.

Ola Skifte (The University of Tromsoe, Norway) presented a short account of his investigations of ectomycorrhizal and saprophitic macrofungi associated with *Dryas octopetala* in Spitsbergen.

A short break preceded Alexander Ye. Kovalenko's lecture (Botanical Institute, St. Petersburg, Russia). He analyzed *Hygrophoraceae* of the Russian Arctic. The session was closed by the report by Yury K. Novozhilov, the only myxomycete specialist present at ISAM 5. The idea of the necessity of a large-scale research was repeated more than once in the report.

**August 18.** The participants went by train to the Polar Urals and worked on the southern macroslope of Slantsevaya Mt. covered with spruce-larch and birch-alder woods, and different types of alpine tundra.

That was the field excursion which gave everyone the opportunity to take their time, and to collect not only specimens, but also striking impressions made on them by the magnificent mountainous scenery.

August 19. The first part of the day was free, so the mycologists could identify the collections made the day before.

At the evening session four lectures were presented. Torbjoern Borgen spoke about the results of his studies of *Cortinarius* subgenus *Telamonia* in Greenland. The next speaker was Heikki Kotiranta (Finnish Environmental Institute, Helsinki). He told how to protect threatened polypores, referring to the Finnish experience. His lecture was illustrated with beautiful slides. His compatriot Esteri Ohenoja (The University of Oulu) continued the proceedings after a short break. She delivered a lecture on the genus *Inocybe* in the arctic regions of Canada, where she collected in 1971 and 1974. Stanislav Arefyev (The Institute of North Development, Tyumen, Russia) reported on xylotrophic fungi of the subarctic towns of Russia, giving an example from Nadym. His lecture contained a number of unusual ideas, which set off a heated dispute between the author and Knudsen.

At the end of the scientific session the posters by the young mycologists Anna Liisa Paulus (The University of Oulu, Finland), Ursula Peintner (Institute for Microbiology, the University of Innsbruck, Austria) and Anna Ivanova (Moscow State University, Russia) were discussed. August 20. The scientists went by helicopter to Cape Nyarusalye, located on the coast of the Kara Sea. It was very low, wet and boggy ground, covered mainly with *Salix glauca*. Before the helicopter could land the pilots had to look for dry plots on tops of small hills. But the mycobiota of this special piece of land was so rich and diverse that some participants decided afterwards that if the symposium had been closed that day it would have been just the right thing to do (to get some extra time for work with collections). Quite a few believed that just that day they had come very close to a number of scientific discoveries. The rest of the day was spent in large mycological companies, exchanging information and shrewd remarks.

August 21. The whole morning and even part of the afternoon were dedicated to the same occupation the scientists had been immersed into the previous evening. They did not want to stop even at five p.m. when the last scientific session of the symposium started.

That session was conducted by Andrzej Chlebicki, as President was getting ready for his own report, which was preceded by three others. Morten Lange delivered a lecture on his new records of the arctic gasteromycetes from the genera *Clavatia* and *Bovista*. It was really excellent, and when he finished, all the participants began to applaud. Tatyana Penzina made a report on the mountainous mycobiota of the northern Baikal area. Henning Knudsen spoke about the preliminary results of the the West Siberian fungi study conducted together with Victor Mukhin. The concluding part of ISAM 5 was President's lecture about the origin and evolution of the cryophylic mycobiota of Eurasia. As the final point of the symposium, the persisting idea about the common origin of the whole arctic mycobiota sounded again.

And the difficult and tiring day was finished by a wonderful and emotional farewell party where the participants were saying good-bye to Esteri Ohenoja and Annu Paulus.

August 22. The mycologists went by the small ship «Ecologist» down the Ob river to Katrovozh village located in the northern taiga zone. The long rainy way took them four hours leaving only two for collecting. The site was highly influenced by the village and contained few species as compared to the previous trips. It was just such a place where Morten Lange expected to find *Bovista nigrescens*, and he was very happy after he had succeeded.

As the way back took the entire afternoon the team were home when it was completely dark and identifying work was postponed until morning.

**August 23.** After working with the collections in the first part of the day, the business meeting began. President spoke about the results of the ISAM and nearly everyone took the floor afterwards to say greatful words to the organizers and to sum up their personal achievements. It was noted that the representatives of different branches of mycology had got an opportunity to study the same regions. Besides, many young mycologists participated in the work of ISAM 5, and it was new for this kind of symposia.

All the participants were unanimous in their opinion to arrange the next Symposium in Greenland in 2000. They elected Torbjoern Borgen to be President of ISAM 6.

That day was concluded by lots of fun due to Henning Knudsen's birthday party. All the participants came to wish him happiness and scientific success.

August 24. The researchers went to Slantsevaya Mt. in the Polar Urals again, because the first collection from the site was very interesting. That day it was as windy as the first time, but that wind did not bring rain, it delivered snow. The biologists were wet all through and cold. They were climbing the rocks to get warm. The collections rapidly grew and an hour before the train arrival the scientists were standing around a big field fire and crying with smoke. The long way back exhausted the remains of the mycologists' forces and identifying process waited untill the following morning.

**August 25**. The Danish delegation got together for their last laboratory session in Labytnangi. All of them (including also Ola Skifte from Norway) were leaving on Monday, so, they tried to do as much as possible and had stopped only by night to take part in their farewell party.

**August 26**. That was the last helicopter trip to a wonderful place in the Polar Urals called Yangana-Pe. The range consisted of limestone and was covered with light larch forests and alpine tundra with carpets of beautiful lichens and mosses.

The helicopter pilots kindly showed the guests many places of interest in the tundra, and the passengers could see and take pictures of waterfalls, swans in small lakes, colourful hills and plains, beautifully lit clouds. In Labytnangi the participants left the helicopter and the Danes, who were then delivered directly to Salekhard airport.

**August 27**. That was the date of ISAM 5 closing. It was spent in sad preparations for leaving. In the evening Andrzej and Bozena Chlebicki and Heikki Kotiranta were holding a joint party. The following morning the Poles left by train, and the Finn by plane almost simultaneously.

**August 28**. The last to part with Labytnangi was Ursula Peintner, who went away on August 29, and the organizing committee stayed one more day to complete the story by flying back to Yekaterinburg on August 30.

#### **ISAM 5 FIELD EXCURSIONS**

Collecting sites were located in the northern part of the West Siberian plain, in different vegetational zones: the southern type of the subarctic tundra, forest-tundra and northern taiga, as well as on the eastern macroslope of the Polar Urals with vertical zonality.

August 16. The Kharbei river Valley. 67°01' N, 66°40' E.

Southern bushy tundras and forest-tundra with larch (Larix sibirica Ledeb.) dominated by dwarf birch (Betula nana L.) and mixed with Salix phylicifolia L., S. pulchra Cham., Alnus fruticosa Rupr. Herb layer consisted of Carex globularis L., Rubus arcticus L., Vaccinium uliginosum L., Empetrum nigrum L., Carex rotundata Wahlenb., Lycopodium dubium Zoega and Angelica archangelica L. Moss-lichen layer was well developed, with predominance of Pleurozium schreberi (Brid.) Mitt., Aulacomnium turgidum (Wahlenb.) Schwaegr., Polytrichum commune Hedw., P. strictum Brid., Dicranum elongatum Schleich. ex Schwaegr., D. congestum Brid., Cladonia gracilis ssp. elongata (Wulfen.) Vain., C. amaurocraea (Flörke) Schaer., Cladina stellaris (Opiz) Brodo, C. arbuscula ssp. mitis (Sandst.) Burgaz, Nephroma arcticum (L.) Torss., and Parmelia septentrionalis (Lynge) Ahti. August 17. The vicinities of Gornoknyazevsk village. 66°37' N, 66°50' E.

Northern taiga zone. Larch-spruce (*Picea obovata* Ledeb.) forests in combination with birch (*Betula pubescens* Ehrh.) stands growing on sandy soil.

August 18 and 24. The Polar Urals, Rai-Iz natisif, the southern slope of Slantsevaya mountain. 67°01' N, 66°48' E.

Altitudinal belts were well differentiated. At low altitudes (up to c. 100 m above sea level) there were larch-spruce forests with rowan (Sorbus aucuparia L.). Sub-goltsy belt (up to c. 300 m) consisted of elfin-woods with Betula tortuosa Ledeb. and Alnus fruticosa, and open stands of larch. The goltsy belt was presented by different types of alpine tundras. The most common were scree «spotty» crowberry (Empetrum nigrum) — dwarf birch tundras, «spotty» mountain avens (Dryas octopetala L.) tundras with hypoarctic dwarf shrubs and Salix nummularia Anderss., moss — dwarf birch tundras dominated by mosses (Hylocomium splendens (Hedw.) Schimp. in B.S.G., Aulacomnium turgidum, Dicranum spp.) and different liverworts, and moss tundras with mesophilous herbs — Carex misandra R. Br., C. ledebouriana C.A. Mey ex Trev., C. arctisibirica (Jurtz.) Czer., Hierochloë alpina (Sw.) Roem. & Schult., Luzula confusa Lindeb., Lloydia serotina (L.) Reichenb., Polygonum viviparum L., Pedicularis amoena Adams ex Stev., P. oederi Vahl, etc. Along water streams, Salix glauca L. and Salix lanata L. agglomerations were common.

August 20. The coast of the Kara Sea, Nyarusalye Cape. 68°30' N, 67°00' E.

The southern moss bushy tundras dominated by dwarf birch. The most frequent species were Salix phylicifolia, S. pulchra, S. polaris Wahlenb., Empetrum nigrum, Ledum spp., Vaccinium uliginosum, Arctous alpina (L.) Niedenzu as well as Carex arctisibirica, Calamagrostis neglecta (Ehrh.) Gaertn, Mey & Schreb., Luzula frigida (Buchenau), Hierochlon alpina, and Equisetum arvense L. The dominant species of continuous moss cover were Aulacomnium turgidum, Dicranum spp., etc. Moister depressions were occupied by Salix glauca and S. lanata formations with well developed moss layer containing patches of Sphagnum spp. Around numerous pools along the shore, Eriophorum sp. grew.

August 22. Surroundings of Katrovozh village. 66°20' N, 66°05' E.

Northern taiga zone. Spruce-larch forest with continuous moss cover, which consisted of green mosses (*Pleurozium schreberi*, *Hylocomium splendens*). Herbs and dwarf shrubs were not abundant, the most common among them were *Vaccinium myrtillus* L., *V. vitisidaea* L., *Empetrum nigrum*, *Rubus chamaemorus* L., and *Carex globularis*. There were also birch (*Betula pubescens*) stands which were considered to be of the secondary origin.

The forests were in combination with bogs dominated by dwarf birch, *Sphagnum* spp. and lichens.

The whole area was under anthropogenic impact.

August 26. The Polar Urals, Yangana-Pe limestone range. 67°43' N, 67°50' E.

Open stands of larch with dwarf birch. Tundras dominated by mosses and liverworts (*Rhytidium rugosum* (Hedw.) Kindb. *Dicranum spp.*, *Ptilidium ciliare* (L.) Hampe), and hypoarctic dwarf shrubs (*Empetrum spp.*, *Vaccinium uliginosum*, *V. vitis-idaea*, *Ledum spp.*, *Arctous alpina*). Lichens were not abundant.

#### YAMAL-NENETS AUTONOMOUS DISTRICT: NATURAL ENVIRONMENT AND CONDITIONS

VALERY M. SHISHMARYOV

#### Committee for Nature and Natural Resourses Protection of Yamal-Nenets autonomous district, Salekhard, Russia

Abstract: Natural conditions of Yamal-Nenets autonomous district are described. General characteristic of fauna, vegetation and soils is given. Actual problems of nature protection are discussed.

Описываются природные условия Ямало-Ненецкого автономного округа. Дана общая характеристика животного, растительного мира, почвенного покрова и т.д. Обсуждаются актуальные проблемы охраны окружающей среды.

Keywords: the Arctic, the Sub-Arctic, Western Siberia, nature protection.

Famal-Nenets autonomous district (YNAD) was founded in December, 1930. The territory lies in the northmost part of the West-Siberian plain. Its area is 750,300 square kilometres, including the lower course of the Ob river and its tributaries, the basins of the Nadym, Pur and Taz rivers, Yamal, Tazovsky, Gydansky peninsulas, the islands in the Kara sea and the eastern slopes of the Pripolyarye and the Polar Uras. About half the district area (47%) lies beyond the Arctic Circle. In the north marine plains (small shallow lakes, terraces, knolls) that emerged from under sea level during the late glacial and post-glacial age, are adjacent to the shores of the Kara sea and its bays. Towards the south morains and water-ice plains are located, the main features of whose landscape were formed due to the Quarternary glaciers.

The distinctive feature for the district is the predominance of cyclonic type of weather throughout a year, especially during the periods of change between the seasons and in early winter. Due to it, there are very many cloudy and foggy days. Strong winds are also common. The high latitudinal location of the district, meagre influx of solar radiation, long distance from the warm air and water masses of the Atlantic, flat landscape exposed to arctic air masses in summer and cold continental masses in winter account for its hard climate. The climate is influenced by permafrost, proximity of the cold Kara sea, sea bays cutting deep into land, big number of bogs, lakes and rivers. The continent of Asia also has its effect, which can be noticed in distinct winter-summer transformations of air masses and growth of the continentality of climate from the north-west to the east.

The average annual temperature is below zero in the south of the district and below -10°C in the Extreme North. The warmest month in the south is July, in the north late July-early August, when the temperature can be as high as 30 over the whole territory. The coldest month is January with the lowest temperature in the south-east of the district because of the long distance from the sea and increasing continentality of climate. The annual precipitation ranges from 220 mm in the Extreme North to 450 mm in the south, most of it falling in June-September as rain.

The district area is characterized by enormous deposits of phreatic and connate water, enclosed in a number of large and small lakes, vast marsh sites, slow rivers, abundant ground waters and large artesian basins. The main rivers of the district are Ob, Taz, Pur, Nadym, Shchuchya, Polui, Synya. Their source is mainly snow, partially rain and marsh-groundwater. Therefore, river overflowing is caused by snow melting and reaches its acme in June. Ice melting on the rivers of YNAD lasts up to seven-eight months a year. The district can be called a country of lakes. Most of them are comparatively small and shallow, but some, like Yarroto, Shuryshkarsky Sor, have 0.0200 square kilometres of area, and the depth of Bolshoye Shchuchye lake is 136 m. Most lakes are of glacial origin. The huge water reservoirs are marshes. A lot of factors contribute to the forming of marshes, such as the flat surface and tectonic regime of the territory with a tendency to descend, poor drainage, excessive saturation, permafrost.

The soil and vegetation of the territory have two main properties — classical zonality and high hydromorphism. In the Extreme North tundra, arctic, gley and bog peat soils are common. Podzolic soils lie in river areas, which have good flow of excessive moisture. In northern taiga gley and podzolic, bog and podzolic and bog peat soils are common.

Within the district, latitudinal zones of vegetation can be easily isolated — tundra, forest-tundra and the subzone of northern taiga. In arctic tundra, on the coast of the Kara sea, the vegetation is scarce, mainly made up by fruticose lichens, green mosses and the sedge. To the south there is moss-lichen tundra with some shrubs of the dwarf birch and willow. Even farther south vegetation is more abundant and the Labrador-tea, the cloudberry, the bog bilberry, the dwarf birch are distributed here. Willow shrubs in river valleys reach up to three metres of height. In summer the south of tundra is decorated with flowers — yellow globe-flowers, forget-me-nots, yellow and lilac louseworts etc. In tundra among the dwarf woody vegetation there are a big number of mushrooms — russules, the woolly milk lactarius, the shaggy boletus, and berries — the cloudberry, the bog bilberry, the arctic bramble. The zone of forest-tundra 15-200 km wide stretches from the west to the east. Tundra vegetation alternates here with larch, birch and spruce trees. Because of severe climate and close to surface permafrost in forest-tundra light forests prevail, trees grow slowly and are short. North taiga is characterized by widely spread permafrost and prevailing woodless large-knolled sphagnioprata that form large territories. Forests take up about one third of the area, are very light and short (8-10 m). Among them the most common are larch forests. More humid habitats are occupied by spruce-birch-larch and spruce forests.

The animals of the territory described are fairly versatile. In the zone of tundra the arctic fox, the wild reindeer, the arctic wolf, the hare, the stoat, and a number of mice — lemmings, snow mice, shrews, occur. On the isles and the coast of the Kara sea the polar bear is found. In coastal waters of the sea whales are represented by the white whale, and seals by the walrus, the Grenlandic seal, the bearded seal. In summer over 75 bird species live in tundra (the snowy owl, the willow grouse and ptarmigan, the snow bunting, skuas, waders, ducks, swans, geese). Almost all birds spend just summer in tundra, only the snowy owl and the ptarmigan stay over winter, too. In southern tundra the common lizard, the newt (Siberian salamander), the brown frog and the narrow-mouthed toad. In forest tundra both tundra and taiga animals live. The elk, the brown bear, squirrels, muskrats, the three-toed woodpecker, the two-barred crossbill and flocks of willow grouses. Only about twenty years ago the musk ox was acclimatized and its families have been living in Gydansky peninsula for two years.

The animals of taiga is much more versatile — the squirrel, the Alpine hare, the brown bear, the wolf, the fox, the stoat, the sable and others. The insectivorous — the mole, the



The Sub-Polar Urals Приполярный Урал



Rhodiola quadrifidum Pall. The Polar Urals Родиола четырехчленная. Полярный Урал



The Sub-Polar Urals Приполярный Урал

Dryas octopetala L. Yamal Дриада восьмилепестная. Ямал





Campanula rotundifolia L. The Sub-Polar Urals Колокольчик круглолистный. Приполярный Урал

Fomitopsis cajanderi (P.Karst.) Kotl. & Pouz. Included in the Red Book of Yamal-Nenets autonomous district Трутовик Каяндера. Занесен в Красную книгу Ямало-Ненецкого

автономного округа



by H. Kotira



The Varykhadyta river Река Варыхадыта

Polyporus squamosus Huds.: Fr. Included in the Red Book of Yamal-Nenets autonomous district Трутовик чешуйчатый.

Занесен в Красную книгу Ямало-Ненецкого автономного округа





The Sub-Polar Urals Приполярный Урал

Albatrellus syringae (Parm.) Pouz. Included in the Red Book of Yamal-Nenets autonomous district

Щитоносец сиреневый. Занесен в Красную книгу Ямало-Ненецкого автономного округа





Trichaptum pargamenum (Fr.) G. Cunn. Власяница изменчивая



Amanita muscaria (L.: Fr.) Hooker. Included in the Red Book of Yamal-Nenets autonomous district Мухомор красный. Занесен в Красную книгу Ямало-Ненецкого автономного округа



Asplenium viride Huds. Костенец зеленый



Dichomitus squalens (P. Karst.) Reid. Included in the Red Book of Yamal-Nenets autonomous district Трутовик шероховатый. Занесен в Красную книгу Ямало-Ненецкого автономного округа



Lyophyllum ulmarium (Bull.: Fr.) Kuhn. Included in the Red Book of the Yamal-Nenets autonomous district Бокоух ильмовый. Занесен в Красную книгу Ямало-Ненецкого автономного округа

Datronia scutellata (Schw.) Gilbn. et Ryv. Included in the Red Book of Yamal-Nenets autonomous district. Трутовик ольховый. Занесен в Красную книгу Ямало-Ненецкого автономного округа



shrew, the hedgehog; the bats — the long-eared bat, the hoary bat. The birds are more diverse in taiga than in tundra: ducks, geese, snipes, great snipes, curlews, waders etc. In addition, there are the goshawk, the golden eagle, the rough-legged hawk, the white-tailed sea eagle. The reptiles and fresh-water inhabitants — the viper, the grass snake, the grey toad and the common lizard. A big number of bogs and humid air are favourable for the reproduction of insects, especially the two-winged (mosquitoes, biting midges, true midges, gadflies), and the May beetle, the pine midget, the pine Siberian silkworm and gipsy moth, the hill ant and others.

Fish has the great importance for economy. A lot of food in river floodplains and lakes and sufficient number of spawning sites distribute to the reproduction of fish. There are over 40 fish species in the water reservoirs of the district, thirty of them are industrial. There are a big number of Sturgeons — the great Siberian sturgeon and the sterlet; Salmons — the Siberian white salmon; lake white-fishes — muksun, the Siberian and broad whitefishes, cisco and others.

The territory of YNAD is very rich in fossil fuels, because of its geological evolution and tectonic structure. Especially in gas and oil. Along with enormous gas deposits in the Sub-Polar and Polar Urals a number of promising deposits and ore exposures of lead, bauxites, chromites, copper, iron, gold and rare metals. Considerable stores of gravel, limestone, granite and brown coal were discovered there, too. They outline the current condition and the perspectives of long-term economic development of not only the region but also of Russia.

We are facing an important task to utilize the fossil resources causing as little damage to nature as possible, as both are necessary for the man. At present in Yamal-Nenets autonomous district we have Verkhne-Tazovsky reserve, ten state zoological preserves and Synsko-Voikarskaya ethnic territory. They were set up to protect different animal and plant species inhabiting the area. The materials on Yamal reserve, the ethnic natural park Numto and four preserves have been collected. The establishing of Gydansky reserve has been officially approved. The urgent need to reserve the territory has arisen. Strictly protected sites will soon make about 8% of the district area. The law basis for nature protection has been set up in the district. The projects «On the territories specially protected», «On hunting and hunting industry», «On fishing and fish industry», rules for fishing and hunting have been developed. The methods of estimating damage caused to animals and plants have been drawn.

Despite the hard times and no due financing, the assessment of animals by making cadasters has started in the district. The rating of the numbers of elk and wild reindeer fulfilled from the air revealed the anthropogenic influence on their distribution, caused by the industrial exploration of new territories. For example, in Purovsky district the population of the wild reindeer was ousted to the north, so far not occupied by oil and gas producing plants. Nevertheless the numbers of nadym-purovsky population has increased nearly 3.5-fold as compared with the 1980s and has about 20,500 individuals now. There are about 5,000 elks, 800 brown bears, over 12 mln ducks and 470,000 geese in the district. In 1996 the sea mammals were rated. The monitoring of fish resources and fish environments is being conducted. The urgent measures against poaching have been developed and launched.

To cause the least possible damage to biological resources while exploring fossil fuel deposits, ecology experts carefully study the parts of projects that concern estimates of human impact on animals and plants. Their principles rest on Peter the Great's words: «All the estates in service and the owners of manufactures and other craftsmen must remember: all the projects must be properly made in order not to impoverish the Treasury in vain and not to do wrong to the Motherland».

#### COMMUNITIES OF XYLOTROPHIC FUNGI IN URBAN CENTRES OF THE NORTH OF WESTERN SIBERIA

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Abstract: The structure of xylotrophic fungal communities has been studied in the towns of the West Siberian Sub-Arctic and Hypo-Arctic. The highest diversity is displayed by the communities with moderate anthropogenic transformation. The obtained results enable us to use the characteristics of xylotrophic fungal communities in bioindication and biomonitoring.

Исследовалась структура ксилотрофных грибов в городах Субарктики и Гипоарктики Западной Сибири. Самыми богатыми оказались сообщества, подвергшиеся умеренной антропогенной трансформации. Полученные результаты позволяют использовать характеристики сообществ ксилотрофных грибов для целей биоиндикации и биомониторинга.

Keywords: Basidiomycetes, wood decay, communities.

Хуlotrophic fungi are the most important group of biological destructors, characteristic of all biogeocenoses which include trees and shrubs. They are also widely distributed in the northern thermodeficient zone of Western Siberia, which represents quite a large plane sector of the Sub-Arctic and Hypo-Arctic. According to the research by Mukhin (Мухин, 1984, 1987, 1991a, 1995), 175 xylotrophic species have been found in the northern taiga zone of Western Siberia, 119 in the forest-tundra, 32 species in shrub tundras. Although materials reported from the region have to do mostly with fungal communities, which suffer no or scarce human impact, Mukhin (Мухин, 1984) rightfully supposes that a number of species are adventitious (*Gloeophyllum odoratum* (Wulfen) Imaz.), which is clear from the investigation of the railway and wood-cutting site conducted in Labytnangi in the 1950s. Anthropogenic communities of xylotrophic fungi that appeared in the north of Western Siberia during oil-gas industrialization in the 1970-1990s are even more interesting to study.

Research undertaken in more favourable forest conditions of some European countries and Russia (e.g. Adamczyk & Ławrynowicz, 1991; Skirgiełło, 1991; Юпина, 1987; Малеев и др., 1989; Переведенцева & Механошин, 1990; Мухин, 1991b; Василяускас, 1991; Бондарцева & Свищ, 1991; Крутов, 1992; Югасова, 1992; Яковлев, 1992; Тихомирова & Тобиас, 1994; Брызгалов, 1995), has displayed high sensitivity of xylotrophic fungi to anthropogenic transformation factors, possibilities of their



Fig. 1. Western Siberia, study area: 1- forest-tundra; 2- subarctic forests; 3- northern taiga; 4- middle taiga; 5- southern taiga

application to bioindication and monitoring under forest conditions, and peculiarity of urban fungal communities. These speculations and considerable scientific interest in the northern ecosystems gave rise to our research in 1995 within the programme «Yamal» of the Russian Joint-Stock Company Gazprom (Биологическое разнообразие..., 1995; Арефьев, 1996).

In this work xylotrophic fungal communities of the industrial centres of Western Siberia located to the north of the forest zone hydrothermal optimum beyond the watershed of Sibirskiye Uvaly are considered. The forest-tundra zone is represented by the towns of Labytnangi and Novy Urengoi, the northern taiga zone by Noyabrsk and Beloyarsky and the district centre Beryozovo. The transitional zone between them, which refers to the vicinities of the hypoarctic forest-tundra (Комплексное..., 1980), is represented by the town of Nadym and district centre Krasnoselkup (Fig. 1).

#### Material and methods

The long-term purpose of the research is mycoindication and mycomonitoring of the forest environmental condition, that is why the most appropriate subject is the consorcium of xylotrophic fungi (first of all, so-called polypores) evolving on birch wood. A wide geographical and biotopic birch distribution and its constant presence in natural and anthropogenic communities is what matters here. Polypores are the most advanced group of xylotrophic fungi, which decompose the basic pool of wood. Their fruitbodies develop quite regularly, live throughout a year and are comparatively easy to identify, which is important for field quantitative studies.

Quantitative surveys of fungi were held in 1995-1996 according to the simplified (without mentioning the area) method by Mukhin (Мухин, 1984). In sites that are homogenious in their main biogeocenotic features, fungi and fruitbodies were studied on wood substrates (usually a whole tree or its intact part). All fruitbodies of one species evolving on a substrate regardless of their number have been considered to be one individual. Species occurrence has been calculated as a ratio (%) of infected substrates to all registered substrates. For the comparative evaluation of specific diversity Simpson's (R) and Shannon's (-H) indices of diversity have been determined. In general, within this work 21 sites have been studied and 3386 specimens of 38 xylotrophic species on 2526 substrates have been considered.

Afterwards, the results have been arranged in accordance with four main types of anthropogenic transformation: natural and almost natural communities; burnt forests, usually of anthropogenic origin; urban and suburban communities with complex anthropogenic transformation (random cuts and mechanical damage to trees, air contamination, trampling, floodings, various pyrogenic damages, waste and other factors); parks and other artificial stands of cities and settlements.

#### **Results and discussion**

The data from the Table show that the biggest specific diversity is often reported from urban and suburban anthropogenic communities (from 14 species in the foresttundra to 23 in the northern taiga, R = 4.2-10.9, respectively). The total of specific diversity of natural communities is lesser and is constituted by 8-15 species (R = 3.2-4.5). Burnt forests are intermediate in this regard, having the biggest variety of diversity indices (7-23 species, R = 2.5-5.1). The same refers to the peculiarity of mentioned communities species composition. Out of eight species, found only in one of the studied sites, six have been encountered in anthropogenic communities, two in burnt forests, none in natural cenoses.

The specific diversity of monotypic communities increases southwards from the foresttundra to the northern taiga. The biggest diversity in all the characteristics (23 species, R = 10.9) has been reported from the environs of Beryozovo, located in the taiga zone in the vast valley of the Severnaya Sosva and Ob rivers. Besides, in sites with infertile sandy soils it can be lower than in northern localities having relatively more fertile soils. Thus, comparatively low specific diversity of fungi is conspicuous in the environs of Noyabrsk (14 species, R = 7.0), which is located in the taiga zone in the sandy watershed of Sibirskiye Uvaly. It is even lower than for similar communities of Beryozovo and Beloyarsky, located in the same latitude and for the community of Novy Urengoi, situated in forest-tundra (19 species, R = 7.2).

#### TABLE

#### Wood-decaying fungi occurrence (% substrates) in the urban centres of Western Siberia

	Towns, settlements; type of community anthropogenic transformation Family Ib "-" NII Nd "-" "-" Ks "-" "Nb Rl "-" Rr "-"														
Family	Lb	"_"	NU	Nd	" <u>"</u> "	"_"	Ks	"-"	"_"	Nb	Bl	"_"	Br	"_"	"-"
Species	Ь	cat	cat	nat	b	cat	nat	b	cat	cat	Ь	cat	nat	cat	prk
APHYLLÖPHORALES															
PORIACEAE															
Bjerkandera adusta	-	1	<1	<1	-	2	•	<1	3	1	•	4	-	3	6
Cerrena unicolor	-	44	19	3	1	4	2	2	27	6	<1	6	-	14	10
Daedaleopsis confragosa	5	1	1	2	1	-	•	2	2	2	5	1	6	1	10
Datronia mollis	-	-	-	-	-	-	-	-	-	-	-	<1	-	-	6
Fomes fomentarius	-	-	3	39	10	29	17	49	52	13	44	36	54	6	16
Fomitopsis pinicola	-	-	-	<1	1	-	-	2	1	3	3	10	2	-	-
Gloeophyllum sepiarium	11	-	1	-	1	-	-	1	-	1	1	-	-	-	•
Gloeoporus dichrous	3	1	8	2	2	1	2	3	2	•	1	1	-	-	3
G. taxicola	-	-	-	-	-	<1	-	-	-	•	-	-	-	-	-
Hapalopilus rutilans	-	-	-	<1	-	-	-	<1	1	-	1	-	-	1	-
Irpex lacteus	5	-	-	-	2	-	-	1	-	-	3	1	-	1	3
Lenzites betulinus	-	-	<1	-	-	-	•	•	-	-	<1	1	-	3	-
Piptoporus betulinus	54	1	3	18	63	11	54	55	16	13	57	10	34	11	-
Postia subcaesia	-	-	-	-	-	-		-	-	•	-	<1	-	-	-
P. tephroleuca	-	-	<1	-	-	-	-	<1	1	-	1	-	-	1	-
Pycnoporus cinnabarinus	-	-	<1	-	-	-	-	1	-	-	3	-	-	-	-
Skeletokutis nivea	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Trametes cervina	-	-	-	-	-	-	•	<1	•	-	-	-	-	-	•
T. hirsuta	-	-	-	-	-	-	-	•	-	-	-	<1	-	-	-
T. pubescens	-	-	2	-	-	-	-	<1	-	-	1	-	-	1	-
T. versicolor	-	13	26	2	1	9	-	2	26	18	4	29	3	22	16
+T. ochracea															
Trichaptum biforme	-	-	-	-		•	2	-	1	2	49	22	2	3	3
CORTICIACEAE															
Chondrostereum	-	24	-	-	-	-	-	<1	5	-	<1	-	-	15	3
purpureum															
Cylindrobasidium laeve	-	7	<1	-	<1	7	-	-	4	-	-	7	-	10	19
Laxitextum bicolor	-	-	-	-	•	-	-	-	-	1	-	-	-	6	-
Phlebia tremellosa	-	-	1	<1	<1	-	-	2	2	2	2	1	-	1	-
Plicatura nivea	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
HYMENOCHAETACEA	E														
Hymenochaete tabacina	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Inonotus obliguus	16	5	23	15	1	6	11	3	5	3	-	2	8	-	23
I. radiatus	-	2	4	1	-	1	2	•	3	-	-	1	2	1	-
Phellinus igniarius	5	2	18	35	13	14	22	8	5	19	2	21	16	6	-
P. laevigatus	-	1	1	1	-	1	-	<1	1	-	<1	2	2	2	-
STECCHERINACEAE															
Steccherinum ochraceum	-	-	-	-	-	-	-	<1	-		-	2	-	2	-
STEREACEAE												_		_	
Stereum hirsutum	-	10	12	2	5	5		1	13	26	8	7	-	15	3
S rugosum	-	-	-	-							<1	-	-		
S subtomentosum	-	-	-	-	-	-		-	-	-	3	-	-	-	3
CONIOPHORACEAE											-				•
Conjonhora nuteana			-	-				-			9	3	-	_	-
The total of: specimens	37	206	253	288	216	237	60	552	129	104	471	532	80	182	39
species	7	14	19	15	14	13	8	22	19	14	23	23	10	23	14
Simpson's index. R	2.9	42	7.2	45	2.5	56	3.2	33	7.6	$\dot{i}$	51	77	37	100	91
Shannon's index - H	1.4	1 8	22	18	15	20	15	17	22	วา	20	) 1 ) 1	1.6	7 6	7.1 7.1
Shumono muor, - 11	1.77	1.0	4.4	1.0	1.5	2.0	1.5	1.7	4.5	2.2	2.0	2.5	1.0	2.0	4.4

Note. Towns, settlements: Lb — Labytnangi; NU — Novy Urengoi; Nd — Nadym; Ks — Krasnoselkup; Nb — Noyabrsk; Bl — Beloyarsky; Br — Beryozovo. Types of community anthropogenic transformation: b — burnt forests; nat — natural and almost natural communities; cat — complex anthropogenic transformation of natural in origin urban and suburban communities; prk — parks and other artificial stands.

The peculiarity of anthropogenic fungal communities also grows from the north to the south. *Plicatura nivea* (Sommerf.: Fr.) P. Karst. has been found only in Labytnangi (forest-tundra), *Gloeoporus taxicola* (Pers.: Fr.) Gilb. & Ryvarden — only in Nadym (hypoarctic forests). In the northern taiga zone there are four species like that: *Trametes hirsuta* (Wulfen: Fr.) Pilát and *Postia subcaesia* (David) Jülich in Beloyarsky, *Hymenochaete tabacina* (Fr.) Lév. and *Skeletocutis nivea* (Jungh.) Keller in Beryozovo. *Trametes cervina* (Schwein.) Bres. has been found only in the burnt forest next to Krasnoselkup (hypoarctic forests), *Stereum rugosum* Pers.: Fr. — in the burnt place next to Beloyarsky. These particular species have been found in isolated cases, which clearly bears an incidental character.

Frequent and widespread species are a good quantitative characteristic of the community types under discussion. In natural forest-tundra fungal communities trunk parasites prevail — Inonotus obliquus (Pers.: Fr.) Pilát and Phellinus igniarius (L.: Fr.) Quél., followed by Inonotus radiatus (Sowerby: Fr.) P. Karst., which is more likely to be found on alder (Myxun, 1993). Southwards, closer to the northern taiga, they are added and then substituted by Fomes fomentarius (L.: Fr.) Fr. as a dominant, and Piptoporus betulinus (Bull.: Fr.) P. Karst. as a subdominant, Daedaleopsis confragosa (Bolton: Fr.) Schroet, Phellinus laevigatus (P. Karst.) Bourdot & Galzin, Fomitopsis pinicola (Sw.: Fr.) P. Karst. being in a recessive state. These fungi infect dead drying trees as ontocenogeny of forest communities proceeds. There are comparatively few birch-injured substrates of natural origin in the Sub-Arctic and Hypo-Arctic. Usually Gloeoporus dichrous (Fr.: Fr.) Bres. evolves on fallen wood, infected by the parasite Inonotus obliquus, Cerrena unicolor (Bull.: Fr.) Murrill on non-infected but injured substrates. Representatives of other ecological groups are incidental in occurrence.

As anthropogenic transformation takes place and natural ontocenogenic processes decrease, fallen wood is supplied mostly by cut wood and that from other kinds of injury. Therefore, in ripe forests the species mentioned are joined by a big group of ruderal species, which infect a host via wounds («wound species»), and depending on anthropogenic transformation level become dominants or subdominants. When young forests, where native ecological group species are absent, are transformed, ruderal wound species constitute the whole fungal community.

The most typical and eurytopic ruderal wound species is Trametes versicolor (L.: Fr.) Pilát, and also close to it T. ochracea (Pers.) Gilb. & Ryvarden (up to 30% substrates). Active species are also Cerrena unicolor (up to 44% in Labytnangi), Stereum hirsutum (Willd.: Fr.) Gray (up to 36% in Noyabrsk), Cylindrobasidium laeve (Pers.: Fr.) Chamuris (up to 19% in parks of Beryozovo), in damp sites — Chondrostereum purpureum (Pers.: Fr.) Pouzar (up to 24% in Labytnangi), Gloeoporus dichrous (up to 8% in Novy Urengoi), Postia tephroleuca (Fr.) Jülich (up to 1%), in ruderal habitats Phlebia tremellosa (Schrad.: Fr.) Burds. & Nakasone (up to 2%) occur regularly, though not so often. Datronia mollis (Sommerf.: Fr.) Donk, Laxitextum bicolor (Pers.: Fr.) Lentz, Bjerkandera adusta (Willd.: Fr.) P. Karst., Lenzites betulinus (L.: Fr.) Fr. (found in the forest-tundra zone on imported birch logs) are not very common either. But southwards in Beryozovo and Beloyarsky their frequency of occurrence increases to 3-6%.

In burnt places forest environment is most damaged, therefore in general they are characterized by more severe conditions for the development of xylotrophic fungi (Baженов и др., 1963; Вакуров, 1975). However, they also possess quite a wide range of ecological niches, which is proved by such optimum-oriented species presence as *Trametes cervina*. Trunk parasites are not typical of burnt forests because of nearly total absence of living trees. Most burnt trees quickly dry dead. *Piptoporus betulinus* becomes a prominent dominant, which supersedes *Fomes fomentarius* and infects about 80% of substrates. Under forest conditions *Piptoporus betulinus* is characteristic of tree tops, where wood decay conditions become severe. In the south of the area studied, in particular, in the vicinity of Beloyarsky, *Trichaptum pargamenum* (Fr.) G. Cunn. (49%) becomes very abundant, infecting alburnum of burnt trunks; another fungus characteristic of pyrogenous birch forests of the south of Western Siberia appears — *Stereum subtomentosum* Pouzar (to 3%).

Soon after a fire burnt trees often fall down, usually due to root ruptures, because they host some wound species of xylotrophic fungi, especially Stereum hirsutum. Other wound species such as Cerrena unicolor, Chondrostereum purpureum, Bjerkandera adusta, Trametes versicolor are comparatively rare in burnt forests. Irpex lacteus (Fr.: Fr.) Fr., Gloeophyllum sepiarium (Wulfen: Fr.) P. Karst. (in the forest-tundra zone especially), Trametes pubescens (Schumach.: Fr.) Pilát, Hapalopilus rutilans (Pers: Fr.) P. Karst. and especially Pycnoporus cinnabarinus (Jacq.: Fr.) P. Karst., which is not found outside burnt forests, are the species usually rare for birch, but very numerous in burnt forests of the studied area. Most of these species are somehow associated with wounds of trees and sometimes are found in anthropogenic urban communities on damaged or burnt wood.

Evidently, all the anthropophilous xylotrophic species mentioned could be encountered in the north of Western Siberia long before its contemporary industrial exploration, first of all in burnt forests or on few wound substrates in forests and light forests. In new industrial urban mycocenoses the ecological status of such widely distributed species as Trametes versicolor, T. ochracea, Chondrostereum purpureum, Cylindrobasidium laeve, Phlebia tremellosa has become more certain. However, in natural forests and burnt forests these species are still rare, on injured substrates typical of the north Cerrena unicolor, Gloeoporus dichrous, Stereum hirsutum prevailing. Although there are plenty of appropriate substrates, such numerous ruderal wound species in Western Siberia as Bjerkandera adusta. Lenzites betulinus, Datronia mollis, and the pyrophilous Stereum subtomentosum, Trichaptum pargamenum are not widely distributed northwards.

#### Conclusion

Thus, the communities of xylotrophic fungi in the urban centres of the north of Western Siberia differ considerably from natural ones, which are mainly constituted by parasitic species. When anthropogenic transformation of natural communities is moderate, the diversity of ecological factors and, consequently, ecological niches increases, therefore various ecological groups of fungi, a number of species of more southern natural distribution, are included in them (parasitic, native-forest, wound, ruderal, pyrogenic). As a result, communities with comparatively high specific diversity appear, and they resemble anthropogenic and burnt forest communities of other Western Siberia regions. The results show high sensitivity of fungal communities to the factors of the anthropogenic transformation of environment under the northern conditions and make it possible to use them for ecosystems indication and monitoring.

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#### CORTINARIUS SUBGENUS TELAMONIA IN GREENLAND

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Abstract: Based on 31 collections, the Greenlandic taxa of Cortinarius subgen. Telamonia sects. Telamonia, Armillati, Bicolores and Brunnei are revised. The descriptions, drawings of habit and spores of C. agathosmus Brandrud et al., C. ionophyllus M.M. Moser, C. venustus P. Karst., C. paragaudis Fr. ssp. paragaudis, C. aff. evernius (Fr.: Fr.) Fr. and C. disjungendus P. Karst. are given. Moreover, notes on C. alboviolaceus (Pers.: Fr.) Fr. and C. subbalaustinus R. Hry. are given. Except for C. alboviolaceus, they are all new to Greenland.

> Рассматриваются гренландские виды Cortinarius подрода Telamonia, секций Armillati, Bicolores, Brunnei и Telamonia. Даются описания и рисунки внешнего вида и спор C. agathosmus Brandrud et al., C. ionophyllus M.M. Moser, C. venustus P. Karst., C. paragaudis Fr. ssp. paragaudis, C. aff. evernius (Fr.: Fr.) Fr. и C. disjungendus P. Karst. Приводятся заметки о C. alboviolaceus (Pers.: Fr.) Fr. и C. subbalaustinus R. Hry. За исключением C. alboviolaceus, все виды указываются для Гренландии впервые.

Keywords: Cortinarius, taxonomy, distribution.

 $\mathcal{L}$ ange (1957) stated that much more work was needed on the genus *Cortinarius* in Greenland. Since his initial study little has been published: a commented species-list from the Disko Island, Lamoure et al. (1982), six taxa from East Greenland (Kobayasi et al., 1971) and a preliminary paper on sect. *Dermocybe* (Borgen & Hyiland, 1988). Lange moreover stated that the mycobiota of low arctic, oceanic dwarf-shrub heaths was rich and diverse, but badly known.

In 1978 the author began the study of the macromycota in South and West Greenland, mainly around Paamiut (62° N, 49°40' W). In dwarf-shrub heaths of the fiords I could confirm Lange's statement by recording many taxa new to Greenland.

A lot of important studies on the genus have been made during the later years in the arctic-alpine regions. A number of small, apparently endemic taxa from the subgenus *Telamonia* were described, especially from *Salix herbacea* snow-patches and Dryas-heaths. Gradually, attention has been given to the occurrence of lowland taxa in the arctic-alpine regions, and the question whether some of the «endemic» taxa might fall within the variation of lowland taxa or not (Bendiksen et al., 1993; Moser, 1967, 1993). Moreover, several alpine *Cortinarii* appeared to occur in lowland dunes with *Salix repens* (Arnolds & Kuyper, 1995; Elborne, unpubl.). Consequently, more opportunities for identification of *Cortinarii* from arctic and alpine regions are now available.

In this paper some middle-sized taxa associated with dwarf *Betula* in dwarf-shrub heaths have been selected and all available collections from Greenland studied. Moreover, a record of *C. subbalaustinus* from a coniferous plantation in South Greenland is briefly discussed.

#### **Collecting sites**

1. Nanortalik (municipality), localities near Tasermiut Fiord (60°16' N, 44°33-40' W). Sublocalities: 1A — conifer plantation about 1 km E of the river Kuussuaq; 1B — at the eastern bank of the lake Tasersuaq, halfway between the river Kuussuaq and Qinngua valley, the climate is subarctic and suboceanic.

2. Narsaq (municipality) (61°14' N, 45°32' W). At the head of Tunulliarfik Fiord, at Qanassiassat («Rosenvinges Plantation»), the climate is subarctic and subcontinental.

3. Ivittuut (municipality) (Ivigtut) (61°14' N, 48°05' W), Kangilinngiut (Groennedal), near «Bryggerens Elv», the climate is sub- to lowarctic and suboceanic.

4. Paamiut (Frederikshab) (municipality)  $(61^{\circ}57'-62^{\circ}19' \text{ N}, 48^{\circ}53'-49^{\circ}40' \text{ W})$ . Sublocalities: 4A — in the town area; 4B — Kangilineq (Kvaneoeen); 4C — Taartoq (Moerke Fiord); 4D — Eqaliut, at the head of the Fiord; 4E — Qassit Kangerluarsua, at the head of the Fiord; 3F — Nigerlikasik, at the head of Kuannersooq (Kvanefjord). The climate is lowarctic, 3A is hyperoceanic, 3B and 3C are oceanic, 3D and 3E are oceanic to suboceanic, while 3F is subcontinental.

5. Nuuk (Godthab) (municipality) (64°16' N, 50°54' W). Qooqqut (Qorqut), the climate is lowarctic and suboceanic.

#### Material and methods

The subject of the investigation is the genus *Cortinarius* (Basidiomycetes, Agaricales, Cortinariaceae) subgenus *Telamonia* sections *Telamonia*, *Sericeocybe*, *Armillati*, *Bicolores* and *Brunnei*. The taxonomic circumscription is mainly based on Brandrud et al. (1990, 1992, 1994), Moser (1967) and Soop (1995, 1996).

Macroscopic features were studied on fresh material, and slides were made of most collections of all the species. The applied colour codes are abbreviated: Kornerup, Wanscher (1978) = K&W; Munsell (1975) = Mu.; Henderson, Orton & Watling (1969) = CIC, and Cailleux (1981) = Caill.

For each species the dried material of representative collections was completely sectioned, other collections were sufficient only to ensure safe identification. An Olympus CHS-microscope with oil immersion, achromatic lens (x 100, n.a. 1.30) was used. Hand sections were studied in 2% KOH, occasionally with addition of congored or phloxine. In radial sections of a pileus the shape, size and pigmentation of the elements were studied. In transversal sections of the hymenium the pigmentation, the size and shape of basidia, trama-elements and sterile cells on the edge were investigated. Clamp-connections were searched for in all tissues.

In each collection 10-20 ripe spores were randomly selected from cortina-remnants in one specimen. They were measured, the average (av.), quotient (Q) and average quotient (Q (av.)) were calculated. The spore-shape, presence/absence of a suprahilar depression and plage were scrutinized. The size of verrucae was described with the terms punctate, verruculose and verrucose, and their distribution on the spores was noted, in accordance with the suggestions by Arnold (1993). The drawings of habit are made at x 1, of spores at approximately x 2,000.
The collectors' names are abbreviated: T. Borgen (TB), H. Knudsen (HK), T. Laessoe (TL), J.H. Petersen (JP), A. Petersen (AP) and F. Rune (FR).

The Greenland material is from (C) and the herbaria of T. Borgen (TB) and F. Rune (FR). Swedish collections of C. *disjungendus*, C. *evernius* and C. *subbalaustinus* from the private herbaria of K. Soop (KS) and J. Vesterholt (IV) were studied for comparison.

The authors' names for basidiomycetes are quoted from Nordic Macromycetes II (1992) or fully quoted. C. paragaudis ssp. paragaudis is generally abbreviated C. paragaudis.

### List of species

Cortinarius subgen. Telamonia (Fr.) Trog Sect. Telamonia (Fr.) Gillot & Lucand

*Cortinarius agathosmus* Brandrud, H. Lindstr. et Melot. Docum. mycol. 1989. 20(77). P. 93.- Fig. 1.

Sel. icon.: Brandrud et al., 1990, A05.

Pileus up to at least 50 mm broad, broadly (sub-)umbonate, then  $\pm$ expanded, margin decurved, dry and dull, innate, radially whitish fibrillose, with scattered, persistent, whitish, velar squamules,  $\pm$ glabrous in central part, becoming somewhat cracked to subsquamulose, grey-brown to dark brown (less warm than Mu. 10YR3/4), initially with a brownish violet tinge especially towards the margin, hygrophanous, fading centrifugally, sometimes with a «ring zone», in addition with radial streaks and patterns, becoming slightly paler. Lamellae adnate with teeth to narrowly emarginate (sub-)distant, fairly broad, brownish violet, paler towards the edge. Stipe up to 90 x 13 mm, cylindric, dry and dull, lengthwise whitish fibrillose, with adpressed, thick, fibrillose, whitish velar remnants, in some specimens almost peronate, or with girdles, at base occasionally with a pale violet tomentum. Below the stipe cover violet in apex, downwards pale brown, or violet at base. Cortina initially pale violaceous white. Context in pileus rather thick and firm, pale- to brownish violet, in stipe rigid and hard, in apex sometimes deep violet, downwards ochraceous, or pale violet in the base, hygrophanous, when faded very pale grey-brown (7.5YR7/2), at base more ochreous (near 10YR7/3). Smell sweetish and fairly strong, reminiscent of *C. traganus*, but more sweetish, taste mild.

Spores (50/5/4):  $(9.0-)10.0-12.5 \times 6.0-8.0 \mu m$ , in average  $10.6-11.5 \times 6.6-7.4 \mu m$ , Q = (1.35-)1.45-1.80(-1.90), Q(av.) = 1.55-1.70, (broadly-)ellipsoid to subamygdaloid, rarely with a suprahilar depression, yellow-brown to brown, minutely to distinctly and densely (dark-)brown, verruculose, rarely slightly coarser at apex, plage not observed, or indistinct. Basidia 4-spored,  $35-45 \times 9.5-12 \mu m$ , Q = 3.5-4.5, with hyaline to yellow-brown, intracellular pigment. Edge fertile. Hymenophoral trama subregular, elements  $60-100 \times 8-18 \mu m$ , (sub-)cylindric, pigment intracellular, hyaline to yellow-brown, or yellowish, membranal: Cortina elements  $\pm 6-6.5 \mu m$  broad, cylindric, pigment intracellular, hyaline, granulose to pale yellowish, yellowish membranal, or minutely encrusted. Pileipellis a dry, thin cutis, elements repent,  $3-5 \mu m$  broad, cylindric, pigment intracellular, subhyaline to pale yellowish, in places yellowish, membranal, or minutely encrusted. Hypoderm distinct, elements  $9-18 \mu m$  broad, (sub-)cylindric to inflated, hyaline, with yellowish membranal pigment. Pileus trama elements 8-13(-25) µm broad, (sub-)cylindric to inflated, pigment pale yellowish, membranal, or minutely encrusted. Clamp-connections in all tissues.

Material examined: Paamiut, loc. 4D: Eqaluit, TB 84.153 (C); TB 94.69; TB 95.42a,b and TB 96.118.

Habitat and distribution: In acid, dwarf-shrub heaths in the fiords with *Betula glandulosa*, *Empetrum hermaphroditum*, lichens (e.g. *Cladonia* spp.) and mosses. The sites are lowarctic and (sub-)oceanic. Probably common. August.

Notes: In comparison with the protoloque of C. agathosmus (Brandrud et al., l. c.) I was unable to find any other difference than slightly larger spores in some collections. However, according to Lindström (in press), this identity is not certain, due to the presence of slightly violaceous velar remnants on young pilei and because C. agathosmus has not been recorded outside boreal *Picea*-forests, so far. On the other hand, he does not exclude possible identity. It should be mentioned that Soop (1996) described C. agathosmus with violaceous velar- and cortina-remnants and reported on collections from the Swedish mountain-birch zone, which are in accordance with my concept.

It has not been possible to identify all Greenland records of sect. *Telamonia* with certainty. Some well documented collections from a coniferous plantation in South Greenland (loc. 1A) are at least very close to *C. ionophyllus*, confirmed by Lindström (in press), but two of these (HK, TB & JP 64, TB 91.134) had the same sweetish smell as *C. agathosmus*. According to my notes, this taxon possibly occurs outside the plantation, associated with *B. glandulosa*.

Cortinarius ionophyllus M.M. Moser. Nov. Hedw. 1967. 14. P. 504.- Fig. 2a,b.

Sel. descr.: Moser l. c. — Brandrud et al., 1992: B22.

Sel. icon.: Brandrud et al., 1992: B22.

Pileus 28-70 mm, convex to broadly subumbonate, then plano-convex, margin at first incurved, dull and dry, in places with pale velar remnants, brownish, adpressed fibrillose to minutely squamulose, (ochre-)brown, some specimens with hygrophanous streaks and patches. Lamellae broadly adnate to narrowly emarginate, subdistant, broad, initially dark reddish violet (near K&W 18C3.5), then  $\pm$ brownish violet, in maturity dark brown ( $\pm$ Mu. 5YR3.5/2), edge paler, fimbriate-eroded. Stipe up to 90-110 x 6-12 mm, rigid, cylindric or slightly attenuated, initially with a pale brown velar shirt, leaving a distinct, persistent, whitish ring-zone, downwards breaking up in floccules; otherwise whitish to pale brownish fibrillose, below the stipe cover brownish violet. Context  $\pm$ blue-violet, most intense in the stipe apex, smell (strongly-)raphanoid, smell of lamellae reminiscent of cranberries.

Spores (37/4/3): 9.0-11.0(-11.5) x 6.0-7.0 µm, on the average 9.7-10.3 x 6.3-6.7 µm, Q = (1.40-)1.45-1.70(-1.75), Q(av.) =1.55, (broadly-)ellipsoid or occasionally subamygdaloid, exceptionally with a small suprahilar depression, dark yellow-brown to purplish brown, minutely vertuculose, to fairly strongly dark brown vertucose, especially at apex, plage mostly indistinct. Basidia 4-spored. Edge of lamellae substerile (partly due to

basidioles ?), to fertile. Hymenophoral trama subregular, elements 60-94 x 5.5-18 µm broad, pigment yellowish membranal, or slightly encrusted. Pileipellis a dry, fairly thin cutis, elements repent, 4-10 µm broad, cylindric, mostly thin-walled, pigment intracellular, yellowish to pale yellow-brown, or minutely encrusted. Hypoderm indistinctly differentiated, elements radially arranged, 5-19 µm broad, cylindric to slightly irregular, pigment yellowish, membranal and pale brownish, intracellular. Pileitrama more irregular, elements 7-12 µm broad, almost hyaline with yellowish membranal pigment. Clamp-connections in all tissues.

Material examined: Nanortalik: loc. 1A, Near Kuusuaq at Tasermiut Fiord: FR 96.106; Paamiut: loc. 4D: Eqaluit, TB 93.172, TB 93.173; loc. 4E: Qassit Kangerluarsua: TB 94.37b.

Habitat and distribution: On dry, acid dwarf-shrub heaths dominated by *Cladonia* spp. and *B. glandulosa*. The sites are lowarctic and (sub-)oceanic. August. It may be more common than the few records indicate, since I first realized the existence of this species in 1994.

Notes: The somewhat incomplete description is based on the collections from loc. 4. However, the collections undoubtedly belong here and are confirmed by Lindström (in press). The identity of FR 96.106 is not quite certain. The identification is based on a photo taken in situ among *Picea* needles, and dried material.

Cortinarius venustus P. Karst. Grevillea. 1878. 7(42). P. 64.- Fig. 3.

Syn.: C. calopus P. Karst., see Brandrud et al., 1994.

Sel. descr.: Brandrud et al., 1990: A22.

Sel. icon.: Brandrud et al., 1994: C50.

Pileus 20-45 mm, convex to slightly umbonate, then expanded, dry and dull, glabrous to radially fibrillose, pale yellowish clay, or pale reddish clay (Caill. M69), when older deeper orange-brown in central parts (N57-P59). Lamellae emarginate, subdistant, rather broad, when young about CIC fulvous, then slightly darker (at most P57), edge paler, eroded. Stipe 80-100 x 6-8 mm, with a cavity, cylindric, initially unicoloured violet-white, or whitish, lengthly fibrillose with pale violet velar girdles in the middle. Cortina pale bluish violet to violet-white. Context fairly firm, whitish, smell sweetish-aromatic like *C. torvus*, taste not tried.

Spores (24/2/2): 8.5-9.5(-10.0) x 5.0-6.5(-7.0) µm, on the average 8.9 x 5.7-6.1 µm, Q = (1.35-)1.40-1.65(-1.75), Q(av.) = 1.45-1.55, ellipsoid, very rarely subamygdaloid, pale yellow-brown, (minutely-)punctate to slightly verruculose, occasionally more verrucose at apex, plage not seen. Basidia 4-spored. Gill-edge (sub-)fertile. Hymenophoral trama subregular, elements 64-94 x 4.5-14 µm broad, almost hyaline, with yellowish membranal pigment. Pileipellis a thin cutis, elements radially arranged, 2.5-10 µm broad, cylindric, pigment yellow-brown, intracellular, brownish granulose, or encrusted. Hypoderm subregular, elements radially arranged, (5-)6-18 µm broad, subcylindric to irregular, pigment hyaline to pale brownish, intracellular, pale brownish yellow, membranal, or brownish, distinctly encrusted. Pileus trama elements 10-24 µm broad, subcylindric to inflated, *pigment subhyaline*, membranal, fairly thin-walled. Clamp-connections in all tissues. Material examined: Nanortalik: loc. 1A, east of Kuussuaq at Tasermiut Fiord: TB 91.135, leg. HK; loc. 5, Nuuk: Qooqqut: TB 87.35 (C).

Habitat and distribution: The first collection is from a coniferous plantation dominated by *Picea glauca*, *Pinus contorta* and *Larix sibirica*; the second collection was made in a low copse of *Alnus crispa*, *Salix glauca* and *Betula nana*. The sites are low- to subarctic and suboceanic. August. Rare.

Sect. Sericeocybe P.D. Orton ex Nezdojm.

Cortinarius alboviolaceus (Pers.: Fr.) Fr. Syst. mycol. 1821. P. 218.

Spores (78/6/5):  $(8.0-)8.5-10.0(-10.5) \times 5.5-6.5 \mu m$ , av. =  $8.7-9.3 \times 5.8-5.9 \mu m$ , Q = (1.40-)1.45-1.70, Q(av.) = 1.50-1.60, ellipsoid, more rarely subamygdaloid, sometimes with a suprahilar depression, (pale-)yellow-brown, dark brown, densely and minutely verruculose to distinctly verrucose, occasionally coarser towards the apex, plage indistinct. Gill-edge substerile (due to basidioles ?). Basidia 4-spored. Pileipellis a thick cutis, elements repent,  $3-8 \mu m$  broad, pigment intracellular, very pale violet, (sub-)hyaline to pale yellowish, or membranal, pale yellowish. Hypoderm distinct. Clamp-connections in all tissues.

Material examined: Nanortalik: loc. 1B: at the lake Tasersuaq, S of Tasermiut Fiord: HK, TB & JP 378 (C); Narsaq: loc. 2: Qanassiassat: HK, TB & JP 169 (C); Ivittuut, loc. 3: Kangilinnguit: TB 91.245; Paamiut: loc. 4C: Taartoq, TB 94.18; loc. 4D: Eqaluit, TB 93.181; loc. 4E: Qassit Kangerluarsua, TB 94.49, leg. AP.

Habitat and distribution: On dwarf-shrub heaths in the fiords with B. glandulosa and in copses with B. pubescens. The sites are sub- to lowarctic and oceanic to subcontinental. August. Widely distributed, but apparently uncommon.

Notes: C. alboviolaceus was merely mentioned by Borgen & Høiland (1988: 412).

Sect. Armillati Kühner. et Romagn. ex M.M. Moser

Cortinarius paragaudis Fr. ssp. paragaudis. Epicrisis. 1838. P. 295.- Fig. 4a,b.

Sel. descr.: Brandrud et al., 1992; B22 — Soop, 1990: 101.

Sel. icon.: Brandrud et al., 1992: B 32 (neotype).

Pileus up to 45 mm broad, hemisphaerical, subcampanulate to subumbonate, then more expanded, margin in-, later decurved, dull and dry, in primordia covered with pale red, velar remnants, then more scattered, very pale reddish to (red-)brown, underneath slightly fibrillose, whitish to very pale pinkish, then whitish to pale grey-brown, later pale buff. Ground colour in centre when young dark grey-brown (near Mu. 5YR4/2.5), later dark brownish (near 10YR4/4, without olive flush), outwards reddish brown (5YR4/3), later paler grey-brown ( $\pm 10YR6/4$ ), partly visible as veins, hardly changing on drying. Lamellae broadly adnate to narrowly emarginate, subdistant, 4-6 mm broad, initially whitish to very







5

Fruitbodies and spores (x 2,000) of the Cortinarius species.
Fig. 1. Cortinarius agathosmus, TB 84.153.
Fig. 2. C. ionophyllus: a — TB 93.173, b — TB 93.172.
Fig. 3. C. venustus, TB 87.35.
Fig. 4. C. paragaudis ssp. paragaudis: a — TB 94.063, b — TB 95.093.
Fig. 5. C. evernius, TB 94.53.
Fig. 6. C. disjungendus, TB 93.168

pale clay, then pale brown,  $\pm 7.5$ YR6/4, towards the margin concoloured or paler, subglabrous. Stipe 45-105 x 9-20 mm, in apex 7-10 mm wide, somewhat fusiform and downwards attenuated, cylindric, or clavate, solid, with adpressed velar girdles, later more indistinct, pale red-brown (slightly darker than 5YR7/4 to  $\pm 7.5$ YR7/5), then dirty brownish, lengthwise fibrillose, whitish to very pale salmon, later red-brown in places, ground colour pale brown, base with a thick, whitish, to very pale reddish tomentum. Cortina whitish. Context thick in the central part of the pileus, dark reddish brown, later dirty, greyish brown, in age whitish when faded, in stipe-apex watery marbled, pale greyish rose, in base purplish red-brown, 5YR4/3-3/3, later dirty greyish brown, pale when faded, not very firm, almost inodorous, taste mild.

Spores (48/4/3): 6.5-7.5(-8.0) x 5.0-6.0(-6.5) µm, on the average 6.9-7.3 x 5.7-5.9 µm, Q = 1.10-1.40(-1.45), Q(av.) = 1.20-1.25, subglobose to broadly ellipsoid, occasionally subamygdaloid, pale (red-)brown to (dark-)brown, rarely punctate, mostly verruculose, to somewhat verrucose, rarely slightly coarser at apex, suprahilar depression absent, plage rare. Basidia 4(-5)-spored. Basidioles present. Gill-edge (sub-)fertile. Hymenophoral trama subregular, elements 45-122 x 4-17 µm, subcylindric, pigment intracellular, hyaline and granulose, pale yellowish, pale brown to earth-brown, or membranal. Hyphae of cortina 3.5-9 µm broad, cylindric, with yellowish membranal pigment. Velar hyphae on stipe 4-5 µm broad, branched, some with reddish intra- and extracellular pigment. Pileipellis a thin, dry cutis, elements 2.5-7 µm broad, cylindric, in upper part hyaline, below with greyish yellow- to yellow-brown intracellular pigment, also with membranal and very slightly encrusted pigment. Hypodermal elements 7-23 µm broad, cylindric, irregular, frequently inflated, pigment yellow-brown membranal, encrusted, or yellow-brown intracellular. Clamp-connections in all tissues.

Material examined: Paamiut: loc. 4A: in the «rotten mountains», 2.5 km E of Paamiut, TB 94.063, TB 95.093; loc. 4D: Eqaluit, TB 93.175.

Habitat and distribution: The first two collections are from a windy *Empetrum*-heath, with lichens and some *B. glandulosa*. The last collection came from a more sheltered, less oceanic, otherwise similar habitat. August. Probably rare. The sites are lowarctic and (hyper-)oceanic.

Notes: The small collections TB 94.063 and 95.093 were very similar to the description and photo of the neotype (Brandrud et al., 1992). The large collection TB 93.175 had a much paler pileus, in places whitish to pale buff, except the centre. According to Lindström (in press), it falls within the variation of C. paragaudis. In the neotype description the gill-edge is described as sterile, but according to Arnold (1993), this feature is variable in Telamonia due to weather conditions.

Sect. Bicolores (M.M. Moser) Melot

Cortinarius aff. evernius (Fr.: Fr.) Fr. Obs. mycol. 1818. P. 79.- Fig. 5.

Pileus 30-36 mm broad (young specimens), broadly to more distinctly subumbonate, margin broadly in-, later decurved, dry and dull, a primordium completely covered with white velar fibrils, later more scattered and paler, radially arranged, ground colour dark reddish brown (Mu. 5YR3/4), to slightly more intensive than CIC umber, hygrophanous, slowly, centrifugally fading, turning more yellow-brown (final colour not seen). Lamellae broadly adnate, subclose, fairly broad, up to 7 mm, when young pale chocolate brown (more intense than 5YR4/4) towards the base with a brownish violet tinge, then dark brownish violet, in maturity pale chocolate brown (about 5YR4/4), edge concoloured, subglabrous. Stipe 80-100 x 9-16 mm, in age fistulose, downwards slightly attenuated, base fusiform in one specimen, downwards with indistinct, fibrillose, whitish velar remnants, ground colour  $\pm$ lilac (about K&W 15.5B/C3), cortina white, also covering the outermost pileus-margin. Context fairly thick, not brittle, concoloured in the pileus, towards the lamellae with a brownish violet tinge, in stipe apex unicoloured brownish violet to dull violet (15D4), downwards pale ochreous (7.5YR7/4,7/6), hygrophanous, smell strongly and persistently iodoform-raphanoid.

Spores: (28/2/2):  $(8.0-)9.0-10.5(-11.0) \ge 5.0-6.0 \ \mu\text{m}$ , on the average 9.3-9.5  $\ge$  $5.3-5.3 \,\mu\text{m}$ , Q = 1.50-2.10, Q(av.) = 1.70-1.80, ellipsoid, oblong, amygdaloid, dacrymoid to sublimoniform, frequently with a suorahilar depression, fairly dark brown to red-brown, (minutely-)punctate to slightly vertuculose, mostly stronger vertucose at apex, plage indistinct. Edge subfertile, sterile elements, partly basidioles ?, 10-15(-32) x 3.5-8 µm, subcylindric to clavate, with subhyaline to very pale brown, intracellular pigment. Basidia 4-spored, 28-37 x 8-9  $\mu$ m, Q = 3.5-4.5, cylindric, with hyaline, yellow-brown to earthbrown, intracellular ρigment. Hymenophoral trama subregular, elements 41-88 x 7-11.5 μm, cylindric, some minutely encrusted, others with yellow-brown Pamorphous pigment-clumps. Cortina elements 4-9 µm broad, pigment hyaline, membranal. Pileipellis a very thin, dry cutis, elements radially arranged, repent, cylindric, 2.5-6.5(-9) µm broad, pigment granulose, (yellow-)brown, intracellular, yellow membranal and dark brown encrusted. Hypoderm indistinct, elements 4-12(-16) µm broad, cylindric to subinflated, pigment hyaline to pale brownish, intracellular, pale brown-yellow membranal, and minutely encrusted. Pileus-trama elements 9-22 µm broad, pigment subhyaline to dark yellow-brown, intracellular, membranal, or encrusted. Clamp-connections in all tissues.

Material examined: Greenland: Paamiut: loc. 4E: Qassit Kangerluarsua, TB 94.50, leg. AP; TB 94.53, also observed in loc. 4D (Eqaluit). Sweden: JV 90-357, KS-CO31.

Habitat and distribution: The sites are lowarctic and (sub-)oceanic. The second collection is from a steep, slightly moist grass slope towards a river, near *Salix glauca*, with mosses, *Cladonia* spp. and *B. glandulosa*. Late August. Probably rare.

Notes: This taxon differs from *C. evernius* (Moser, 1967: 510; Brandrud et al., 1990, A11, ibid., 1992: 17, neotype; Arnold, 1993: 111) in the following features. The pileus fades slowly (colour of completely dried out pilei is not known), very distinct raphanoid/iodoform-like smell, different spore-shape and lack of distinct hypoderm. It was compared with two Swedish collections of *C. evernius*, and the microscopic differences were fully confirmed. Further field observations are needed to complete the description (both collections were rather young) and to decide on the true status of the species.

Sect. Brunnei Kühner et Romagn. ex Melot

**Cortinarius disjungendus** P. Karst. Acta Soc. pro Fauna et Flora Fennica. 1892. 9(1). P. 6.- Fig. 6. Sel. descr.: Soop, 1995: 31.

Sel. icon.: Soop., l. c.

Pileus 55-58 mm, umbonate-convex, margin straight, dry and dull, when younger towards the margin increasingly whitish fibrillose, otherwise glabrous, dark brown (near Mu. 10YR4/ 3.5, but without olive flush), hygrophanous, fading from the centre to more yellowish brown (7.5YR5/6 is too intensive). Lamellae narrowly emarginate, subdistant, up to 9 mm broad, edge whitish fimbriate and slightly eroded, slightly darker than CIC fulvous. Stipe up to 100 x 10 mm, cylindric, solid, whitish fibrillose lengthwise, some of them loose (indistinct velar remnants?), dry and dull, when rubbed pale brownish, at apex with scattered, fibrillose, whitish remnants of cortina. Context thick at centre, thin towards the margin, concoloured in upper part (otherwise faded), when entirely faded whitish, firm, not changing on bruising, smell unpleasently earth-like, then like *C. raphanoides*, when cut more fungoid, taste mild.

Spores (26/2/1):  $(9.5-)10.0-12.0 \times (6.0-)6.5-7.5 \mu m$ , on the average:  $10.4-10.9 \times 6.7-6.8 \mu m$ , Q = 1.40-1.75, Q(av.) = 1.5-1.60, verruculose to coarsely dark brownish verrucose, especially towards the apex, yellow-brown to  $\pm$ reddish brown, ellipsoid to subamygdaloid, frequently with a plage, a minor part with a suprahilar depression. Gill-edge fertile, a few sterile elements observed,  $20 \times 3.5-5 \mu m$ , probably basidioles. Basidia 4-spored,  $32-33 \times 8.5-10 \mu m$ , Q = 3.5-4.5, subcylindric to subclavate, hyaline to yellow-brown. Hymenophoral trama subregular, elements  $\pm 110-145 \times 9.5-13.5(-18) \mu m$ , (sub-) cylindric, pigment grey-yellow membranal, pale granulose to yellow-brown intracellular. Pileipellis a thin, dry cutis of  $3-7.5 \mu m$  broad, repent, cylindric elements  $7.5-17.5 \mu m$ , broad, (sub-)cylindric, pigment yellowish membranal and hyaline to pale brownish, intracellular. Trama elements of pileus  $15-22 \mu m$  broad,  $\pm$ isodiametric, pigment yellowish membranal, or encrusted. Clamp-connections in all tissues.

Material examined: Paamiut: loc. 4D: Eqaluit, TB 93.168. — Sweden: KS 556, KS 629.

Habitat and distribution: In a lowarctic, oceanic, dwarf-shrub heath with *B. glandulosa*, *S. glauca*, lichens and mosses. Late August. Probably rare.

Notes: The description is incomplete, since quite young specimens are lacking. I did not observe any darkening of the context, but otherwise it is well in accordance with the description and photo given by Soop (l. c.). Fragments of two Swedish collections, from subalpine *Betula*-forests, quoted by Soop, and the Greenland material had the same dark colours in dry state, in accordance with his description. The spore features are quite identical, and I was unable to observe other essential differences. According to Lindström (in press) my collection is well in accordance with Karsten's type and material collected by himself (Brandrud et al., in prep.).

Sect. Firmiores (Fr.) Henn.

Cortinarius subbalaustinus R. Hry. Docum. mycol. 1991. 21(81). P. 46.

Material examined: FR 95-103, from a plantation dominated by Larix sibirica. Pinus

contorta, Picea glauca and native B. glandulosa, near the river Kuussuaq at Tasermiut Fiord, 30.08.1995.

Notes: Lindström (in press) informed me that a good colourslide by Rune figures «a typical *C. subbalaustinus*». It is therefore included in the Greenland mycobiota. The material is probably misplaced (Rune, in press), the content of the capsule turned out to be a *Laccaria*. *C. subbalaustinus* is known from subalpine areas in Scandinavia (Brandrud et al., 1992), so its presence in South Greenland was not quite unexpected.

## Conclusion

In the subarctic parts of South Greenland, *C. ionophyllus*, *C. subbalaustinus and C. venustus* were collected in a coniferous plantation dominated by *Larix sibirica*, *Pinus contorta*, *Picea glauca* and some native *Betula glandulosa*. It is therefore difficult to judge on the ectomycorrhizal hosts. But according to the photo by Rune, it is very probable that *C. ionophyllus* is associated with *Picea glauca* (planted as seedlings from Anchorage, Alaska).

C. alboviolaceus is uncommon, but widely distributed in the subarctic and lowarctic parts of South and South-West Greenland, up to Paamiut. It is the only taxon which so far is recorded from the subarctic *B. pubescens* copses. However, this is not conclusive, as middle-sized *Telamonia*-species in these copses are hardly investigated yet.

C. agathosmus, C. disjungendus, C. aff. evernius, C. ionophyllus and C. paragaudis are so far only recorded from Paamiut, while C. venustus was collected in Qooqqut, near Nuuk, both in lowarctic South-West Greenland. They are most probably ectomycorrhizal with B. glandulosa, except C. venustus which seems to be attached to the closely related B. nana, both are new hosts. A wider distribution of the treated species is expected, when more areas become scrutinized for Cortinarii. However, none of the species have been recorded from Disko Island (69° N), at the upper border of the lowarctic area, in spite of intensive investigation (Petersen, 1977; Lamoure et al., 1982; Borgen & Elborne, unpubl.) or from continental Kangerlussuaq (67° N), where the mycobiota is also well investigated (Lange, 1957; Knudsen et al., unpubl.). None of the species have been found in East Greenland, where the mycobiota is fairly well-known in parts of Jameson Land at 70° N (Elborne, Knudsen & Petersen, 1988; Boertmann, 1982, 1983, 1988, 1989, unpubl.) and some localities around Tasiilaq (Ammassalik) (Kobayasi et al., 1971; Strandberg & Rune, 1985, unpubl.). The potential Greenland distribution of the treated taxa is therefore undoubtedly rather limited within the lowarctic area.

In Europe, C. alboviolaceus is widespread from the nemoral to the low alpine region of Scandinavia. C. agathosmus, C. ionophyllus, C. paragaudis and C. venustus are typical fungi of the boreal zone in Scandinavia, mostly ectomycorrhizal with Picea/Pinus, but C. ionophyllus, C. paragaudis and C. venustus are also able to enter the subalpine zone (Soop, in press), associated with B. pubescens. In North Norway, C. paragaudis is ectomycorrhizal with B. nana in the lowarctic area (Bendiksen, in press). C. disjungendus and C. subbalaustinus are ectomycorrhizal with B. pubescens in the boreal and subalpine parts of Scandinavia.

C. agathosmus, C. disjungendus, C. ionophyllus and C. venustus are supposedly new to the lowarctic region. C. agathosmus and C. venustus are additional examples of ectomycorrhizal fungi shifting host from *Picea* to (dwarf-)*Betula* (Jacobsson, 1984; Knudsen & Borgen, 1992).

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#### DRYADICOLOUS MICROFUNGI OF THE POLAR URALS

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Abstract: 31 taxa of microfungi have been noted on dead leaves, inflorescences and twigs of Dryas octopetala s. l. from 13 localities along the transect of Rai-Iz Massif, the Polar Urals. The altitudinal distribution of microfungi and correlation between age of individual Dryas specimens and biodiversity of microfungi have been studied.

> 31 таксон микроскопических грибов был обнаружен на отмерших листьях, соцветиях и ветках Dryas octopetala s. l. в 13 местообитаниях вдоль трансекты массива Рай-из на Полярном Урале. Описано высотное распределение микроскопических грибов и зависимость биоразнообразия микромицетов от возраста растений.

Keywords: Dryas, microfungi, the Arctic, the Polar Urals, distribution.

She aim of the investigation was to define changes in the altitudinal distribution of microfungi. The material has been collected in the serpentine Sob Valley, across the transect passing from Polarny Ural railway station to the nearest glacier in the Rai-Iz Mts. All microfungi were collected in 1995 from 13 localities on 67 plant specimens. The age and altitude of all collected *Dryas* specimens has been estimated. The upper part of the Sob Valley is situated in the NW of the Rai-Iz Massif in the Polar Urals. There are various tundra and semidesert communities on the slopes and plateau (Chlebicki, 1996). The isolated colonies of *Dryas* populations have reached 795 m a.s.l.

Earlier mycological investigations were carried out in the same Sob Valley near Krasny Kamen railway station, on Slantsevaya Mt. (Казанцева, 1968; Сирко, 1968). Tomilin gathered microfungi in the environs of Sivaya Maska, SW of Vorkuta, in forest-tundra ecosystems (Томилин, 1970). I have not found any information concerning dryadicolous microfungi in this area.

Material gathered in 1995 is preserved in KRAM, Wrocław; earlier phanerogam collections of *Dryas octopetala* are preserved in LE, St. Petersburg.

#### **Collecting sites**

Abbreviations: herb. — herbarium; coll. — collected by; a.s.l.- above sea level; y. — age of plants (years).

All specimens have been collected by the author in the environs of Polarny Ural railway station in the Sob Valley. In addition, the materials collected by K.N. Igoshina, A.V. Tolmachov, O.V. Rebristaya and S.V. Sandomirskaya and deposited in the phanerogam herbarium in St. Petersburg (LE) have been studied. These materials have full citations of collecting sites in the text.

THE POLAR URALS, environs of Polarny Ural railway station in the Sob Valley:

(1) Tundra on moraine near the Sob river, 180 m a.s.l., c. 2 km S of the railway station, July 12, 1995.

(2) Patches of alpine tundra on the N slope of Shlem Mt., 520 m a.s.l., c. 4 km SW of the railway station, July 13, 1995.

(3) Tundra on moraine near the Sob river, 250 m a.s.l., c. 5 km S of the railway station.

(4) Old glacial cirque, on the N slope of Shlem Mt., 510-560 m a.s.l., c. 5 km S of the railway station, July 14, 1995.

(5) Arctic desert on the ridge of Shlem Mt., 640 m a.s.l., c. 6 km S of the railway station, July 14, 1995 (one specimen with viscid glands on leaves = D. *punctata*).

(6) Rocky surface of old moraine, 470 m a.s.l., c. 6 km S of the railway station, July 14, 1995.

(7) Alpine tundra on a stream terrace in the Sob Valley, 350 m a.s.l., c. 7 km S of the railway station, July 21, 1995.

(8) Alpine tundra on a stream terrace in the Sob Valley, 360 m a.s.l., c. 8 km S of the railway station.

(9) Flat surface of old moraine, 535 m a.s.l., c. 11 km S of the railway station, July 22, 1995.

(10) Rocky slope on the NW face of a nameless mountain, 710-730 m a.s.l., c. 11.5 km S of the railway station, July 22, 1995.

(11) Rocky slope of NWW face of a nameless mountain, 575 m a.s.l., c. 12 km S of the railway station, July 22, 1995.

(12) Patches of tundra near a nameless pass, 510 m a.s.l., c. 12 km S of the railway station.
(13) Arctic desert on a surface of a small moraine, c. 2 km before a melting ice face, 780-795 m a.s.l., c. 14 km S of the railway station, July 22, 1995.

## List of species

«Ascotricha» sp., Xylariales

On dead wood of a twig, on 34 y. old plant, one collection, 710 m a.s.l. Perithecia slightly embedded in wood, covered with long hairs, ostiole naked, asci 8-spored, 65-80 x 10-12  $\mu$ m, ascospores olivaceous-brown, one-celled, 14-20 x 6-9  $\mu$ m, with longitudinal germ-slit (Fig. 1.5). Holm and Holm (1993a) described similar lignicolous species, *Anthostoma polaris* K. & L. Holm, with ascospores devoid of a germ slit. The latter species probably belongs to the genus *Barrmealia*, recently determined by Rappaz (1995). The collection from the Polar Urals belongs to the genus *Ascotricha* Berk. However, it cannot be fully described because very scanty material is available (two ascocarps with some asci and ascospores).

Material examined: 10 (34 y.).

Cainiella johansonii (Rehm) E. Müller, Xylariales

On both sides of leaves, midribs and petioles, common species in the Sob Valley; 14 collections, range: 180-710 m a.s.l., absent from the highest locality, on 22-67 y. old plants.

Apart from them, I have found this species in the materials from the South and North Urals.

Material examined: 1 (50 y., 60 y.), 3 (39, 43 y.), 8 (22, 34, 40, 41, 43 y.), 9 (27 y.), 10 (43 y.), 11 (67 y.). The Polar Urals, Rai-Iz Mt., near the Sob river, on leaves of D. octopetala, coll. K.N. Igoshina; the Khodata Valley, on petioles of D. octopetala, August 19, 1961, coll. K.N. Igoshina (LE).

Crocicreas variabile Nograsek & Matzer, Helotiales

On the lower side of leaves, among tomentum. Ascospores hyaline, four-celled,  $18-20 \times 3-4 \mu m$  (Fig. 1.4). Rather abundant species; 13 collections, range: 180-710 m a.s.l., absent from the highest locality, on plants 17-60 y. old. I have found apothecia on the upper leaf surface with epiderm scraped by insects. It is a recently described species (Nograsek & Matzer, 1991), so far known from the Austrian Alps and the environs of Abisko in Sweden.

Material examined: 1 (23, 24, 50, 56 y.), 3 (43 y.), 4 (22 y.), 5 (17 y.), 6 (60 y.), 9 (46, 47 y.), 10 (34, 43, 55 y.).

Epipolaeum absconditum (Johanson) L. Holm, Dothideales

It occurs in the median furrow of the upper side of a leaf; probably rather common in this area; 11 collections, range: 180-785 m a.s.l., on 10-60 y. old plants. It is a rare species known from Scandinavia (Holm, 1979), the Alps (Nograsek, 1990), Spitsbergen (Holm & Holm, 1993a) and the Pyrenees (Chlebicki, 1995).

Material examined: 1 (50 y.), 6 (10, 20, 24, 30, 60 y.), 9 (27, 34, 39 y.), 10 (55 y.), 13 (28 y.).

#### Gibbera holmii Nograsek, Dothideales

On the upper side of leaves, one collection, 180 m a.s.l., on 60 y. old plant. The material is very scanty, consists of two ascocarps only. Ascocarps setose, setae brown and pointed, aseptate or rarely with one septum, asci 44-46 x 8-10  $\mu$ m, ascospores hyaline, pointed at both ends, septa submedian, 13-16 x 4-4.8  $\mu$ m (Fig. 1.3). The shape of these ascospores is intermediate between G. *latispora* and G. *holmii* s. str.

Material examined: 1 (60 y.).

Gibbera latispora (M.E. Barr) L. Holm, Dothideales

On dead leaves and especially on petioles, 11 collections, range: 180-795 m a.s.l., on 22-76 y. old plants. Ascospores hyaline, ellipsoid-cylindric (Fig. 1.1). In some collections ascospores were coated like in the genus *Macroventuria* (Fig. 1.2).

Material examined: 1 (50 y.), 3 (22 y.), 8 (34, 43, 46 y.), 9 (39, 47 y.), 10 (34, 37, 55 y.), 13 (76 y.).

#### Gnomoniella vagans Johanson, Diaporthales

On dead hypanthium and pedicel; two collections. Ascospores with small hyaline appendage; a few perithecia on plants 22-43 y. old, growing in tundra on a moraine, 250 m a.s.l.

Material examined: 3 (22, 43 y.).

#### Hypoderma dryadis Nannf. ex L. Holm, Rhytismatales

On the upper side of dead leaves; 31 collections, range: 180-795 m a.s.l., on 8-76 y. old plants. A common species in this area, rare in Europe, reported by Holm (1979), Nograsek and Matzer (1991). Vassilyeva (Васильева, 1987) has found it in Kedon, the Magadan district (as *H. rostrupii*). I have found it in the material from the South Urals.

Material examined: 1 (23, 24, 50, 56, 60 y.), 2 (36 y.), 4 (26 y.), 5 (14, 16, 17 y.), 6 (10, 17, 19, 20 y.), 8 (38, 41 y.), 9 (37, 39, 40, 48 y.), 10 (34, 55 y.), 11 (67 y.), 12 (46, 59 y.), 13 (8, 37, 41, 47, 58, 76 y.). The South Urals, the north slope of Iremel Mt., on leaves of *D. octopetala*, July 7, 1952, coll. P.L. Gorchakovsky; the Polar Urals, Rai-Iz Mt., on the upper side of leaves of *D. octopetala* ssp. subincisa, July 18, 1962, coll. K.N. Igoshina, herb. Chlebicki 3 291; at the confluence of the Malaya Usa and Bolshaya Usa rivers, on leaves of *D. octopetala*, July 23, 1958, coll. A.V. Tolmachov and O.V. Rebristaya; Vagra-shor, 30 km S of Polarny Ural railway station, on leaves of *D. octopetala* ssp. subincisa, August 7, 1961 (LE).

#### Isothea rhytismoides (Bab. ex Berk.) Fr., Phyllachorales

A very characteristic parasitic species, widely distributed in the arctic and alpine regions of the northern hemisphere, rare in the Sob Valley. Six collections, range: 520-710 m a.s.l., absent from the highest locality, collected on 34-36 y. old plants.

Material examined: 2 (36 y.), 10 (34 y.). The Polar Urals: Rai-Iz Mt., on the upper side of leaves of *D. octopetala* ssp. subincisa, July 18, 1962, coll. K.N. Igoshina; Rai-Iz Mt., near the Sob river, on leaves of *D. octopetala*, coll. K.N. Igoshina; at the confluence of the Malaya Usa and Bolshaya Usa rivers, on leaves of *D. octopetala*, July 23, 1958, coll. A.V. Tolmachov and O.V. Rebristaya; the Middle Urals, the environs of the Chusovaya and Sylva rivers, on leaves of *D. octopetala*, July 16, 1934, coll. K.N. Igoshina (LE).

Lachnum crystallophorum Nograsek & Matzer, Helotiales

On the lower side of leaves. A rare species, only one collection, 510 m a.s.l., on 46 y. old plant. Apothecia with long hairs incrusted with crystals; ascospores twice as long as those in typical varieties. It is probably an endemic variety for the Polar Urals (Chlebicki, in press).

Material examined: 12 (46 y.).

## Leptosphaeria sp., Dothideales

On dead petioles. Very characteristic species with 4-spored asci. A full description will be given by Chlebicki (in press).

Material examined: The Polar Urals, the Khodata Valley, on leaves of *D. octopetala*, August 8, 1961, coll. K.N. Igoshina (LE).

*Leptosphaeria dryadophila* Huhndorf, Dothideales Syn.: *Melanomma dryadis* Johanson

On dead sepals of previous year's flowers; five collections, 180-710 m a.s.l., on 26-56 y. old plants. A scattered species in this area, absent from the highest locality, found only on old plants. A common species on *Dryas* inflorescences, recently transferred to the genus *Leptosphaeria* by Huhndorf (1992).

Material examined: 1 (56 y.), 4 (26 y.), 10 (34 y.), 12 (46 y.), 13 (41 y.).

Leptosphaerulina dryadis (Starbäck) L. Holm, Dothideales

On the upper side of dead leaves. Rare species in the Sob Valley, two collections, 180 m a.s.l., on 24-50 y. old plants. A common species on *Dryas* in Europe and North America.

Material examined: 1 (24, 50 y.).

Lophiostoma macrostomum (Tode: Fr.) Ces. & De Not., Dothideales

On dead twigs and lignified petioles. A rare lignicolous saprophyte in this area, three collections, first noted on 50 y. old plant, 180 m a.s.l. Chlebicki (1995) has found it in the material from Yamal Peninsula near the Kamenny Cape.

Material examined: 1 (50 y.). The Polar Urals, the Khodata Valley, 6 km of the estuary of the river, E of Vorkuta, on twig of *D. octopetala*, July 29, 1961, coll. S.V. Sandomirskaya; Rai-Iz Mt. near Krasny Kamen, E of Vorkuta, on twig of *D. octopetala* ssp. subincisa, July 26, 1926, coll. K.N. Igoshina (LE).

Lophiostoma winteri (Sacc.) G. Winter, Dothideales

On the lower side of leaves. Ascocarps partially immersed, ascospores typical of this taxon; one collection, on 59 y. old plant, 510 m a.s.l. The occurrence on leaves of this common lignicolous species is probably incidental.

Material examined: 12 (59 y.).

## Lophium sp., Hysteriales

On both sides of dead leaves. A very rare species, one collection, on 60 y. old plant, 180 m a.s.l. A full description of this colection will be reported by Chlebicki (in press). Material examined: 1 (60 y.).

#### Massarina balnei-ursi (Rehm) K. Holm & L. Holm, Dothideales

On decorticated wood of dead twigs. A rare lignicolous species in this area, four collections, range: 535-795 m a.s.l., on 8-76 y. old plants. So far reported from the Alps (Holm & Holm 1985, Nograsek, 1990), Sweden (Nograsek, 1990) and Yakutia (Chlebicki, 1995).

Melaspilea lecideopsoidea (Rehm) K. Holm & L. Holm, Melaspileaceae (inc. sed.)

On dead twigs, 14 collections, 180-710 m a.s.l., on 18-59 y. old plants. The most common lignicolous species in this area, absent from the highest localities.

Material examined: 1 (56 y.), 3 (32, 39 y.), 4 (26 y.), 7 (18, 32 y.), 8 (25, 33, 40, 46, 48 y.) 10 (34 y.), 12 (59 y.). The Polar Urals, the environs of the Synya River, on dead twigs of *D. octopetala*, July 13, 1926, coll. B.N. Gorodkov (LE).

#### Mycosphaerella octopetalae (Oudem.) Lind., Dothideales

On the upper side of leaves; 70 collections, range: 180-795 m a.s.l., on 8-76 y. old plants. The most common foliicolous species on young and old specimens of *Dryas*.

Material examined: 1 (23, 24, 50, 56, 60 y.), 2 (36 y.), 3 (19, 20, 22, 24, 32, 39, 43 y.) 4 (22, 26, 30, 35 y.,), 5 (14, 16, 17 y.), 6 (10, 17, 19, 20, 24, 30, 60 y.), 7 (18, 23, 32, 39 y.), 8 (22, 25, 33, 34 38, 40, 41, 43, 46, 48 y.), 9 (27, 34, 37, 39, 46, 49 y.), 10 (34, 37, 43, 55 y.), 11 (67 y.), 12 (45, 46, 49 y.), 13 (8, 28, 37, 41, 47, 58, 62, 76 y.). The Polar Urals: Rai-Iz Mt., on the upper side of leaves of D. octopetala ssp. subincisa, July 18, 1962, coll. K.N. Igoshina; Rai-Iz Mt., near the Sob river, on leaves of D. octopetala, coll. K.N. Igoshina; the Khodata Valley, on leaves of D. octopetala, August 19, 1961, coll. K.N. Igoshina; at the confluence of the Malaya Usa and Bolshaya Usa rivers, on leaves of D. octopetala. July 23, 1958, coll. A.V. Tolmachov and O.V. Rebristaya; Pay-pudyna Valley, SE of Vorkuta, on leaves of D. octopetala ssp. subincisa, July 7, 1961, coll. S.V. Sandomirskaya; Vagra-shor, 30 km S of Polarny Ural railway station, on leaves of D. octopetala ssp. subincisa, August 7, 1961; Khodata Valley, 6 km of the estuary, E of Vorkuta, on twig of D. octopetala, July 29, 1961, coll. S.V. Sandomirskaya; Rai-Iz Mt. Near Krasny Kamen, 137 km E of Vorkuta, on leaves of D. octopetala ssp. subincisa, July 26, 1926, leg. K.N. Igoshina (LE).

#### Naemacyclus lambertii var. dryadis K. Holm & L. Holm, Rhytismatales

On the lower side of dead twigs, three collections, 350 m a.s.l., on 22-39 y. old plants. This taxon is distinguished by white apothecia. It is rare in this area.

Material examined: 8 (22, 34, 39 y.).

*Nectriella dacrymycella* (Nyl.) Rehm, Hypocreales Syn.: Sphaeria dacrymycella Nyl.



Fig. 1. Ascospores of some microfungi from the Polar Urals:
1 — Gibbera latispora; 2 — G. latispora with coated ascospores; 3 — Gibbera holmii;
4 — Crocicreas variabile; 5 — 'Ascotricha' sp; 6 — Wettsteinina dryadis;
7 — Scleropleella hyperborea; 8 — Nectriella dacrymycella

On a dead petiole. Perithecia very small, somewhat flattened, pale honey yellow, with some hyaline and elongated cells on the upper surface, ostiolar area collapse, asci 42-46 x 8-10  $\mu$ m, ascospores hyaline, two-celled, (11)14-15 x 4-5  $\mu$ m (Fig. 1.8). Lowen (1991) wrote that the ascomata of *N. dacrymycella* are non-setose. It is the first locality of nectrioid species on *Dryas*.

Material examined: The Polar Urals, 110 km E of Vorkuta towards Salekhard, on a petiole of *D. octopetala*, July 22, 1922, coll. K.N. Igoshina (LE).

Otthia dryadis K. Holm et al., Dothideales

On dead wood of twigs and lignified petioles. A rare species, known from five collections, range: 180-470 m a.s.l., on 20-60 y. old plants. Lignicolous species with a scattered distribution in the Sob Valley, absent above 500 m a.s.l., restricted to 177  $\pm$ old plants.

Material examined: 3 (20 y.), 6 (60 y.), 7 (39 y.), 8 (43 y.), 12 (59 y.).

#### Phaeosphaeria dryadea Nograsek, Dothideales

On dead leaves, two collections (on slides only), 500 m a.s.l., on plant 24 y. old. A very rare species in the Sob Valley. So far reported from the Alps (Nograsek, 1990) and Eastern Carpathians (Chlebicki, 1995).

Material examined: 3 (24 y.). The Polar Urals, Pour-Pay Mt., W of Salekhard, 500 m a.s.l., on a petiole of *D. octopetala*, July 23, 1923 (LE).

Pleospora ascodedicata K. Holm et al., Dothideales

On old leaves and twigs, two collections, range: 180-640 m a.s.l., on 14-54 y. old plants. A rare species with a few ascocarps only. Noted in the Alps, Scandinavia (Nograsek, 1990), Spitsbergen (Holm & Holm, 1993b) and Yakutia (Chlebicki, 1995).

Material examined: 1 (56 y.), 5 (14 y.).

*Pleospora penicillus* (Schm.: Fr.) Fuckel var. *ambigua* (Berl. & Bres.) Crivelli, Dothideales

On dead leaves and pedicels. Probably not common in this area. I have noted two collections only; 350 m a.s.l., on 26 y. old plant. Ascocarps setose, setae up to 80 µm long, ascospores brown, 30-32 x 9-10 µm, with 5-7 transversal septa. It is a widespread species (Holm & Holm, 1993b) on various host-plants.

Material examined: 7 (26 y.). The Polar Urals, Berezovoye near the Yelets river, on pedicel of *D. octopetala* ssp. subincisa, August 4, 1965, coll. K.N. Igoshina (LE).

Scleropleella hyperborea (Fuckel) L. Holm, Dothideales

On dead pedicel, one collection. Ascospores brown, four-celled (Fig. 1.7). A very rare species in the Polar Urals.

Material examined: the Polar Urals, Pendyrma-Pay, on dead pedicel of *D. octopetala*, July 25, 1925, coll. K.N. Igoshina (LE).

Septoria sp. 5, Coelomycetes

On leaves and petioles, one collection, 710 m a.s.l., on 34 y. old plant. A parasitic species with filiform, curved and hyaline conidia, 8-celled,  $48-60 \times 1 \mu m$ . The identification of mitosporic fungi from the genus Septoria which colonize *Dryas* leaves is very difficult. So far only *S. ehrendorferi* Petrak has been reported (Fisher et al., 1995). I have collected five different *Septoria*-like fungi on *Dryas*.

Material examined: 10 (34 y.).

## Sphaerotheca volkartii Blumer, Erysiphales

On the lower side of leaves, one collection. A rare parasitic ascomycete, known from the Alps, Scandinavia (Holm, 1979) and the Tatra Mts. (Sałata, 1985; Chlebicki, 1995).

Material examined: the Polar Urals, the Khodata Valley, on leaves of *D. octopetala*, August 8, 1961, coll. K.N. Igoshina (LE).

Stomiopeltis dryadis (Rehm) L. Holm, Dothideales

On the upper side of leaves, petioles and stipules; three collections, range: 180-535 m a.s.l., on 19-60 y. old plants. Scanty and scattered in this area, decrease with increasing altitude, absent above 600 m a.s.l.

Material examined: 1 (60 y.), 9 (19 y.). The Polar Urals, the Khodata Valley, 6 km of the estuary, E of Vorkuta, on twig of *D. octopetala*, July 29, 1961, coll. S.V. Sandomirskaya (LE).

Sydowiella dryadis Vassilyeva var. macrospora Nograsek, Diaporthales

On dead twigs, four collections, range: 180-640 m a.s.l. A rare lignicolous species in the Sob Valley, absent in the highest localities.

Material examined: 1 (50 y.), 4 (26 y.), 5 (17 y.), 8 (46 y.).

Wettsteinina dryadis (Rostr.) Petr., Dothideales

On both sides of dead leaves. Three collections only. Ascospores at first one-septate and hyaline, mature ascospores four-celled, brownish (Fig. 1.6). Mostly a foliicolous species with wide distribution on various members of the genus *Dryas* in the arctic and alpine regions.

Material examined: the Polar Urals, Rai-Iz Mt., on the lower side of leaves of D. octopetala ssp. subincisa, July 18, 1962, coll. K.N. Igoshina; Pay-pudyna, SE of Vorkuta, on leaves of D. octopetala ssp. subincisa, July 7, 1961, coll. S.V. Sandomirskaya; Rai-Iz Mt. near Krasny Kamen, E of Vorkuta, on leaves of D. octopetala ssp. subincisa, July 26, 1926, coll. K.N. Igoshina (LE).

#### Conclusion

Twenty species were present on leaves (including stipules and petioles), eight species inhabited dead twigs, three were reported on pedicels and two on hypanthium. The biggest number of microfungi inhabit leaves. Also Fisher et al. (1995) noted that leaves were richer in endophyte taxa than twigs or roots. A group of the most common species includes: Mycosphaerella octopetalae, Hypoderma dryadis, Epipolaeum absconditum, Melaspilea lecideopsoidea, Cainiella johansonii and Crocicreas variabile. Some of these species, such as Mycosphaerella octopetalae, Epipolaeum absconditum and Hypoderma dryadis occur in the whole range of the host-plant. Others have scattered localities restricted to a few hostplant specimens, e.g. Gnomoniella vagans, Massarina balnei-ursi, Gibbera holmii and Isothea rhytismoides.

The comparison between characters of spores from the Tatra Mts. (Poland), the Alps, Scandinavia, the Polar Urals and Spitsbergen shows that the ratio of coloured to hyaline spores increases towards the north (Fig. 2). That increasing ratio indicates that in the Polar Urals more arctic conditions are present than in Scandinavia and Central Europe. It seems that deeply pigmented walls of spores and the presence of gelatinous sheaths are ecological adaptations to the increasing UV-B radiation at high altitude. It is important to note that the light coloured apothecia of *Crocicreas variabile*, *Lachnum crystallophorum* and *Naemacyclus lambertii* are located only on the shaded lower side of leaves and twigs.

The surface nearest to the melting ice has been devoid of any vascular plants. Somewhat older moraine has scattered pioneers such as *Alectoria ochroleuca*, *Racomitrium lanuginosum*, *Salix arctica* and *Cerastium* sp. The isolated colonies of *Dryas octopetala* reach 795 m a.s.l. and are about 2 km away from the glacier. They commonly occur on old moraines and slopes in the Sob Valley beneath 600 m a.s.l. The species diversity of microfungi mostly decreases with increasing altitude. However, at the range limit a small increase is shown (Fig. 3). It is connected with the occurrence of the old specimens at this border. The old specimens are inhabited by a greater number of microfungal species (Fig. 4), especially by lignicolous species. In the higest locality I have collected six species of microfungi, among them lignicolous *Massarina balnei-ursi*. It seems that the population of *D. octopetala* near its vertical limit is stable. The number of microfungi per host-plant specimen varies from 1 to 9. The most widely distributed host-plants are inhabited by 3-4 taxa of microfungi.

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Fig. 2. The participation of pigmented and hyaline spores of dryadicolous microfungi in the arctic-alpine environments of Europe, based on matterials of Holm (1979), Holm & Holm (1985, 1993a,b, 1994), Nograsek (1990), Nograsek & Matzer (1991), Chlebicki (1995) and his unpublished data. T — Tatra Mts., A — the Alps, S — Scandinavia, PU — the Polar Urals, SP — Spitsbergen



Fig. 3. The species diversity of dryadicolous microfungi in relation to increasing altitude. N — number of species, M — altitude (m a.s.l.)



Fig. 4. The species diversity of dryadicolous microfungi in relation to the age of host-plants. N — number of species

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## THE MICROFUNGAL GROWTH FROM MYCELIAL FRAGMENTS AND FROM SPORES IN LOW TEMPERATURE CONDITIONS

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Abstract: The vitality of colony-forming units — Mucor hiemalis, Penicillium spinulosum and Alternaria alternata — has been much lower at 4°C, than at 25°C. Vitality of spores and mycelium fragments has been different at low temperatures (4°C). Delay in both spores and mycelium fragments sprouting has been recorded at low temperature, and some morphological changes of mycelium have been reported — in septate density (A. alternata), yeast-like growing (M. hiemalis).

Жизнеспособность колониеобразующих единиц — Mucor hiemalis, Penicillium spinulosum и Alternaria alternata — была существенно ниже при 4°C, чем при 25°C. Жизнеспособность спор и фрагментов мицелия при низких температурах (4°C) различалась. В частности, при этих температурах отмечена задержка в прорастании как спор, так и фрагментов мицелия, а также наблюдались некоторые морфологические изменения мицелия — изменение плотности септирования (A. alternata), появление дрожжеподобного роста (M. hiemalis).

Keywords: microfungi, low temperature, mycelial, growth, hyphal fragments, spores.

Both mycelial fragments and fungal spores can be found as colonial growth units in natural soils. The fungal colony growth from mycelial fragments is not well known, while the growth of fungal colonies from spores has been studied on solid media and in submerged cultures very well (Trinci, 1984; Prosser, 1993).

It had been shown in our previous investigations (Марфенина и др., 1994) that the microcolonial growth from hyphal fragments depends on ecological conditions. Nothing is learned about the microcolonial growth from fragments under the effect of low temperatures. These conditions are typical of the arctic and alpine zones. We have not got much knowledge of the comparison of viability of hyphal fragments and fungal spores in «cold» soils.

The aim of our investigation is to study the growth of microfungal colonies from mycelial fragments and from spores at a low temperature.

## Material and methods

The objects of investigation were three microfungal species which were typical of northern podzolic and primitive soils (Мирчинк, 1988; Паринкина, 1989; Каратыгин & Нездойминого, 1994): Alternaria alternata (Fr.) Keissler, Mucor hiemalis Wehmer and Penicillium spinulosum Thom. These species which belong to different taxonomic groups differ in mycelial structure. A. alternata is a representative of the section of prospore fungi in the class *Deuteromycetes*. The mycelium is septate and dark-coloured, and contains melanin in the cell wall.

*M. hiemalis* belongs to the order *Mucorales* of the class *Zygomycetes*. The mycelium is light, coenocytic, noncellular.

P. spinulosum is a representative of the section of phialospore fungi in the class Deuteromycetes. It has septate, light mycelium.

The pure mycelial culture of species was grown in Czapek's liquid medium at 25°C. The fungal mycelium was fragmented by a standart method which had usually been used in the preparation of soil for analysis, that is, shaking the mycelial suspension on a mechanical shake-table (180 rpm) for 10 min. (Эвягинцев и др., 1991). The density of mycelial suspension was about 6.10<sup>3</sup> hyphal fragments per 1 ml.

After the fragmentation, a drop of mycelial suspension (0.05 ml) was put on slides which had preliminarily been covered with a 2 mm layer of Czapek's agar medium, and the drop was spread over the surface. The slides were incubated at 18°, 25°C for 3 days and at 4°C for 5 days.

The length of the mycelial fragment after the fragmentation was from 10 µm to 250 µm for septate mycelium, and from 40 µm to 700 µm for coenocytic mycelium. According to the mycelial structure of a fungal species the hyphal fragments were separated into classes on their length (Mappenuna и др., 1994). Each class of length contained as many as ten fragments in three replicates. The total number of growing fragments for each class of length, increasing in length and counting the number of growing apices in each of the growing microcolonies was investigated daily with the aid of microscopy.

The spore germination and microcolonies growth from spores was observed simultaneously by the method described above. The density of spore suspension was about  $10^6$  spores per 1 ml for *M*. *hiemalis* and *P*. *spinulosum*, and  $10^5$  spores per 1 ml for *A*. *alternata*.

The fragment viability and spore germination were determined according to their growth on a nutrient medium. The growth of fungal microcolonies was described through some parameters as the total length of growing mycelium, lgL ( $\mu$ m); specific growth rate (hr<sup>-1</sup>); hyphal growth unit, HGU ( $\mu$ m) which is the ratio of total length to the number of growing apices (Caldwell & Trinci, 1973; Trinci, 1984).

#### **Results and discussion**

Our previous investigation showed that the hyphal fragment viability depends on a type of fungal mycelium and increases with increasing in initial fragment length at a higher (18°-30°) temperature (Марфенина и др., 1994). The same tendency was observed at a low (4°C) temperature; long fragments were more viable in comparison with short fragments. However, the total number of growing hyphal fragments and germinated spores at 4°C was lower than that at 18°C, 25°C (Fig. 1).

The negative effect of low temperature showed in an increase in the critical size of a fragment (CSF). The CSF is a minimal size of fragments which were able to grow (Mapфенина и др., 1994). Only large ones (>140 $\mu$ m) were able to grow at a low temperature. Tha situation was common for the mycelial fragments of *M. hiemalis* and *P. spinulosum* (Fig. 1). As opposed to it, the CSF of dark-coloured fragments of *A. alternata* did not change with a decrease in temperature and short (30-90  $\mu$ m) fragments were able to grow both at the temperature of 25°C and the temperature of 4°C.













53

It was found that the mycelial fragments and spores differed in their ability to grow at a low temperature — 4°C. The germination level of large, dark-coloured spores of species *A. alternata* was higher than mycelial fragments viability at 4°C (Fig. 1). Otherwise, the hyphal fragments of *M. hiemalis* were more viable in comparison with spores at a low temperature. The difference between the viability of fragments and spores was mostly seen in the case of *P. spinulosum*. We observed that large hyphal fragments of *P. spinulosum* (>150 µm) grew, but spores did not germinate at 4°C (Fig. 1). The spore germination began only after an increase in temperature, for example, from 4°C to 9°C.

In tundra soils the main part of fungal biomass is represented by fungal mycelium, and the proportion of spores is less than in southern zonal soils. One of the reasons for that is abundant available organic matter which is slowly utilized by the soil fungi under cold arctic conditions (Демкина, Мирчинк, 1983; Мирчинк, 1988; Паринкина, 1989). Another reason for that may be that the possibilities of growth persisted under low temperature conditions for mycelial fragments of some typical soil species, while their spores remained dormant.

The delay in spore germination — fungistasis — can be observed widely in soils (Dobbs & Hinson, 1953) and can be determined by a fungal species, the availability of nutrients and inhibitors of spore germination (Lockwood, 1977). The fungistasis can be of a biotic and abiotic nature. Decrease in temperature was the reason for the spore germination delay in our experiment.

At a higher  $(18^{\circ}-25^{\circ}C)$  temperature mycelial growth both from fragments and from spores began immediately after the inoculation of solid medium by fungal suspension. At 4°C the spore germination of the species *A. alternata* and *M. hiemalis* began on the second day and lasted for 3-4 days. Most spores germinated on the third and fourth days (Fig. 2).

Delay in the growth of hyphal fragments was observed also under low temperature conditions. Its effect could be seen clearly for fragments of A. alternata. The fragments began to grow 2-3 days later as compared to the cases with the temperature of 18°, 25°C (Fig. 3). Thus, under low temperature conditions the fungistatic effect occurred both on spores and hyphal fragments.

The autolysis of nongrowing hyphal fragments was observed at a low  $(4^{\circ}C)$  temperature. The lysis of fungal mycelium was described in soil conditions by some authors (Lloud & Lockwood, 1966), but the details of the process are still not clear. We found that the hyphal autolysis for coenocytic, noncellular mycelium of M. hiemalis began sooner (on the second day) than for septate mycelium at  $4^{\circ}C$ . The autolysis of nongrowing hyphal fragments of P. spinulosum began on the third day and lasted for 3-5 days. For dark-coloured mycelium of A. alternata the autolysis was not observed during the experimental time, that could be connected with high resistance of melanin which is contained in fungal cell walls.

Some characteristics of microfungal growth could differ under different temperature conditions. The growth rate for all examined fungal species was decreasing at 4°C in comparison with that at 25°C (Fig. 3, Table). The growth response in branching did not depend on temperature for M. hiemalis and P. spinulosum. Except for A. alternata, the branching pattern was higher (the HGU decreased) at a low temperature compared with that at 18° and 25°C. The HGU can change due to the alteration of transport by vesicles and branching initiation in different species in some environment (Prosser, 1993). For example, the change of HGU was mentioned for microcolonies of Neurospora crassa under the effect of a high temperature (Trinci, 1984).







Fig. 2. The spore germination at different temperatures. A – 4°C; B – 25°C. I – A. alternata; II – M. hiemalis. l – 1-st day; 2 – 2-nd day; 3 – 3-rd day; 4 – 4-th day; 5 – 5-th day



Fig. 3. The length (lg L) of mycelium growing from the hyphal fragments and fungal spores at different temperatures. A –  $4^{\circ}$ C; B – 25°C. I – A. alternata: the length of hyphal fraagments (µm): I – 30-60; 2 – 60-100; 3 – 100-150; 4 – >150. II – M. hiemalis: the length of hyphal fragments (μm): *I* – 80-140; *2* – 140-200; *3* – 200-350; *4* – 350-500; *5* – >500; *6*, *7*, *8*, *9* – spores

#### TABLE

Effect	of	different	temperat	ture co	nditions	on	specific	growth	rate	and
		br	anching	pattern	of some	e m	icrofung	i		

Fungal	Type of	Specific grow	th rate (hr-1)	Hyphal growth unit		
species	fungal	4°C 25°C		25°C (μm)		
	structure			4°C	25°C	
Mucor	spores	0.0331±0.016	0.3412±0.22	49±11	63±21	
hiemalis	fragments	8	23	65±19	49±9	
		0.0143±0.008	0.1967±0.04			
		8	14			
Penicillium	spores	0	0.2085±0.03	0	46±10	
spinulosum	fragments	0.0015±0.000	60	48±19	50±17	
		4	0.1153±0.01			
			99			
Alternaria	spores	0.0275±0.008	0.1719±0.08	66±36	284±53	
alternata	fragments	7	13	57±37	154±65	
		0.0095±0.005	0.1156±0.05			
		5	50			

The branching initiation can be connected with the septa formation (Fiddy & Trinci, 1976; Prosser, 1993). The occurrence of septa and septal sealing depends on a microenvironment. The density of septation should be minimized when external resourses availability is minimized, and vice versa (Rayner et al., 1995). In our experiment a decrease in temperature from 25°C to 4°C was the cause of the distance decrease between the septa in the mycelium of *A. alterata* accordingly from 26-29 µm to 9-12 µm. As it was pointed out in the previous investigation (Марфенина и др., 1994), the mycelium with high septation frequency is more viable.

Changes in morphology of fungal mycelium, temperature and nutrient-dependent dimorphism have been described for *Mucorales* — *Mucor racemosus* (Philips & Borgia, 1985), *M. rouxii* and some other fungi (Garraway & Evans, 1984). We also found that low temperature influenced the morphology of the coenocytic mycelium of *M. hiemalis*. This formed mainly yeast-like cells, and coenocytic mycelial growth was limited at 4°C. At first, septa were formed in hyphal fragments at a distance of 10-12  $\mu$ m between each other, then this compartments began to swell up to 16-22  $\mu$ m in diameter. After that the new compartments began to bud.

### Conclusion

Thus, the fungal microcolony growth has got some specific characteristics under low temperature conditions:

- the growth delay exists both for spores and hyphal fragments;
- the viability both of spores and mycelial fragments is considerably reduced;
- low mycelial growth rate occurs; some morphological variations of mycelium (the density of septation, yeast-like growth) can be observed;

— the level of spore germination in some microfungal species could be even less than the viability of growing fragments.

So, the type of fungal colonial growth units (spores or hyphal fragments) could be important for the microcolonial growth under both environmental and laboratory conditions at a low temperature.

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#### RESULTS AND SOME ASPECTS OF EXPLORATION OF THE RUSSIAN ARCTIC MYCOBIOTA

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Abstract: About 1,400 species of fungi have been reported from the Russian Arctic by now. More than 70 of them are new to science. Data on the systematic composition of the mycobiota of the whole Arctic and that of its particular areas are offered.

> К настоящему времени для арктических районов России описано около 1400 видов грибов. Среди них более 70-ти являются новыми для науки. Представлены данные о систематическом составе арктической микобиоты в целом и для ее отдельных районов, в частности.

Keywords: the Arctic, mycobiota, biodiversity.

 $\mathcal{A}_{ ext{t}}$  present there is an urgent need for the intensification of the mycological investigations on the vast territory of the Russian Arctic (RA). It is known that fungi as the main component of the heterotrophic block of ecosystems, as destructors of plant material play an important role in functioning and stabilization of the ecosystems of the Arctic. In the Arctic the role of fungi is especially significant, because other microorganisms at low temperatures lose their ability to use hardly available compounds. In many cases fungi along with lichens are the first sensitive indicators of the anthropogenic destruction of the fragile ecological systems of the Arctic. Today the level of large generalizations concerning the taxonomical biodiversity and biology of fungi in the RA does not correspond to the role played by fungi in the arctic ecosystems. In this relation the level of mycobiota research is considerably lower than that of higher plants and other groups of lower plants. The problem for mycologists consists in reduction and elimination of this retardation in the near future. The territory of the RA considered here comprises vast tundra areas stretching from the coast of the Barents and White Seas in the west to the Bering Strait in the east. The timberline forms the southern boundary. Adjacent uplands with mountainous tundra vegetation (the Khibin Mts., Polar Urals, Kolyma and Koryakskoye Uplands) are included in this territory. These are the boundaries of the RA that have been accepted for the edition «Flora of the Arctic of the USSR». The research of the RA mycobiota has lasted for already more than a hundred years.

## The History of Mycological Research in the Russian Arctic

The history of the research of the mycobiota in the RA can be subdivided into three principal stages. At the first stage the research of the mycobiota of the RA had been carried out mainly by mycologists from Scandinavian countries. They had realized a number of scientific expeditions in different Arctic regions of Russia. The principal of them was the Swedish expedition of A.E. Nordensköld (1878-1879) on the ship «Vega». During that expedition, rich mycological material had been collected from many points of the Arctic coast of Russia. A number of basic articles on mycobiota of the RA on the material of those expeditions had been published. These were articles by the classical authors of mycology like K.W.G.L. Fuckel, C.A.J.A. Oudemans, I. Jörstad, J. Lind and others. The contribution of Finnish mycologists to the study of the north of Kola Peninsula (J.I. Liro, P. Karsten, L.E. Kari and others) is significant. R. Singer had described a few species of Agaricales from Franz Josef Land. In fact, at the first stage of research the strong basis for further mycological work had been established. The special value of the first stage work is that practically all the collections of fungi have been preserved to the present day in the herbaria of Scandinavian countries. These collections are accessible for researchers. The main work of those years was the article by Dr. J. Lind, in which he listed 160 species of micromycetes from various regions of the RA. A few dozens of species were described as new to science.

The second stage in the study of the mycobiota of the RA has been realized since the middle of the thirties mainly due to the efforts of Russian mycologists. The most significant contribution at this stage was made by V. Tranzschel (Kola Peninsula), K. Benua, B.P. Vassilkov, B. Tomilin, N. Kazantseva, V.A. Mukhin (the Polar Urals, the Sub-Arctic of middle Western Siberia and the Magadan subarctic area), B. Tomilin, I. Stepanova (Taimyr), Z. Azbukina (the Magadan Arctic regions), L. Vassilyeva (Wrangel Island, the Kolyma Mountains), A. Schkarupa (Yakutia) and others. During that period, the research was being carried out, as a rule, in cooperation with experts in higher plants, that seriously increased the efficiency of research. In this relation, the herbaria of higher plants collected by Russian florists and geobotanists have an important value for mycologists. Mycologists have a possibility of identifying fungi actually from all the locations of the Arctic on the basis of the analysis of higher plants herbaria.

It is possible to say that at the present time the third, modern, stage of the RA mycobiota study begins. Its distinctive feature is international cooperation between mycologists from different countries.

## The Main Results and Prospects of Mycological Research in the Russian Arctic

The following results have been achieved at these two stages of investigations. By now about 100 authors and co-authors have published more than 300 articles on the RA mycobiota. On the territory of the RA (within the borders accepted in «Flora of the Arctic of the USSR») more than 1,350 species of fungi have been discovered (without lichens, yeasts and soil fungi) sharing relationships with 600 species of host-plants. More than 70 of them have been described as new to science, and part of these species are, probably, endemics. To the present time about 1,200 species of lichens have been registered in the RA. Thus, the number of species of fungi found on the territory of the RA at present is nearly equal to the number of lichen species. The recorded species belonging to the most significant taxonomical groups are distributed as seen in Table 1. If we accept the borders of the RA in a narrower sense, for example, as it was accepted in the famous project of «Panarctic Flora», the number of species will be 25-30 per cent lower.

#### TABLE 1

## Systematic arrangement and number of fungal species from the main taxa found in the Russian Arctic until now

Divisions	Orders	Number of spp.	Per cent of total
Myxomycota		20	1.4
Chytridiomycota	Blastocladiales	2	0.1
	Chytridiales	13	1.0
Labyrinthulomycota	Thraustochytriales	7	0.5
Oomycota	Peronosporales	14	1.0
	Pythiales	3	0.2
Ascomycota	Diaporthales	35	2.5
	Diatrypales	4	0.3
	Dothideales	296	21.4
	Erysiphales	20	1.4
	Hypocreales	5	0.4
	Laboulbeniales	10	0.7
	Leotiales	95	6.9
	Pezizales	44	3.2
	Phyllachorales	5	0.4
	Protomycetales	1	0.1
	Sordariales	1	0.1
	Taphrinales	7	0.5
	Xylariales	12	0.9
Basidiomycota	Agaricales (incl.	262	19.0
-	Cortinariaceae)		
	Boletales	21	1.5
	Hymenogastrales	1	0.1
	Lycoperdales	5	0.4
	Lachnocladiales	4	0.3
	Poriales	6	0.4
	Russulales	53	3.8
	Thelephorales	2	0.1
	Tremellales	2	0.1
Teliomycetes	Uredinales	108	7.8
Ustomycetes	Ustilaginales	55	4.0
	Exobasidiales	8	0.6
Deuteromycota	Hyphomycetes	56	4.1
	Coelomycetes	205	14.8
Total		1382	100
LICHENS		1065	
TOTAL		2447	

It is necessary to emphasize that some works on the mycobiota of the RA have essential drawbacks. In particular, many species indicated in the published lists require taxonomical auditing and checking, many specimens mentioned in the articles are absent from mycological herbaria and they are inaccessible for study. All these circumstances considerably depreciate some works on the RA mycobiota carried out during the past years. We should note that the quality of mycofloristic articles of the second stage is in many cases much lower than that of similar articles by western mycologists. In the studies of taxonomical biodiversity, the mycobiota of the RA is comparable with that of large regions of Russia (for example, central European Russia, the Far East, Siberia), but considerably lower as far as it concerns large regions of the foreign Arctic (Greenland, the Canadian Arctic, Alaska, Spitsbergen). The territory of the RA concerning mycobiota is surveyed extremely non-uniformly (Tables 2, 3). Along with fairly well investigated regions there are vast regions which are absolutely unstudied. Taimyr and Kola Peninsulas, the Polar Urals are quite well investigated regions where about 400-500 species of fungi are known. The poorly investigated or absolutely unexplored regions are Timan and Gydan tundras, the north of Yamal Peninsula, Chukotka, the north coast of Yakutia and many arctic islands.

During the first period of research by Scandinavian mycologists 165 species were found on Novaya Zemlya Island. This number of species has not increased, as the island was closed for military reasons, and scientific work had not been possible there for many years.

We also hope that mycologists will take part in the solution of many problems concerning Beringia. As it is known, botanists and lichenologists work successfully in this field. The research of the mycobiota of Wrangel Island and the Beringian coast of Chukotka are of a considerable scientific interest, but the information on the fungi of these territories is absolutely negligible. The possibilities of mycogeographic analysis are limited because of the uneven research of the RA territories. Taxonomically the fungi of the RA are not investigated uniformly, either. Parasitic fungi (the orders *Uredinales, Ustilaginales, Erysiphales*) are more or less known. The groups of saprotrophic fungi are investigated much worse. Poorly investigated taxonomical groups of fungi are *Deuteromycetes, Discomycetes*, all «*Chrysophyta*». The problem of the research of lichenicolous fungi, a large ecological group playing the important role in the ecosystems of the Arctic, is urgent for the RA. Besides, there is not enough information on the fungi inhabiting mosses, mushrooms, insects. It is necessary for mycologists to pay special attention to poorly investigated groups of fungi, especially on the species of *Chrysophyta*.

The further inventory of species is necessary for the purpose of achieving the greatest completeness. As it is known, Dr. D.L. Hawksworth's formula rates a number of fungal species on a certain territory, depending on a number of species of the higher plants growing on this territory in ratio 4:1 (including lichens). Thus, one species of a plant contains on the average four species of fungi. Under conditions of high latitudes this ratio increases due to the quantity of fungi on one plant getting larger. As it is known, on the RA territory about one and a half thousand species of higher plants grow. We estimate the real number of fungi inhabiting the RA territory as 4,700 or 5,000 species (without lichens). In other words, the degree of study of the mycobiota of the RA makes about 20 per cent. It means that at the present time 20 per cent of all fungal species really existing in nature are known. This is much less than the respective parameter for other groups of plants: higher plants, mosses, and lichens. The mycobiota of the RA includes cosmopolitan, temperate nemoral, hemiboreal, boreal, subarctic, and arctic species. Approximately 20 percent of the biota is constituted by arctic/alpine/subarctic/subalpine elements. It is estimated that the southernmost subarctic area comprises c. 1,000 species, whereas in the North Arctic, or «real» Arctic, the number is closer to 450. It is not yet possible to separate exactly the species into the western North American, Beringian and eastern Eurasian elements, as it has been done with the vascular plants. Mycologists should not restrict themselves to simple registration of fungal species on some territory, but they should try to determine their role in specific ecological situations of the arctic conditions. It is necessary to note insufficient

## TABLE 2

# Comparison of the recorded fungi from different regions of the Russian Arctic

Locations	Chytridiales	Peronosporales	Saprolegniales	Traustochytriale
				s
Murm.	4	8	9	0
Arkhangelsk	0	0	0	0
Tyum.	0	1	0	0
Polar Urals	2	0	0	0
Taimyr	2	2	1	0
Yakutia	0	2	0	0
Chukotka	5	0	0	0
(contin.)				
Koryak	0	0	0	0
Magadan	0	8	0	0
Locations	Diaporthales	Diatrypales	Dothideales	Erysiphales
Murm.	4	1	42	5
Arkhangelsk	1	0	30	0
Tyum.	0	0	2	0
Polar Urals	11	1	67	8
Taimyr	9	1	167	8
Yakutia	11	1	98	8
Chukotka	1	4	84	10
(contin.)				
Koryak.	0	0	0	0
Magadan	0	0	10	13
Locations	Hypocreales	Laboulbeniales	Leotiales	Pezizales
Murm.	0	9	33	4
Arkhangelsk	0	2	8	5

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Murm.	0	9	33	4
Arkhangelsk	0	2	8	5
Tyum.	0	0	3	3
Polar Urals	3	0	16	14
Taimyr	2	0	48	17
Yakutia	0	1	20	6
Chukotka	1	0	1	4
(contin.)				
Koryak	0	0	0	3
Magadan	2	0	1	0

Locations	Phyllachorales	Rhytismatales	Taphrinales	Xylariales
Murm.	3	0	5	3
Arkhangelsk	0	2	0	0
Tyum.	0	0	0	0
Polar Urals	3	10	3	3
Taimyr	6	9	0	8
Yakutia	1	9	0	3
Chukotka	3	1	0	4
(contin.)				
Koryak.	0	0	0	1
Magadan	1	2	0	1
# (Table 2 continued)

Locations	Agaricales (incl. Cortinariales)	Boletales	Russulales	Lachnocladiales
Murm.	99	7	23	4
Arkhangelsk	14	2	3	0
Tyum.	26	6	16	0
Polar Urals	99	11	37	1
Taimvr	112	1	16	0
Yakutia	34	3	16	0
Chukotka	86	14	29	0
(contin.)				
Korvak	12	9	12	0
Magadan	0	0	0	0
Magadan	<u>v</u>	· · · · ·	0	
Locations	Poriales	"Gasteromycetes"	Exobasidiales	Uredinales
Murm.	0	0	6	65
Arkhangelsk	0	0	0	11
Tyum.	0	0	0	2
Polar Urals	6	3	0	39
Taimyr	0	3	0	34
Yakutia	0	1	1	15
Chukotka	0	2	0	42
(contin.)				
Koryak.	0	0	0	1
Magadan	0	0	1	41
Locations	Ustilaginales	Hyphomycetes	Coelomycetes	Total
Murm.	33	10	42	415
Arkhangelsk	1	1	13	93
Tyum.	2	0	1	62
Polar Urals	8	14	42	400
Taimyr	10	8	86	550
Yakutia	7	25	87	349
Chukotka	23	2	4	320
(contin.)				
Koryak.	0	0	0	38
Magadan	15	2	2	99

# TABLE 3

# Comparison of the recorded species of fungi and lichens from main islands of the Russian Arctic

Locations	Chytridiales	Traustochytriales	Diaporthales	Dothideales
Franz-Josef Land	0	0	0	5
Kolguyev Isl.	0	0	1	7
Novaya Zemlya	1	0	0	62
Vaigach Isl.	0	0	0	19
New Sibirian Isl.	0	0	0	1
Northern Zemlya	0	0	0	0
Arch.				
Wrangel Isl.	5	7	1	32

# (Table 3 continued)

Locations	Erysiphales	Leotiales	Pezizales	Phyllachorales
Franz-Josef Land	0	0	0	0
Kolguyev Isl.	0	6	5	0
Novaya Zemlya	0	24	2	4
Vaigach Isl.	0	3	0	0
New Sibirian Isl.	0	1	4	0
Northern Zemlya Arch.	0	0	0	0
Wrangel Isl.	3	0	0	2

Locations	Rhytismatales	Xylariales	Agaricales (incl. Cortinariales)	Boletales
Franz- Josef	0	0	4	0
Land				
Kolguyev Isl.	1	0	0	0
Novaya Zemlya	3	1	1	0
Vaigach Isl.	0	0	0	0
New Sibirian Isl.	0	0	22	0
Northern Zemlya	0	0	9	0
Arch.				
Wrangel Isl.	0	3	17	0

Locations	Russulales	Uredinales	Ustilaginales	Hyphomycetes
Franz- Josef	0	1	0	0
Land				
Kolguyev Isl.	0	9	1	0
Novaya Zemlya	1	14	9	10
Vaigach Isl.	0	0	0	0
New Sibirian Isl.	1	0	0	0
Northern Zemlya	0	0	0	0
Arch.				
Wrangel Isl.	3	15	12	0

Locations	Coelomycetes	TotalFungi	Lichens
Franz- Josef Land	1	11	129
Kolguyev Isl.	4	34	-
Novaya Zemlya	34	166	÷ 517
Vaigach Isl.	8	30	-
New Sibirian Isl.	0	29	229
Northern Zemlya	0	9	167
Arch.			
Wrangel Isl.	0	100	310

number of theoretical articles on the taxonomical and ecological analysis of the mycobiota of the RA. Apparently, the time for more mycological generalizations still lies ahead. The outstanding examples of deep theoretical insights and generalizations on the ecology and biogeography of the arctic fungi were given by D.B.O. Savile, J. Lind, I. Jörstad and others. However, their brilliant theoretical conclusions are not complete without data from the RA. In this relation, Russian mycologists' falling behind botanists, lichenologists and bryologists is rather critical. A serious inference was elicited by J. Lind and N. Lavrov on the basis of the biogeographical analysis of micromycetes of the Russian sector of the Arctic. In particular, they have noted that the mycoflora of the European part of the RA is connected in its origin with the mycoflora of north Europe and Greenland, whereas the mycobiota of the Asian sector has Beringian and North American origin. It is possible to say that the modern arctic mycobiota of the Russian sector is young as a whole. The basic kernel of mycoflora has developed as late as in the late Pliocene or in the Pleistocene. Mycologists can accept the way of formation proposed for the higher plants by A. Tolmachov and B. Yurtsev as valid also for the the mycobiota of the RA. According to these authors, the RA flora is derivative of the Neogenic Boreal area, the direct predecessor of which was the high-mountain flora of treeless tops. These plants decended later to the northern plains during the late Neogene and mixed up there with the remainders of the flora of woodlands. The significant part of fungi apparently accompanied this migration. J. Lind, D.B.O. Savile and other mycologists noted that the whole circumpolar mycobiota had appeared much earlier in large mountain ranges (the Urals, the Alps, the Rocky Mountains, the Caucasus). The manuscript «The Fungi of the RA» is being prepared at present at the Botanical Institute. This manuscript contains the annotated checklist of more than 1,300 fungal species (without yeasts and soil fungi) from different regions of the RA. The manuscript sums up the results of mycofloristic studies of the RA. This publication will be useful and necessary for all the experts who are interested in the problems of the Arctic. We request foreign specialists to share the information on fungi from the RA territory for the manuscript, if such information is available. However, we have problems with financing the publication. At the present time at the Botanical Institute the work on the database on the RA mycoflora has begun. The database is being arranged in the format FoxPro, but only the first steps in this direction have been made. Now we have four or five thousand examples of fungi, the number of which will increase. The database should be compatible with similar databases, for example, with the databases of other groups of arctic plants.

## Conclusion

In conclusion, it is possible to say that the essential contribution to the study of biodiversity of the RA mycobiota has been made. However, mycologists should make more effort to reduce the retardation from the study of arctic flora of other plant groups. In mycological relation, the RA should not be a blank on the general map of the whole Arctic. During the last years contacts with mycologists of different countries have been set up. The subsequent study of the RA will go on under the flag of international cooperation.

## NOTES ON THE NORTH URAL APHYLLOPHORALES (BASIDIOMYCETES)

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Abstract: 73 Aphyllophorales have been found in the Polar Urals. Most of them are *Corticiaceae*, followed by polypores (22 species). The description of their substrate is given, as well as a few notes on the microstructure of the collected species. All the threatened species, except *Peniophora laurentii*, have been found in the most pristine forest.

На Полярном Урале обнаружено 73 вида афиллофоровых грибов. Большинство из них относится к кортициевым. Трутовые грибы образуют вторую по значимости группу (22 вида). Приводится описание субстратов, на которых они развиваются, а также отмечены анатомические особенности базидиом. За исключением Peniophora laurentii, виды, находящиеся под угрозой исчезновения, найдены в девственном лесу.

Keywords: Aphyllophorales, biodiversity, the Polar Urals.

She senior author visited the Ural Mountains for the first time in 1992. Then he was collecting for a day in the valley along the railroad from Labytnangi to Vorkuta in Rai-Iz. In 1996 both the authors collected in Rai-Iz plus the two other places mentioned here. However, the two latter sites were visited very briefly — for about two hours each. The senior author has made the identifications and written the article.

## Collecting sites and methods

All the study areas are situated in Tyumen region, Yamal-Nenets autonomous district:

- 1. Rai-Iz. 20.07.1992, Kotiranta; 24.08.1996, Kotiranta & Penzina.
- 2. Yangana-Pe. 26.08.1996, Kotiranta & Penzina.
- 3. Nyarusalye Cape. 20.08.1996, Kotiranta and Penzina.

Detailed descriptions of the sites are given in «ISAM 5 field excursions» (see p. 13). The mean spore length (L), width (W) and length/width ratio (Q), is measured from 10 spores if not stated otherwise. The abbreviations used are: KOH (2-4% KOH in water), IKI (Melzer's reagent) and CB (cotton blue). CB- means that there is no reaction in cotton blue, IKI- that there is no reaction in Melzer's reagent. The measurements include the ornamentations of rough spores. The species are arranged alphabetically, without regard to their systematic position. The authors here are not found in any manual, but we roughly follow Eriksson et al. (1973 and later volumes, *Corticiaceae*), Niemelä (1995, *Polyporaceae*), Jülich (1984, *Heterobasidiomycetes*). The literature is cited only in a few cases, but we mostly follow the species concepts used in the following works: Eriksson et al. (see above), Jülich and Stalpers (1980), Hallenberg (1985), E. Langer (1994), G. Langer (1994), Ryvarden and Gilbertson (1993, 1994). Detailed (Russian) literature about the ecology of *Aphyllophorales* in Southern Yamal (mainly written by V.A. Mukhin) is listed by Kotiranta (1995).

## List of species

Amphinema byssoides (Pers.: Fr.) J. Erikss.

Rai-Iz, fairly strongly decayed *Picea*, Kotiranta 10205 (H); strongly decayed *Alnus*, Kotiranta 12693 & Penzina (H); fallen *Alnus*, Kotiranta 12697, 12698 & Penzina (H). Notes: Hyphal system monomitic, hyphae clamped, 3.5-4(-5) µm wide, with thickened walls, smooth or finely encrusted. Branches at right angles close to the clamp. The branches narrower at the base, similar to those seen in the genus *Hyphodontia*. In slides all the hyphae turn yellowish in KOH. Cystidia like hyphidia projecting over 100 µm over the hymenium. Basidia 15-21 x 5-5.5 µm, spores ellipsoid 4.4-5.0 x 2.9-3.1 µm, L=4.7 µm, W=3.0 µm, Q=1.6 (nr. 12697); 4.9-5.6 x 2.8-2.9 µm (nr. 10205).

Amylocorticium laceratum (Litsch.) Hjortstam & Ryvarden

Yangana-Pe, hard Larix, Kotiranta 12725 & Penzina (H).

Notes: Monomitic, all hyphae clamped, in trama thin-walled, 2-3  $\mu$ m wide in subhymenium 2  $\mu$ m wide, richly branched. Basidia often stipitate, clavate, (10-)15-20 x 5-6  $\mu$ m, with four stout sterigmata, which are at first straight, later curved. Cystidia none. Spores allantoid-subcylindrical, with a prominent apiculus, often glued in pairs or tetrads, 6.8-8.8 x 2.3-3.8  $\mu$ m, L=7.8  $\mu$ m, W=3.0  $\mu$ m, Q=2.6, thin-walled, slightly amyloid. The spores of this specimen are larger than mentioned by Eriksson and Ryvarden (1973) as Athelopsis lacerata.

Amylostereum chailletii (Pers.: Fr.) Boidin

Rai-Iz, fairly hard, corticate *Picea*, Kotiranta 10210 (H) — Yangana-Pe, corticate *Larix* on the ground, Kotiranta 12729 & Penzina (H). Notes: Both specimens are sterile.

Antrodia serialis (Fr.) Donk

Rai-Iz, decorticate *Picea* log, Kotiranta 12690 & Penzina (H). Notes: Small, sterile specimen.

Athelia decipiens (Huhn. & Litsch.) J. Erikss.

Rai-Iz, fairly strongly decayed Picea, Kotiranta 10208 (H).

Notes: Monomitic, totally without clamps. Basal hyphae with somewhat thickened walls, up to 5  $\mu$ m wide, subhymenial hyphae thin-walled, 3.5  $\mu$ m wide. Basidia 12-14 x 4.5-5  $\mu$ m, with four sterigmata. Cystidia none. Spores ellipsoid, often glued in tetrads, ab. 5 x 3  $\mu$ m, thin-walled, inamyloid.

## **Basidioradulum radula** (Fr.: Fr.) Nobles Syn.: Hyphoderma radula (Fr.: Fr.) Donk

Rai-Iz, dead Salix sp., Kotiranta 10235 (H); at the base of dead Salix sp., Kotiranta 10279 (H).

Notes: Monomitic, hyphae thin-walled, clamped, parallel in aculeal trama, 2.5-3.5  $\mu$ m wide. Subhymenial hyphae short-celled, richly branched, 4.5  $\mu$ m wide. Basidia 19-20 x 5.5-6  $\mu$ m, basally clamped with four sterigmata. Cystidia of two kinds: cylindrical and moniliform, (48-)55-70 x 6-6.5  $\mu$ m, not projecting over the hymenium. Spores allantoid, 7.7-9.2 x 2.9-3.2  $\mu$ m, L=8.6  $\mu$ m, W=3.0  $\mu$ m, Q=2.9 (nr. 10235); 8.0-9.1 x 2.7-3.2  $\mu$ m, L=8.4  $\mu$ m, W=2.9  $\mu$ m, Q=2.9, thin-walled, IKI-.

## Botryobasidium candicans J. Erikss.

Rai-Iz, strongly decayed, decorticate, moss-covered, large *Picea*, Kotiranta 10290 (H). Notes: Simple septate thoroughly. Basidia 15 x 8 µm, spores navicular (biapiculate), 7.0-8.5 x 3.4-4.3 µm.

## Botryobasidium subcoronatum (Höhn. & Litsch.) Donk

Rai-Iz, fairly strongly decayed, almost corticate, small *Picea*, Kotiranta 10204 (H); fairly strongly decayed, fairly large, decorticate *Larix*, Kotiranta 10229 (H); brown-rotted *Picea/Larix*, Kotiranta 12722 & Penzina (H).

Notes: Monomitic, all hyphae clamped, basal ones up to 10  $\mu$ m wide, other up to 7.5  $\mu$ m wide. Spores navicular (6.7-)8.0-9.1 x 2.9-3.3  $\mu$ m.

**Botryobasidium vagum** (Berk. et M.A. Curtis) D.P. Rogers Syn.: Botryobasidium botryosum (Bres.) J. Erikss.

Rai-Iz, large, fairly strongly decayed, partly corticate *Larix*, Kotiranta 10247 (H). Notes: Monomitic, simple septate throughout. Basal hyphae up to 11 µm wide. Spores broadly navicular (biapiculate), 9.4-10.3 x (4.7-)5.0-5.7 µm.

## Ceraceomyces tessulatus (Cooke) Jülich

Rai-Iz, fairly small, fairly strongly decayed, mostly corticate, moss-covered *Picea*, Kotiranta 10203 (H).

Notes: Monomitic, all hyphae clamped, basal ones up to 5.5  $\mu$ m wide, covered with crystals. Basidia basally clamped, 23-26(-35) x 5-5.5  $\mu$ m. Cystidia none. Spores ellipsoid, with a fairly prominent apiculus, 5.0-7.0 x 2.6-3.8  $\mu$ m, L=6.2  $\mu$ m, W=3.3  $\mu$ m, Q=1.9, thin-walled, IKI-

Ceriporia reticulata (Hoffm.: Fr.) Domański

Rai-Iz, large, fairly strongly decayed, partly corticate, moss-covered *Larix*, Kotiranta 10255 (H); strongly decayed *Alnus*, Kotiranta 12714 & Penzina (H). Notes: Monomitic, simple septate, hyphae thin-walled, 3.5-4.5  $\mu$ m wide. Basidia clavate, basally simple septate, 15-22 x 5.5-6  $\mu$ m. Cystidia none. Spores allantoid, often basally bent, 7.0-9.9 x 2.7-3.1  $\mu$ m, L=8.2  $\mu$ m, W=2.9  $\mu$ m, Q=2.8 (nr. 10255); 6.8-9.8 x 2.8-3.5  $\mu$ m, L=7.9  $\mu$ m, W=3.1  $\mu$ m, Q=2.6 (nr. 12714), thin-walled, IKI-.

Cerrena unicolor (Bull.: Fr.) Murrill

Rai-Iz, fairly large, fairly hard, corticate *Betula*, Kotiranta 10277 (H). Notes: Spores ellipsoid, 5.1-5.2 x 2.7-3.0 μm, thin-walled, IKI-.

**Chaetodermella luna** (Romell ex Rogers & H.S. Jacks.) Rauschert Syn.: Chaetoderma luna (Romell) Parmasto

Rai-Iz, small, decorticate Picea, Kotiranta 10269 (H).

Notes: All hyphae clamped, negative in Melzer's reagent, thin- to slightly thick-walled in KOH. Basidia basally clamped, 52-72 x 6 μm. Cystidia cylindrical, thick-walled, up to 220 μm long and 8 μm wide, projecting about 70 μm over the hymenium. Spores fusoid, 13.7-17.2 x 3.8-5.0 μm, L=15.7 μm, W=4.2 μm, Q=3.7, inamyloid (n=15).

### Coniophora arida (Fr.) P. Karst.

Rai-Iz, large, fairly strongly decayed, decorticate, moss-covered *Larix*, Kotiranta 10250 (H). Notes: Spores 12.0-12.7 x 7.0-7.7 µm, thick-walled, hyaline in KOH, dextrinoid.

Daedaleopsis confragosa (Bolton: Fr.) Schröt.

Rai-Iz, dead Salix sp., Kotiranta 10284 (H); at 1.6 metres hight on dead Salix sp., Kotiranta 10286 (H).

Notes: Spores allantoid, 6.6-7.8 x 1.6-1.9  $\mu$ m, L=7.3  $\mu$ m, W=1.8  $\mu$ m, Q=4 (nr. 10284); (7.3-)8.0-9.3 x 1.7-2.0(-2.4)  $\mu$ m (nr. 10286), very thin-walled, CB-. D. septentrionalis (P. Karst.) Niemelä, which is generally more northern, and grows solely on *Betula* spp. has slightly shorter and narrower spores. Moreover, the hymenophore is clearly lamellate. Spores allantoid, 6.5-7.1 x 1.4-1.7  $\mu$ m, L=6.9  $\mu$ m, W=1.5  $\mu$ m, Q=4.5 (Kotiranta 10747, n=13).

Datronia scutellata (Schwein.) Gilb. & Ryvarden

Rai-Iz, Alnus twig at 1 metres height, Kotiranta 12712 & Penzina (H).

Notes: Fruitbody small, relatively thick. Upper side blackish, sepia brown. Hymenophore pale greyish ochre, pores small, (5-)6(-7)/mm, margin clear, sterile. Hyphal system trimitic. Skeletals strongly cyanophilic, 2-3 µm wide. Generative hyphae clamped, thinwalled, 3 µm wide. Spores cylindrical, 8.4-9.6 x 2.9-3.4 µm, L=9.0 µm, W=3.1 µm, Q=2.9, thin-walled, CB-. Threatened species in this area (Мухин & Котиранта, 1997).

#### Datronia stereoides (Fr.: Fr.) Ryvarden

Yangana-Pe, dead corticate *Alnus*, Kotiranta 12740 & Penzina (H). Notes: Fruitbody thin, pores 3-4/mm. Sterile specimen.

#### Dendrothele amygdalispora Hjortstam

Rai-Iz, corticate *Salix* sp., Kotiranta 12692 & Penzina (H) — Nyarusalye Cape, small *Salix* sp. branches, Kotiranta 12677, 12678, 12679, 12680, 12682, 12683, 12684 & Penzina (H).

Notes: Fruitbody resupinate, small, greyish white, fairly hard. Hyphal system monomitic, hyphae simple septate (best visible in KOH), hyphae 1.5-2.5  $\mu$ m wide, covered with crystals. Young basidia finger-like, about 4  $\mu$ m wide. Ripe basidia basally simple septate, 21-22 x 6-9  $\mu$ m, with four stout, slightly curved, up 8  $\mu$ m long and 2  $\mu$ m wide (base) sterigmata. Cystidia none, but dendrohyphidia common — rare, richly branched, 1  $\mu$ m wide, covered with abundant crystals. Spores biapiculate, amygdaliform, often glued in tetrads, 10.0-13.9 x 6.8-9.0  $\mu$ m, L=11.3  $\mu$ m, W=7.7  $\mu$ m, Q=1.5 (nr. 12692); 8.5-11.2 x 4.7-7.3  $\mu$ m, L=10.1  $\mu$ m, W=6.1  $\mu$ m, Q=1.6 (nr. 12677); 9.3-12.0 x 5.7-7.5  $\mu$ m, L=10.6  $\mu$ m, W=6.5  $\mu$ m, Q=1.6 (nr. 12678); 8.5-12.0 x 5.8-6.9  $\mu$ m, L=10.6  $\mu$ m, W=6.4  $\mu$ m, Q=1.7 (nr. 12679); 9.2-11.3 x 6.0-7.0  $\mu$ m, L=10.2  $\mu$ m, W=6.5  $\mu$ m, Q=1.6 (nr. 12682); 9.0-11.0 x 6.3-7.0  $\mu$ m, L=10.0  $\mu$ m, W=6.6  $\mu$ m, Q=1.5 (nr. 12684), thick-walled, cyanophilous, IKI-.

#### Eichleriella deglubens (Berk. & Broome) D.A. Reid

Rai-Iz, Sorbus aucuparia branch on the ground, Kotiranta 10260 (H); fairly large, fairly hard, partly corticate Sorbus aucuparia, Kotiranta 10272 (H).

Notes: Resupinate, translucent lilac greyish, aculei pale, margin white. Monomitic, all hyphae clamped. Basal hyphae with clearly thickened walls, 2.5-3  $\mu$ m wide, subhymenial hyphae thin-walled, 2.5-3  $\mu$ m wide. Basidia four-celled, 30-35 x 9-14  $\mu$ m. Cystidia none. Spores broadly allantoid (adaxial side concave), sometimes germinating, 13.6-18.0 x 5.9-7.1  $\mu$ m, L=16.4  $\mu$ m, W=6.8  $\mu$ m, Q=2.4 (nr. 10272, n=13); 16.3-19.0 x 6.5-6.8  $\mu$ m (nr. 10260), thin-walled, CB-, IKI-.

#### *Exidiopsis griseobrunnea* K. Wells & Raitviir

Rai-Iz, fallen *Alnus*, Kotiranta 10288 (H) — Yangana-Pe, corticate alder branch, Kotiranta 12741 & Penzina (H). Notes: Spores allantoid, 10.0-12.1 x 3.2-3.8 μm, thin-walled, CB-, IKI-.

#### Fomes fomentarius (L.: Fr.) Fr.

Rai-Iz, corticate Betula trunk, Kotiranta & Penzina (H).

Globulicium hiemale (Laurila) Hjortstam

Yangana-Pe, strongly decayed larch, Kotiranta 12733 & Penzina (H).

Notes: Monomitic, hyphae thin-walled, clamped, 2-3  $\mu$ m wide. Basidia clavate, 45-50 x 14-15  $\mu$ m, basally clamped, with four, up to 10  $\mu$ m long sterigmata. Cystidia none, but apically encrusted hyphidia abundant between the basidia. Spores subglobose to globose, 10.0-11.5 x 9.5-12.0  $\mu$ m, L=10.9  $\mu$ m, W=9.2  $\mu$ m, Q=1.2, with a prominent apiculus, thin-walled, IKI-.

#### Gloeoporus dichrous (Fr.: Fr.) Bres.

Rai-Iz, small, fairly hard, decayed by *Inonotus obliquus*, corticate *Betula* stub, Kotiranta 10212 (H).

Notes: Hyphal system monomitic, hyphae thin-walled, clamped. Basidia form a dense palisade, cylindrical, 17-18 x 3-4 µm. Cystidia none. Spores allantoid, 3.8-4.1 x 0.8-1.0 µm, L=4.0 µm, W=0.9 µm, Q=4.6, very thin-walled, CB-, IKI-.

Gloeophyllum sepiarium (Wulfen: Fr.) P. Karst.

Yangana-Pe, corticate Larix, Kotiranta 12730 & Penzina (H).

#### Hymenochaete «laricis»

Rai-Iz, small Larix branch, Kotiranta 10263 (H).

Notes: Outwardly the species is very similar to Hymenochaete tabacina, except the setae that are only hardly visible under the lens (x 50). Microscopically it is easily separable, because the setae are not as sharp as in H. tabacina, they project only slightly over the hymenium, and they are much smaller, normally 40-90  $\mu$ m long, versus the setae of H. tabacina, which are over 130  $\mu$ m long. The spores are allantoid, (4.2-)5.0-6.0(-6.7) x (1.2-)1.4-1.6  $\mu$ m, thin-walled, IKI-. This species seems to grow solely on Larix spp.

### Hyphoderma pallidum (Bres.) Donk

Rai-Iz, large, fairly strongly decayed, partly corticate, moss-covered *Larix*, Kotiranta 10246 (H).

Notes: Hyphal system monomitic, hyphae clamped, thin-walled, 3  $\mu$ m wide. In subiculum brown resinous globules. Basidia clavate, (18-)20-25 x (5-)6-6.5  $\mu$ m. Cystidia subulate 45-50 x 5-6 (middle part)  $\mu$ m. Spores allantoid, (7.6-)8.0-9.0 x (2.9-)3.1-3.4  $\mu$ m, thin-walled, IKI-.

#### Hyphoderma praetermissum (P. Karst.) J. Erikss. et Å. Strid.

Rai-Iz, large, fairly strongly decayed, partly corticate, moss-covered *Larix*, Kotiranta 10254, 10256b (H); dead *Salix* sp., Kotiranta 10267 (H) — Yangana-Pe, fairly strongly decayed, decorticate *Larix*, Kotiranta 12726 & Penzina (H); strongly decayed decorticate *Larix*, Kotiranta 12734 & Penzina (H).

Notes: Monomitic, all hyphae clamped. Basal hyphae with thickened walls, 3.5  $\mu$ m wide, subhymenial and tramal hyphae thin-walled, richly branched, 3-4  $\mu$ m wide. Basidia (23-)26-30(-35) x 6-7  $\mu$ m. Cystidia of two kinds: subulate gloeocystidia (45-)50-80 x 7-10  $\mu$ m

and cylindrical cystidia, which are apically slightly widening and sometimes covered with sparse crystals, 40-50 x 6-8  $\mu$ m. Spores short-allantoid to narrowly ellipsoid, 7.0-8.1 x 3.8-5.0  $\mu$ m, L=7.6  $\mu$ m, W=4.2  $\mu$ m, Q=1.8 (nr. 12726); 8.7-9.8 x 4.3-5.0  $\mu$ m, L=9.2  $\mu$ m, W=4.3  $\mu$ m, Q=2.1 (nr. 12734) fairly thin-walled, CB-, IKI-.

#### Hyphoderma setigerum (Fr.) Donk

Rai-Iz, dead Salix phylicifolia, Kotiranta 10285 (H); corticate Alnus, Kotiranta 12695 & Penzina (H) — Yangana-Pe, corticate Alnus, Kotiranta 12739 & Penzina (H). Notes: Hyphal system monomitic, all hyphae clamped, with slightly thickened walls, 4-5  $\mu$ m wide. Basidia basally clamped, sometimes basally covered with crystals, cylindrical, constricted in the middle part, (24-)30-45(-48) x 6-6.5  $\mu$ m, with four, up to 7  $\mu$ m long sterigmata. Cystidia clamped, thick-walled, heavily encrusted, 6.5-8  $\mu$ m wide, projecting over 80  $\mu$ m over the hymenium. Spores suballantoid-subcylindrical, 9.6-11.3 x (3.0-)3.5-4.0(-4.5)  $\mu$ m, thin-walled, CB-, IKI-.

#### Hyphodontia alutacea (Fr.) J. Erikss.

Rai-Iz, strongly decayed, decorticate *Picea*, Kotiranta 12705 & Penzina (H).

#### Hyphodontia alutaria (Burt) J. Erikss.

Yangana-Pe, strongly decayed, decorticate *Larix*, Kotiranta 12731 & Penzina (H); decorticate *Larix* roots, Kotiranta 12735 & Penzina (H).

Notes: Cystidia of two kinds: subulate, thick-walled, apically encrusted lagenocystidia abundant, 30-41 x 4-5  $\mu$ m, with often brownish basal part in IKI; hyphae-like cystidia, with clamps and roundish swellings (4  $\mu$ m in diam.) very common. Spores broadly ellipsoid, 4.0-5.0 x 3.2-3.9  $\mu$ m, L=4.5  $\mu$ m, W=3.5  $\mu$ m, Q=1.3 (nr. 12735), thin-walled IKI-.

#### Hyphodontia aspera (Fr.) J. Erikss.

Rai-Iz, strongly decayed spruce, Kotiranta 12708 & Penzina (H). Notes: Basidia 17-20 x 4-4.5(-5) μm. Spores broadly ellipsoid, 5.0-5.6 x 3.9-4.4, L=5.3 μm, W=4.1 μm, Q=1.3, thin-walled, IKI-.

#### Hyphodontia crustosa (Pers.: Fr.) J. Erikss.

Rai-Iz, dead Alnus, Kotiranta 10226, fallen Alnus, Kotiranta 10245 (H); Sorbus aucuparia branch, Kotiranta 10261 (H); Salix sp. twig, Kotiranta 10282 (H). Notes: Monomitic, hyphae clamped, thin- to slightly thick-walled, up to 4  $\mu$ m wide, often covered with crystals. Basidia 18-24.5 x 4.5(-5)  $\mu$ m, with four, up to 5  $\mu$ m long sterigmata. Cystidia none, but subulate hyphal ends («cystidioles») at the aculeal apices, 32-54 x 3-4(-4.5)  $\mu$ m. Spores narrowly ellipsoid-subcylindrical, (5.5-)5.8-6.5 x 2.5-3.0  $\mu$ m, thin-walled, IKI-.

#### Hyphodontia pallidula (Bres.) J. Erikss.

Rai-Iz, large, fairly strongly decayed, decorticate, moss-covered *Larix*, Kotiranta 10243 (H); large, fairly strongly decayed, partly corticate, moss-covered *Larix*, Kotiranta 10251 (H). Notes: Hymenium dextrinoid. Basidia (12.5-)14-17 x 3-4 µm. Without lagenocystidia. Spores ellipsoid, adaxial side more or less straight, (3.6-)4.0-4.6 x 2.5-2.7 µm, thin-walled, IKI-

### Hyphodontia quercina (Pers: Fr.) J. Erikss.

Rai-Iz, strongly decayed Alnus, Kotiranta 12694 & Penzina (H); small Alnus twig, Kotiranta 12699 & Penzina (H); corticate Alnus, Kotiranta 12711 & Penzina (H). Notes: Basidia 26-30 x 4.5-5  $\mu$ m. Spores cylindrical — suballantoid, 6.6-8.0 x 2.9-3.1  $\mu$ m, L=7.1  $\mu$ m, W=3.0  $\mu$ m, Q=2.4 (nr. 12694); 6.5-7.7 x 2.5-3.3  $\mu$ m, L=7.1  $\mu$ m, W= 2.9  $\mu$ m, Q=2.5 (nr. 12699), thin-walled, IKI-.

Hyphodontia subalutacea (P. Karst.) J. Erikss.

Rai-Iz, large, fairly hard, partly corticate *Picea*, Kotiranta 10276 (H). Notes: Basidia (8-) 10-13 x (3.5-) 4-4.5  $\mu$ m. Cystidia long, tubular, thick-walled (up to 2.5  $\mu$ m), projecting over 60  $\mu$ m over the hymenium. Spores allantoid, 6.4-7.0(-7.5) x 1.5-1.7  $\mu$ m, thin-walled, IKI-.

Inonotus obliquus (Pers.: Fr.) Pilát

Rai-Iz, Betula, Kotiranta 10213 (H).

Inonotus radiatus (Sowerby: Fr.) P. Karst.

Rai-Iz, Betula, Kotiranta 10214 (H).

Lactiporus sulphureus (Bull.: Fr.) Murrill

Rai-Iz, dead *Larix*, Kotiranta 10291, coll. Tsabar (H). Threatened species in this area (Мухин & Котиранта, 1997).

### Laurilia sulcata (Burt) Pouzar

Rai-Iz, fairly large, fairly strongly decayed *Larix*, Kotiranta 10198 (H); large, fairly strongly decayed, partly corticate, partly moss-covered *Larix*, Kotiranta 10248, 10249 (H); large, fairly strongly decayed, mostly corticate, partly moss-covered *Larix*, Kotiranta 10264 (H). Notes: Spores subglobose, 5.0-6.0 x 4.6-5.8  $\mu$ m, L=5.5  $\mu$ m, W=5.0  $\mu$ m, Q=1.1 (nr. 10198); 5.6-6.9 x 4.9-6.1  $\mu$ m, L=6.2  $\mu$ m, W= 5.4  $\mu$ m, Q=1.1 (nr. 10264), finely echinulate, strongly amyloid. Threatened species in this area (Мухин & Котиранта, 1997).

#### Laxitextum bicolor (Pers.: Fr.) Lentz

Rai-Iz, corticate Alnus on the ground, Kotiranta 12720 & Penzina (H).

Notes: Spores cylindrical, adaxial side mostly slightly concave, with a negligible apiculus, 5.0-6.0 x 2.5-3.0  $\mu$ m, L=5.4  $\mu$ m, W=2.8  $\mu$ m, Q=1.9, very finely echinulate to almost smooth, amyloid.

### Litschauerella sp.

Yangana-Pe, decorticate, strongly decayed *Larix*, Kotiranta 12732 & Penzina (H). Notes: Hyphae thin-walled, CB+, clamped (low clamps), 1.5  $\mu$ m wide, covered with crystals. Basidia terminal to pleural, sometimes stipitate, 20-23 x 6-7  $\mu$ m, with four, up to 7  $\mu$ m long sterigmata. Cystidia bi-tri-rooted, thick-walled, CB-, covered with sparse, sharp-pointed crystals on the apical end, basally more or less smooth, 103-125 x 9-11  $\mu$ m, with liana-like, 1.8  $\mu$ m wide, hyphae around. Spores subglobose, 6.9-8.0 x 6.3-7.5  $\mu$ m, L=7.5  $\mu$ m, W= 7.0  $\mu$ m, Q=1.1, smooth, IKI-, slightly cyanophilous. The smooth spores separate this specimen from *L. clematitis* (Bourd. et Galz.) Erikss. & Ryvarden. Eriksson and Ryvarden (1976, p. 843) introduce a smooth spored *Litschauerella*, viz. *Litschauerella* sp. Eriksson 4157. It could be our specimen, but the basidia are larger in our specimen, and there are also terminal basidia. Moreover, the spores are smaller in our specimen. The cyanophilic reaction of the cystidia could not be verified in our specimen. The identity of *L. clematitis* is briefly discussed also in Kotiranta and Saarenoksa (1990).

#### *Megalocystidium leucoxanthum* (Bres.) Jülich Syn.: Gloeocystidiellum leucoxanthum (Bres.) Boidin

Rai-Iz, dead Alnus branch, Kotiranta 10266 (H).

Notes: Monomitic, hyphae clamped, thin- to slightly thick-walled,  $3.5-4 \ \mu m$  wide. Gloeocystidia numerous, moniliform. Spores ellipsoid,  $12.6-16.1 \ x \ 5.3-7.0 \ \mu m$ , L=13.4  $\mu m$ , W=6.1  $\mu m$ , Q=2.4 (n=12), smooth, amyloid, except the apiculus. This specimen fits better to *M. leucoxanthum* var. *brevisporum* (Parm.) Boidin, Lanquetin et Gilles than to *M. leucoxanthum* «*f. salicis*», mainly because of the shape of the spores, which are more allantoid in the latter than in our specimen. See also Parmasto (1965a, p. 225), Eriksson and Ryvarden (1975, p. 427-429), Boidin et al. (1997, p. 66).

### Merismodes anomalus (Pers.: Fr.) Sing.

Rai-Iz, dead Salix sp., Kotiranta 10278 (H).

### Peniophora aurantiaca (Bres.) Höhn. & Litsch.

Rai-Iz, dead Alnus, Kotiranta 10232 (H); Alnus twig, Kotiranta 10271 (H) — Yangana-Pe, Alnus twig, Kotiranta 12737, 12742 & Penzina (H).

Notes: Monomitic, hyphae thin-walled, clamped, 3-5  $\mu$ m wide. Basidia large, clavate, 65-85 x 10-12  $\mu$ m, basally clamped, with four, up to 8  $\mu$ m long, curved sterigmata. Cystidia of two kinds: thick-walled, encrusted metuloids, 70-85 x 9-11  $\mu$ m, and gloeocystidia which may be apically obtuse, or subulate, and in the latter case often have a schizopapillae, 70-120 x 9-13  $\mu$ m. Sometimes also mal-formed, apically forked gloeocystidia seen. Spores broadly ellipsoid, 13.2-16.0 x 7.3-8.5  $\mu$ m, L=14.4  $\mu$ m, W=7.9  $\mu$ m, Q=1.8 (nr. 12737); 14.4-18.0 x 8.0-10.3  $\mu$ m, L=16.1  $\mu$ m, W=9.2  $\mu$ m, Q=1.7, with thickened wall, IKI-.

### Peniophora laurentii Lundell

Rai-Iz, *Betula* twig, Kotiranta 12691 & Penzina (H) — Nyarusalye Cape, *Betula nana* twig, Kotiranta 12676 & Penzina (H).

Notes: Monomitic, subiculum IKI grey (nr. 12676), hyphae relatively thin-walled, often branched at right angles, simple septate, 3-4 µm wide. Basidia clavate, 41-50 x (4.5-)5-6 µm. Cystidia of two kinds: thick-walled, apically encrusted metuloids fairly few, gloeocystidia numerous, (90-)140-175(-over 200) x 9-10 µm. Spores broadly cylindrical, often basally bent, 7.2-10.6 x 3.3-4.0 µm, L=8.8 µm, W=3.8 µm, Q=2.3 (nr. 12676), thin-walled, IKI-.Threatened in this area (Мухин & Котиранта, 1997).

Phanerochaete laevis (Pers.: Fr.) J. Erikss. & Ryvarden

Rai-Iz, small Picea, Kotiranta 10230 (H).

Notes: Monomitic, simple septate, hyphae fairly thin-walled. Basidia cylindrical, basally simple septate, 26-31 x 4.5-5  $\mu$ m. Cystidia narrowly cylindrical, about 55 x 10  $\mu$ m, encrusted, except the naked acute apical end. Spores short-cylindrical to ellipsoid, 4.7-5.2 x (2.3-)2.5-2.8  $\mu$ m, thin-walled, IKI-.

#### Phellinus chrysoloma (Fr.) Donk

Syn.: Porodaedalea chrysoloma (Fr.) Fiasson & Niemelä

Rai-Iz, large, fairly hard, corticate *Picea*, Kotiranta 10210 (H); large, fairly hard, corticate *Larix*, Kotiranta 10262 (H).

Notes: Pores labyrinthiform 1-3/mm (nr. 10210); (3-)4(-5)/mm (nr. 10262). Hymenial setae sharp-pointed, golden brown,  $(36-)40-50(-55) \times (6-)8-10(-12) \mu m$ . Spores broadly ellipsoid, ventral side more or less straight, 5.1-5.5 x 4.0-4.5  $\mu m$ , with thickened walls, IKI-.

**Phellinus ferrugineofuscus** (P. Karst.) Bourdot Syn.: Phellinidium ferrugineofuscum (P. Karst.) Fiasson & Niemelä

Rai-Iz, strongly decayed *Picea*, Kotiranta 12706 & Penzina (H). Threatened in this area (Мухин & Котиранта, 1997).

Phellinus igniarius var. alni (Bond.) Niemelä

Rai-Iz, corticate Alnus trunk, Kotiranta & Penzina (H).

*Phellinus nigrolimitatus* (Romell) Bourdot & Galzin Syn.: *Ochroporus nigrolimitatus* (Romell) Fiasson et Niemelä

Rai-Iz, large, fairly strongly decayed, decorticate, moss-covered *Larix*, Kotiranta 10240 (H). Notes: Pores (4-)5/mm. Setae golden brown, straight, 27-34 x 6-7.5 µm. Threatened in this area (Мухин & Котиранта, 1997).

Phellinus punctatus (P. Karst.) Pilát

#### Syn.: Fomitiporia punctata (P. Karst.) Murrill

Rai-Iz, dead, erect Salix sp., Kotiranta 10268 (H).

Notes: Hyphal system monomitic. Hyphae thin- to thick-walled, simple septate, up to 5  $\mu$ m wide. Setae none. Spores broadly ellipsoid to subglobose, 5.5-7.0 x 5.1-6.6  $\mu$ m, L=6.5  $\mu$ m, W=6.0  $\mu$ m, Q=1.1, thick-walled, dextrinoid, except the apiculus.

Phellinus viticola (Schwein.: Fr.) Donk

Rai-Iz, corticate Larix stump, Kotiranta & Penzina (H).

Phlebia albida H. Post.

Rai-Iz, dead Salix sp. twig, Kotiranta 10283 (H).

Notes: Fruitbody effused-reflexed, cap thin. Monomitic, all hyphae clamped. Basidia clavate, basally clamped, 40-50 x 4.5-5.5  $\mu$ m. Cystidia none. Spores suballantoid, often basally bent, 5.8-7.7 x 2.4-2.7  $\mu$ m, L=6.5  $\mu$ m, W=2.5  $\mu$ m, Q=2.6, thin-walled, IKI-. The basidia are longer than mentioned by Eriksson et al. (1981).

Phlebiella pseudotsugae (Burt) K.H. Larss. & Hjortstam

Rai-Iz, fairly small, fairly strongly decayed, corticate *Picea*, Kotiranta 10207 (H); large, fairly strongly decayed, decorticate *Larix*, Kotiranta 10227 (H); large, fairly strongly decayed, decorticate, moss-covered *Larix*, Kotiranta 10242, 10244 (H); large, strongly decayed, decorticate, moss-covered *Larix*, Kotiranta 10259 (H) — Nyarusalye Cape, fairly wet, fairly hard piece of an oar ashore, Kotiranta 12673 & Penzina (H). Notes: Monomitic, all hyphae clamped, richly branched, thin-walled, except those next to the substrate, 2-3(-4) µm wide. Basidia mostly pleural, (16-)18-24(-26) x (4.5-)5-6.5 µm, with four, up to 4 µm long sterigmata. Cystidia none. Spores ellipsoid to subfusiform, 6.0-7.3 x 3.0-3.8 µm, L=6.6 µm, W=3.5 µm, Q=1.9 (nr. 10227, n=12); 6.1-7.4 x 3.7-4.1 µm, L=6.71 µm, W=3.9 µm, Q=1.7 (nr. 10244); 6.5-7.3 x 3.0-3.9 µm, L=6.9 µm, W=3.3 µm, Q=2.1 (nr. 12673); 6.1-7.2 x 3.1-3.8 µm (nr. 10207); 6.5-7.9 x (3.3-)3.5-3.8(-4.0) µm (nr. 10242); 5.8-6.5 x 3.6-4.2 µm (nr. 10259), with thickened walls, IKI-.

Plicatura nivea (Sommerf.: Fr.) P. Karst.

Yangana-Pe, Alnus twig, Kotiranta 12743 & Penzina (H).

Radulomyces confluens (Fr.: Fr.) M.P. Christ.

Rai-Iz, on the bark of dead *Alnus*, Kotiranta 12715 & Penzina (H). Notes: Monomitic, hyphae clamped. Hymenium turns yellow when treated with KOH. Cystidia none. Spores broadly ellipsoid, 7.0-8.2 x 5.0-5.7  $\mu$ m, L=7.6  $\mu$ m, W=5.3  $\mu$ m, Q=1.4, with thickened walls, CB-, IKI-.

Scytinostroma praestans (H.S. Jacks.) Donk

Rai-Iz, Larix branch, Kotiranta 10231 (H); small, hard, decorticate Larix, Kotiranta 10237 (H).

Notes: Fruitbody resupinate, white with a pinkish hue. Hyphal system dimitic, generative hyphae very thin- to thin-walled, clamped, 2.5-3  $\mu$ m wide, skeletobinding hyphae 1.1-1.8  $\mu$ m wide, thick-walled, dextrinoid, strongly cyanophilic. Basidia basally clamped, cylindrical to tubular, mostly basally swollen, (23-)32-47 x 3.5-5.5  $\mu$ m (in the middle part), with four, up to 7  $\mu$ m long, straight sterigmata. Gloeocystidia abundant, thin-walled, often with schizopapillae, 31-39 x 4-5  $\mu$ m. Spores navicular, (10.9-)13.5-15.1 x 2.2-3.2  $\mu$ m, very thin-walled, CB-, IKI-.

Sistotrema octosporum (J. Schröt. ex Höhn. & Litsch.) Hallenb.

Yangana-Pe, on the bark of lying *Larix*, Kotiranta 12728 & Penzina (H). Notes: Monomitic, basal hyphae straight, sparingly clamped, 5-7 $\mu$ m wide, with thickened walls. Tramal hyphae 3-4  $\mu$ m wide, thin-walled, some with oily contents. Basidia urniform, basally clamped, 12-15 x 5-6  $\mu$ m, with 6-8(-10) sterigmata. Cystidia none. Spores oblong, tapering towards the fairly prominent apiculus, often glued in pairs-octets, 4.6-5.4 x 2.2-2.5  $\mu$ m, L=5.2  $\mu$ m, W=2.3  $\mu$ m, Q=2.2, thin-walled, CB-, IKI-.

#### Skeletocutis stellae (Pilát) Domański

Rai-Iz, large, fairly strongly decayed, mostly corticate, moss-covered *Larix*, Kotiranta 10265 (H).

Notes: Fruitbody resupinate. Pore layer creamish, except in some parts greyish red (brick red). Pores small, 8-9/mm. Hyphal system dimitic, generative hyphae clamped; hyphae in dissepiment edge encrusted. Spores allantoid, 3.2-3.8 x 0.5-0.7 μm, thin-walled, CB-, IKI-. Threatened in this area (Мухин & Котиранта, 1997).

Sphaerobasidium minutum (J. Erikss.) Oberw. ex Jülich

Rai-Iz, strongly decayed, brown-rotted *Picea*, Kotiranta 12703 & Penzina (H). Notes: Hyphal system monomitic, hyphae thin-walled, clamped, up to 2.5  $\mu$ m wide. Basidia at first barrel-shaped, later obconical, basally clamped, 6.5-8(-9.5) x (4-)5  $\mu$ m, with four, very thin, straight, up to 3  $\mu$ m long sterigmata. Cystidia conical, apically widened, thin-walled, (17-)20-22 x (3.5-)4  $\mu$ m. Spores narrowly ellipsoid to shortallantoid, ventral side always concave, 4.0-4.5 x 2.0-2.8  $\mu$ m, L=4.2  $\mu$ m, W=2.4  $\mu$ m, Q=1.8, thin-walled, CB-, IKI-.

Stereum sanguinolentum (Alb. & Schwein.: Fr.) Fr.

Rai-Iz, fairly large, fairly hard, corticate Larix, Kotiranta 10233 (H). Notes: Spores ellipsoid, 6.4-8.2 x 2.7-3.9  $\mu$ m, L=7.3  $\mu$ m, W=3.6  $\mu$ m, Q=2.1, thin-walled, amyloid.

#### Thanatephorus cucumeris (Frank) Donk

Rai-Iz, fairly large, fairly hard, partly corticate Sorbus aucuparia, Kotiranta 10274 (H).

Notes: Monomitic, simple septate. Basal hyphae brownish (in IKI), with up to 1.2  $\mu$ m thick walls, sparingly branched (8-)10-15  $\mu$ m wide. Tramal and subhymenial hyphae 6.5-8.9  $\mu$ m wide. Basidia barrel-shaped, basally simple septate, (13-)15-18 x 8-9  $\mu$ m, with four stout, up to 10  $\mu$ m long sterigmata. Cystidia none. Spores ellipsoid, adaxial side straight or slightly concave, 8.2-10.5 x 4.7-5.5  $\mu$ m, L=9.2  $\mu$ m, W=5.0  $\mu$ m, Q=1.9, producing secondary spores, thin- to slightly thick-walled. The substrate (wood) and the concave adaxial side of the spores are not typical of *T. cucumeris* (Kotiranta & Saarenoksa, 1993).

### Trechispora cohaerens (Schwein.) Jülich & Stalpers

Rai-Iz, very strongly decayed, decorticate *Picea*, Kotiranta 12717 & Penzina (H). Notes: Monomitic, hyphae thin-walled, clamped. Basal hyphae covered with swallow-tailshaped crystals. Basidia cylindrical, 10-14.5 x 3.5-4 µm, basally clamped. Spores broadly ellipsoid, 3.0-3.5 x 2.3-2.8 µm, L=3.2 µm, W=2.5 µm, Q=1.3, smooth, slightly thickwalled, faintly cyanophilic.

## Trechispora farinacea (Pers.: Fr.) Liberta

Rai-Iz, strongly decayed *Picea* and dead *Phellinus ferrugineofuscus*, Kotiranta 12707 & Penzina (H).

Notes: Monomitic, clamped. Crystals rosette-looking. Basidia terminal, 9-11 x 4.5 µm. Spores ellipsoid, 3.6-3.8 x 3.0-3.4 µm, densely verruculose.

## Trechispora laevis K.H. Larss.

Rai-Iz, strongly decayed, decorticate *Picea*, Kotiranta 12704 & Penzina (H). Notes: Monomitic, clamped. No crystals seen. Basidia 10-13 x 3.5-4.5  $\mu$ m, often slightly constricted in the middle part. Cystidia none, but few hyphidia present, 27 x 4  $\mu$ m. Spores ellipsoid, adaxial side clearly concave, 3.5-4.0 x 2.7-3.1  $\mu$ m, L=3.8  $\mu$ m, W=2.9  $\mu$ m, Q=1.3, densely verruculose.

## Trechispora microspora (P. Karst.) Liberta

Rai-Iz, strongly decayed Picea, Kotiranta 12700 & Penzina (H).

Notes: Monomitic, clamped, basal hyphae sparingly clamped, up to 4.5  $\mu$ m wide, tramal hyphae thin-walled, 2.5  $\mu$ m wide, in swellings up to 6  $\mu$ m. Crystals acerose. Basidia 8-10 x 4(-5)  $\mu$ m. Cystidia none. Spores ellipsoid, tapering towards the base, 3.4-3.6 x 3.0 (-3.3)  $\mu$ m, with few, low, roundish warts, except in the naked basal end.

## Trechispora mollusca (Pers.: Fr.) Liberta

Rai-Iz, very strongly decayed, decorticate *Picea*, Kotiranta 12716 & Penzina (H). Notes: Fruitbody resupinate, poroid, creamish. Hyphal system monomitic, hyphae clamped, without any hymenocysts. Crystals rosette-shaped. Spores broadly ellipsoid to subglobose, 3.8-3.5 µm, densely verruculose.

Trichaptum abietinum (Pers.: Fr.) Ryvarden

Rai-Iz, small, fairly hard, almost decorticate *Picea*, Kotiranta 10199 (H). Notes: Spores broadly allantoid-subcylindrical, 6.0-7.0 x (2.3-)2.6-2.9 µm, thin-walled, CB-, IKI-.

#### Trichaptum laricinum (P. Karst.) Ryvarden

Rai-Iz, large, strongly decayed, corticate *Larix*, Kotiranta 10270 (H). Notes: Spores allantoid, 5.3-7.0 x 1.8-2.3 µm, L=6.1 µm, W=2.1 µm, Q=2.9, thinwalled, CB-, IKI-.

#### Tubulicrinis calothrix (Pat.) Donk

Rai-Iz, fairly small, fairly strongly decayed, decorticate *Picea*, Kotiranta 10209 (H); small, fairly hard, decorticate *Larix*, Kotiranta 10234 (H); strongly decayed, decorticate *Picea*, Kotiranta 12709 & Penzina (H).

Notes: Monomitic, hyphae clamped, thin- to fairly thick-walled, 2.5-3.5  $\mu$ m wide. Basidia 9-13 x 4-5  $\mu$ m, often constricted in the middle part. Cystidia cylindrical, (58-)70-90 x (5-)6-7  $\mu$ m, usually bi-rooted, apically obtuse, often covered with a crystalline cap. The thick, strongly amyloid wall is apically asymmetrically thinning. Spores subcylindrical to suballantoid, 5.5-6.2 x 1.5-1.9  $\mu$ m, L=5.8  $\mu$ m, W=1.8  $\mu$ m, Q=3.3 (nr. 12709); 6.3-6.7 x 1.5-1.8  $\mu$ m (nr. 10209); 6.4-6.9 x 1.7-1.8  $\mu$ m (nr. 10234), thin-walled, CB-, IKI-.

Tubulicrinis aff. regificus (H.S. Jacks. & Dearden) Donk

Rai-Iz, strongly brown-rotted Picea stump, Kotiranta 12718 & Penzina (H).

Notes: Basidia 16-19 x 5-6  $\mu$ m, with four, up to 4.5  $\mu$ m long sterigmata. Cystidia capitate, (85-)100-126  $\mu$ m, thick-walled, IKI-, the capillary lumen widening gradually to the roundish, 9-11  $\mu$ m wide apex. Spores broadly allantoid, adaxial side always slightly concave, 8.0-9.6 x 3.1-4.0  $\mu$ m, L=8.9  $\mu$ m, W=3.5  $\mu$ m, Q=2.5, slightly thick-walled, CB-, IKI-. This specimen resembles very much the drawings by Eriksson (*T. aff. regificus*) in Hjortstam et al. (1988, p. 1576-1577).

Tubulicrinis sororius (Bourdot & Galzin) Oberw.

Rai-Iz, fairly small, hard, decorticate *Larix*, Kotiranta 10238a (H); *Picea/Larix* bark, Kotiranta 12723 & Penzina (H).

Notes: Monomitic, clamped, hyphae thin-walled, 2-3  $\mu$ m wide. Basidia clavate, 12-13 x 4.5  $\mu$ m, IKI-. Cystidia capitate, (52-)62-82(-90) x 4.5-6  $\mu$ m, apically clearly widened to a roundish, (6-)7.5-10  $\mu$ m wide head. Cystidia thick-walled, except the roundish part, IKI very pale greyish, CB-. Spores allantoid, 5.1-6.2 x 1.2-1.7  $\mu$ m, L=5.8  $\mu$ m, W=1.4  $\mu$ m, Q=4.1 (nr. 12723); 5.5-6.0 x 1.6-2.0  $\mu$ m (nr. 10238a), thin-walled, CB-, IKI-. The spore size given by Hjortstam et al. (1988) is slightly larger.

Vararia investiens (Schwein.) P. Karst.

Rai-Iz, strongly decayed, decorticate Picea, Kotiranta 12702 & Penzina (H).

Notes: Generative hyphae clamped. Basidia tube-like or utriform, often constricted about 5  $\mu$ m below the apex, 40-62 x 4-5  $\mu$ m. Spores fusoid, about 12.5 x 4  $\mu$ m, IKI-, except the often collapsed proximal part, which is lightly amyloid.

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## ARCTIC GASTEROMYCETES III. ADDITIONAL NOTES ON BOVISTA AND CALVATIA FROM SOUTH GREENLAND AND FROM TYUMEN REGION, SIBERIA

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Abstract: The relation of Bovista cretacea Th. Fr. recorded from South Greenland and from the Tyumen region to B. paludosa Lév. is discussed. Calvatia excipuliformis (Scop.: Pers.) Perdeck is recorded from South Greenland. Calvatia turneri (Ellis et Everh.) Demoulin et M. Lange and C. cretacea (Berk.) Lloyd are both found common in Tyumen region. Records of C. connivens M. Lange and of C. septentrionalis M. Lange are also included. Their relation to C. arctica Ferd. et Winge is discussed. The occurrence of species of Lycoperdon, Bovistella and Crucibulum are briefly commented.

> Рассматриваются особенности Bovista cretacea Th. Fr., найденого в Южной Гренландии и на севере Тюменской области по отношению к B. paludosa Lév. Описан Calvatia excipuliformis (Scop.: Pers.) Perdeck, обнаруженный в Южной Гренландии. Calvatia turneri (Ellis et Everh.) Demoulin et M. Lange, C. cretacea (Berk.) Lloyd являются широко распространенными видами для Субарктики Западной Сибири. Обсуждаются особенности C. connivens M. Lange и C. septentrionalis M. Lange в отношении к C. arctica Ferd et Winge. Дается краткий обзор встречаемости арктических видов из родов Lycoperdon, Bovistella и Crucibulum.

Keywords: Gasteromycetes, the Arctic, biodiversity.

She paper deals with the material collected in the birch wood zone around Tunulliarfik Fiord (61° N, 45-46° W), in South Greenland, 1995, and in taiga and tundra localities in the Polar Urals and Yamal Peninsula in 1996 (see «ISAM 5 field excursions», p. 13). It is a supplement to my previous studies of the two genera (Lange, 1987, 1990). The collections cited are deposited in herbarium C.

## List of species

Bovista cretacea Th. Fr.

The species is described from North Scandinavia. Here it was rediscovered by Eckblad (1955, 1971). Kreisel (1967) has a full description based mostly on this material. He separates the species from *B. paludosa* Lév. on the small, cup shaped subgleba, and quotes the low warts on the exoperidium as a distinct feature. The capillitium of *B. cretacea* has threads sparingly branched with frequent septa, and both septal and dichotomous branching,

as well as some unbranched threads. *B. paludosa* has more frequently branched threads with few septations. The spore characters of the two species are almost identical.

The material from Greenland and from Tyumen region quoted below is on this basis referred to *B. cretacea*, probably being the first records outside Scandinavia. The low polygonal warts on the young exoperidium, and the low cup- shaped subgleba are constant characters in all the four collections. ML 29-95, and ML 44-96 both have most threads sparingly branched or unbranched, while the other two collections have most threads frequently branched, and only few unbranched ones are seen. In all specimens the capillitium is thick-walled, cinnamon buff, up to 10-12  $\mu$ m broad, and the ripe spores are very uniform, 4.5-5.0  $\mu$ m, globose, or generally slightly asymmetric, finely punctate, pedicells 7-14  $\mu$ m. ML 28-96 differs in having unripe pointed oblong spores, 5.0x3.5  $\mu$ m. In the remaining specimens, the unripe spores are globose. The typical *B. paludosa* is known from many localities in Central Europe, and is also on record from northern localities in Sweden and Finland (cp. Ulvinen, 1969). However, the specimen distributed by Lundell, Nannfeldt and Holm (Fungi exsiccati suecici No. 3076, from Hörjedal) should be referred to *B. cretacea*.

Material examined: Greenland: ML 29-95, Qassiarsuk 29.08.1995, on moist grassy slope, 2 clustered specimens; ML 32-95, ibid., in moist grass and moss, 10 clustered specimens. Tyumen region: ML 28-96, Labytnangi 14.08.1996, under *Larix* and *Betula*, 8 specimens, leg. E. Ohenoja; ML 44-96, Yangana-Pe 26.08.1996, 3 solitary specimens in moss, leg. T. Borgen.

#### Bovista nigrescens Pers.: Pers.

The species is quite common in South Greenland (Lange, 1987). Several specimens were collected in 1995. The single Siberian collection was found in a taiga locality, in a subcultivated grass field. The entire material corresponds to current descriptions of this well known species.

Material examined: Greenland: ML 15-95, Narsaq 16.08.1995, on the church lawn; ML 18-95, ML 19-95, Narsarsuaq 27.08.1995, in *Betula* scrub in the valley; ML 28-95, Qassiarsuk 29.08.1995, on moist grassy slope. Tyumen region: ML 19-96, Katrovozh 23.08.1996, grass field in wood of *Picea*.

#### Calvatia excipuliformis (Scop.: Pers.) Perdeck

The species is not known from truly arctic zones. I have a series of records from lowland stations in Iceland, and also a single dubious record from South Greenland (Lange, 1990). The occurrence in Greenland is substantiated by two new collections. Both are of the subsessile type, with moderately developed subgleba. The exoperidium is long remaining white, with rather fine and dense connivent spines. In ML 20-95, one of the three fruiting bodies has a large sector of the exoperidium composed of low warts.

The capillitium has sulcate walls with long fissures and ragged fragmentation as typical of the species. However, 50% of the fragmentations are septal, and threads with preserved septa are seen. On the significance of ragged septation, conf. M. Lange, 1993.

Fries (1914) described var. *alpina* from subalpine Swedish localities. It should be studied whether this disregarded taxon has the above described capillitial characters.

Material examined: Greenland: ML 20-95, Narsarsuaq 28.08.1995, Betula scrub in the valley; ML 24-95, ibid., Blomsterdalen 28.08.1995, on sand dune under Salix.

Calvatia turneri (Ellis et Everh.) Demoulin et M. Lange

A common species in arctic regions and also known from alpine stations. In Tyumen region it was frequently found in noncalcareous tundra localities. The specimens belong to the southern type described by Hollos as *C. tatrensis*, characterized by small to minute connivent spines which soon turn pale brown. The species reminds of *C. excipuliformis*, but is easily recognized by its septate-fragmented capillitium with blunt-mucronate end segments.

Material examined: Tyumen region: ML 11, 12, 13-96, Rai-Iz, Slantsevaya Mt. 18.08.1996; ML 32-96, ibid. 24.08.1996; ML 14, 15, 16, 17-96, Cape Nyarusalye 20.08.1996.

## Calvatia cretacea (Berk.) Lloyd

This is the classical arctic species of *Calvatia*, with coarse polygonal warts and fragmented capillitium with flagellar end segments. It has a preference for calcareous soils.

Material examined: Tyumen region: ML 09-96, ML 29-96, Rai-Iz, Slantsevaya Mt. 18.08.1996, above the timberline; ML 38, 39, 40-96, Yangana-Pe 26.08.1996.

## Calvatia connivens M. Lange

A member of a closely allied series of species with the coarsely warty *C. arctica* Ferd. & Winge as a classical member. All species in this group have a capillitium which long remains subelastic, and the gleba pass through violaceous stages during ripening. *C. connivens* has connivent spines which generally form an areolated pattern. Only a single collection from Tyumen region is referred to here; it has typical, rather narrow capillitial threads.

The Greenland collection differs from the description in capillitial characters, most threads with short segments, mostly  $10-20 \mu m$  broad (conf. Lange, 1990).

Material examined: Greenland: ML 30-95, Qassiarsuk 29.08.1995, on a moist grassy slope. Tyumen region: ML 08-96, Rai-Iz, Slantsevaya Mt. 18.08.1996, above the timberline, leg. H. Knudsen.

## Calvatia septentrionalis M. Lange

The species is characterized by small low polygonal warts of the exoperidium. The capillitium of the two collections cited below was found up to 9 µm broad, often sigmoid.

Material examined: Tyumen region: ML 10-96, Rai-Iz, Slantsevaya Mt. 18.08.1996, above the timberline, leg. H. Knudsen; ML 45-96, Yangana-Pe 26.08.1996, leg. H. Knudsen.

It is evident that three species, C. arctica, C. connivens and C. septentrionalis, are very variable in their development. This is true for the characters of the exoperidium, the capillitium, and the spore sculpture. The development of the exoperidium makes the three species well recognizable in the field, but the correlation between variations in the microscopical characters makes it possible to refer them to a broad concept of C. arctica.

Apart from the above-mentioned species, in my collections from the excursions during ISAM 5 there are 25 finds referred to Lycoperdon. L. perlatum Pers.: Pers. was found frequent in the mixed Betula stands in Labytnangi and in other stations below the timberline, together with L. nigrescens Pers. The latter species was also found in the mountains and in the tundra localities. There are several other species of Lycoperdon in the collections, but the classification of the arctic Lycoperdon is not sufficiently known to make identification feasible.

ML 25-96, Labytnangi 14.08.1996, leg. E. Ohenoja, is a very small specimen, evidently to be referred to *Bovistella* Morgan. It is not sufficiently ripe to support a description, but the diaphragm and the cellular subgleba, the *Bovista* type of spores and of capillitium, makes the generic position clear. However, it does not resemble any known species of the genus.

Finally the record includes numerous finds of *Crucibulum laeve* (Huds.) Kambley which is of common occurrence on the wooded sidewalks in Labytnangi (ML 30-96, Labytnangi 25.08.1996).

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#### HEBELOMA IN THE ARCTIC AND ALPINE TUNDRA IN ALASKA

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Abstract: Seven species of Hebeloma have been described (H. pusillum J.E. Lange, H. pusillum var. longisporum Bruchet, H. kuehneri Bruchet, H. remyi Bruchet, H. alpinum (Favre) Bruchet, H. bruchetii Bon, Hebeloma sp.) that are known from the arctic and alpine tundras of Alaska. The key to this group of species and the detailed description of each of them have been presented.

Описано семь видов рода Hebeloma (H. pusillum J.E. Lange, H. pusillum var. longisporum Bruchet, H. kuehneri Bruchet, H. remyi Bruchet, H. alpinum (Favre) Bruchet, H. bruchetii Bon, Hebeloma sp.) из арктических и горных тундр Аляски. Разработан ключ для определения данной группы грибов и дано подробное описание каждого вида.

Keywords: Hebeloma, the Arctic, taxonomy, distribution.

The species of *Hebeloma* are all taxa which are known from similar habitats in Europe and treated or described by Bruchet (1970, 1974) and Favre (1948, 1955, 1960). The species in the Alps in tundra and those from northern Europe in arctic tundra have different mycorrhizal hosts but they are species of dwarf willow, especially *Salix herbacea* L. (Moser, 1983, 1992).

There are a wide variety of arctic and aloine tundra habitats in Alaska, which include Salix, Betula, and Dryas, and support ectomycorrhizal species of fungi. The diversity of higher fungi and potential ectomycorrhizal hosts is low along the Arctic coast which has a colder summer climate (5-7°C in summer) and where only dwarf species of Salix are found (Miller, 1982, 1993; Antibus et al., 1991; Horak & Miller, 1992). Further south, in North Slope tundra, a more diverse assemblage of Salix species, including both dwarf species as well as shrub species (possibly Salix alaxensis (Anderss.) Covill) is found in less exposed situations. In mycorrhizal hosts, Betula nana L. and Dryas octapetala L. are common components of the alpine tundra flora. Areas of this type were sampled in this study at Eagle Summit over 100 miles north of Fairbanks and in McKinley (Denali) Park as well as aloine tundra sites in the St. Elias Mountains in the Yukon Territory of Canada. Analysis of over 40 collections reveals some interesting patterns of distribution which could be linked to host specific mycorrhizal associations. Along the Arctic coast with its low diversity of higher plants Hebeloma pusillum J.E. Lange and H. pusillum var. longisporum Bruchet along with H. kuehneri Bruchet are the dominant species of Hebeloma. They are most often recorded in association with Salix rotundifolia Tauty. and S. pulchra Cham. In fact, H. kuehneri is found primarily on the North Slope in coastal tundra and recorded further south only once. By contrast, H. pusillum and the variety longisporum are found both in the arctic tundra on the North Slope and in the Yukon Territory near Cultus Bay at Kluane Lake. It is also recorded from the Kaskawulsh Nunatak, an isolated area of revegetation, in the Kaskawulsh Glacier in the Donjak Mountains near Kluane Lake, Yukon Territory (Miller, 1987). Hebeloma alpinum (Favre) Bruchet, has not been found in the vicinity of the Arctic coast but further inland, 60 miles from the coast, at the Meade River Tundra Biome Site and further south along the western coast of Alaska at Kotzebue. In both cases it is associated with shrub species of Salix which occur on the North Slope but not in the harsh climate near the Arctic coast. Two records of *H. crustuliniforme* (Bull.) Ouél. were found, one associated with bush willow at the Meade River in North Slope tundra and the other in a taiga transition site associated with Salix along the Steese Highway. It is a common soecies in taiga and in the boreal forests in Alaska and Canada which was not the focus of this study. Hebeloma remui Bruchet was found once at Barrow on the coast associated with dwarf willow and H. bruchetii Bon once in association with shrub Salix at Kotzebue. A new species of *Hebeloma* (OKM 11166) with larger spores. was found at the Meade River with shrub willows but there was insufficient data on the fresh characters to determine the species with certainty. The only species previously reported with large spores in the genus is H. gigaspermum Gröger & Zschieschang found in boreal forest in Scandinavia (Moser, 1992).

All collections are housed in the Massey Herbarium (VPI) at Virginia Tech unless otherwise indicated. Ridgway (1912) colours begin with capitals. Methuen colours (Kornerup & Wanscher, 1967) colour designations are indicated by M followed by the page, row, and number. All microscopical details and colours were observed in 3% KOH unless otherwise mentioned.

### Key to the Alaskan and Yukon Species of Hebeloma in tundra and alpine tundra

1. Partial veil present or absent, cheilocystidia cylindric	
to ventricose with a long neck	2
1. Partial veil absent, cheilocystidia capitate to clavate, occasionally cylindric never ventricose	5
2. Partial veil dense, white and persisting over the lamellae until mid maturity or remaining attached to the stipe	3
2. Partial veil fugaceous, sometimes leaving a thin annular zone	4
3. Spores 11.5-14(-16) x 6-8 $\mu$ m ellipsoid, associated with dwarf willows.	H. remyi
3. Spores 7.3-9.9 x 4.3-6 μm, broadly elliptical, associated	
with bush willows	. H. bruchetii
4. Spores 9.5-12 x 6-7.3 μm, amygdaliform, dextrinoid in Melzer's solution, pileus 5-20 mm broad, associated with dwarf willows	. H. kuehneri
4. Spores 12.5-21 x 7-9(-15) μm, amygdaliform to ellipsoid, ileus 23-35mm broad, associated with bush willows	OKM11166
5. Fruiting body small, pileus 7-16(-30) mm broad, associated	
with dwarf willows in tundra or alpine tundra	6

5. Fruiting body robust, pileus 35-45 mm broad or larger, exudation drops	S
on the young lamellae, associated with bush willows or other mycorrhizal	hosts 7
6. Spores 10.8-12.7 x 6.5-7(-8) μm	.H. pusillum
6. Spores 11-14.5 x 6.5-8 µm H. pusillum var.	longisporum
7. Marginal exudation drops (weeping lamellae) with a clear exudate, ommon with <i>Salix</i> shrubs in inland and southern tundra habitats	. H. alpinum
7. Marginal exudation drops (weeping lamellae) with a yellow to yellow-brown exudate, infrequent with <i>Salix</i> and in arctic and lpine tundra, common elsewhere in the boreal forest of Alaska	<i>u</i>
and the Yukon Territory (not covered here)	ustuliniforme

## Species descriptions

Hebeloma pusillum J.E. Lange. Flora Agaricina Danica. 1938. Vol. III.- Figs. 1.1-1.3, 2a,b.

Pileus (7-)11-16 mm broad, convex, nearly plane in age, viscid, striate, brown (M 7D6), often somewhat darker in center with obscure whitish fibrils especially near the margin which is enrolled at first. Lamellae emarginate to adnexed, broad, with short, irregular, thick lamellulae, light brown, darker in age with white fimbriate edges. Stipe (7-)13-15 x 1-1.5 (-2) mm wide, equal, light brown ground colour appearing nearly white with scattered white fibrils. Partial veil absent.

Pileipellis a loose mixocutis of cells, 2.7-7.0  $\mu$ m in diam., thin-walled, with terminal cells 61 x 4.5  $\mu$ m, subcapitate, all with clamps, hyaline. Subpellis a textura angularis with hyphae 4.5-18.0  $\mu$ m in diam., with clamps, walls yellow-brown with yellow-brown «striped» incrustations. Pileitrama more loosely interwoven than the subpellis, same as subpellis but hyaline or nearly so. Cheilocystidia 58-66 x 9.8-10.7  $\mu$ m, narrowly cylindric, capitate, apex 9.5-11.0  $\mu$ m wide, thin-walled, hyaline. Basidia 30-33 x 8.9-9.8  $\mu$ m, clavate, thin-walled, 4-spored with some 2-spored, hyaline. Spores 10.8-12.9 x (6.2-)6.5-6.9(-8.0)  $\mu$ m, amygdaliform in profile, thin-walled, yellow-brown.

Habit, habitat, and distribution: common among dwarf *Salix*, especially *Salix rotundifolia* on the North Slope arctic coastal plain, and occasionally in alpine tundra in Alaska and the Yukon Territory, fruiting in July and August.

Material examined: USA: Alaska; Anchorage, Aug. 10, 1971, Wells-Kempton 5143 (TYPE) (MICH) H. pusillum var. longisporum Bruchet, Borough of Barrow; Beaufort Lagoon, Nuvagapak Pt., July 1, 1970, B. Murray & M. Johnson, B. Murray 4059. Near Imikpuk Lake, Aug. 3, 1971, P. Penhale, W. Campbell, OKM 10342. Barrow Village, Aug. 22, 1971, G.A. Laursen, OKM 10528. IBP Site, Barrow, Aug. 22, 1971, G.A. Laursen & O.K. Miller, OKM 10529. Barrow IBP Site 12, Aug. 1972, G.A. Laursen, OKM 10743. Barrow, IBP Site 4, Aug. 1, 1972, G.A. Laursen & O.K. Miller, OKM 10848. Barrow, IBP Site 5, G.A. Laursen, OKM 10868. IBP Site 16 miles SW of Barrow, Aug. 5, 1972, N. Wieland, OKM 10893. Barrow, IBP Site 4, Aug. 10, 1976, O.K. Miller, OKM 15474.

CANADA: Yukon Territory, Kaskawulsh Nunatak, July 26, 1967, B.& D. Murray, OKM 5874. Cultus Bay, Kluane Lake, July 15, 1967, O.K. Miller, OKM 5616.

Notes: The small size, capitate cheilocystidia, amygdaliform spores, lack of a veil and association with dwarf willows are the distinctive characters of H. *pusillum*. Several minute buttons with caps as small as 2 mm wide clearly shows the lack of a partial veil. The cheilocystidia and spores are typical of the size and shape of those of H. *pusillum*. Fresh description taken from OKM 10528.

Hebeloma pusillum var. longisporum Bruchet. Bull. Soc. Linn. Lyon. 1970. Vol. 39, suppl. 6. P. 58.

Pileus (3-)7-30 mm convex, plano-convex in age, weakly to strongly umbonate, glabrous, viscid, margin enrolled at first. Lamellae adnate, subdistant, ventricose, brown, white fimbriate margins. Stipe 13-23 mm long, 1-2 mm wide, equal or slightly larger at the base, white fibrils on upper surface rest glabrous, light brown (nearly white). Partial veil absent.

Pileipellis of loosely interwoven, thin-walled hyphae,  $3.5-6.3 \mu m$  in diam., with clamps, hyaline. Subpellis interwoven hyphae and inflated ovoid to irregular cells,  $3.5-9.0(-27) \mu m$  in diam., with clamps, yellow-brown walls and some contents. Cheilocystidia  $39-73 \times 8-10 \mu m$ , mostly capitate to clavate with a long hypha-like base,  $4.4-5 \mu m$  in diam., hyaline, appeared to have clamps at the base. Basidia clavate, 4-spored, thin-walled, hyaline. Spores  $11.2-13.3(-14.6) \times 6.5-7.7(-8.2) \mu m$ , amygdaliform to broadly ellipsoid, punctuate, thin-walled, yellow-brown.

Habit, habitat, and distribution: usually gregarious often on high center polygons, with *Salix rotundifolia* on the Arctic coastal plain. Fruiting in July and August.

Material examined: USA: Alaska; Borough of Barrow, IBP Site 12, July/Aug. 1972, G.A. Laursen, OKM 10748. Meade River, IBP Site, Aug. 19, 1972, O.K. Miller & G.A. Laursen, OKM 11104. Barrow, IBP Site, Aug. 16, 1974, G.A. Laursen, OKM 11800. Barrow, IBP Site, Aug. 23, 1974, O.K. Miller & G.A. Laursen, OKM 11890. Barrow, Gas Pipe Ridge, Aug. 28, 1974, O.K. Miller & G.A. Laursen, OKM 11951. Cape Simpson, near oil seep, July 28, 1976, O.K. & H. Miller, OKM 15303, OKM 15319. ENGLAND: Epsom Common, Oct. 3, 1955, P.D. Orton 594 (E). ITALY: Trient, 14.19.83, R. Poeder 83/432 (IB). SCOTLAND: Papa Westray, Orkney, Aug. 20, 1992, Watling 24808 (E).

Notes: The general size and lack of a partial veil, combined with the capitate cheilocystidia, are those of H. *pusillum* but with the large spores it was described by Bruchet (1970) as H. *pusillum* var. *longisporum*. In every case when specific ecological data was recorded this taxon was associated with Salix rotundifolia even though several other species of willow occur in the area. The variety was recorded only on the Arctic coastal plain.

Hebeloma kuehneri Bruchet. Bull. Soc. Linn. Lyon. 1970. Vol. 39, suppl. 6. P. 125-126.- Figs. 1.4-1.8, 2c. Pileus 5-20 mm broad, obtusely convex, almost conic to umbonate, moist to viscid, tacky, Saccardo's Umber, disc Sepia, inrolled margin light Pinkish Cinnamon, with a thin, opaque, frosty glaze and appearing shiny or gleaming when young, older caps dull. Lamellae deeply adnexed, close, broad (to 4 mm deep), 2-3 tiers of lamellulae, thin, moist, Avellaneous, edges minutely roughened. Stipe 10-30 mm long, 2-5 mm wide, tapering slightly toward base, brittle, fibrous, «pinkish cinnamon», with loose patchy fibrils when young soon disappearing and never seen on older mature stipes. Context of pileus 2 mm thick above central inner hollow cavity, «light buff» to «cartridge buff». Context of stipe stuffed when young, hollow in age. Odour fungoid, acid after five minutes. Taste mellow, nutty, sesame.

Pileipellis of tangled hyphae,  $3.5-9.8 \ \mu m$  in diam., thin-walled, clamped, arising from a solid, subpellis which is yellow-brown, often cellular with cells  $6.2-13.4 \ \mu m$  in diam., also with clamps. Pileitrama of broad, loosely interwoven hyphae  $4.5-11.6 \ \mu m$  in diam., thinwalled, with clamps. Lamellar trama of parallel hyphae  $4.5-9.0 \ \mu m$  in diam., thin-walled, with crystalline material on the gill-edges, with clamps, hyaline. Cheilocystidia  $37-63 \ x \ 6.3 8.0(-11.6) \ \mu m$ , mostly ventricose often with a long neck to nearly cylindric or occasionally somewhat fusiform, not capitate, numerous to abundant, thin-walled, hyaline. Basidia 31- $32.5 \ x \ 8-9 \ \mu m$ , broadly clavate, 4-spored, hyaline. Spores  $9.5-11.6(-12.5) \ x \ 5.8-6.9( 7.3) \ \mu m$ , amygdaliform to broadly ellipsoid, thin-walled, yellowish brown.

Habit, habitat, and distribution: found with *Salix rotundifolia*, *S. pulchra*, and other species of *Salix* in deep moss on the Arctic coastal plain but also recorded from dwarf willows in subalpine tundra at Eagle Summit and north of Fairbanks, fruiting in late July and August.

Material examined: USA: Alaska; Eagle Summit, Aug. 5, 1972, D. & B. Murray, OKM 9156. Borough of Barrow, near Imikpuk Lake, Aug. 3, 1971, G.A. Laursen, OKM 10346. Barrow, IBP Site 2, Aug. 10, 1971, G.A. Laursen, OKM 10440. Barrow, IBP Site 3, July 27, 1972, G.A. Laursen & O.K. Miller, OKM 10788. Barrow, IBP Site 4, Aug. 3, 1972, G.A. Laursen, & O.K. Miller, OKM 10800. Barrow, IBP Site 4, Aug. 3, 1972, G.A. Laursen, OKM 10872. 16 Miles SW of Barrow, Aug. 5, 1972, N. Wieland, OKM 10899. Icy Cape, Aug. 17, 1974, G.A. Laursen, OKM 11809. Barrow, IBP Site 4, Aug. 23, 1974, G.A. Laursen & O.K. Miller, OKM 11889. Meade River, IBP Site, Aug. 30, 1974, O.K. Miller & G.A. Laursen, OKM 12042. Cape Simpson Oil Seep # 2, July 28, 1976, O.K. & H. Miller. Steese Hwy. Mile 161, O.K. & H. Miller, C. Croghan, OKM 18253. FINLAND: Oulankajoki, Aug. 24, 1978, M. Moser 78/294 (E). FRANCE: Vanoir; 7/9/1969, A. Bruchet 69BR8 (LY). NORWAY: Spitsbergen; Aug. 13, 1988, M. Moser 88/82 (E). SCOTLAND: Orkney; Sept. 27, 1990, R. Watling 22558 (E).

Notes: The small size, colouration, cheilocystidia, and spores are typical of those studied in the material of Bruchet and described by Vesterholt (1989). It is described and illustrated in colour by Senn-Irlet et al. (1990). The only collection not made on the North Slope in arctic tundra is OKM 18253 found among birch and spruce along the Steese Highway north of Fairbanks. Fresh description from OKM 10800.

Hebeloma cf. remyi Bruchet. Bull. Soc. Linn. Lyon. 1970. Vol.39, suppl. 6. P. 29-32.-Figs. 1.9-1.11.

91

Pileus 10-18 mm broad, even, brown, glabrous, convex with a very low umbo, margin inrolled at first with a fibrous thick veil which persists on the margin until mid-maturity. Lamellae white, fimbriate, with fine edges. Stipe equal or enlarged slightly at the base, to mid-maturity with the scant remains of the partial veil on the upper surface, light brown to nearly white at the apex. Partial veil a cortina, nearly white, thick, persisting over the lamellae until mid-maturity leaving fibrils on the surface of the upper stipe and margin of the pileus which disappear at maturity.

Pileipellis a loose tangle of thin-walled hyphae, 2.6-5.4  $\mu$ m in diam., with clamps, hyaline. Subpellis a textura intricata of inflated, ovoid to irregular cells, interspersed with hyphae (all cells 7-18  $\mu$ m in diam.), with clamps, deep yellow-brown walls and incrustations, yellow cell contents in some. Pileitrama of loosely interwoven cells, (3.5-)7-18  $\mu$ m in diam., mostly hypha-like with some inflated cells, clamp-connections present, hyaline. Lamellar trama of parallel hyphae, 3.6-9.0  $\mu$ m in diam., with clamps, hyaline. Cheilocystidia 42-85 x 4.6-9.0  $\mu$ m, variable, filiform, filiform-capitate, filiform-ventricose, often flexuous, long and short, thin-walled, with clamp-connections at the base, hyaline. Basidia 36-52 x 8.5-10.5  $\mu$ m, clavate, thinwalled, 4-spored, hyaline. Spores 11.6-13.8(-16.3) x (5.6-)6.2-7.7 (-8.2)  $\mu$ m, oblong-ellipsoid to amygdaliform, weakly verrucose, thin-walled, light yellow-brown.

Habit, habitat, and distribution: in tundra on a high center polygon, dominated by dwarf willows, fruiting in August, and known only from the vicinity of Barrow, Alaska.

Material examined: USA: Alaska; Barrow, IBP Site. Aug. 16, 1974, O.K. Miller & G.A. Laursen, OKM 11801.

Notes: The presence of a cortinate veil, persistent until mid-maturity on the inrolled margin of the pileus places this species in the subgenus *Hebeloma*. section *Hebeloma*. The spores range from oblong-ellipsoid to amygdaliform, the sporocarps are very small and the arctic tundra habitat with willows places it close to *H. kuchneri*. It differs by having the persistent cortinate veil not present in other small North Slope taxa, mostly oblong-ellipsoid spores, and the tendency to have subcapitate to capitate cystidia. The other very small Alaskan arctic taxon, *H. pusillum* in sect. *Denudata* (Fr.) Sacc., lacks a partial veil, has smaller spores, 9-12 x 5-5.5  $\mu$ m, and capitate cheilocystidia. It is also associated with willows. *Hebeloma minus* Bruchet also lacks a veil and is in sect. *Denudata*. It is a minute species with a pileus attaining only 16 mm in diam. with large spores, 12-15(-16.5) x 6-7.5  $\mu$ m and up to 80  $\mu$ m long, cylindric cheilocystidia. It is associated with *Salix herbacea* and known at present only from Europe.

Hebeloma alpinum (Favre) Bruchet. Bull. Soc. Linn. Lyon. 1970. Vol. 39, suppl. 6. P. 68-73.- Figs. 1.12-1.14.

Pileus 20-40 mm broad, convex to plano-convex in age, light brown to slightly darker brown in center, lighter brown on margin, glabrous with attached debris. Lamellae adnate, subdistant, medium broad, with one to two tiers of lamellulae, brown with very fimbriate edges (use lens) with very delicate exudation drops on the gill-edges of young immature specimens. Stipe 15-27(-35) x 2-4(-8) mm, expanding somewhat toward the base,



Fig. 1. Anatomical structures of the Hebeloma species (×1,000).
Hebeloma pusillum OKM 5874: 1 – basidia; 2 – cheilocystidia; 3 – spores;
H. kuehneri OKM 10800: 4 – basidia; 5 – cheilocystidia; 6 – spores; H. kuehneri OKM 9156: 7 – cheilocystidia; 8 – spores; H. remyi OKM 11801: 9 – basidium; 10 – cheilocystidia; 11 – spores; H. alpinum OKM 10505: 12 – basidium; 13 – cheilocystidia;
14 – spores; H. bruchetii OKM 15492: 15 – cheilocystidia; 16 – spores; 17 – Hebeloma OKM 11166: spores





Fig. 2. Fruitbodies of Hebeloma pusillum (a, b) and H. kuehneri (c). Natural size

glabrous, with tufts of fibrils visible on upper stipe on some, with no obvious sign of a partial veil. Partial veil absent.

Pileipellis a mixocutis of hyaline, thin-walled hyphae, 2.6-11.7  $\mu$ m in diam., with clampconnections. Subpellis more densely interwoven, hyphae 5.3-9.8(-13.5)  $\mu$ m in diam., some cells somewhat inflated, with clamp-connections. Pileitrama same as subpellis but hyaline, reaching 23  $\mu$ m in diam. Lamellar trama thin-walled, hyaline hyphae 3.5-10.5  $\mu$ m in diam., with clamp-connections. Cheilocystidia numerous, 54-65 x 8-10  $\mu$ m elongate-clavate, thinwalled, hyaline. Basidia 35-41 x 9.5-10.2  $\mu$ m, clavate, thin-walled, hyaline, 4-spored. Spores 11.6-14.2(-17.2) x (6.0-)6.9-8.2  $\mu$ m (two spores measured 17.2 x 6.0  $\mu$ m), amygdaliform in profile, broadly ovoid in face view, thin-walled, evenly rugose, yellow-brown.

Habit, habitat, and distribution: on high bluffs at the Meade River, 60 miles south of the Arctic Ocean, near Kotzebue on well drained sandy spits, among shrub willows and birch (*Salix* and *Betula*), 2-5 meters high, known from the inland arctic tundra to marine habitats near Kotzebue. Constantly associated with larger shrub willows, fruiting in August.

Material examined: USA: Alaska; Morrison Bay, Aug. 12, 1971. G.A. Laursen, OKM/ GAL 10505 . Meade River, IBP Site, Aug. 20, 1971, O.K. Miller & G.A. Laursen, OKM 11159. Kotzebue, Aug. 12, 1976, O.K. Miller & G.A. Laursen, OKM 15486, OKM 15496, OKM 15498, OKM 15500. SWITZERLAND: Alp Laret (near Ftan), Aug. 27, 1984, Watling 17707 (E).

Notes: The macroscopic measurements of H. alpinum were made from dried material. It was noted that they possessed watery droplets on the gills and tufts of fibrils at the stipe apex. The large amygdaliform spores, robust sporocarps, and elongate-capitate cheilocystidia are typical of the species as described by Bruchet (1970), and illustrated in colour by Senn-Irlet et al. (1990). It is closely related to H. crustuliniforme which has yellowish droplets on the gills, is a typical robust species, but is not encountered near the ocean on the North Slope or in other locations in alpine tundra with dwarf species of Salix. The only clear differences from H. crustuliniforme are the watery exudation droplets, smaller size, and tundra habitat. Favre and Bruchet describe H. alpinum as the largest and most robust species of Hebeloma in either alpine tundra or arctic tundra in Europe. Our collections would then constitute an arctic tundra circumboreal distribution of this taxon to Alaska and certainly are larger than other tundra species of Hebeloma from Alaska.

#### Hebeloma bruchetii Bon. Bull. Féd. Dauphiné-Savoie. 1986. N 102. P. 21.- Figs. 1.15-1.16.

Pileipellis a tangled mixocutis of thin-walled, clamped hyphae  $3.5-5.3 \ \mu m$  in diam., hyaline. Subpellis of interwoven, often incrusted hyphae,  $3.5-7.1 \ \mu m$  in diam., yellowbrown. Pileitrama similar to subpellis but lighter yellow to nearly hyaline. Lamellar trama of parallel, thin-walled hyphae  $2.7-4.5 \ \mu m$  in diam., with clamp-connections, hyaline. Cheilocystidia 18-69 x  $3.6-10 \ \mu m$ , cylindric to ventricose with a long narrow neck, flexuous, variable in length, occasionally forked or with intermediate septa, numerous, thin-walled, equal or less often slightly enlarged at apex, often clamped, hyaline. Basidia 18 x  $5.3 \ \mu m$ , clavate, thin-walled, 4-spored, hyaline. Spores  $7.3-9.9 \ x \ 4.3-6.0 \ \mu m$ , broadly ellipsoid, thin-walled, yellowish, in Meltzer's solution light yellowish orange. Habit, habitat, and distribution: in arctic tundra along a sandy spit, Kotzebue, Alaska, H.H. & O.K. Miller.

Material examined: USA: Alaska; Kotzebue, O.K. & H.H. Miller, Aug. 12, 1976, OKM 15492 (VPI). NORWAY: Kofjordsdalen; Troms, Aug. 7, 1995, Poeder/Moser 95/70 (E). Spitsbergen; Aug. 15, 1988 M. Moser 88/105 (E). Svalbard; Aug. 11, 1988, M. Moser 88/55 (E). SWITZERLAND: Grisons; Aug. 30, 1966, Bruchet 66BR55, 2 (LY). Samnaun; Aug. 28, 1984, R. Watling 17831 (E).

Notes: There were only two pilei but one was whole and showed a well developed partial veil still partially attached to the stipe. The well developed partial veil, cheilocystidia which are extremely variable in length and often branched, and the floccose pileipellis are distinctive characters. Our fungus is closest to *H. bruchetii*, which is the only species in alpine or arctic tundra with a combination of a partial veil and small spores. There is no fresh description and a very small amount of material which means that it would help if we could come across more of this taxon in the as yet unidentified material.

Hebeloma sp., OKM 11166.- Fig. 1.17.

Pileus 23-35 mm in diam. dried, robust, with a short thick stipe,  $22 \ge 6$  mm. There are no other notes with the collection.

Pileipellis a refractive mixocutis with thin-walled clamped hyphae, hyaline. Cheilocystidia 57.5-73.0 x 9.0-9.8  $\mu$ m, narrowly clavate with a long narrow hyphal-like base, hyaline. Spores (12.5-)13.3-18.1(-21.5) x (6.9-)7.3-9.9(-15.8)  $\mu$ m, amygdaliform in face view and fusiform in profile with an apical projection, surface finely punctate, thin-walled, yellow-brown.

Habit, habitat, and distribution: solitary in tundra among willows, USS IBP Site 2, Meade River, 60 mi. SE of Barrow, Alaska, Aug. 21, 1972.

Material examined: USA: Alaska; Borough of Barrow, Meade River, IBP Site 2, Aug. 21, 1972, O.K. Miller & G.A. Laursen, OKM 11166.

Notes: This unknown taxon has the largest spores recorded so far in the Alaska study. There is only one species, to my knowledge, which has spores of comparable size. The species *H. gigaspermum* Gröger & Zschieschang (Gröger & Zschieschang, 1980) has spores which are  $(9-)12-17(-21) \ge 7-9.5 \mu m$ . It is found, however, in boreal forest habitats in Scandinavia. The habitat is described by Gröger & Zschieschang (1980) as occurring on humus and organic soil under *Alnus*, *Salix*, and *Betula* (Moser, 1992) which would be similar to the habitat at the Meade River in the bend of the Colville river where this collection was made. Our material is rather robust and has a short and a comparatively thick stipe of 6 mm, even dried. There is no taxon described in either Europe or North America which occurs in arctic or alpine tundra taxa which fits the general aspect and microscopic description of this taxon. The presence of *Salix* with our taxon and the one from Scandinavia could mean that our taxon is more widespread in North America in taiga habitats which have not been intensively collected. The recording of fresh characters may well reveal whether or not it can be referred to *H. gigaspermum*.

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## MYXOMYCETES OF THE RUSSIAN SUBARCTIC AND ARCTIC AREAS (PRELIMINARY REPORT)

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Abstract: A large material of Myxomycetes collected in Russian arctic and subarctic areas is presented for the first time. Distribution and ecology is given based on 625 collections representing 81 species.

Впервые представлены материалы о видовом составе миксомицетов Русской Арктики и Субарктики (81 вид), особенностях их распространения и экологии.

Keywords: Myxomycetes, the Arctic, the Sub-Arctic, biodiversity.

 $\mathcal{M}_{ ext{yxomycetes}}$  (plasmodial slime moulds) are common inhabitants of decaying plant material in temperate forests. Most species of myxomycetes appear to be cosmopolitan (Madelin, 1984), but the distribution of some species is limited to alpine and boreal regions (Kowalski, 1968, 1973; Stephenson & Laursen, 1990; Ing, 1994; Novozhilov & Schnittler, 1997: Новожилов, 1986a). As shown by several studies in Alaska (Stephenson & Laursen, 1990, 1997), Scandinavia (Eliasson & Strid, 1976; Härkönen, 1979a,b; Schinner, 1983; Johannesen, 1984), and northwestern Russia (Schnittler & Novozhilov, 1996; Новожилов, 1981, 1985) the boreal forest (taiga) zone seems to be one of the regions with the highest richness in myxomycetes that are relatively well studied. Probably some species common to the taiga can move further northwards to the zone of forest-tundra and tundra, invading new and unusual microhabitats. At present, the myxomycete biotas of forest-tundra, tundra and herb-rich grassland ecosystems of high-latitude arctic and subarctic regions have received relatively little study (Goetzsche, 1984, 1989, 1990; Stephenson & Laursen, 1990, 1993). Russia, with its vast arctic territories, is no exception and remains a «white soot» in this respect. Available information on the myxomycetes of the Russian Arctic is fragmentary and rather meager. Only a few papers with species lists for such areas as the Khibin Mountains (Novozhilov & Schnittler, 1996a, 1997), Chukotka (Stephenson et al., 1993; Новожилов, 1986b), and Taimyr Peninsula (Novozhilov & Schnittler, 1996b) have been published previously. The primary objective of the research reported in this paper was to obtain data on the distribution and ecology of myxomycetes in forest-tundra and tundra ecosystems in several areas of the Russian Arctic and Sub-Arctic. This paper represents a first survey of the myxomycete biota of this region.

## Material and methods

Specimens of myxomycetes have been collected by the authors during the last 12 years (1984-1996). The studied region is the Arctic sensu lato (including the Sub-Arctic), which extends within the borders of the former USSR from Kola Peninsula to the eastern coast of Chukotka. The specific areas of field research are situated in various parts of the Arctic and Sub-Arctic, including Kola Peninsula (KP), Yamal Peninsula (YP), Polar Urals (PU), Taimyr Peninsula (TP), Putorano Plateau (PP), and Chukotka (CH). The best studied areas are the Khibin Mountains and Taimyr Peninsula. This paper is devoted mostly to a consideration of the myxomycete biotas of the northern taiga, forest tundra, and tundra, so we examined first of all the species that have been collected at the borders of these zones in the most typical plant communities found within the studied territories, vegetation types, and collecting localities.

The main sources of information used to develop this paper were herbarium specimens of myxomycetes and collections obtained from moist chamber cultures of selected substrates, especially those on which corticolous and fimicolous species occur. Moist chamber cultures were prepared as described by Härkönen (1977, 1981) and Stephenson (1985, 1989). A computer database was used to compile all the taxonomic, ecological, and distribution data on the species of myxomycetes represented among the collections examined in the present study.

## **Results and discussion**

Eighty one species of myxomycetes representing twenty nine genera were identified from the 625 collections from the Arctic and Sub-Arctic of Russia. Species/genus ratios are rather similar in different parts of the Sub-Arctic and Arctic and vary from 1.6 to 2.5. This parameter indicates rather low myxomycete species diversity at high latitudes, which contrasts with that characteristic of the myxobiota of temperate and tropical regions, where this ratio ranges from 2.2 to 4.6 (Stephenson et al., 1993; Новожилов, 1981). The number of species of myxomycetes considerably decreases as one proceeds northwards. At present, 130 species of myxomycetes representing 36 genera are known from more than 1,000 collections recorded as the result of myxomycete investigations in subarctic and arctic regions throughout the world. By way of comparison, 300 species have been recorded from India (Venkataramani & Kalyanasundaram, 1986) and more than 275 species from eastern North America (Martin & Alexopoulos, 1969). In northeastern Russia, 155 species of myxomycetes have been recorded (Schnittler & Novozhilov, 1996; Новожилов, 1981). The differences in these data sets can be attributed to different intensities of collecting and also to the influence of various ecological factors on the latitudinal distribution of myxomycetes.

Coefficient of community indices calculated from the various data sets, which range from 0.420 to 0.532, indicate fairly high levels of similarity among the areas studied. Numbers of species of myxomycetes in the Arctic decrease from the south to the north, but this trend is not observed when moving from the west to the east. Local fluctuations in myxomycete species composition in the Arctic usually depend upon ecological factors related to topographic relief and the character of the plant communities present in the particular area being studied.
Among the factors affecting the distribution of myxomycetes, climate (temperature and humidity) and substrate are usually considered to be the most important (Venkataramani & Kalyanasundaram, 1986; Stephenson et al., 1993; Ing, 1994; Schnittler & Novozhilov, 1996). Hydrothermal conditions in the regions of the Arctic and Sub-Arctic considered in this study are characterized by high moisture and a warmth deficiency. Consequently, the majority of myxomycete species found in the Arctic can be referred to as cryophilic and chionophylic (nivicolous).

Climate factors influence the distribution and occurrence of tree species forming forests in different regions of the Sub-Arctic and Arctic. A characteristic feature of many myxomycete species is their use of plant debris as a microhabitat, where the two trophic stages (plasmodia and myxamoebae) in the life cycle find food and shelter. In addition, this type of plant debris provides the microgradients of humidity and temperature necessary for the formation of fruiting bodies (Venkataramani & Kalyanasundaram, 1977).

Some species of myxomycetes occur primarily on the bark surfaces of living trees and shrubs and thus form a distinctive ecological group of what are referred to as corticolous (or epiphytic) myxomycetes (Braun & Keller, 1977; Härkönen, 1977; Mitchell, 1978a,b; Keller & Braun, 1979; Stephenson, 1985; Новожилов, 1988). This circumstance explains the very important role of arboreal vegetation in the life of these myxomycetes. Tree species occur in the Arctic in a rather definite order, according to their distribution in the forest zone. For example, pine (*Pinus silvestris*) occurs only in the extreme north-west of European Russia, spruce (*Picea obovata*) occurs in the rest of the European part and also in West Siberia, larch (*Larix sibirica* and *L. gmelinii*) is found in West and East Siberia, respectively, whereas Siberian dwarf pine (*Pinus pumila*) and *Chosenia arbutifolia* are limited to Chukotka.

#### Substrate relationships in the Arctic areas

The lack of coarse woody debris (snags, stumps, logs, and large branches) is one of the most crucial limiting factors for many species of bryophytes, lichens, fungi, protozoa, insects, and animals (Samuelsson et al., 1994). Species richness is correlated with the amount of dead wood and litter present. In an old-growth forest, the large number of niches provided by the stability of the forest litter and the addition of large downed trees results in a large number of species of insects (Chandler, 1987). Myxomycetes display a similar tendency (Stephenson, 1988; Ing, 1994). The majority of species found in the boreal zone belong to the group of xylophils and occur in association with wood and bark debris, and leaf litter (Härkönen, 1977, 1978, 1981; Eliasson, 1981; Schnittler & Novozhilov, 1996; Schnittler & Novozhilov, in press; Новожилов, 1981). Some xylophilic species have been recorded from the Sub-Arctic and Arctic in the forest-tundra zone (Goetzsche, 1984, 1990). The fact that these species have managed to invade the Arctic in the tundra zone is not related to a decrease in the number of available microhabitats. The most ubiquitous species of myxomycetes occupy a wide range of different types of substrates, such as litter and shrub debris, grass debris, and the dung of herbivorous mammals and birds. This tendency is most clearly seen within the transitional zone of forest tundra and tundra. The overall distribution pattern of myxomycetes in tundra is connected with an increase in their occurrence on litter and the dung of animals. The xylophilic species diversity in forest-tundra and tundra considerably decreases compared to the taiga zone, but the abundance of some species remains rather high.

Xylophilic species in more southern areas of tundra inhabit the dead parts of shrubs and bushes. For example, in the present study Comatricha nigra was frequently recorded from dead twigs of Duschekia. Licea minima, usually collected in taiga on rotten wood, was frequently recovered in moist chambers on shrub debris. Small twigs of shrubs (Salix spp. and Duschekia spp.) with exfoliating bark represent a rather suitable substrate for some species. When very moist, such bark easily becomes exfoliated, forming numerous small gaps or shelters in the bark. These shelters play the role of natural moist chambers, where the plasmodium can survive under unfavourable conditions. A particularly important role in determining myxomycete distribution at high latitudes is played by the presence of such specific substrates as the dung of herbivorous mammals and birds, including the lemming (Lemmus lemmus). mountain hare (Lepus timidus), polar hare (Lepus arcticus), elk (Alces alus), caribou (Rangifer tarandus), partridge (Perdix sp.), cock of the wood (Tetrao urogallus), and black grouse (Lyrurus tetrix). The ecological group of coprophilic species is widely represented in the Arctic (Eliasson & Lundqvist, 1979; Cox, 1981; Goetzsche, 1989; Stephenson & Landolt, 1992). The dung of mammals and birds forms a microhabitat with a favourable hydrothermal and nutrition regime. Such species as Arcuria cinerea, A. incarnata, Arcuodes incarnata, Didymium clavus, D. crustaceum, D. difforme, D. melanospermum, Licea minima, Perichaena depressa, P. cf. liceoides, Physarum bivalve, P. oblatum, and Trichia munda were found predominantly on this substrate. Shrub debris is also a special type of microhabitat and among the species characteristically associated with shrub debris were Arcuria cinerea, Craterium leucocephalum, Didymium anellus, D. clavus, D. crustaceum, D. difforme, D. dubium, D. nigripes, D. squamulosum, Diderma niveum, Echinostelium minutum, Lamproderma arcurioides, Leocarpus fragilis, Lepidoderma carestianum, Licea minima, Macbrideola cornea, Mucilago crustacea, Physarum bivalve, P. cinereum, P. nutans, Trichia alpina, T. botrytis, T. munda, and Craterium leucocephalum.

The data presented herein generally correspond to observations that have been made on the distribution of myxomycetes in Alaska (Stephenson & Laursen, 1993), Greenland (Goetzsche, 1989), and Iceland (Goetzsche, 1984, 1990). For example, in Greenland the percent of specimens found on dung was 18.9%, and 60% occurred on litter (Goetzsche, 1989); in Alaska the figures were 1.16% and 52.3%, respectively (Stephenson & Laursen, 1993). The percentage of specimens found on herbaceous plant debris in the north taiga zone is connected with the relative abundance of nivicolous species, which were found at the border of forest in high grass communities in the Khibin Mountains (Novozhilov & Schnittler, 1997) and Polar Urals (Novozhilov, unpublished data). Among these nivicolous species were such examples as Diacheopsis effusa, Diderma deplanatum, D. niveum, Didymium dubium, Lamproderma carestiae, L. fuscatum, L. sauteri, Lepidoderma aggregatum, L. granuliferum, Physarum cinereum, and Trichia alpina.

Results obtained from moist chamber cultures indicate that many species of epiphytic myxomycetes also occur far to the north, where they are associated with the bark of shrubs and bushes. Prominent examples include Arcyria cinerea, A. incarnata, A. obvelata, A. pomiformis, Ceratiomyxa fruticulosa, Comatricha laxa, C. nigra, Cribraria violacea, Echinostelium minutum, E. brooksii, Enerthenema papillatum, Licea kleistobolus, L. minima, L. operculata, L. parasitica, Macbrideola cornea, Paradiacheopsis fimbriata, Perichaena chrysosperma, Physarum nutans, P. viride, Prototrichia metallica, Trichia lutescens, T. munda, and T. varia. Apparently having an ability to form fruiting bodies very quickly, these species are easily adaptive to changing hydrothermal conditions. Some

of them (e.g., Arcuria cinerea) also can be found on other types of substrates such as litter and the dung of animals, and these species are referred to as typical everybionts. Substrate specificity in myxomycetes leads to the differences observed for the myxomycete biotas of northern taiga and tundra, with the occurrence of some species only on certain types of substrates. In high grass communities of the taiga zone, some nivicolous species in the orders Physarales and Trichiales are encountered more frequently than in tundra. The significantly higher percentage of collections on litter and dung in tundra, compared to the collections from taiga communities, is a result of the relative abundance of members of the orders Liceales, Trichiales, and Physarales. Moreover, some typical xylophilic species (e.g., Arcyria cinerea, Arcyria incarnata, Arcyodes incarnata, Perichaena depressa, Trichia munda, and Licea minima) are also typically collected from this substrate. Probably it is not possible to speak about taxonomic specificity or community endemism of myxomycete biotas in tundra as compared to biotas of taiga communities. The principal difference relates to the distribution of species on substrates and not the species composition. However, as one moves northwards many species (especially xylophilic) disappear and this leads to a change in the taxonomic structure of biotas.

## Taxonomic structure of myxomycete biota of the Sub-Arctic and Arctic

As already mentioned, the taxonomic diversity of myxomycetes at high latitudes considerably decreases as one moves northward. It is evident that in all subarctic and arctic biotas members of the family *Trichiaceae* are the most prominent myxomycetes. Another feature of these biotas, when compared with biotas of other biogeographical zones (temperate and tropical), is a considerable decrease in the number of species in the family *Cribrariaceae*.

Another large family, the *Physaraceae*, which includes the single largest myxomycete genus (*Physarum*), also is less prominent at high latitudes than in the tropical zone. In order to demonstrate this difference, we can use the indices of species number of separate family pairs. From an examination of the ratio of species number in the four largest families: *Trichiaceae*/*Physaraceae* and *Cribrariaceae*/*Physaraceae*, it is evident that the role of the *Trichiaceae* compared to the *Physaraceae* is highest in the Arctic and lowest in tropical regions. It is notable that the increase in T/P indices in the Arctic is connected with the greater number of species of *Trichia* and the smaller number of species of *Physarum* when compared to tropical regions.

The same biogeographical pattern was demonstrated earlier in comparisons of the biotas of northwestern Russia and the Neotropics (Новожилов, 1981) and the biotas of eastern North America and South India (Stephenson et al., 1993). Another tendency along the latitudinal gradient is the decrease of the role of members of the family *Cribrariaceae* in the Arctic as compared to their role in the temperate zone. The quantitative ratio of species in the *Cribrariaceae* to species in the *Physaraceae* increases in regions with temperate and cold temperate climates, where coniferous forests (taiga) dominate. This general tendency is rather evident when the relative proportions of the two groups in the arctic biota are compared with their proportions in the biotas from temperate and subtropical and tropical regions.

In this respect, the myxobiota of subarctic and arctic regions is similar to those of subtropical and tropical regions. The species number ratio of *Cribrariaceae* to

Physaraceae, calculated from the data sets for the different study areas, ranged from 0.03 for southern India to 0.70 for eastern North America and 0.58 for northeastern Russia. This ratio declines again in the subarctic and arctic regions. It is one of the most evident features of the global pattern of taxonomic diversity in myxomycetes biotas. The distribution of species within any area assumes a definite pattern and is connected with relationships of myxomycetes to substrates. The dominant role of coniferous forests in the temperate and boreal zones is evidently the most important biotic factor on a global basis, which defines the relative species abundance of *Cribrariaceae* in the boreal and temperate forests in contrast to tropical forests on the one hand and tundra regions at high latitudes on the other hand. This pattern is connected with an increase in the species abundance of members of the *Physaraceae*, which occur principally on litter and on the dung of animals in trooical forests and in tundra. The lack of comparable data for other regions of the world does not allow us to carry out more detailed comparisons of the taxonomic structure (especially the relative contribution made by different genera) of different biotas. We can only state that the taxonomic structure of the myxomycete biota differs in different climate zones.

According to one theory accounting for the evolution of taiga forest from mountainconiferous forests of Eurasia (Толмачев, 1943), it is supposed that some typical alpine chionophilic myxomycete species occurring most frequently in mountains can go far to the north. This is indirectly confirmed by the discovery of alpine myxomycete species in the plain taiga forests of northwestern Russia (Новожилов, 1986b). Some of these species were found in the Khibin Mountains and Polar Ural tundra, in specific shelter microhabitats such as on mosses under rocks near melting snow (Novozhilov & Schnittler, 1997).

This corresponds with the point of view of Ing (1994), who indicated that the genera *Diderma*. *Didymium*. *Physarum*. *Lamproderma*. *Lepidoderma* and *Diacheopsis* are essentially «alpine» genera (Kowalski, 1970, 1971, 1975) containing many species that are obligate chionophiles. On the basis of data available at the present time, it is hard to conclude to what extent the arctic myxomycete biota has been derived from that of the taiga forests. To reveal the genesis of the myxomycete biota of the Arctic, additional accurate researches are necessary, especially in transitional zones between taiga, forest-tundra, and tundra (including mountain tundra).

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## THE INOCYBE SPECIES FOUND IN THE CANADIAN ARCTIC AND WEST SIBERIAN SUB-ARCTIC, WITH ECOLOGICAL NOTES

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Abstract: All the six presented taxa of *Inocybe* have been reported both from Arctic Canada (Repulse Bay, the District of Franklin, Baker Lake and Rankin Inlet, the District of Keewatin, and Fort Churchill, Manitoba) and Western Siberia (Yamal-Nenets autonomous district, near the Polar Urals). The species are *Inocybe dulcamara*, *I. calamistrata*, *I. rimosa*, *I. lacera*, *I. geophylla*, and *I. leiocephala*. The ecology and associated plants, especially mosses, are reported.

> Представлены данные о 6 видах рода Inocybe, обнаруженых в арктических районах Канады (залив Рипалс, округ Франклин, Бейкер Лейк и Ранклин Бей, округ Киуэйтин, и Форт Черчилль, Манитоба) и в Западной Сибири (Ямало-Ненецкий автономный округ, вблизи Полярного Урала): Inocybe dulcamara, I. calamistrata, I. rimosa, I. lacera, I. geophylla и I. leiocephala. Анализируются их экологические особенности, и представлены материалы о видовом составе растений, с которыми они ассоциированы.

Keywords: Inocybe, Arctic Canada, Western Siberia, the Arctic, the Sub-Arctic, ecology, plant sociology, Bryophyta.

She published information on the genus *Inocybe* occurring in the subarctic and arctic areas of northern America is very scanty and totally lacking from NW Russia. In Arctic Siberia, Yakutia, larger fungi were reported by Lebedeva (Лебедева, 1928) who, however, did not mention any Inocybe species. From the Canadian Arctic and Alaska there are some notes given by Miller et al. (1973), Laursen & Ammirati (1982) and Laursen & Chmielewski (1982). There are more data from Greenland (Lange & Skifte, 1967; Lamoure et al., 1982) and northern Fennoscandia, including Svalbard (Lange, 1957; Kobayasi et al., 1968; Ohenoja, 1971; Gulden & Torkelsen, 1996).

## **Collecting sites**

The Canadian material was collected in August 1971 and 1974 in the subarctic and arctic zone at Fort Churchill (CH), Manitoba ( $58^{\circ}45'$  N,  $94^{\circ}04-30'$  W), and in the arctic localities, at Repulse Bay (RB), the District of Franklin ( $66^{\circ}31'$  N,  $86^{\circ}15'$  W), and Rankin Inlet (RI) and Baker Lake (BL), the District of Keewatin ( $62^{\circ}49'$  N,  $92^{\circ}05'$  W and  $64^{\circ}20'$  N,  $96^{\circ}00'$  W), in the east of the Northwest Territories. The town Fort Churchill is situated at the timberline along the SW shore of Hudson Bay. The villages Baker Lake and Rankin Inlet lie in the low arctic zone. The habitats and

climate of the research areas have been described in the previous article by E. & M. Ohenoja (1993) dealing with *Lactarius* species in these localities.

In Siberia, the collections were made on August 12-22, 1996, during the Fifth Symposium on Arcto-Alpine Mycology (ISAM 5). Besides E. Ohenoja, Anna Liisa Paulus, Outi Särkisilta and Ursula Peintner collected some specimens from the area. The research area in Siberia belongs to Tyumen Region. A description is given in "ISAM 5 field excursions" (see  $\rho$ . 13).

Collections were made in the valley of the Ob River, along its western tributary, near Oktyabrsky, in a young, mesic forest on the slope near the river dominated by birch (*Betula tortuosa*), willows (*Salix* spp.) and alder (*Alnus fruticosa*), and in the coniferous forest near Gornoknyazevsk (GK). In the valley of the river Kharbey (KR) *Inocybe* specimens were collected on a sandy road. The most northern locality visited belongs to the southern bushy tundra, Cape Nyarusalye, c. 1 km S of of the Kara Sea shore (KS). Large material was collected on the eastern macroslope of the Polar Urals, Slantsevaya Mt., in the alpine tundra (PT) and at timberline (PF). Some collections were also made in the surroundings of the town of Labytnangi.

## Material and methods

Within the distance of about one square decimetre from the fungal fruitbodies moss species have been checked. Vascular plants (herbs and shrubs) have been checked up to the distance of a square meter. They are called here associated species. Mosses and liverworts, and a part of vascular plants were determined by Martti Ohenoja. The nomenclature in the moss lists (Tables 1-6) follows mainly Ignatov & Afonina (1992), Konstantinova et al. (1992) and Ireland et al. (1987). Esteri Ohenoja described the localities and habitats visited. Most of the *Inocybe* species were identified by Jukka Vauras.

The collections cited are deposited in the Herbarium (OULU) of Oulu University. Some duplicate specimens are located in the Mycological Herbarium, Plant Research Institute, Canada Department of Agriculture (DAOM) in Ottawa.

## Results

In Canada, all the 88 samples of *Inocybe* were collected by E. & M. Ohenoja, in the low and middle arctic areas in eastern N.W.T., in 1971 and 1974. In Siberia, c. 50 samples of *Inocybe* were collected by E. Ohenoja et al. The material dealed with in this article included six taxa which were found both in Canada and Siberia, that is, *Inocybe* calamistrata, I. dulcamara, I. geophylla var. geophylla, I. lacera, I. leiocephala, and I. rimosa. In addition, two species, I. hirculus Vauras (Vauras, 1994) and I. castanea Peck (syn. I. sapinea Velen.) were identified from the Siberian material.

## Classification of the treated taxa of Inocybe

Subgenus Mallocybe	I. dulcamara	(Pers.) Ρ.	Kumm.
Subgenus Inosperma			
Section Cervicolores	I. calamistra	<i>uta</i> (Fr.: Fr	.) Gillet

Section Rimosae	I. rimosa (Bull.: Fr.) P. Kumm.
Subgenus Inocybe	
Section Fibrillosae	I. lacera (Fr.: Fr.) P. Kumm. var. lacera
Section Tardae	I. geophylla (Sowerby: Fr.) P. Kumm.
Section Splendentes	I. leiocephala Stuntz

#### I. dulcamara (Pers.) P. Kumm.

In this study, *I. dulcamara* grew mostly on moss tundra, often associated with dwarf *Salix* and *Dryas octopetala*, but also with *Cassiope*. According to our experience in Fennoscandia, the species is calciphilous, growing both on dry sandy and on moist turfy soils. Also most of its associates both in Russian and American localities can be classified as calciphilous (Table 1).

I. dulcamara is a fairly common species in several European countries, for example in Sweden (Hallingböck, 1994) and western Germany (Krieglsteiner, 1991). It has also been recorded from Arctic Alaska (Laursen & Chmielewski, 1982), Greenland (Lange, 1957; Lamoure at al., 1982) and Svalbard (many authors, cf. Gulden & Torkelsen, 1996). Moser (1982) mentions it as a species of «Kampfzone». Senn-Irlet (1993) found it to be a dominant species in the alpine mesotrophic mires in the Swiss Alps. Lange (1957) mentioned Betula nana, Salix and Vaccinium uliginosum as associates of the species in Greenland, and according to Gulden & Torkelsen (1996), it grows in Svalbard often gregariously in heaths among Salix polaris and Dryas.

The subgenus *Mallocybe* includes several closely related taxa, and in this study our concepts of *I. dulcamara* has been a collective one. The spores of the studied specimens were often larger than the ones (8-10.5(-11) x 5-6(-6.5)  $\mu$ m) reported, for example, by Stangl (1989).

#### I. calamistrata (Fr.: Fr.) Gillet

In Canada, *I. calamistrata* was fairly common in the subarctic, low arctic and middle arctic zones. It was collected both on turfy and sandy soils, often in moist depressions, but also on dry heaths. In Siberia, it was found just above the timberline, growing with *Betula nana*, *Salix reticulata*, *Dryas octopetala* etc. Many of the plant species associated with it can be classified as calciphilous (Table 2).

The species is fairly widespread in the northern hemisphere (cf. Kuyper, 1986). According to Lange (1957), it seems to be common in arcto-alpine areas. It has been reported from Arctic Alaska (Laursen & Chmielewski, 1982), Greenland (Lange, 1957; Kobayasi et al., 1971; Lamoure et al., 1982), Svalbard (Gulden & Torkelsen, 1996), northern Fennoscandia (Lange & Skifte, 1967), and from the mountains of middle Scandinavia (Kuyper, 1990). In Finland it seems to be most frequent in Enontekian Lapland, Kilpisjärvi area where it grows on moist, nutrient-rich, calcareous soils in subarctic birch forests.

The spores of *I. calamistrata* are broader in the specimens collected in the Alps or from the arctic to subarctic areas than in those from temperate or hemiboreal zones. Kühner (1988) described *I. subhirsuta* from the French Alps as a vicariant species to

## TABLE 1

# Associated plants of *Inocybe dulcamara* in the subarctic-arctic environment

Associated plant species	Middle	Low Arctic			Sub-Arc	
	RB	RI	BL	PT	CH	PF
Alnus fruticosa						x
Betula glandulosa			x			
Betula pubescens						x
Larix laricina					x	
Picea glauca					x	
Salix arctophila			X			
S. cordifolia		X				
S. herbacea		X	x			
S. planifolia			x			
S. pseudopolaris		x				
S. reticulata (c)	x	X	x		x	
Carex bigelowii		X	x			
Cassiope tetragona (c)	х	X				
Dryas integrifolia (c)	Х	x	x		x	
Equisetum variegatum (c)		x				
Polygonum viviparum (c)		x				
Rhododendron lapponicum (c)		x				
Saxifraga hirculus (c)		x				
Amblystegium serpens			x			
Aongstroemia longipes		X				
Aulacomnium acuminatum			x			
A. palustre		X	х			
A. turgidum (c)		x				
Barbula convoluta (c)					x	Х
B. unguiculata (c)		X				
Brachythecium erythrorrhizon					x	
B. groenlandicum (c)	x	x			x	
Bryoerythrophyllum cf.		x				
alpigenum						
B. recurvirostrum (c)	x	x				
Bryum cf. algovicum		x		1		
B. capillare		X				
B. knowltonii (c)	x	x			x	
B. pallens	X					
B. cf. pallescens	x	x			ļ	
B. pseudotriquetrum (c)	x	X			x	

(Table 1 continued)

Associated plant species	Middle	Low Arctic		c	Sub-Arcti	
	RB	RI	BL	РТ	CH	PF
B. pseudotriquetrum var.			х			
bimum						
B. wrightii (c)		X				
Callicladium haldanianum (c)	x	x				
Calliergon stramineum	•	X	x			
Campylium stellatum (c)	x	x	x		x	X
Ceratodon purpureus			x		x	
Cinclidium arcticum		x				
C. stygium (c)		x	х			
C. subrotundum (c)	x	x				
Cyrtomnium	x	x		x		
hymenophylloides (c)						
Dichodontium pellucidum						X
Dicranum angustum			x			
D. elongatum	x					
D. groenlandicum				x	1	
D. cf. laevidens		x				
Didymodon fallax (c)	x					
D. rigidulus (c)					x	
Distichium capillaceum (c)	x	x		x	x	x
D. inclinatum (c)		x			x	
Ditrichum flexicaule (c)	x	x	x	x	x	x
Drepanocladus aduncus var.	x					
polycarpus						
Encalypta affinis (c)	x					
Eurhynchium pulchellum (c)	x	x				
E. pulchellum var.		x				
diversifolium (c)						
Fissidens adianthoides		x				
F. osmundoides		x	x			
Hygrohypnum luridum (c)			x			
Hylocomium splendens		x				
Hypnum bambergeri (c)		x		x		
H. lindbergii	x	1			<u> </u>	
Isopterygiopsis pulchella	1	x		x	<u> </u>	
Leptobryum pyriforme	x	x		<u></u>		
Limprichtia revolvens (c)	1	x	x		<u> </u>	
Meesia triquetra (c)		x				
M. uliginosa (c)	x	x	x			

(Table 1 continued)

RBRIBLPTCHPFM. uliginosa (c)xxxxxMnium blyttii (c)x </th <th>Associated plant species</th> <th>Middle</th> <th colspan="3">Low Arctic</th> <th colspan="2">Sub-Arct</th>	Associated plant species	Middle	Low Arctic			Sub-Arct	
M. uliginosa (c)xxxxMnium blyttii (c)xM. marginatum (c)xxxMyurella julacea (c)xxxXxxxM. sibirica (c)xxxM. tenerrima (c)xxxOncophorus virens (c)xxxOrthothecium chryseon (c)xxx		RB	RI	BL	PT	СН	PF
M. uliginosa (c)xxxMnium blyttii (c)xM. marginatum (c)xxM. marginatum (c)xxMyurella julacea (c)xxXxxM. sibirica (c)xxXxxM. tenerrima (c)xxXxxOncophorus virens (c)xxOrthothecium chryseon (c)xx							
Mnium blyttii (c)xM. marginatum (c)xxMyurella julacea (c)xxXxxM. sibirica (c)xxXxxM. tenerrima (c)xxXxxOncophorus virens (c)xxOrthothecium chryseon (c)xx	M. uliginosa (c)	x	x	x			
M. marginatum (c)xxMyurella julacea (c)xxxM. sibirica (c)xxxM. tenerrima (c)xxxOncophorus virens (c)xxOrthothecium chryseon (c)xxx	Mnium blyttii (c)	X					
Myurella julacea (c)xxxxM. sibirica (c)xxxxM. tenerrima (c)xxOncophorus virens (c)xOrthothecium chryseon (c)xx	M. marginatum (c)				x		х
M. sibirica (c)xxxM. tenerrima (c)xxOncophorus virens (c)xOrthothecium chryseon (c)x	Myurella julacea (c)		x	x	x		x
M. tenerrima (c)xxOncophorus virens (c)xOrthothecium chryseon (c)x	M. sibirica (c)		x		x		х
Oncophorus virens (c) x Orthothecium chryseon (c) x	M. tenerrima (c)	x	x				
Orthothecium chryseon (c)	Oncophorus virens (c)		x				
	Orthothecium chryseon (c)			x			
O. intricatum (c) x	O. intricatum (c)		x				
O. strictum (c) x x	O. strictum (c)	x					x
Philonotis fontana x	Philonotis fontana						X
P. fontana var. pumila (c) x x x	P. fontana var. pumila (c)	x	x	x			
Plagiomnium ellipticum x x	Plagiomnium ellipticum	x	X				
Platydictya jungermannioides x x x	Platydictya jungermannioides	x	X			x	
	(c)						
Pleurozium schreberi x	Pleurozium schreberi		X				
Pohlia bulbifera x	Pohlia bulbifera			x			
P. cruda x x x	P. cruda	x	x	x			
Polytrichastrum alpinum var. x	Polytrichastrum alpinum var.			x	Ĩ.		
fragile	fragile		1				
P. norvegicum x	P. norvegicum		x				
Pseudocalliergon trifarium (c) x	Pseudocalliergon trifarium (c)		x				
Pseudoleskeella tectorum (c) x	Pseudoleskeella tectorum (c)		x				
Rhizomnium andrewsianum   x	Rhizomnium andrewsianum		X				
R. punctatum x x	R. punctatum		x	x			
Rhytidium rugosum (c) x	Rhytidium rugosum (c)				x		
Sanionia uncinata x x x	Sanionia uncinata	x	x	x			
Tomentypnum nitens (c) x x x	Tomentypnum nitens (c)		x	x	x		
Tortella fragilis (c) x x x x	Tortella fragilis (c)		X	x	x	x	
T. tortuosa (c) x	T. tortuosa (c)				x		
Anastrophyllum minutum x	Anastrophyllum minutum	x	1	1			
Aneura pinguis (c) x	Aneura pinguis (c)	x					
Arnellia fennica (c) x	Arnellia fennica (c)	x				1	
Barbilophozia quadriloba x	Barbilophozia quadriloba			x			
Blepharostoma trichophyllum x x x x x	Blepharostoma trichophyllum	x	x	x		x	
Cephalozia bicuspidata x x	Cephalozia bicuspidata	x		1	1	x	
C. cf. connivens x x	C. cf. connivens	x	x	1		1	
Cephaloziella arctica x x x	Cephaloziella arctica		x	x	x	1	<u> </u>
Frullania tamarisci x	Frullania tamarisci				x		

(Table 1 continued)

Associated plant species	Middle	Low Arctic			Sub-A	Arctic
	RB	RI	BL	РТ	CH	PF
Lophozia collaris (c)		X			X	
L. cf. excisa (c)	x					
L. grandiretis			x			
L. heterocolpos (c)		x				
L. kunzeana			x			
L. sudetica			x		x	
Mannia pilosa (c)		x				x
Nardia geoscyphus		x				
Odontoschisma macounii (c)		x				
Plagiochila arctica				x		
P. porelloides		x				
Ptilidium ciliare		x	x			
Scapania mucronata			x			
Solenostoma gracillimum			x			
Tritomaria quinquedentata	X		x			

Note. Here and in the other tables, c – calciphilous. The localities are given on pp. 106-107.

## TABLE 2

# Associated plants of *Inocybe calamistrata* in the subarctic-arctic environment

Associated plant species	ant species Low Arctic			Sub-Arctic
	RI	BL	PT	СН
Betula nana			x	
Larix laricina				x
Picea glauca				x
Salix herbacea	x	x		
Salix reticulata (c)	x		X	
Dryas integrifolia (c)	x			x
Dryas octopetala (c)			X	
Parnassia palustris				x
Vaccinium uliginosum	x			x
Aulacomnium palustre		x		
Brachythecium salebrosum	x			
Bryum capillare	x	x		x
Campylium stellatum (c)	X			X

# (Table 2 continued)

Associated plant species	Low Arctic			Sub-Arctic
	RI	BL	PT	СН
C. stellatum var. protensum (c)			x	
Ceratodon purpureus		x		x
Cyrtomnium hymenophylloides (c)	X		x	
Dichodontium pellucidum	X			
Dicranum congestum	Х			
Distichium capillaceum (c)	X		x	X
Ditrichum flexicaule (c)		x	x	x
Hypnum bambergeri (c)			X	
Isopterygiopsis pulchella	X	x		
Meesia uliginosa (c)				X
Myurella julacea (c)				X
Orthothecium chryseon (c)		x		
O. strictum (c)		x	x	x
Platydictya jungermannioides (c)				x
Pohlia nutans		X		
Polytrichastrum norvegicum	Х			
Polytrichum juniperinum		x		
P. piliferum	Х			
Rhytidium rugosum (c)		x		
Sanionia uncinata	Х	x		
Tortella fragilis (c)			х	
Tortella tortuosa (c)	Х		x	
Trichostomum arcticum (c)			x	
Anthelia juratzkana	х			
Cephalozia bicuspidata		X		
Cephaloziella rubella		x		
Jungermannia polaris (c)		x		
Scapania curta		X		

Associated plant species	Middle	Low Arctic			
	RB	RI	BL	СН	
Betula glandulosa			x		
Larix laricina				X	
Picea glauca				х	
Salix arctophila			x		
S. calcicola (c)		X	x		
S. herbacea	х		x		
S. pseudopolaris		X			
S. reticulata (c)	Х	Х	x		
Arctostaphylos uva-ursi		X			
Arctagrostis latifolia (c)	х				
Arctous alpina		······	x		
Carex membranacea (c)	x			· · · · · · · · · · · · · · · · · · ·	
C. misandra (c)			X		
C. scirpoidea (c)		X			
Cassiope hypnoides			X		
C. tetragona (c)	х	X	x		
Chrysanthemum integrifolium	x				
(c)					
Dryas integrifolia (c)	X	Х	X		
Empetrum nigrum				X	
Epilobium latifolium	х				
Kobresia myosuroides (c)			X		
Orthilia secunda			x		
Oxyria digyna (c)	x				
Phyllodoce coerulea			x		
Polygonum viviparum (c)	X	X	x		
Rhododendron lapponicum (c)		X	X		
Tofieldia pusilla (c)		Х			
Vaccinium uliginosum		Х	X	X	
Aulacomnium palustre			X		
Barbula convoluta (c)	x	X			
B. unguiculata (c)		X			
Brachythecium salebrosum	x				
Bryum capillare		X			
Bryum cyclophyllum		x			
Campylium arcticum (c)	x	X		x	
C. stellatum (c)		X			
Cinclidium arcticum (c)	x	x			
C. stygium (c)		X			
C. subrotundum (c)	x				
Climacium dendroides		X			
Cnestrum alpestre (c)	x				

Associated plants of Inocybe rimosa in the subarctic-arctic environment

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(Table 3	continued)
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Associated plant species	Middle	Low Arctic		
	RB	RI	BL	СН
Cyrtomnium	X	X		
hymenophylloides (c)				
C. hymenophyllum (c)	x	x		
Dicranum groenlandicum		x		
Didymodon fallax			x	
Distichium capillaceum (c)	x	x	x	х
D. inclinatum (c)	x			
Ditrichum flexicaule (c)		x		
Encalypta alpina (c)	x			
Fissidens adianthoides	x			
F. bryoides (c)	x			
F. osmundoides	x	x		
Hylocomium splendens			x	
Isopterygiopsis pulchella	x		x	
Leptobryum pyriforme	X			
Limprichtia cossoni (c)	X		x	
L. revolvens (c)	X	x		
Meesia longiseta (c)		x		
M. uliginosa (c)		x		
Myurella julacea (c)		x		
M. sibirica (c)	x	x		
Oncophorus wahlenbergii		x		
O. virens (c)		x		
Orthothecium chryseon (c)		x		
O. strictum (c)	x	x	x	
Plagiomnium ellipticum	x	x		
Platydictya jungermannioides		x		
(c)				
Pohlia crudoides			X	
P. nutans			X	
Polytrichastrum norvegicum		x		
Racomitrium canescens	x			
Rhytidiadelphus triquetrus	x			
Sanionia uncinata		x		
Scorpidium scorpioides		x		
Sphagnum sp.			x	
Tayloria lingulata	x	x	x	
Timmia austriaca (c)		X		
T. megapolitana var. bavarica		X		
(c)				
Tomentypnum nitens (c)		X	x	

# (Table 3 continued)

Associated plant species	Middle	Low Arctic		
	RB	RI	BL	СН
Tortella arctica (c)	x	X		
T. fragilis (c)		Х	x	
Trematodon brevicollis (c)	x			
Warnstorfia fluitans			x	
Warnstorfia fluitans			X	
Aneura pinguis (c)		Х		
Blepharostoma trichophyllum	x	Х	x	
Cephalozia pleniceps		х		
Cephaloziella arctica	x			
Lophozia cf. collaris (c)		Х		
L. gillmanii (c)		х		
L. heterocolpos (c)		x	x	
Odontoschisma macounii (c)	x	x		
Orthocaulis kunzeanus	X	-	x	
Cetraria delisei		X		
C. nivalis		Х		

## TABLE 4

# Associated plants of *Inocybe lacera* var. *lacera* in the subarctic-arctic environment

Associated plant species	Low Arctic	Sub-Arctic		
	RI	PF	GK	
Alnus fruticosa		x		
Betula pubescens		х	X	
Larix sibirica		х	X	
Picea obovata		х	X	
Salix reticulata (c)	X			
Dryas integrifolia (c)	X			
Distichium capillaceum (c)	X			
Isopterygiopsis pulchella	X			
Leptobryum pyriforme			X	
Meesia uliginosa (c)	X			
Myurella sibirica (c)	X			
Pleurozium shreberi		X		
Rhytidium rugosum		X		
Barbilophozia hatcheri	X			
Cephaloziella arctica			X	
Lophozia sudetica			X	

TABLE 5

Associated plant species	Low A	Sub-Arctic	
	BL	KS	СН
Larix laricina			x
Picea glauca			x
Bryum capillare	X		
B. cf. Salinum	х		
Climacium dendroides	Х		
Dicranum groenlandicum		x	
Hylocomium splendens		x	
Pleurozium schreberi			x
Sanionia uncinata	х		
Tomentypnum nitens (c)		x	
Tritomaria		x	
quinquedentata			
Lophozia sudetica		x	

Associated plants of Inocybe geophylla in the suarctic-arctic environment

# Table 6

Associated plants of *Inocybe leiocephala* in the subarctic-arctic environment

Associated plant species	Low Arctic					
	RI	BL	KS	PT		
Betula nana				x		
Cassiope tetragona (c)	Х					
Dryas octopetala (c)				x		
Aulacomnium turgidum (c)				x		
Bryum arcticum (c)		x				
B. wrightii (c)		x				
Campylium stellatum (c)	Х					
Ceratodon purpureus				x		
Cinclidium stygium (c)	Х					
Dicranum cf. congestum			x			
D. fuscescens				x		
Ditrichum flexicaule (c)	Х					
Hylocomium splendens				x		
Limprichtia revolvens (c)	Х					
Meesia uliginosa (c)	Х					
Philonotis fontana var. pumila	Х					
Pleurozium schreberi	Х					
Pohlia nutans		5		x		
Polytrichum juniperinum				x		
Rhytidium rugosum (c)				x		
Sanionia uncinata		x	x	x		
Orthocaulis hyperboreus (c)		x				

117

*I. calamistrata*, which differs in having broader spores. We prefer to follow the opinion of Kuyper (1990) that *I. subhirsuta* is a synonym of *I. calamistrata*.

*I. rimosa* (Bull.: Fr.) P. Kumm. Syn.: *I. fastigiata* (Schaeff.) Quél.

*I. rimosa* is a widespread species which has been recorded from Greenland (Lange, 1957; Kobayasi et al., 1971; Lamoure et al., 1982) and Svalbard (several authors, cf. Gulden & Torkelsen, 1996). Senn-Irlet (1993) found it in the Swiss Alps in the mesotrophic mire communities of *Saxifrago-Caricetum* frigidae type. Lange (1957) reported it to grow in Greenland under *Salix*. Associated plants of *I. rimosa* in this study are given in Table 3.

This variable species or species group has been described under a number of names (Kuyper, 1990). The species of this group from the arcto-alpine habitats have been described by Moeller (1945) as *I. nana* F.H. Moeller and *I. pusilla* F.H. Moeller, by Kühner (1988) as *I. godfrinioides* Kühner, *I. guttulifera* Kühner and *I. microfastigiata* Kühner, and by Bon (1992) as *I. bulbosissima* (Kühner) Bon. The bulk of the present material deviates from the typical specimens of *I. rimosa* of the boreal or hemiboreal zones in their having smaller size and often bulbous base of the stipe and less rimose pileus. In microscopical characters they, however, key out as typical specimens of *I. rimosa*.

#### I. lacera (Fr.: Fr.) P. Kumm. var. lacera

*I. lacera* is a common, widespread and variable species. In our material from Canada only one collection represents the taxon *I. lacera* var. *lacera*. This specimen was collected in low arctic tundra, on a heath with *Dryas integrifolia* and *Salix reticulata*. In NW Siberia, this variety was found in subarctic forests. For other associated plants, see Table 4.

The species has been recorded from Arctic Alaska (Laursen & Ammirati, 1982), eastern Siberia (Kalamees & Vaasma, 1981), Svalbard (Gulden & Torkelsen, 1996), and from Greenland (Lange, 1957), where it was growing with associates *Meesia triquetra* and *Philonotis fontana* (Lange, 1957). According to Kalamees & Vaasma (1981), the find from Kamchatka represents a specimen not referable to the European material, with large spores (13-22  $\mu$ m). Senn-Irlet (1993) reports the species from the Swiss Alps growing in the mesotrophic mire community, *Saxifrago-Caricetum* frigidae and in *Salicetum helveticae*. According to our experience from Finland and northern Scandinavia, it is a common species even in the tundra of Lapland.

#### I. geophylla (Sowerby: Fr.) P. Kumm.

According to Kuyper (1986), *Inocybe geophylla* occurs under frondose and coniferous trees, and it is common and widespread in Europe and North America. It has also been recorded from Svalbard (Karsten, 1872; Dobbs, 1942; Ohenoja, 1971) and Greenland (Lange, 1957). According to Moser (1982), the species seldom extends beyond the zone above the timberline in the Alps.

In this study, I. geophylla was found in Canada in the forest tundra, in mesic mossy stand with Picea glauca and Larix laricina, as the variety lilacina (Peck) Gillet. In

#### TABLE 7

#### The Inocybe species found in the subarctic and arctic localities studied in Canada. Number of collections

Species	Middle	Low Arctic			Sub-Arctic				
_	RB	RI	BL	KS	PT	CH	PF	KR	GK
Inocybe	6	17	4		1	5	1		
dulcamara									
I. calamistrata	1	6	2	1	1	2			
I. rimosa	8	11	6		1	3		1	
I. lacera var.		1					2		1
lacera									
I. geophylla			1	2					
I. leiocephala		1						1	

Siberia it grew in mossy tundra as the variety *geophylla*. Associated plant names are given in Table 5.

#### I. leiocephala Stuntz

Syn.: I. subbrunnea Kühner

According to our observations, *I. leiocephala* is the most common species of the section Splendentes in northern Fennoscandia, being fairly frequent on nutrient-rich soils in the forests with mountain birch, and occurring also above the timberline. We have also seen specimens collected in Iceland. Senn-Irlet et al. (1990) reported it to be rather common in the Alps, growing with dwarf willows or *Dryas*.

The species was found in Canada in low arctic tundra, on turf amongst thin mosses at the side of a ditch-like frost crack in *Alectoria-Cassiope* heath. In Siberia it grew at the timberline. Associated plants are given in Table 6. This is the first report of this species from Arctic Canada and Arctic Russia. The spores of the collected specimens are somewhat larger (9.5-11(-12) x 6-7  $\mu$ m) than those given by Kuyper (1986), but otherwise the specimens fit well the material from Fennoscandia.

# Conclusion

In Canada, the most common species were, according to the collections (Table 7), Inocybe dulcamara (31 samples), I. rimosa (28) and I. calamistrata (10). The occurrence of the species in different localities is given in Table 7. In Russia, I. rimosa and I. lacera were found more often than the other species, but the amount of the collections was, all in all, small, because the visit was short, and the comparison is not reasonable. The species of *Inocybe* are mycorrhizal. The fruitbodies of *Inocybe* were mostly found in tundra, in the vicinity of dwarf shrubs, *Salix* species (Tables 1-6). However, in some cases only *Dryas* was present near the *Inocybe*. The habitats of *I. lacera* var. *lacera* were fairly dry both in the subarctic and arctic zones, and also *I. dulcamara* grew often in dry tundra, with *Cassiope tetragona*, *Cladonia* and *Alectoria* species. *I. leiocephala* preferred mossy, mesic tundra, while *I. rimosa* and *I. calamistrata* were species occurring mainly in snow beds and shores.

The material offered in this article presents the species occurring both in Canada and northwestern Russia, and describes about one third of the taxa found in the studied areas. The specimens of *Inocybe*, which do not fit any described species, were also included in the material. On the contrary, some *Inocybe* species, such as *I. soluta*, *I. subcarpta*, *I. leptophylla*, are, according to our observations, fairly common in northern Fennoscandia, but were not found in the present study area. The material collected in Siberia shows the same species as in northern Fennoscandia and Arctic Canada, but about one half of it could not be identified.

It is difficult to describe the phenology of the found *Inocybe* species because of short stay in every locality. Many species of the genus usually fruit at the beginning of fungal seasons, and they have been found to be abundant in the Arctic in the first half of August.

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# LEAD AND CADMIUM CONTENTS OF BASIDIOMYCETES ALONG A HEAVILY TRAFFICATED HIGH MOUNTAIN PASS ROAD IN THE AUSTRIAN ALPS

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Abstract: Along a heavily trafficated high mountain pass in the Austrian Alps 23 specimens of 9 basidiomycetes have been collected, and their heavy metal contents (Cd, Pb) measured. The measured lead concentrations (range: 1.47-25.5  $\mu$ g/g dry weight, mean value: 9.53  $\mu$ g/g dw, accumulation factor 0.49 ± 00.28 fold) have been much higher than those reported from the Sw iss Alps by Irlet and Ieder (1995). The cadmium values have varied between 0.44 and 6.51  $\mu$ g/g dw (mean value 4.14  $\mu$ g/g dw, accumulation factor 30.7 ± 17.6 fold), and have been lower than the Swiss values. *Cortinarius favrei* D.M. Hend. has exhibited a particular ability to accumulate both lead and cadmium. This species also complies with several other criteria for a suitable bioindicator of heavy metal pollution in alpine environments.

В Австрийских Альпах вдоль высокогорной дороги с оживленным движением найдено 23 экземпляра 9 видов класса Basidiomycetes. Измерен уровень содержания в них тяжелых металлов (Cd, Pb). Концентрация свинца в грибах (интервал: 1,47 - 25,5 мкг/г сухой массы, средний показатель: 9,53 мкг/г с.м., коэффициент накопления  $0,49 \pm 0,28$ ) намного выше, чем в Швейцарских Альпах. Содержание кадмия варьировало между 0,44 и 6,51 мкг/г с.м. (средний показатель 4,14 мкг/г с.м., коэффициент накопления  $30,7 \pm 17,6$ ) и было ниже в сравнении с горными районами Швейцарии. Показано, что Cortinarius favrei D.М. Hend. обладает наибольшей способностью к накоплению тяжелых металлов и в горных районах он может служит биоиндикатором на соответствующего типа загрязнение окружающей среды.

Keywords: Alpine Basidiomycetes, heavy metals, lead, cadmium, biomonitoring.

She mountains of Austria occupy more than half of the country's area. Major cities like Innsbruck, Klagenfurt, and Salzburg are either in or adjacent to the mountains. The mountains of Austria have considerable areas above timberline, including a significant number of glaciers and glacier complexes. In recent decades the use of these mountain landscapes has changed considerably. In particular, tourism has become the dominant economic sector. One trend has been the increase in day and weekend tourism, which together with transit from north to south Europe leads to the overloading of transport and traffic. The mountains of Tyrol cover the country from the German border in the north to the Swiss and Italian borders in the south. Obergurgl is a village in the Oetz valley, situated in the central Alps of Tyrol, at an altitude of about 2,000 m (just below timberline). In the 1960s, the University of Innsbruck founded an Alpine Research Station in Obergurgl. From the village the Timmelsjoch pass road (11°5' E, 46°55' N) leads over the Alps to Italy, reaching an altitude of 2,474 m a.s.l. The pass road is open in summer only, where it is heavily trafficated mostly by tourists who want to enjoy the beautiful scenery of the Tyrolean Alps. Basidiomycetes are known to accumulate heavy metals in their mycelia and basidiomata (Tyler, 1980, 1982; Dietl, 1987, Gast et al., 1988; Borella et al., 1991; Turnau & Kozlowska, 1991; Peintner & Moser, 1996). This property can be used for bioindication. The aim of this study was to survey the heavy metal situation in the alpine zone with special emphasize on the influence of a heavily trafficated road.

#### Material and methods

Fungi were collected in August 1995 in the Timmelsjoch area (Oetz Valley, Tyrol, Austria) near the high-alpine Timmelsjoch road (2,300-2,400 m), in Poschach near Untergurgl (2,000 m) and in the Rotmoos valley, an untouched alpine valley 10 km away. Fungal species suitable as bioindicators should be frequent, and form fleshy basidiomata, as at least 0.5 g dry weight (= dw) material is required for heavy metal analysis. The heavy metal content of 14 species were determined by measuring 28 collections. Collections (at least 2 basidiomata) were made of fungi of the same species fruiting on an area of 1 m<sup>2</sup> maximum. Visible soil particles were cleaned off in the field. The samples were dried at 40°C. Furthermore soil samples were taken at a distance of 5 m, 10 m, 20 m, 50 m, 100 m, 200 m, 500 m and 1,000 m from the street. All soil samples were taken in or near dwarf willow habitats, where also the fruitbodies were collected. For the pH-value of the soil samples at 10 m, 1,000 m of the street was pH 4.35  $\pm$  0.07, the water content was 24.06  $\pm$  12.80% H<sub>2</sub>O.

The fungal collections were pulverized by crushing them between two sheets of clean paper. Then they were dried at 105°C again. Samples of 1 g dry weight (= dw) maximum were added to 3 ml of perchloric acid and 0.5 ml  $H_2O_2$  The decomposition was effected by a high performance microwave digestion unit. The solutions were diluted to a volume of 20 ml. The soil samples were sifted to 2 mm; from each sample three parallels were measured with 1 g dw, 2 g dw and 3 g dw respectively. The soil was added to 10 ml of perchloric acid. After the decomposition in a sand bath the solutions were diluted to 50 ml with two times destilled water.

The concentrations of the soil samples were determined by an atomic absorption spectrometer (Perkin Elmer HGA-400 2380 with graphit unit), Cd and Pb were measured with a polarographic analyser (Metrohm 646 VA Processor). A comparison between the two methods showed corresponding results.

#### Results

The cadmium contents of the nine basidiomycete species from the Timmelsjoch area range between 0.44  $\mu$ g/g dry weight (= dw) and 6.51  $\mu$ g/g dw (mean value mv = 1.86  $\mu$ g/g dw, standard deviation sd = 1.84  $\mu$ g/g dw, number of collections n = 23). The

#### Ursula Peintner

#### TABLE 1

Cadmium and lead values of basidiomycetes collected in 1995 in the Timmelsjoch area (2,400-2,500 m)

Basidiomycete species	Cd (µg/g	acc.	Pb (µg/g	acc. factor
	dw)		dw)	
Anellaria semiovata Coll. 1	5.36	39.70	6.54	0.27
Anellaria semiovata Coll. 2	1.61	11.94	4.17	0.17
Bovista nigrescens Coll. 1	1.47	10.09	3.70	0.15
Cortinarius chrysomallus	1.97	14.61	22.50	0.94
Cortinarius favrei Coll. 1	2.56	18.99	12.24	0.51
Cortinarius favrei Coll. 11	6.51	48.21	11.55	0.48
Cortinarius favrei Coll. 23	4.02	29.81	15.46	0.65
Cortinarius favrei Coll. 3	6.49	48.11	15.83	0.66
Cortinarius favrei Coll. 6	3.28	24.30	11.39	0.48
Cortinarius favrei Coll. 7	1.97	14.62	11.37	0.48
Cortinarius kuehneri Moser	1.65	12.22	1.47	0.06
Coll. 1				
Inocybe rhacodes Coll. 1	0.58	4.31	18.45	0.77
Inocybe rhacodes Coll. 2	1.45	10.72	16.62	0.70
Laccaria laccata Coll. 1	0.53	3.89	21.73	0.91
Laccaria laccata Coll. 2	0.54	4.00	12.22	0.51
Lactarius nanus Favre Coll. 2	4.06	30.04	5.13	0.21
Russula chamiteae Coll. 90/90	0.64	4.71	1.92	0.08
Russula chamiteae Coll.	1.15	8.52	7.52	0.31
95/105				
Russula norvegica Coll. 1	0.97	7.21	5.63	0.24
Russula norvegica Coll. 1	1.40	10.38	8.76	0.37
Russula norvegica Coll. 3	2.06	15.29	25.53	1.07
Russula norvegica Coll. 4	0.44	3.23	17.11	0.72
Russula norvegica Coll. 4	1.45	10.72	9.86	0.41

cadmium values of the other two collecting sites are not comparable because it was not possible to collect the same species. The highest cadmium values were measured in basidiomata of *Cortinarius favrei* D.M. Hend. (range: 1.97-6.51  $\mu$ g/g dw, mv = 4.14-1.95  $\mu$ g/g dw, sd = 47 %, n = 6). Laccaria laccata (Scop.: Fr.) Berk. & Broome showed the lowest values (0.5  $\mu$ g/g dw, n = 2). The cadmium values of *Inocybe rhacodes* J. Favre (0.6-1.4  $\mu$ g/g dw, n = 2), *Russula norvegica* D. Reid (0.4-2.1  $\mu$ g/g dw, n = 5) and *R. chamiteae* Kühner (0.6-1.1  $\mu$ g/g dw, n = 2) were also comparatively low (Table 1). The cadmium values of the soil were highest at a distance of 5 to 50 m from the street (0.27 ± 0.10  $\mu$ g/g dw). Between the distance of 100 m and 1,000 m cadmium values were 0.13 ± 0.019  $\mu$ g/g dw; as all the fungi were collected at this distance, these values were taken for the calculation of the accumulation behaviour. The accumulation factor

#### TABLE 2

Cadmium and lead values of basidiomycetes collected in 1995 in the areas near Obergurgl called Poschach (2,100m) and Rotmoos Valley (2,400m)

Basidiomycete species	Cd (µg/g dw)	Pb (µg/g dw)
Lactarius lepidotus A.H. Sm. &	<0.4	2.12
Hesler		
Lyophyllum putidum (Fr.)	<0.4	3.31
Singer ss. J.E. Lange		
Russula favrei M.M. Moser	<0.4	1.54
Coll. 95/98		
Bovista nigrescens Pers. : Pers.	2.42	2.57
Coll. 2		
Russula nana Killerm.	1.81	0.00

for cadmium varied from species to species between less than 3- fold to 48.2-fold. C. favrei accumulated cadmium  $30.7 \pm 17.6$  — fold (n = 6), R. norvegica  $9.4 \pm 5.5$ - fold (n = 5).

The lead values of the basidiomata collected in the Timmelsjoch area ranged between 1.47 and 25.5  $\mu$ g /g dw (mv = 9.53  $\mu$ g/g dw, sd = 6.73  $\mu$ g/g dw). 5 collections from the other two collecting sites range between no detectable values to 2.5  $\mu$ g/g dw (Table 2). The highest amount of lead was detected in the basidiomata of *C. chrysomallus* Lamoure (22.5  $\mu$ g/g dw, n = 1), *I. rhacodes* (16.7-18.5  $\mu$ g/g dw, n = 2), *C. favrei* (range: 11.4-15.8  $\mu$ g/g dw, n = 6), *L. laccata* (range: 12.2-21.7  $\mu$ g/g dw, n = 2). In two collections of *R. norvegica* rather high amounts of lead were measured (25.5  $\mu$ g/g dw, 17.1  $\mu$ g/g dw) while the other three collections showed lead values below 10  $\mu$ g/g dw. The most constant values were found in *C. favrei* (12.97-2.1  $\mu$ g/g dw, n = 6, sd = 16.2%). The lead values of soil were the highest at a distance of 10 m to 50 m from the street (49.9  $\pm$  14.7  $\mu$ g/g dw). Between 100 m and 1,000 m the cadmium values were 31.9  $\pm$  11.4 mg/g dw; these values were taken for the calculation of the accumulation pattern: the accumulation factor for lead varied between 0.08-fold and 1.07-fold, which means that all investigated fungal taxa exclude lead. *C. favrei* (0.54  $\pm$  0.22- fold, n = 6) and *R. norvegica* (0.56  $\pm$  0.38- fold, n = 5) exhibited the highest accumulation factors.

#### Discussion

The accumulation or exclusion of heavy metals in basidiomata depends on two factors: the fungal species and the chemical element. Measuring the heavy metal contents of basidiomata can be a suitable method of surveying the impact of pollution, provided that at least 8-10 different fungal species are investigated with enough samples (Gast et al., 1988). To our knowledge, there is only one other investigation of heavy metal contents of alpine basidiomycetes: Irlet and Rieder (1985) measured lead and cadmium contents of basidiomycetes from undisturbed areas in the Swiss Alps (1,900-2,500 m). A comparison

#### Ursula Peintner

#### TABLE 3

Cadmium and lead contents of some alpine basidiomycetes. Comparison of the values measured in basidiomata collected along the Timmelsjoch pass road with values from undisturbed alpine locations (1,900-2,500 m) in the Swiss Alps (Irlet & Rieder, 1985)

Basidiomycete species	Cd (µ	g/g dw)	Pb (μg/g dw)		
	Swiss Alps	Timmelsjoch	Swiss Alps	Timmelsjoch	
Cortinarius favrei	5.0	2.0-6.5	2.8	11.3-15.5	
Laccaria laccata	2.3	0.5	16.0	12.2-21.7	
Russula norvegica	3.9	0.4-2.0	4.9	5.6-25.5	
Inocybe rhacodes	2.0	0.6-1.4	3.7	16.6-18.5	
Anellaria semiovata	0.6	1.5-5.0	6.3	4.1-6.5	
Bovista nigrescens	5.5	1.5	3.9	3.7	

of their results with the data obtained in the Timmelsjoch area (Table 3) showed that the cadmium content of the basidiomata collected along the Timmelsjoch pass road are — except for the coprophilous species *Anellaria semiovata* (Sow.: Fr.) A. Pearson & Dennis — lower than those from basidiomata collected in the Swiss Alps. However, the lead concentrations of the alpine fungi from Timmelsjoch are much higher as compared with the data from Switzerland. This especially applies to the symbiontic taxa.

These results confirm the observations made in earlier investigations (Peintner & Moser, 1996), where from 33 studied taxa, mycorrhiza forming species of the genus Cortinarius showed a particularly high ability to accumulate cadmium and to have high amounts of lead in the basidiomata as well. C. favrei seems to have more constant accumulation patterns of lead and cadmium than R. norvegica or L. laccata. Furthermore. C. favrei satisfies more criteria as a suitable bioindicator for lead and cadmium: it is rather frequent and distributed over a wide range of arctic-alpine habitats. C. favrei belongs to the subgenus Myxacium and is one of the most easily recognized Cortinarius species in the arctic and aloine habitats. It is one of the early and common mushrooms and reaches far up in the mid-alpine belt. It forms mycorrhiza with several species of dwarf willow (Salix sp.). Favre (1955) considered it to be mainly an acidophilous species in the Alps, able to grow on calcareous soils as well. In Norway it is very common and seems to be fairly indifferent to the ρH-value of soils and to snow cover (Gulden et al., 1985). According to Ohenoja (1971), C. favrei is known from arctic-alpine sites in Continental Europe. Scotland, Novaya Zemlya-Kola area, Svalbard, Greenland, Canada and Alaska. However, more detailed information about the mechanisms and constancy of the accumulation behaviour of C. favrei is required. For the following reasons little is known yet about the accumulation behaviour of basidiomycetes: heavy metals are, like nutrients, absorbed by the mycelia growing in soil. The mechanisms by which some species accumulate certain elements but exclude others are still unclear. As the mycelium in its natural habitat usually cannot be observed, we only can measure the heavy metal concentrations of the basidiomata produced by this mycelium. Therefore it is impossible to establish the period, in which heavy metals were accumulated by the mycelium, as we usually have no knowledge about its age

and extension. Maybe just for this reason — that is, accumulation of heavy metals over a wide area and a relatively long time — the fungi have an advantage of being very sensitive accumulation indicators.

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## LEPIOTA CORTINARIUS VAR. DRYADICOLA, AN ARCTIC-ALPINE TAXON?

#### Ursula Peintner

Abstract: The first record of *Lepiota cortinarius* var. *dryadicola* Kühner in arctic areas is described. This species had been found only two times before in the Alps. A description is given, and the systematic position compared to other members of the *Lepiota cortinarius* complex (*Lepiota cortinarius* var. *cortinarius* and *L. cortinarius* var. *audreae*), as well as the variability of this taxon are discussed.

Впервые в Арктике найден Lepiota var. cortinarius dryadicola Kühner, который до этого был известен в виде двух находок в Альпах. Дано его описание и систематическое положение среди других видов комплекса Lepiota cortinarius (Lepiota cortinarius var. cortinarius и L. cortinarius var. audreae).

Keywords: Lepiota cortinarius (Lange) var. dryadicola (Kühner) Bon, arctic-alpine distribution, taxonomy, Russia.

In arctic and alpine habitats only few *Lepiota* species grow, and they are rather rare (Favre, 1955; Kühner, 1983; Schmidt-Heckel, 1985; Watling, 1987; Enderle & Krieglsteiner, 1989; Guzman & Guzman-Davalos, 1992; Migliozzi & Bizio, 1994; Bon, 1996; Horak, unpublished): up to now *L. cortinarius* var. *dryadicola* Kühner (Bon) and *L. favrei* Kühner ex Bon (= *L. pseudohelveola* Kühner ss Favre) have been reported only from arcto-alpine habitats, while other *Lepiota* species found in alpine habitats usually grow close to mountain areas.

Kühner (1983) described L. dryadicola from «2 carpophores» collected in the French Alps: «Sur soil calcaire, dans un tapis de Dryas. Vanoise; haute vallee de Champagny, bord S du «Lac» de la Gliere, 2,000 m, 14-9-1970, (K. 70-141)». Migliozzi and Bizio (1994) found this taxon for the second time and described one basidioma of L. dryadicola collected in Northern Italy (Fuchiade, Passo S. Pellegrino, Val di Fassa, Italy, at 2,400 m in a cushion of Dryas octopetala).

The collection presented in this work also consists of only one basidioma. As it represents the first record of L. cortinarius var. dryadicola in arctic habitats, its description is given, and the variability of this taxon as well as its taxonomic position are discussed.

#### Material examined

Lepiota dryadicola Typus. France, Savoie, Parc de la Vanoise, Haut vallee de Champagny, Lac de Gliere. Sur Dryas en exposition S. Alt.: 2,000 m. Leg. et det.: R. Kbhner 14.09.1970, «K70/141» = Herbarium Ganavensis 2387/9. Fig. 2a.

Lepiota dryadicola. Russia, Western Siberia, Yamal-Nenets autonomous district, the Polar Urals, Yangana-Pe, 200 m a.s.l., one basidioma. Arctic tundra on limestone. Dryas sp., Salix reticulata, Arctostaphylos sp. Leg. et det. U. Peintner, 26.08.1996; IB 96/773. Figs. 1, 2b.

Lepiota cortinarius Lange. The Netherlands, Oostelyk Flevoland, Bremerbergbos, in mixed forest plantation (*Populus* with *Alnus*, *Corylus* etc.) on calcareous humid clayey soil. 04.10.1981. Leg. et det. C. Bas, Rijksherbarium Leiden: Bas 7795.

Lepiota cortinarius var. audreae Reid. The Netherlands, Brunssum, mine waste of former mine Hendrick, under Betula, 5 specimens collected. 29.09.1981. Leg. Kelderman, det. Kuyper / Bas Rijksherbarium Leiden: Kelderman 1519/1520.

## Results

Lepiota cortinarius var. dryadicola (Kühner) M. Bon, 1994. Docum. Mycol.23(92): 48.

Bas.: Lepiota dryadicola Kühner, 1983. Crypto. Mycol. 4(1): 65.

Syn.: Lepiota audreae (D. Reid) M. Bon var. dryadicola (Kühner) M. Bon, 1993 ad int. Docum. Mycol. Memoire Hors serie 3 Sel.

Illustr.: Migliozzi & Bizio, 1994.

Sel. desc. & figs.: Kühner, 1983; Migliozzi & Bizio, 1994: 37.

Pileus 4 cm in diam., conical, surface disrupting into numerous, small granular scales, which are redbrown against whitish background; these scales are more dense towards the centre forming a calotte on the disc; ground colour: Cail. L69, M69, of the scales Cail. P37, R37. Scales velvety. Margin involute, woolly, exceeding the gills. Lamellae free, dense, up to 5 mm broad, white, with lamellulae (11-12), edge slightly dentate. Stipe slightly clavate, 30 x 6 mm (10 mm on the basis), beige, Cail. L69, M69 with fine reddish-brown girdle like fibrils at the basis. There is no annulus but the lower part of the stem is covered by remnants of the cortinate veil. Flesh beige to wood coloured, soft. Smell acidulous, similar to *Fomitopsis pinicola*. Habitat: arctic tundra on limestone, among *Dryas* sp., *Salix reticulata*, *Arctostaphylos* sp.

Spores thin-walled, hyaline, subfusiform with slighly truncate basis, with suprahilar depression, but not distinctly projectile shaped, with a shape suggestive of spores found in the genus Boletus, (6.8-)8.10  $\pm$  0.4(-9.0) x (2.9-)3.4  $\pm$  0.2(-3.9) µm, Q = (2.2-)2.40  $\pm$  0.2(-2.75), volume = (31-)49  $\pm$  5.5(-71) µm<sup>3</sup>, n = 50. Values in parentheses indicate minima and maxima. Basidia clavate with 4 sterigmata and basal clamp-connection, (20-) 22.8  $\pm$  2.6(-28) x (5.9-)6.6  $\pm$  0.8(-7.8) µm, n = 12. Cheilocystidia thin-walled, hyaline, varying in shape from narrowly clavate, broadly clavate, vesiculose to balloon-shaped, with basal clamp-connection, (24-)29.2  $\pm$  3.5(-36) x (6.7-)9.7  $\pm$  2.4(-15.7) µm, Q = (2-) 3.10  $\pm$  0.5(-3.8), n = 10, edge sterile. No pleurocystidia observed. Scales of the pileus formed of elongated, repent, non-septate, thin-walled, brown or subhyaline hairs. These hairs, up to 260 (320) µm long and (8.0-)16.8  $\pm$  4.0(-23.6) µm wide, n = 45, are mostly cylindrical with (8-)10.5  $\pm$  2.0(-12.0) µm broad, obtuse apices, only very few narrow towards the tip and may appear pointed. They are also narrow basal and terminate



Fig. 1. Lepiota cortinarius var. dryadicola: a – basidioma; b – spores; c — elements of the pileus; d – basidia; e – cheilocystidia



Fig. 2. Lepiota cortinarius var. dryadicola: SEM photographs of the spores: a - Typus K70/141; b - IB 96/773. Scale bar = 1 µm at a clamp-bearing septum. Pigment parietal. The hyphae are bundled together. Stipitipellis of cylindrical, parallel, 4-10 µm wide hyphae. Clamp-connections present in all tissues.

#### Microscopic character of the type material

Spores subfusiform with slighly truncate basis, with suprahilar depression, but not distinctly projectile shaped, (6.4-)7.7  $\pm$  0.6(-10.0) x (3.1-)3.3  $\pm$  0.2(-3.9) µm, Q = (2.0-)2.30  $\pm$  0.1(-2.5), v = (33-)44  $\pm$  8.6(-80) µm<sup>3</sup>, n = 37. Basidia mostly with four sterigmata (rarely two) and basal clamps, (22-)24  $\pm$  1.4(-26) x (5.9-)6.0  $\pm$  0.2(-6.3) µm, n = 10, v = (397-)466  $\pm$  47(-527) µm<sup>3</sup>. Basis of basidia 2.4-4 µm broad, sterigmata up to 4 µm long. Tramal hyphae of the lamellae partly inflated with a diameter of 2.8-6.4 µm, with few anastomoses, clamps obvious. Cheilocystidia clavate to balloon-shaped, colourless, (18-)19  $\pm$  1(-22) x (5.9-)7.3  $\pm$  1(-9) µm, Q = (2-)2.6  $\pm$  0.3(-3.0), n = 11, edge sterile. No pleurocystidia observed. Clamp-connections present in all tissues. Hair-like hyphae of the pileipellis up to 300 µm long and (7.2-) 12  $\pm$  2.6(-17.2) µm broad, (n = 25). Pigment parietal, clamp-connections present. Stipitipellis of cylindrical, parallel, 4-8 µm wide hyphae.

## Variability and distribution

The knowledge of the variability of a taxon known only from 3 collections consisting of altogether four basidiomata, can not be more than tentative. Macroscopically the present collection fits well the description given by Kühner (1983) as well as the picture and description given by Migliozzi & Bizio (1994). Microscopically, there is a little difference between the type material and the present collection: only the cheilocystidia of the present collection are distinctly larger, but they agree with the measures given by Migliozzi & Bizio (1994). All these data together can give us an idea about the variability of this very rare taxon: taking minima and maxima we can assume a range of 6.5-10 x 3-4  $\mu$ m for the spores with a quotient of 2.2-2.6. The basidia vary from 20-30 x 6-8.5  $\mu$ m, the cheilocystidia from 14-36 x 5-17  $\mu$ m. The hairs which form the scales of the pileus can be up to 320  $\mu$ m long and 9-24  $\mu$ m broad. *Lepiota cortinarius* var. *dryadicola* is very rare, but the few collections indicate its arctic-alpine distribution.

#### Taxonomic position

Lepiota cortinarius was described by Lange (1915: Dansk Botanisk Arkiv 2(3): 25) who placed it in the sect. Stenosporae. No original material is conserved in the herbarium of Copenhagen. Since then, typical L. cortinarius has been reported from Europe and Asia (Guzman & Guzman-Davalos, 1992). Smith (1954) reported L. cortinarius from America, but with pleurocystidia. As the spores of the taxa belonging to L. cortinarius complex are not truly projectile-like, Vellinga (1992) suggested to better place them in sect. Lepiota. On the other hand, Bon (1993) recombined two taxa, L. audreae (Reid) M. Bon (Bas.: Lepiota cortinarius var. audreae D. Reid) and L. audreae var. dryadicola (Kühner) M. Bon (Bas.: L. dryadicola Kühner), and placed them into the new subsection Cortinarioidei of sect. Stenosporae. Later (1994) he rightfully published L. cortinarius var. dryadicola (Kühner) M. Bon.

Common features of taxa belonging to the Lepiota cortinarius complex, which clearly separate them from the other species of the genus, are the absence of an annulus but the presence of a cortinate veil and the extraordinary spore form. A clear distinction of taxa on a species level among this complex, as proposed for L. audreae by Bon (1981) and for L. dryadicola by Migliozzi and Bizio (1994) is critical.

Lepiota audreae (Reid) Bon was originally described as Lepiota cortinarius var. audreae Reid (1968): «A typo differt colore intenso». This taxon was raised to a species level for the following reasons (Bon, 1981): the form of the basidiomata is not slender but robust, the smell is geraniform, of fresh wood or of «brioche» (L. cortinarius has no distinct odour), the pileus has bigger, well differentiated scales forming a typical red brown calotte at the centre while L. cortinarius has fine scales and does not form any calotte-like structures. L. cortinarius grows in Abies and Fagus forests, while L. audreae, so far known only from Europe, is thermophilic and prefers Carpinus and Cephalanterio-Fagion forests on calcareous soil.

L. dryadicola was first accepted as a variety of L. audreae by Bon (1993). He argues that L. dryadicola is microscopically more or less identical with L. audreae. L. dryadicola differs only in the smaller size of the basidiomata, in the cap colour, the more «distinct» odour not specified by him, the shorter cheilocystidia, and in the typical alpine habitat, where it grows with Dryas and Salix reticulata. Later Bon (1994) recombined L. cortinarius var. dryadicola following Vellinga's (1992) opinion that L. cortinarius included 3 varieties, L. cortinarius var. cortinarius, var. audreae and var. flava Bas & Vellinga.

Vellinga (1992) supposed that «L. dryadicola is very close or even identical with L. cortinarius». In fact, the former taxon is very close to both L. cortinarius var. cortinarius and var. audreae: the basidiomata of L, cortinarius var. cortinarius are much bigger than those of the *«dryadicola»* and *«audreae»* taxa, the pileus ranging from 40-80 mm, the stipe is 48-90 x 3.5-12 mm with a basal bulb up to 25 mm. Furthermore, they are comparatively pale, described by De Vries (1966, cited in Reid, 1968) as «pale beige-brown» adding that the brown colour of the cap is «strikingly pale», and by Vellinga (1992) as «pale hazel brown, reddish ochraceous brown to pale pinkish brownish isabella». L. cortinarius var. audreae shows a «much darker covering of pileus and stipe breaking up into more discrete squamules, dark brown at the centre and there slightly squarrose-felty, with hazel-brown squamules» (Vellinga, 1992); the basidiomata are smaller (pileus 35-45(-60) mm in diameter, stipe 25-50 x 6-7 mm) L. cortinarius var. dryadicola has equally small but slenderer basidiomata (pileus 35-53 mm, stipe 30-35 x 6-7 mm, basal bulb 10-12 mm) and intermediary colours that are more reddish brown than in L. cortinarius var. cortinarius but not as dark brown as in L. cortinarius var. audreae; the calotte is not as pronounced as in L. cortinarius var. audreae. The smell of L. cortinarius var. cortinarius is described as «strong, fruity, sweetish or not strong and as in L. cristata» (Vellinga, 1992). According to Reid (1968), L. cortinarius var. audreae has a «weak, not unpleasant» smell, while Bon (1981, 1993) described it as geraniform, or of fresh wood or of «brioche». Our collection of L. cortinarius var. druadicola has an acidulous smell. The most distinctive feature is the very different habitat: L. cortinarius var. cortinarius grows in deciduous or mixed forests while L. cortinarius var. audreae is reported to be more thermophilic growing in Carpinus and Cephalanterio-Fagion forests. L. cortinarius var. dryadicola is known only from arcticalpine habitats in association with Dryas and dwarf willow.

There are no significant microscopical differences between the taxa in question: the typically formed spores (measurements from spore prints or from spores taken from the stipe) are  $(7.2)8.2 \pm 0.5(-9.6) \times (3.1)3.3 \pm 0.2(-3.9) \mu m$ ,  $Q = (2.1)2.5 \pm 0.2(-2.8)$ . volume =  $(37-)47 \pm 7(-71) \mu m^3$ , n = 30 in L. cortinarius var. cortinarius,  $(8.0-)8.7 \pm 10^{-1}$  $0.5(-10.0) \ge (3.1)3.4 \pm 0.2(-3.9) \ \mu m, Q = (2.3-)2.6 \pm 0.2(-2.9), \ volume = (41-)54$  $\pm$  7(-65) µm<sup>3</sup>, n = 30 in L. cortinarius var. audreae and (6.8-)8.10  $\pm$  0.4(-9.0) x (2.9-)  $3.4 \pm 0.2(-3.9) \ \mu\text{m}, \ Q = (2.2-)2.4 \pm 0.2(-2.8), \ \text{volume} = (31-)49 \pm 5.5(-71) \ \mu\text{m}^3,$ n = 50 in L. cortinarius var. druadicola. The 4-spored, clamped basidia range between 20-30 x 5.5-9 µm and the cheilocystidia show the same variation in size and form. Only the hyphae forming the small erect scales on the disc show some differences in their length and in the form of their apical parts: L. cortinarius var. cortinarius has up to 600 µm long and  $(10-)14 \pm 2(-18)$  µm thick «hairs» narrowing towards the tip  $((4-)6 \pm 2(-8))$  µm broad, n = 20), therefore they appear slender and pointed. The hyphae of L. cortinarius var. audreae are up to 400  $\mu$ m long and (14-)16 ± 2(-20)  $\mu$ m broad with partly pointed. partly broad obtuse apices ((6-)8  $\pm$  2(-12) µm broad, n = 20). L. cortinarius var. dryadicola showes hairs up to 320  $\mu$ m long and (8.0-)17 ± 4(-24)  $\mu$ m (n = 45) wide, with an (8-)11  $\pm$  2(-12)  $\mu$ m (n = 20) broad apical part, only very few narrow towards the tio.

The fact that hyphae may differ in form and size in one species or even in one specimen was already observed by Reid (1968) who pointed out for *L. cortinarius* var. *audreae* that "The hairs forming the small erect scales on the disc are similar to those described above but much shorter, measuring 110-250  $\mu$ m ....» Also *L. cortinarius* var. *cortinarius* has very short hyphae with mostly obtuse apices at the centre of the pileus, especially in young basidiomata. Consequently, these hyphae seem to elongate during the development of the pileus forming narrower and more pointed apical parts. It is amazing that the longest "hairs" can be found in the big basidiomata of *L. cortinarius* var. *cortinarius*, and the shortest ones in the small and slender basidiomata of *L. cortinarius* var. *dryadicola*. But it is still unclear whether the final length of the hairs depends on the diameter of the pileus, or if it is an independent character.

## Conclusion

There are differences between L. cortinarius var. cortinarius and L. cortinarius var. dryadicola, so a synonymization as proposed by Vellinga (1992) seems not to be justified. The above discussed specific distinctive characters of L. cortinarius var. dryadicola, namely the dwarf size, the differing colours and the unique habitat do not deserve specific rank of this taxon, but they unquestionably justify its distinction as a variety.

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## THE PECULIARITIES OF MACROMYCETE FRUITING IN MOUNTAINOUS REGIONS OF PRIBAIKALYE

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Abstract: The response of fruitbodies of macromycetes to low temperature stress in high elevation forest-tundra (1,200-1,400 m a.s.l.) and in medium elevated mountains (500-700 m a.s.l.) of Pribaikalye is discussed. The fruiting of macromycetes in high elevations of Pribaikalye is not limited by the first snow fall. A psychrotolerant group of fungi can immediately resume their growth during thaws or settled warm days.

> Рассматривается реакция плодовых тел макроскопических грибов на низкие температуры в горной лесотундре (1200-1400 м над ур.м.) и в горно-лесном поясе (500-700 м над ур.м.). В этих условиях плодоношение макромицетов не прекращается с выпадением снега и установлением временного снежного покрова, так как психротолерантные грибы способны быстро возобновлять рост при наступлении положительных температур.

Keywords: Basidiomycetes, ecology.

She mechanisms of biochemical adaptation of fungi to low temperature stress have been reported in a number of papers (Феофилова, 1994; Феофилова и др., 1994). It was interesting to observe under native conditions how the fruitbodies of macromycetes exhibit their ability for such adaptation. In the medium-elevated mountains of Pribaikalye the mass fruiting of macromycetes is usually observed in August-September. In the subgoltsy belt of high elevations of the Barguzin mountain range and the Eastern Sayans the fruiting was assumed to cease concurrently with snow fall in mid-August (Нездойминого, 1968, 1971; Петров, 1981, 1982). The present paper studies the response of the fruitbodies of macromycetes to low temperature stress in high elevation forest-tundra, which is characterized by a considerable fluctuation in day temperatures in the period of mass fruiting of macromycetes.

The observations were carried out in the upper part of the Lena river (the south of the Baikal mountain range, 1,200-1,400 m a.s.l.) in August-September 1995 (Fig. 1). The plant communities of the region are typical of forest-tundra. The region has some specific features resulting from many-year freezing, such as heaving and hummockying of some swampy places, numerous tundra-like creeks and lakes. The river floodplain and lowlands are occupied by thickets of birch and willow bushes. Open forests with larch and a cover of lichens prevail; larch trees have a surface root system and root exposures.



Fig. 1. Lake Baikal and surrounding mountain ranges

Mossy Abies-Pinus sibirica taiga is met here and there along the lower part of the slopes of the dividing borders. The taiga is substituted higher up the slope by spots of Pinus pumila and Duschekia with single larch trees.

Hard winds and drastic changes of weather during a day were observed throughout the entire period of field works in high elevations. Permanent light frosts at night  $(-4^{\circ}C)$  occurred in early September. Snow fall in the day time formed snow cover 5 cm thick, which melted rapidly. Such weather changed to clear, hot days (up to +16°C). At this time diurnal temperature fluctuations averaged 20°C. Snow cover was formed in late September. Thus, weather conditions were responsible for the low temperature stress on the fruitbodies of macromycetes.

### **Results and discussions**

Throughout the entire period of observations a number of large, soil-inhabiting fungi developed normal fruitbodies in spite of repeated complete freezing. They include e.g. Suillus clintonianus Korhonen, Hygrophorus lucorum Kalchbr., Boletinus paluster (Peck) Peck, and Leccinum rotundifoliae (Sing.) A.H. Sm., Triers & Watling. There were numerous needle-shaped ice crystals repeating a hyphal pattern in the trama of frozen crumbled fruitbodies of fungi of different age. Thawing occurred during the first 2-3 hours in the morning. The stems of some fruitbodies had non-typical swellings at the pileus attachment. Some wood attacking fungi only started their mass fruiting after light frosts and snow. They include e.g. Aleurodiscus lividocoeruleus (P. Karst.) Lemke, Hyphoderma sp., Hyphodontia sp., and Gloeophyllum protractum (Fr.) Imazeki on dead wood of larch, Dichomitus squalens (P. Karst.) D. Reid, Trichaptum laricinum (P. Karst.) Ryvarden, and T. abietinum (Dicks.: Fr.) Ryvarden on dead wood of Pinus pumila and larch, Phellinus chrysoloma (Fr.) Donk. on spruce, fir and Pinus sibirica, and, finally, Plicatura nivea (Fr.) P. Karst., Tectella patellaris (Fr.) Murrill, and Peniophora aurantiaca (Bres.) Höhn. & Litsch. on dead wood of Duschekia.

Similar phenomena were previously observed in mid-September in the north of the Baikal range (1,000 m) in pine-larch forests with the ground cover of lichens. Soil-inhabiting fungi like Suillus clintonianus, Hygrophorus speciosus Peck, and Boletus pinophilus Pilát & Dermek fruited in snow fall. Some wood attacking fungi, e.g. Phellinus ferrugineofuscus (P. Karst.) Bourdot, P. chrysoloma, Dichomitus squalens, Gloeophyllum protractum, Trametes hirsuta (Fr.) Pilát, T. ochracea (Pers.) Gilb. & Ryvarden, and Trichaptum abietinum also fruited rather actively at the same time. These phenomena seem to be typical of the high elevations of Pribaikalye.

In contrast to fruitbodies, the mycelium on the substrate is partially prevented from rapid fluctuation of temperature and drying out under low temperature stresses (Бондарцев, 1953; Любарский & Васильева, 1975). The development of a thick cuticular layer, thick-walled hyphae, thick tomentum of the pileus and necrosis of all trama cells in fruit bodies of polypores and stem cells of agarics (Степанова & Васильев, 1996) are likely to be one of the ways of physiological adaptation of the fruitbody to rapid freezing.

The review by Feofilova (Deoquatoba, 1994) on biochemical adaptation of the fungal mycelium to high- and low-temperature stresses pays a particular attention to changes in lipid and carbohydrate status of the cell, as well as to the study of heat shock proteins. Thus, saturated lipids were reported to be substituted for non-saturated ones in fungal cells exposed to low temperature stress; the mycelium and conidia of higher fungi contained polyatomic alcohols involved in prevention of cell proteins from cold effect. Regarding carbohydrates, the balance of trehalose played a particular role as a universal protector in stabilization of membrane lipids. Moreover, specific proteins preventing ice formation inside the cells were found in fungi. These proteins are also synthesized in other organisms inhabiting some plants, bacteria, and fishes of polar regions under the temperatures close to 5°C.

According to the observations of Mukhin and Kotiranta (personal communication) the phenomenon of «under snow» fruiting of fungi takes place in forest-tundra of the West Siberian plain and in Lapland. These phenomena seem to be typical of high elevations and high latitude areas. The psychrotolerant group of fungi, the growth and development of which are possible at low temperatures above zero (Мухин, 1993) manifests itself in the medium elevated mountains of Pribaikalye. Thus, according to our data, fruiting of some polypores in the Pribaikalye mountain-range (500-700 m a.s.l.) starts in mid-February and continues until early April. The formation of a new ring in perennial fruitbodies of polypores was observed at this time in Fomitopsis pinicola (Fr.) P. Karst., Fomes fomentarius (L.: Fr.) Fr. and Phellinus alni Niemelä, P. cinereus Niemelä. The growth of young one-yearold fruit bodies in deadwood and dead standing birch and willow trees was observed in Stereum hirsutum (Willd.:Fr.) Gray, Piptoporus betulinus (Bull.: Fr.) P. Karst., Trametes versicolor (L.: Fr.) Pilát., T. suaveolens L.: Fr., T. ochracea and T. hirsuta. Fruitbodies were normally developed though they were lighter than summer-autumn ones and were immediately colonized by insects.

In our opinion, both early and late fruiting of fungi proceeds owing to similar adaptation mechanisms, since in both cases the stress results from the low temperature impact.

The majority of the above-mentioned fungi of late autumn and winter-autumn layers belong to widespread species but have a synecological optimum in the Hypoarctic (Kotiranta, 1995; Myxuu, 1993). As follows from our observations, in the boreal zone such fungi (and some species with more southern cenoareal) continue their fruiting in cold seasons (late autumn, winter, and early spring), which are close in ecological characteristics to periglacial areas. It is likely to be one of the ways to avoid strong interspecies competition for a substrate. The reduction in the competition is attained by a shift of the period of active fruiting to the time which is not typical of other species. It provides pioneer colonization of suitable substrates. Snow melt water formed in warm trunks in this period contributes to spore germination; and wounds that appeared in trees in winter contribute to penetration of fungi into the inner tissues of trees.

# Conclusion

The following conclusions resulting from the observations performed can be drawn:

1. The fruiting of macromycetes in the high elevations of Pribaikalie is not limited to the first snow fall but continues at least until October.

2. Fungi of a psychrotolerant group are ready to grow in winter period immediately resuming their growth during thaws or settled warm days.

3. Dry and pest-pitted fruit bodies of some polypores found in summer and autumn and usually considered to be traces of the last autumn fruiting can be referred in some cases to a «winter-spring» layer of the current year.

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## THE EVOLUTION OF HIGH LATITUDINAL AND ALTITUDINAL BIOTAS OF XYLOTROPHIC BASIDIOMYCETES

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Abstract: The composition of xylotrofic fungi, associated with Alnus fruticosa Rupr., A. viridis (Chaix.) DC. and A. crispa Pursh in subarctic Siberia, Greenland and the subalpine belt of the Alps has been compared. High species similarity of Alnus-complexes has been shown, and a hypothesis of the origin of the Eurasian cryophilous mycobiota is proposed. According to this the contemporary subarctic and subalpine mycobiotas took their shape in the late Pleistocene in the plain regions of Eurasia.

> Проведен сравнительный анализ видового состава ксилотрофных грибов, приуроченных к Alnus fruticosa Rupr., A. viridis (Chaix) DC. и A. crispa Pursh в субарктических районах Сибири, Гренландии и в субальпийском поясе Альп. Показано высокое видовое сходство Alnus-комплексов и на основе этого выдвинуто предположение о происхождении криофильной микобиоты Евразии. Согласно ему, современная субарктическая и субальпийская микобиоты сформировались в позднем плейстоцене в равнинных областях Евразии.

Keywords: Basidiomycetes, xylotrophic, subarctic, mycobiotas, origin, evolution.

She evolution of cryophilous mycobiotas is one of the most interesting problems of mycogeography. However, mycologists have rarely dealt with it. Their main efforts are spent to study the biodiversity of northern, insufficiently investigated fungi. Nevertheless, the material available makes it possible to analyse the evolution of some types of mycobiotas. In particular, the authors have studied the xylotrophic basidiomycets of the Greenlandic and Siberian Sub-Arctic and the subalpine belt of the Alps. In all the cases special attention was paid to fungi associated with *Alnus fruticosa* Rupr., *A. viridis* (Chaix) DC. and *A. crispa* Purch, which play an important role in ecosystems of the polar timberline and mountains.

A. crispa grows in North America and in Greenland (Деревья и кустарники ..., 1951; Флора ..., 1976). In the latter this species has occurred for about 4,000 years since it came from North America (Fredskild & Odum, 1990). A. fruticosa, mainly a Siberian species, reached northern parts of Western Siberia (coming from Eastern Siberia) as late as the early Holocene (Нейштадт, 1957). A. viridis is known to be limited in distribution to the mountainous areas of Western Europe (Деревья и кустарники..., 1951) and at the present time it is one of the relict species of the region (Srodon, 1980).

The research of the species composition in isolated areas of similar phylogenetic and ecological conditions (Fig. 1), offers favourable opportunities to perform comparative



Fig. 1. Areas of the Alnus species (Hultén & Fries, 1986; Атлас ареалов..., 1977): *I* – A. viridis; 2 – A. fruticosa; 3 – A. crispa

mycogeographical works. This was our main reason for choosing *Alnus*-complexes of xylotrophic basidiomycetes as a model group for the assessment of genetic associations between subarctic and subalpine mycobiotas.

## **Results and discussion**

The mycobiotas of alder thickets of the Eurasian and Greenlandic subarctic and mountainous regions numbers 85 species. Their main part is constituted by aphyllophoralean (80-68%) and agaricalean (13-20%) fungi. Gelatinous groups (*Tullasnellales*, *Dacrymycetales*, *Tremellales*) make 5-13% (Table 1). This ratio between the given taxa is typical of xylotrophic basidiomycete biotas of Eurasia (Мухин, 1978, 1993) and North America (Gilbertson, 1980). Among the aphyllophoralean fungi the corticiaceous species prevail, followed by polypores — *Polyporaceae* s. l., *Hymenochaetaceae*, and *Steccherinaceae* (Table 1).

#### TABLE 1

Order Family	Total the 3 re	l for egions	the Alps Greenland		Western Siberia			
	number	%	number	%	numbe r	%	number	%
Aphyllophorales	62	72.9	29	80.5	26	68.4	44	72.1
Corticiaceae	41	66.1*	20	68.9*	20	76.9*	27	61.4*
Poriaceae	11	17.7*	5	17.2*	1	3.8*	7	15.9*
Hymenochaetaceae	6	9.7*	3	10.3*	4	15.3*	6	13.6*
Stereaceae	2	3.2*	-	-	1	3.8*	2	4.5*
Steccherinaceae	2	3.2*	1	3.4*	-	-	2	4.5*
Agaricales	16	19.0	5	13.9	7	18.4	12	19.6
Tulasnellales	1	1.2	-	-	1	2.6	-	-
Tremellales	5	5.9	1	2.8	4	10.5	4	6.6
Dacrymycetales	1	1.2	1	2.8	-	-	1	1.6

#### The systematic structure of Alnus-complexes

Note. \* — index was counted as the ratio of the numbers of a given family species to the numbers of species in an order.

The dominance of the corticiaceous fungi is characteristic of xylotrophic basidiomycete biota of subarctic shrub tundra (Мухин, 1991). *Alnus*-complexes of xylotrophic basidiomycetes are characterized by low number of species in genera, families (Table 2) and it places them on the same level as the subarctic tundra mycobiota (Мухин, 1991). The number and diversity of taxa is known to diminish as living conditions become more severe for the group under discussion, and the age of floras and mycobiotas decreases (Толмачев, 1974; Мухин, 1993). This is the case of the subarctic and subalpine *Alnus*complexes.

Although no serious changes occur in their systematic structure in various parts of their ecological area, Alnus-complexes at the same time considerably differ in the number of species. In the Siberian subarctic it is 1.6 times higher than in other regions (Table 2). However, fairly high similarity among their species has been noticed. The species similarity ratio between Alnus-complexes of the Alps, Greenland and the West Siberian Sub-Arctic equals 0.46-0.47. The high level is due to the following species: Basidioradulum radula (Fr.: Fr.) Nobles, Gloeocystidiellum leucoxanthum (Bres.) Boidin, Hymenochaete t a b a(Fc.)ilrév.aHyphoderma praetermissum (P. Karst.) J. Erikss.& Å. Strid, H. setigerum (Fr.) Donk, Hyphodontia crustosa (Pers.: Fr.) J. Erikss., Plicatura nivea (Sommerf.: Fr.) P. Karst., Merismodes anomalus (Pers.: Fr.) Sing., Polyporus badius (Pers.) Schwein., Tectella patellaris (Fr.) Murr., Exidiopsis griseobrunnea K. Wells & Raitviir, Inonotus radiatus (Soewrby: Fr.) P. Karst., Peniophora aurantiaca (Bres.) Höhn. & Litsch. They occur in all the regions and include more than a third of the species, associated with Alnus in Greenland and the Alps, and about 20% Alnus-complex species of Western Siberia. Most fungi of the group mentioned above display a very close

#### TABLE 2

Alnus-complex	Number			Ratio		
_	species (sp)	genera (g)	families (f)	sp/g	g/f	sp/f
Of the subalpine belt of the Alps	36	28	9	1.3	3.1	4.0
Sub-Arctic of Greenland	38	28	11	1.4	2.5	3.4
Sub-Arctic of Western Siberia	61	46	12	1.3	3.8	5.0
The total for the regions studied	85	56	14	1.5	4.0	6.1

## Taxonomic characteristics of Alnus-complexes

association with *Alnus* in all the habitats, and their areas reveal mainly arctic and mountain distribution (e.g. Eriksson & Ryvarden, 1975, 1976; Eriksson et al., 1981).

Siberian and Greenlandic Alnus-complexes also include such species as Hapalopilus rutilans (Pers.: Fr.) P. Karst., Hymenochaete tabacina, Hyphodontia quercina (Pers.: Fr.) J. Erikss., Fomitiporia punctata (P. Karst.) Pilát, Stereum rugosum Pers.: Fr., Hohenbuehelia fluxilis (Fr.) Orton, Lentinellus omphalodes (Fr.) P. Karst., Exidia repanda Fr. and Tremella mesenterica Retz.: Fr. The analogous group of fungi, common for Alnus-complexes of Siberia and the Alps, is formed by Botryobasidium obtusisporum J. Erikss., Ceraceomyces serpens (Tode: Fr.) Ginns, Cylindrobasidium laeve (Pers.: Fr.) Chamuris, Datronia scutellata (Schwein.) Gilb. & Ryvarden, Hypochnicium bombycinum (Sommerf.: Fr.) J. Erikss., Steccherinum nitidum (Pers.: Fr.) Vesterholt, Phanerochaete laevis (Pers.: Fr.) J. Erikss. & Ryvarden, Phellinus lundellii Niemelä, Scopuloides rimosa (Cooke) Jülich, Dacryomyces minor Peck, and for the Alps and Greenland by Hyphodontia sambuci (Pers.: Fr.) J. Erikss., H. subalutacea (P. Karst.) J. Erikss., Phanerochaete sordida (P. Karst.) J. Erikss. & Ryvarden.

Several species are present in all the regions, but in some of them they have no association with Alnus — Hapalopilus rutilans, Hymenochaete cinnamomea (Fr.) Bres., Hyphodontia subalutacea, Hypochnicium bombycinum, Steccherinum nitidum, Phlebia albida H. Post, Phanerochaete sordida, Phellinus lundellii, Scopuloides rimosa, Dacryomyces minor. Phellinus igniarius (L.: Fr.) Quél., Polyporus brumalis (Pers.: Fr.) Fr., P. varius (Pers.) Fr. The reason could be incomplete study of their trophic spectrum or regional peculiarity of ecological niches. No matter what it is, their occurrence in high latitudinal and alpine mycobiotas should not be overlooked, as the species inhabiting the same regions, for example Phellinus igniarius, Polyporus brumalis, P. varius, are found in Alnus-complexes only in one of them: the first and the third in Western Siberia, the second in Greenland. It is quite clear that these species also indicate genetic links between the mycobiotas under study, and they can be included in one group comprised of species found everywhere in association with Alnus.

It does not change the conclusion about similarity of *Alnus*-complex species structure of the regions under analysis, it even confirms it. For Greenland and the Alps the coefficient of species similarity is 0.56 in this case, and for Greenland and Western Siberia it is 0.72.

The facts above pose a question to us: what are the reasons for the striking species similarity between the regions so distant and geographically isolated? More or less possible reasons will not be discussed in this short paper, our attention will rather be paid to the main one — high latitudinal and altitudinal mycobiotas are closely connected in their evolution, and may actually be considered as variants of a single cryophilous direction within mycobiota evolution. The history of the Quaternary period offers an explanation.

During the Pleistocene vast areas of Eurasia and North America were covered with glaciers and the Midlatitude belt of the Northern Hemisphere turned into a huge region of cold continental conditions. Last time it happened during the principal climatic minimum of the Pleistocene, which began about 25,000 years ago. The most important climatic features of that period were temperature fall and xerotization (Величко, 1973), and the prevailing plant types were those of xerophyte-tundra-steppe (Величко, 1973), tundra and forest-tundra (Волкова, 1977). Forest plants remained only in river valleys and could арргоаch the tundra located along the glacier peripheries (Сукачев, 1973; Величко, 1973). During that time, A. viridis could, for example, be found in periglacier vegetation (Srodon, 1980). In such conditions the upper timberline was situated much lower than it is now, and the mountain mycobiota had an opportunity to come in contact with the lowland mycobiota. A single cryoxerotic mycobiota could have taken shape at that time. During the glacial age a great exchange of species between Central European mountains and the arctic, aloine and Siberian areas may have occurred (Hadač, 1963). This was also true for fungi, in particular the land bridge between Eurasia and North America that had existed in certain Pleistocene periods (e.g. during the principal thermal minimum), contributed to trans-continental migration (Мурашинский, 1940; Любарский & Васильева, 1975; Пармасто, 1979).

Later climatic changes resulted in a wide distribution of forest landscapes during the Holocene (Hultén, 1937), and so the cryophilous mycobiota was ousted to mountains and high latitudes. Consequently, a formerly single territory complex fell into respective ecogeographical variants. At the present time, the cryophilous high altitudinal biotas of xylotrophic fungi resemble islands, for they are surrounded by ecologically distant mycobiotas. For example, in the Alps subalpine Alnus-complexes are surrounded by mycobiotas associated with coniferous trees (Abies, Larix, Picea, Pinus) forming the alpine forest belt, which is situated lower. According to our investigations, only a part of species of subalpine Alnus-complexes have been found to penetrate into the forest belt together with A. viridis: Basidioradulum radula, Exidiopsis griseobrunnea, Gloeocystidiellum leucoxanthum, Hymenochaete tabacina, Hyphodontia sambuci, H. crustosa, Peniophora aurantiaca, Phanerochaete sordida, Scopuloides rimosa and some others.

Which part of the cryophilous mycobiota has a mountain origin? According to Takhtadzhyan (Taxtagжян, 1957), the origin of cryophilous flora appeared in the mountains of the subtropic progenitor. Probably, the fungal species that gave rise to the evolution of mycobiota arose at the same time. Alpigenic elements can be identified by the analysis of dominant species of subalpine and subarctic mycobiotas. The idea of a correlation between ecological and biological features of the dominant species and the landscape and

#### TABLE 3

## Climatic regime of subalpine and subarctic regions

Climatic characteristic of	The Subalpine belt	The Subarctic zone	
the environment	-		
The vegetation period			
duration	short	short	
Annual temperatures	low	low	
Summer temperatures	relatively high	temperate	
Winter temperatures	relatively high	low, can reach the lowest	
		point	
Snow fall	affluent	on earth	
Soil freezing	no perennial freezing	moderate	
The day length	short	perennial freezing is	
The sunshine intensity	high	long, up to 24 hours	
The day time ground		low	
surface temperature	high		
The 24 hours variability		temperate	
of summer temperature	does not decrease below		
	zero	below zero temperatures	
Precipitation,		are possible in any	
moisture deposition	abundant,	summer period	
Annual temperature	sufficient	inconsiderable,	
range	relatively low	droughts are possible	
		high, can reach the	
		highest points on earth	

climatic situation of their habitats is underlying the facts above (Юрцев, 1966). It is therefore logical to assume that species are characterized by their dominance in their original ecosystems — in lowland or mountains — because, despite the similarity of subalpine and subarctic habitats, they have a number of considerably different characteristics (Table 3, see also Barry & Ives, 1974).

The diversity of the dominant species of *Alnus*-complexes is extremely limited and displays a certain ecogeographical peculiarity (Table 3). Some ideas, based on the latter, are possible to point out. We beleive that the dominance of *Gloeocystidiellum leucoxanthum*. Stereum rugosum. Basidioradulum radula in subarctic Greenland, Exidiopsis griseobrunnea in subarctic Siberia indicates their adaptation to the conditions of high latitudes and reveals their presence in subalpine Alnus-complexes as a secondary component. They are rather rare or absent in the latter. The similar supposition could be made about *Plicatura nivea*. Tectella patellaris, dominant in the subarctic of Western Siberia (Table 4), where the former species is the most abundant among destructors of A. fruticosa wood, and the latter takes the fourth position in the quantitative hierarchy (Мухин, 1993).

#### TABLE 4

#### Active species of Alnus-complexes.

SPECIES	T	The subalpine belt of the Alps		
	Greenland	Western Siberia	Middle Siberia	
Gloeocystidiellum	+	+	-	-
leucoxanthum				
Basidioradulum radula	+	-	-	-
Peniophora aurantiaca	+	+	-	+
Plicatura nivea	-	+	-	-
Stereum rugosum	+	-	-	-
Tectella patellaris	-	+	-	-
Exidiopsis griseobrunnea	-	-	+	-

Among the cryophilous basidiomycetes of *Alnus*-complexes there are none which could be termed alpigenic. Evidently, when subalpine and lowland cryophilous mycobiotas came into contact, the former was enriched or completely substituted by the species which for a long time were the components of lowland cryophilous mycobiotas. The differences mentioned above in the species abundance in the subarctic and subalpine *Alnus*-complexes of xylotrophic basidiomycetes can indirectly prove this point of view. The more developed mycobiotas are more likely to have a stronger influence upon less extensive ecogeographical species compositions and can alter or completely interrupt their autochthonous line of evolution. The same point of view is found in the paper by Müller and Magnuson (1987). According to them, the original flora of the Alps was destroyed during the glacial age, and the modern vegetation of the area consists of the plants that survived under the lowland conditions. Fungi migrated to the Alps together with plants afterwards.

The high evolutionary level of modern continental subarctic mycobiotas is, probably, connected with the history of their origin, which took place on the vast areas of Eurasia and North America. Thus, extremely versatile elements could have affected them and brought about their weak regional and zonal discrimination. There are no particular features (when assessed by the endemic taxa level) which are characteristic of the subarctic mycobiota. Their distribution covers not only the subarctic region, but also some southern zones. It clearly shows that *Alnus*-complexes have no specific xylotrophic basidiomycetes, and the subarctic mycobiota climate type consists only of widely distributed and ecologically flexible species (Мухин, 1993).

However, some species display a distinct connection with the hypoarctic belt. For example, such species as *Exidiopsis griseobrunnea*, *Tectella patellaris*, *Plicatura nivea*, *Cloeocystidiellum leucoxanthum* and *Datronia scutellata* are associated mostly with *A*. *fruticosa* and in their motion southwards along the West Siberian plain they are limited to the area of this species.

We think, they should be considered to be subarctic even though parts of thier areas are outside this zone. This is the result of their latitudinal synecological optima peculiarities. The highest frequency of *Exidiopsis griseobrunnea*, *Tectella patellaris*, *Plicatura nivea*, *Peniophora aurantiaca* covers the polar timberline (Мухин, 1993).

A number of species which are included into subarctic mycobiota, belong to more southern climate types. Thus, *Trametes versicolor* (L.: Fr.) Pilát, *T. hirsuta* (Wulfen: Fr.) Pilát and *Stereum hirsutum* (Willd.: Fr.) Gray have their synecological optima in subtaiga and forest-steppe (Мухин, 1993). Their occurrence in the subarctic *Alnus*-complexes can be explained by cold and continental (cryoxerotic) conditions and existence of tundra-steppe landscapes in the Pleistocene.

In this respect, it is important to point out that the species which could be taken for boreal due to their zonal characteristics are absent in subarctic-alpine *Alnus*-complexes. We tend to believe that it confirms the existence of independent evolution of xylotrophic basidiomycete cryophilous biotas, at least, of that associated with *Alnus*, beginning from the forest biota of the given ecological fungal group.

The influence of boreal mycobiota in the southern (taiga) parts of the A. fruticosa area is evident. Here, Alnus-complexes include the species that have their synecological optima in taiga regions, for example, Fomes fomentarius (L.: Fr.) Fr., Fomitopsis pinicola (Sw.: Fr.) P. Karst., and Bjerkandera adusta (Willd.: Fr.) P. Karst. The total number of the boreal mycobiota climate type species belonging to the Alnus-complexes is about 20 in these regions. However, they are all represented by incidental findings. The presence of forest species does not subsequently exclude subarctic fungi. Thus, in the northern taiga of the West Siberian plain about 50% fungi, associated with A. fruticosa and characteristic of polar timberline Alnus-complexes, occur. Nearly all the species found in cryophilous mycobiotas of Greenland, Western Siberia and the high Alps can be detected among them — 11 out of 13. The systematic structure of hypoarctic Alnus-complexes also remains mainly the same. As we mentioned above (Мухин, 1993), biotas evolving in the common territory interact without mutual absorbtion, but are included one into another (the Russian Matryoshka principle), depending on the position of the host tree communities they are coevolutionarily associated with.

It brings us to the conclusion that *Alnus*-complexes have two groups of species. The first one is composed by fungi which have co-evolved with *Alnus*-complexes — we call it the obligatory group. These species evidently represent the ancient (Pleistocenic?) core of *Alnus*-complexes. They contain fungi characterized by very constant associations with *Alnus* and found in both mountainous and high latitudinal variants of cryophilous xylotrophic basidiomycete biotas. First of all, these are species encountered in all the regions studied, and mostly evolving on *Alnus* wood remains (Table 5). The species noticed in the two out of three investigated regions also belong to the obligatory part of *Alnus*-complexes. In West Siberian and Greenlandic *Alnus*-complexes they number 9 species, West Siberian and Alpine — 10, and only 3 such species belong to *Alnus*-complexes of the Alps and Greenland.

The second group is a facultative part of *Alnus*-complexes. It is constituted by species which possess regional peculiarity and which are found only in definite complexes. There are 10 species of the kind or 28% in subalpine *Alnus*-complexes, and from 10 (Greenland) to 28 (Western Siberia) in subarctic, that makes respectively 26% and 46%. Thus, the facultative species number is considerable — from one third to a half of *Alnus*-complexes.

#### TABLE 5

The quantitative distribution (number of findings) among the substrates of the *Alnus*-complex species in the subarctic forests of South Yamal

SPECIES	Woody remains of the alder	Woody remains of the birch	Woody remains of the willow
Inonotus radiatus	326	13	3
Phellinus igniarius coll.	49	880	350
Cerrena unicolor	8	65	2
Daedaleopsis confragosa	13	3	164
Gloeoporus dichrous	1	17	-
Peniophora aurantiaca	780	-	-
Plicatura nivea	1156	1	-
Tectella patellaris	256	1	4
Flammulina velutipes	1	1	14
Pholiota aurivella	14	5	45
Pleurotus pulmonarius	3	157	-
Tremella mesenterica	121	51	-

Facultative species are substantially different in their trophic preferences. As seen from Table 5, in the Sub-Arctic they are associated rather with other tree species than with Alnus. Some of them (for example, Gloeoporus dichrous (Fr.: Fr.) Bres., Flammulina velutipes (Curt.: Fr.) Sing., Pleurotus pulmonarius (Fr.) Quél.) are incidental elements of Alnus-complexes. To some extent, it accounts for geographical variability of the facultative part composition mainly caused, in our opinion, by the processes of interaction between the mycobiotas having different ecological and historical line of evolution.

## Conclusion

The analysis of xylotrophic basidiomycetes of high latitudinal and subalpine biotas indicates that they should be considered to be contemporary ecogeographical variants of the cryophilous mycobiota evolution in the Quaternary period. They are characterized by: 1 — utterly simplified systematic structure and low level of biodiversity; 2 — the prevailing of corticiaceous fungi; 3 — extremely low species abundance of genera and families; 4 — poor regional and zonal originality.

The biota of subalpine xylotrophic basidiomycetes is not likely to have autochthonous elements, but is made up by the species that have evolved for a long time within the cryophilous biotas of lowland Eurasia. Therefore, if biota of xylotrophic basidiomycetes from high latitudes is an autochthonous formation, the similar subalpine mycobiota is an allochthonic relict formation of the ice age. Cryophilous mycobiotas climate types do not include specialized forms of xylotrophic basidiomycetes and are composed by ecologically tolerant species, capable of evolving within a wide range of natural regimes. However, the obligatory core species can be classified as subarctic due to their synecological optima. There is an alternative, which is the species of the mycobiotas facultative part, characterized by the composition variability and created by cryophilous mycobiotas interaction with other zonal and formational xylotrophic basidiomycete biotas.

Forest-steppe elements within *Alnus*-complexes reveal genetic relations between cryoand xerophilous mycobiotas, that can be explained in terms of cryoxerotic conditions of the Pleistocene and mixed tundra-steppe landscapes occurrence. As for the forest, taiga, mycobiota, there is no evidence of its clear genetic relations with subarctic and subalpine cryophilous mycobiotas. Their convergence is only possible due to their co-existence in the same site.

All these statements are not considered to be final. Their integrity represents only one of many possible hypotheses about the contemporary subarctic and subalpine biotas of xylotrophic basidiomycete origin. We hope to proceed with the subject in greater details in the future.

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## THE ARCTIC-ALPINE AGARIC ELEMENT IN THE POLAR URALS AND YAMAL, WESTERN SIBERIA

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Abstract: From the large material of fungi collected in the Polar Urals and southern part of Yamal peninsula, 28 species of agarics representing 16 genera and 7 families have been selected as indicators of subarctic/arctic and subalpine/alpine environments. Their distribution falls into two groups, a large, circumpolar subarctic-arctic and subalpine-alpine group, and a smaller group which is circumpolar and only subarcticarctic. Nine species are reported as new to Russia.

На основании обширных материалов, собранных на Полярном Урале и в южной части полуострова Ямал, установлено 28 видов агариковых грибов, относящихся к 16 родам и 7 семействам, — индикаторов субарктических/арктических и субальпийских/альпийских условий. Большая часть грибов относится к циркумполярным субарктическим-арктическим и субальпийским-альпийским видам, остальные — к циркумполярным субарктическим. Девять видов впервые приводятся для России.

Keywords: arctic-alpine agarics, Siberia, mycogeography.

During 1990, 1992 and 1996 the authors had the opportunity to collect large material of fungi in the southern part of Yamal peninsula, Western Siberia. From the agarics a number of the more easily recognized species were selected and their distribution investigated based on available literature supported by other collections made by us during the five ISAMs and from collecting trips to Greenland. The increasing interest in arcticalpine fungi has resulted in the publication of many new data on these fungi. The purpose of the present paper is to show the distribution of 28 species selected from a wide variety of genera and families and to see whether some conclusions can be drawn concerning their main distribution, or if some distributional types can be distinguished.

#### **Collecting** sites

In 1990 the authors together with students and colleagues of Mukhin collected in the southern part of Yamal (along the Khadyta river, tundra with *Betula nana* and *Salix* spp.; along the river Shchuchya, tundra with *Salix herbacea*), around Labytnangi (the surroundings of the town with different species of *Salix* and herbs) and Oktyabrsky (forest-tundra with *Larix sibirica*, *Betula nana* and *Salix* spp.), and in the Polar Urals. In 1992 we continued our investigations in this area during the first stage of the First Russian-Scandinavian TransSiberian Mycological Expedition together with Finnish and British colleagues. And finally in 1996 during the Fifth International Symposium on Arctic-Alpine Mycology held in Labytnangi, we had an opportunity to visit some new collecting sites whose descriptions are given on page 13.

Localities mentioned below, are all within the Tyumen region:

1. The Polar Urals: Slantsevaya Mt. Mountain tundra (c. 300-400 m a.s.l.) situated where the railway from Vorkuta crosses the Ural mountains, c. 40 km W of Labytnangi. Scattered about the tundra *Salix* spp., *Betula nana*, *Alnus fruticosa* and *Dryas* sp. and numerous herbs, e.g. *Gentiana lutea*, *Saxifraga* spp., *Veratrum luteum* are found. Yangana-Pe range. Calcareous hills with *Dryas* sp., herbs, mosses and lichens.

2. Cape Nyarusalye. Low tundra near the Kara sea with low Salix glauca, Betula nana, Dryas, and Vaccinium spp.

3. Katrovozh, two hours by boat down the Ob river. Forest tundra and tundra. The area is strongly influenced by the village.

4. Labytnangi. The surroundings of the town with different species of Salix and herbs.

5. Oktyabrsky. Forest-tundra and tundra with *Larix sibirica*, *Betula nana* and *Salix* spp.

6. Along the Khadyta river. Tundra with Betula nana and Salix spp.

7. Along the river Shchuchya. Tundra with Salix herbacea.

The material mentioned below is collected by the authors and deposited in Copenhagen (C).

# List of the arctic-alpine agaric species

#### Amanita groenlandica Bas ex Knudsen & T. Borgen

Ecology: Mycorrhizal with dwarf Betula nana and Salix spp.

Distribution: Described from Greenland (Knudsen & Borgen, 1987), where it is common. Recently also recorded from northernmost Norway (Mathiassen & Granmo, 1995) and Russia (Nezdoiminogo, in press). Besides the material mentioned below another collection from southern Yamal was seen, but unfortunately it was lost when we were entering the helicopter with the rotors going!

Material: Slantsevaya Mt., 13.8.1990, HK 90.313.

#### Amanita nivalis Grev.

Ecology: Mycorrhizal with Betula nana, Salix herbacea and Dryas.

Distribution: One of the first subarctic-subalpine fungi to be described, by Greville from the Scottish highlands, where it is widely distributed (Watling, 1987). Recorded from the Alps (Kühner & Lamoure, 1986), Scandinavia and Iceland (Persson, 1992), Greenland (Knudsen & Borgen, 1987), the Faroe Islands (Petersen et al., 1994) and Russia (Nezdoiminogo, in press). Records from China (Ying & Zang, 1994) seem, according to the description, to be based on a larger species from forest localities.

Material: Slantsevaya Mt., 13.8.1990, HK 90.326; idem, 16.8.1990, HK 90.401; idem, 24.8.1996, HK 96.60.

#### Arrhenia littoralis (Høil.) Gulden

Ecology: Saprotrophic or parasitic on mosses in periodically flooded, saline, coastal meadows. Distribution: Described from northern Norway (Høiland, 1976), since then recorded from Spitsbergen (Gulden & Jenssen, 1988), Alaska (Laursen & Ammirati, 1982) and recently from the Antarctic (Guminska et al., 1994). New to Russia. Material: Cape Nyarusalye, 20.8.1996, HK 96.48.

## Clitocybe lateritia J. Favre

Ecology: Saprotrophic in dry places in subarctic/arctic and subalpine/alpine tundras. Distribution: Described from the Alps where it is rather common (Lamoure, 1972), also recorded from northern Scandinavia and Iceland (Gulden, 1992), Greenland (Borgen & Knudsen unpubl.), Spitsbergen (Gulden & Torkelsen, 1996) and Taimyr in Russia (Нездойминого & Журбенко, 1996). Material: Slantsevaya Mt., 18.8.1996, HK 96.39.

Waterial: Dialitie vaya Witt, 10.0.1770, 1112 70.5

#### Coprinus martinii J. Favre ex P.D. Orton

Ecology: Saprotrophic in marshes, often flooded, growing on the stems and leaves of grasses, sedges and rushes.

Distribution: Widely distributed in cold climates and also in cold springs in temperate climates. Recorded from the Alps (Favre, 1948), UK (Orton & Watling, 1979), Greenland (Borgen & Knudsen unpubl.), Alaska (Laursen & Ammirati, 1982), Norway and Iceland (Dissing & Lundqvist, 1992) and the Falkland Islands (Jalink & Nauta, 1993). New to Russia.

Material: Oktyabrsky, 7.8.1992, HK 92.232.

#### Cortinarius alpinus Boud.

Syn.: C. favrei D. Hend.

Ecology: Mycorrhizal with Salix herbacea, S. arctica, S. retusa, S. reticulata and Dryas in subarctic/arctic and subalpine/alpine tundras.

Distribution: Described from the Alps and later recorded from Scotland (Watling, 1983), northern Scandinavia and Iceland (Brandrud, 1992), the Faroe Islands (Petersen et al., 1994), Spitsbergen (Gulden & Torkelsen, 1996), Alaska (Laursen & Ammirati, 1982) and several places in arctic Russia (Булах и др., 1990) and in Taimyr (Нездойминого & Журбенко, 1996).

Material: Slantsevaya Mt., 24.8.1996, HK 96.57.

Note: Both names are widely used for this very common species.

### Hygrocybe cinerella (Kühner) Arnolds

Ecology: Saprotrophic in subarcticc and arctic tundra, in acid, moist places, e.g. on cushions in bogs.

Distribution: Known only from northern Sweden and Norway, Iceland and Greenland (Boertmann, 1995). New to Russia.

Material: Along the Khadyta, 2.8.1990, HK 90.093; Slantsevaya Mt., 18.8.1996, HK 96.41.

#### Hygrocybe lilacina (C. Laest. ex P. Karst.) M.M. Moser

s Gliophorus I. (C. Laest. ex P. Karst.) Kovalenko, Hygrophorus violeipes M. Lange, H. palustris V.L. Wells & Kempton

Ecology: Saprotrophic in acid, often moist tundra.

Distribution: Reported from many subarctic/arctic and subalpine/alpine areas, e.g. Scandinavia, Iceland, Greenland, Alaska, the Alps, Scotland (Boertmann, 1995), the Faroe Islands (Petersen et al., 1994), from the Magadan region (Коваленко, 1989) and from subalpine areas in Uzbekistan (Baccep & Петрова, 1985). Material: Cape Nvarusalve, 20.8.1996, HK 96.46.

# Hygrocybe xanthochroa (P.D. Orton) M.M. Moser

Syn.: Gliophorus x. (P.D. Orton) Kovalenko

Ecology: Saprotrophic in acid, arctic heaths and tundras.

Distribution: Due to confusion with the closely resembling *H. citrinopallida* (A.H. Sm. & Hesler) Kobayasi the distribution is badly known. So far it has been reported from subalpine and subarctic areas in Germany, Norway, Scotland, Iceland and Greenland (Boertmann, 1995) and from Lithuania and the Magadan region (Коваленко, 1989). Material: Cape Nyarusalye, 20.8.1996, HK 96.45.

## Lactarius alpinus Peck

Syn.: L. pusillus Bres., L. alpigenes Kühner, L. subalpinus Kühner

Ecology: Mycorrhizal with Alnus spp. in subalpine and subarctic areas. In the Alps with A. viridis, in Greenland with A. crispa, in Yamal with A. fruticosa. Also Favre (1948) once found it near Betula, without any Alnus around.

Distribution: Collected in the Adirondack mountains in NE-USA by Peck (1875), Alaska near Anchorage by one of us (HK) during ISAM I, from Greenland (Knudsen & Borgen, 1982), by several authors from the Alps (e.g. Favre, 1948, Marchand, 1980) and from Kamchatka (Kalamees & Vaasma, 1993).

Material: Along the Khadyta, 2.8.1990, HK 90.080; idem, 4.8.1990, HK 90.117; idem, 7.8.1990, HK 90.172; Slantsevaya Mt., 16.8.1990, HK 90.455, idem, 18.8.1996, HK 96.42.

## Lactarius lanceolatus O.K.Mill. & Laursen

Ecology: Mycorrhizal with Salix spp. (Miller, 1982).

Distribution: Reported from Alaska (Miller, 1982), Spitsbergen (Gulden & Torkelsen, 1996), arctic Canada (Ohenoja & Ohenoja, 1993) and Taimyr in Russia (Нездойминого & Журбенко, 1996). It is perhaps identical with other orange *Lactarii* reported from arctic areas, e.g. Kühner's (1975) from Abisko, northern Sweden. Collected in Greenland several times by various collectors (herb. C).

Material: Slantsevaya Mt., 13.8.1990, HK 90.309.

## Lactarius lapponicus Harmaja

Ecology: Mycorrhizal with *Betula*, e.g. *B. pubescens* and *Alnus* sp. Distribution: Recorded from northern Scandinavia (Persson et al., 1992) and from Greenland (Elborne & Knudsen, 1990). New to Russia. Material: Cape Nyarusalye, 20.8.1996, HK 96.49. Note: Distinguished from other orange *Lactarii* in subarctic areas by the milk, which rapidly

Lactarius *oseudouvidus* Kühner

turns distinct yellow.

Ecology: Mycorrhizal with Salix spp. and Betula nana.

Distribution: Described from the Alps (Kühner, 1975) and later from the arctic-alpine areas of Scandinavia and Iceland (Persson et al., 1992), Greenland (Knudsen & Borgen, 1982), the Faroe Islands (Petersen et al., 1994), arctic Canada (Ohenoja & Ohenoja, 1993), Spitsbergen (Gulden & Torkelsen, 1996) and Russia (Nezdoiminogo, in press). Material: Oktyabrsky, 15.8.1990, HK 90.369; Slantsevaya Mt., 16.8.1990, HK 90.406; idem, 18.8.1996, HK 96.38.

### Lactarius robertianus Bon

Ecology: Mycorrhizal with Salix spp., perhaps also with dwarf Betulas.

Distribution: Only recently described from the Alps by Kühner (1975) and Bon (1985). Known also from Spitsbergen (Gulden & Torkelsen, 1996) and Greenland (Borgen & Knudsen, unpubl.). New to Russia.

Material: Slantsevaya Mt., 18.8.1996, HK 96.37; Cape Nyarusalye, 20.8.1996, HK 96.50.

### Lactarius salicis-herbaceae Kühner

Ecology: Mycorrhizal with Salix herbacea in moist places.

Distribution: Recorded from the Alps (e.g. Kühner & Lamoure, 1986), also known from northern Scandinavia and Iceland (Persson et al., 1992), Greenland (Knudsen & Borgen, 1982), arctic Canada (Ohenoja & Ohenoja, 1993) and Taimyr in Russia (Нездойминого & Журбенко, 1996).

Material: Near the river Shchuchya, 29.7.1990, HK 90.035.

*Lactarius torminosulus* Knudsen & Borgen Syn.: *L. subtorminosus* Knudsen & Borgen non Coker 1918.

Ecology: Mycorrhizal with *Betula nana* and *B. pubescens*, often in moist places. Distribution: Recently described from Norway, Sweden, Iceland, Greenland and Russia (Knudsen & Borgen, 1994).

Material: Along the Khadyta, c. 20 km E of biol. station, 12.8.1990, HK 90.284; Slantsevaya Mt., 13.8.1990, HK 90.331; idem, 16.8.1990, HK 90.421; at Kharbei N of Labytnangi, 16.8.1996, HK 96.20.

Leccinum rotundifoliae (Singer) A.H.Sm., Thiers & Watling

Ecology: Mycorrhizal with Betula nana and B. pubescens.

Distribution: Widely distributed in North America (Smith et al., 1967), Greenland (Knudsen & Borgen, 1987), northern Scandinavia and Iceland (Persson, 1992), Spitsbergen (Gulden & Torkelsen, 1996), Estonia (Kalamees & Lasting, 1974) and Kamchatka, Russia (Kalamees & Vaasma, 1993).

Material: Along the Khadyta, c. 200 km NE of Salekhard, 4.8.1990, HK 90.114; idem, 9.8.1990, HK 90.230.

#### Lepista multiformis (Romell) Gulden

Ecology: Saprotrophic, often fruiting in large colonies or fairy rings, along pingos and other places where new nutrients become available.

Distribution: Northern Scandinavia and Iceland (Gulden, 1992), Alaska (Laursen & Ammirati, 1982), Spitsbergen (Gulden & Torkelsen, 1996), Greenland (Borgen & Knudsen, unpubl.), the Alps (pers. comm. M. Moser) and Taimyr in Russia (Неэдойминого & Журбенко, 1996).

Material: Slantsevaya Mt., 25.7.1990, HK 90.003.

#### Marasmius epidryas Kühner

Ecology: Saprotrophic on dead leaves of Dryas spp.

Distribution: A common species in arctic-subarctic and alpine-subalpine areas where *Dryas* grows, seemingly absent from lowlands (Gulden, 1985). Recorded from the Alps (Favre, 1960), northern Scandinavia and Iceland (Knudsen & Noordeloos, 1992), Spitsbergen (Gulden & Torkelsen, 1996), Alaska (Gulden, Jenssen & Stordal, 1985), Canada (Miller, 1968) and Taimyr in Russia (Нездойминого & Журбенко, 1996). Material: Slantsevaya Mt., 16.8.1990, HK 90.396; Yangana-Pe, 26.8.1996, HK 96.59.

Mycena simia Kühner Syn.: Mycena epipterygia (Scop.: Fr.) Gray var. badiceps M. Lange)

Ecology: Saprotrophic in deep mosses in moist places. Distribution: Known from Greenland (Lange 1955) and the Alps (Kühner & Lamoure 1958). New to Russia.

Material: Along the Khadyta, c. 20 km E of biol. station, 12.8.1990, HK 90.290; Slantsevaya Mt., 16.8.1990, HK 90.448.

**Omphaliaster borealis** (M. Lange & Skifte) Lamoure

Ecology: Saprotrophic in acid heaths.

Distribution: Widely distributed in northern Scandinavia (Printz 1992), Spitsbergen (Gulden & Torkelsen 1996), Greenland (Borgen & Knudsen, unpubl.) and the Alps (pers. comm. U. Peintner, and Krieglsteiner 1991). New to Russia.

Material: Cape Nyarusalye, 20.08.1996, leg. U. Peintner, deposited in Innsbruck.

Omphalina hudsoniana (H.S. Jenn.) H.E. Bigelow

Ecology: Lichenized and saprotrophic on peaty ground in heaths and tundra. Distribution: Known from many alpine and arctic areas, e. g. in central European mountains (Poelt & Vezda, 1981), Spitsbergen (Gulden & Torkelsen, 1996), northern Scandinavia (Lange, 1992), Alaska, Canada and Greenland (Thomson, 1984), and Taimyr, Siberia (Zhurbenko, 1996).

Material: Cape Nyarusalye, 20.8.1996, HK 96.51.

**Rickenella** pseudogrisella (A.H. Sm.) Gulden Syn.: Mycena p. A.H. Sm., Omphalina p. (A.H. Sm.) M. Lange

Ecology: Saprotrophic and symbiotic with the liverwort *Blasia pusilla* and *Nostoc-*algae. Growing in large quantities on naked clayey soil along the small river in Labytnangi. Distribution: Known from northern Scandinavia and Iceland (Lange, 1992, Ryman, 1984) and North America (Smith, 1947). New to Russia. Material: Labytnangi, 30.7.1990, HK 90.058.

### Russula citrinochlora Singer

Ecology: Mycorrhizal with Salix spp. and with Polygonum viviparum, possibly also with Betula spp.

Distribution: Described from the Altai mountains by Singer, who also recorded it from Austria (Singer, 1938), recently also recorded from Greenland (Knudsen & Borgen, 1992).

Material: Along the Khadyta, c. 20 km E of biol. station, 12.8.1990, HK 90.282; Cape Nyarusalye, 20.8.1996, HK 96.56.

#### Russula maculata Quél. ssp. alpina (Singer) Knudsen & T. Borgen

Ecology: Mycorrhizal with Dryas spp. in dry, calcareous localities.

Distribution: Known from the Alps (Austria, France) and the High Tatra mountains (Slovakia)(Fellner & Landa, 1993). These authors raised it to a specific rank. Although we agree with the differences they point out between var. *alpina* and the main variety, var. *maculata*, so far we are not ready to agree with their conclusion that the subspecies should be raised to a specific level. The point raised by Knudsen & Borgen (1992) was that two closely related but geographically separated taxa are often referred to as subspecies, a taxon category rarely used by mycologists. New to Russia.

Material: Slantsevaya Mt., 16.8.1990, HK 90.407; idem, 16.8.1990, HK 90.414.

### Russula nana Britzelm.

Ecology: Mycorrhizal with Salix spp., Polygonum viviparum and rarely Dryas. Distribution: In subarctic-arctic and alpine areas, recorded from the Alps (Krieglsteiner 1991), Greenland (Knudsen & Borgen, 1982, Iceland and northern Scandinavia (Knudsen & Stordal, 1992), Spitsbergen (Gulden & Torkelsen, 1996), the Faroe Islands (Petersen et al., 1994) and Taimyr in Russia (Нездойминого & Журбенко, 1996). Material: Slantsevaya Mt., 16.8.1990, HK 90.404.

#### Russula norvegica D.A. Reid

Ecology: Mycorrhizal with Salix spp. and Polygonum viviparum on acid ground. Distribution: A common species in subarctic-arctic and subalpine-alpine areas, e.g. in northern Scandinavia and Iceland (Knudsen & Stordal, 1992), Greenland (Knudsen & Borgen, 1982), Taimyr in Russia (Нездойминого & Журбенко, 1996) and in the Alps (Krieglsteiner 1991). More rarely it is found in exposed dunes in temperate areas like Denmark (Knudsen & Stordal, 1992).

Material: Labytnangi, 30.7.1990, HK 90.072; along the Khadyta, c. 200 km NE of Salekhard, 2.8.1990, HK 90.095; Oktyabrsky, 15.8.1990, HK 90.377; idem, 15.8.1990, HK 90.378; idem, 15.8.1990, HK 90.381; Slantsevaya Mt., 16.8.1990, HK 90.415; idem, 16.8.1990, HK 90.419; Cape Nyarusalye, 20.8.1996, HK 96.54.

#### Stropharia alpina (M. Lange) M. Lange

Ecology: Saprotrophic, in dry *Racomitrium* heaths and among lichens.

Distribution: Described from Greenland, later recorded from Iceland and the Faroe Islands (Lange, 1980), from Norway (Ryman, 1992) and Taimyr in Russia (Нездойминого & Журбенко, 1996). Apparently confined to subarctic-arctic areas.

Notes: Distinguished from *S. aeruginosa* and allied species by the larger spores, a poorly developed ringzone, paler colour and a less viscid cap.

Material: Slantsevaya Mt., 18.8.1996, HK 96.44.

## Discussion and conclusion

The species listed above represent a small number of the agarics which are more or less specialized to growing in cold climate types. Although the International Symposia on Arcticalpine Mycology have considerably increased the amount of knowledge in this field, there is still much to do. The examples above have been selected from the best investigated groups and include more or less easily recognized taxa. Care has been taken to ensure that all the species have their main distribution in these climates, but graduation is possible between the species. The most widespread seems to be *Russula norvegica*, which is widely distributed in subarctic-arctic and subalpine-alpine areas, but can also be found in temperate zones (e. g. in Denmark), in exposed dunes with dwarf willows. The other species are more strictly confined to subarctic-arctic and subalpine-alpine areas.

Although the data are still very scarce for many species, it seems that all the included species have a circumpolar distribution. This is based on the fact that they are all found at least in two different areas, one in the Western hemisphere and the other in the Eastern hemisphere. Naturally, when more species are known from these areas, it may turn out that some have a restricted distribution in the arctic area, but there seems to be no doubt that at least most arctic agarics have a circumpolar distribution.

The included species can be divided into two major groups in regard to their distribution: those which are subarctic-arctic and subalpine-alpine, and those which are only subarctic-arctic. The latter group includes only nine species: Amanita groenlandica, Arrhenia littoralis, Hygrocybe cinerella, Lactarius lanceolatus, L. lapponicus, L. torminosulus, Leccinum rotundifoliae, Mycena simia and Stropharia alpina. Of these,

Arrhenia littoralis is confined to salt-influenced, arctic sea coast meadows, a locality type which by definition does not occur in aloine areas. Mucena simia has a close relative in the Alps (M. epipterygia var. brunneola J. Favre ex Maas G.), and further research may show them to be identical. The reason for the absence of the remaining species from the Alos is not clear, but at least three of them have dwarf *Betulas* as their main mycorrhizal host: Lactarius lapponicus, L. torminosulus and Leccinum rotundifoliae. Betula nana is present in the Alps, but the populations are small and scattered, and this — a result of the history of the area — may be a reason for the lack of these species. In Mukhin & Knudsen (1998) we concluded that the subalpine xvlotrophic basidiomycetes on Alnus viridis did not include any taxa which had originated in the Alos or had its major occurrence in the Alos. Concerning the agarics of the present investigation our conclusion will be almost the same. However, it seems that a small element of subaloine-aloine taxa of agarics does exist, including e.g. Hygrocybe glacialis T. Borgen & Senn-Irlet and Hudropus dryadicola (Kühner) Horak. Whether this number will increase when a comparison of the large and difficult brown-spored genera Cortinarius, Inocybe, Hebeloma and Galerina has been made, or disappear because these species will be found in subarctic-arctic areas too, we do not know. In our opinion, there is, however, no doubt that the number of specific subalpine-alpine fungi will remain considerably lower than the number of specific subarctic-arctic taxa and this again much lower than the number of taxa in common for both cold-climate area types.

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## INDEX TO THE LATIN NAMES OF FUNGI

#### A

abietinum, Trichaptum 79, 138 absconditum, Epipolaeum 40,47 adusta, Bjerkandera 21, 22, 23, 148 aeruginosa, Stropharia 159 agathosmus, Cortinarius 26, 28, 29, 36 aggregatum, Lepidoderma 101 albida, Phlebia 77, 144 alboviolaceus, Cortinarius 26, 31, 36 Aleurodiscus 138 alni, Phellinus 139 alpigenes, Lactarius, 155 alpina, Stropharia, 159, 160 alpina, Trichia 101 alpinum, Hebeloma 87, 88, 91, 95 alpinus, Cortinarius, 154 alpinus, Lactarius, 155 Alternaria 51, 52, 54, 57 alternata, Alternaria 51, 52, 54, 57 alutacea, Hyphodontia 73 alutaria, Hyphodontia 73 Amanita 153, 159 Amphinema 68 amygdalispora, Dendrothele 71 Amylocorticium 68 Amylostereum 68 Anellaria 124, 126 anellus, Didymium 101 anomalus, Merismodes 75, 143 Anthostoma 39 Antrodia 68 arctica, Calvatia 82, 83 Arcyodes 101, 102 Arcyria 101, 102 arcyrioides, Lamproderma 101 arida, Coniophora 70 Arrhenia 153, 160 ascodedicata, Pleospora 45

Ascotricha 39 aspera, Hyphodontia 73 Athelia 68 Athelopsis 68 audreae, Lepiota 129, 132, 133 aurantiaca, Peniophora 75, 138, 143, 145, 147, 148, 149 aurivella, Pholiota 149

# B

badius, Polyporus 143 balnei-ursi, Massarina 43, 47 Barrmealia 39 Basidioradulum 69, 143, 145, 146, 147 betulinus, Lenzites 21, 22, 23 betulinus, Piptoporus 21, 22, 23, 139 bicolor, Laxitextum 21, 22, 74 biforme, Trichaptum 21 bivalve, Physarum 101 Bjerkandera 21, 22, 23, 148 **Boletinus** 138 Boletus 129, 138 bombycinum, Hypochnicium 144 borealis, Omphaliaster 157 Botryobasidium 69, 144 botryosum, Botryobasidium 69 botrytis, Trichia 101 Bovista 82, 83, 124, 125, 126 Bovistella 82, 85 brooksii, Echinostelium 101 bruchetii, Hebeloma 86, 87, 95, 96 brumalis, Polyporus 144 bulbosissima, Inocybe 118 byssoides, Amphinema 68

# С

Cainiella 39, 47 calamistrata, Inocybe 106, 107, 108, 112, 118 119, 120 calopus, Cortinarius 30 calothrix, Tubulicrinis 80 Calvatia 82, 83, 84, 85 candicans, Botryobasidium 69 carestiae, Lamproderma 101 carestianum, Lepidoderma 101 castanea, Inocybe 107 Ceraceomyces 69, 144 Ceratiomyxa 101 Ceriporia 69 Cerrena 21, 22, 23, 70, 149 cervina, Trametes 21, 22, 23 Chaetoderma 70 Chaetodermella 70 chailletii, Amylostereum 68 chamiteae, Russula 124 Chondrostereum 21, 22, 23 chrysoloma, Phellinus 76, 138 chrysoloma, Porodaedalea 76 chrysomallus, Cortinarius 124, 125 chrysosperma, Perichaena 101 cinerea, Arcyria 101, 102 cinerella, Hygrocybe 154, 159 cinereum, Physarum 101 cinereus, Phellinus 139 cinnabarinus, Pycnoporus 21, 23 cinnamomea, Hymenochaete 144 citrinochlora, Russula 158 citrinopallida, Hygrocybe 155 clavus, Didymium 101 clintonianus, Suillus 138 Clitocybe 154 cohaerens, Trechispora 79 Comatricha 101 confluens, Radulomyces 77 confragosa, Daedaleopsis 21, 22, 70, 149 Coniophora 21, 70 connivens, Calvatia 82, 84, 85 Coprinus 154 cornea, Macbrideola 101 Cortinarius 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 122, 124, 125, 126, 154, 160

cortinarius, Lepiota 128, 129, 132, 133, 134 Craterium 101 crassa, Neurospora 54 cretacea, Bovista 82, 83 cretacea, Calvatia 82, 84 Cribraria 101 cristata, Lepiota 133 Crocicreas 40, 47 Crucibulum 82, 85 crustacea, Mucilago 101 crustaceum, Didymium 101 crustosa, Hyphodontia 73, 143, 145 crustuliniforme, Hebeloma 87, 88, 95 crystallophorum, Lachnum 41, 47 cucumeris, Thanatephorus 78 Cylindrobasidium 21, 22, 23, 144

# D

dacrymycella, Nectriella 43, 45 dacrymycella, Sphaeria 43 Dacryomyces 144 Daedaleopsis 21, 22, 70, 149 Datronia 21, 22, 23, 70, 71, 144, 147 decipiens, Athelia 68 deglubens, Eichleriella 71 Dendrothele 71 deplanatum, Diderma 101 depressa, Perichaena 101, 102 Diacheopsis 101, 103 Dichomitus 138 dichrous, Gloeoporus 21, 22, 23, 72, 149 Diderma 101, 103 Didymium 101, 103 difforme, Didymium 101 disjungendus, Cortinarius 26, 34, 36 dryadea, Phaeosphaeria 45 dryadicola, Hydropus 160 dryadicola, Lepiota 128, 132, 133 dryadis, Hypoderma 41, 47 dryadis, Leptosphaerulina 42 dryadis, Melanomma 42 dryadis, Otthia 42

dryadis, Stomiopeltis 46 dryadis, Sydowiella 46 dryadis, Wettsteinina 46 dryadophila, Leptosphaeria 42 dubium, Didymium 101 dulcamara, Inocybe 106, 107, 108, 109, 119, 120

# E

Echinostelium 101 effusa, Diacheopsis 101 Eichleriella 71 Enerthenema 101 epidryas, Marasmius 157 Epipolaeum 40, 47 epipterygia, Mycena 157, 160 evernius, Cortinarius 26, 33, 34, 36 excipuliformis, Calvatia 82, 83, 84 Exidia 144 Exidiopsis 71, 143, 145, 146, 147, 148

## F

farinacea, Trechispora 79 fastigiata, Inocybe 118 favrei, Cortinarius 122, 124, 125, 126, 154 favrei, Lepiota 128 favrei, Russula 125 ferrugineofuscum, Phellinidium 76 ferrugineofuscus, Phellinus 76, 79, 138 fimbriata, Paradiacheopsis 101 Flammulina 149 fluxilis, Hohenbuehelia 144 fomentarius, Fomes 21, 22, 23, 71, 139, 148 Fomes 21, 22, 23, 71, 139, 148 Fomitiporia 77, 144 Fomitopsis 21, 22, 129, 139, 148 fragilis, Leocarpus 101 fruticulosa, Ceratiomyxa 101 fuscatum, Lamproderma 101

# G

Galerina 160 geophylla, Inocybe 106, 107, 108, 117, 118, 119 Gibbera 40, 47 gigaspermum, Hebeloma 87, 96 glacialis, Hygrocybe 160 Gliophorus 155 Globulicium 71 Gloeocystidiellum 75, 143, 145, 146, 147 Gloeophyllum 21, 23, 72, 138 Gloeoporus 21, 22, 23, 72, 149 Gnomoniella 41, 47 godfrinioides, Inocybe 118 granuliferum, Lepidoderma 101 griseobrunnea, Exidiopsis 71, 143, 145,146, 147, 148 groenlandica, Amanita 153, 159 guttulifera, Inocybe 118

# Η

Hapalopilus 21, 23, 144 Hebeloma 86, 87, 88, 89, 90, 91, 95, 96, 160 hiemale, Globulicium 71 hiemalis, Mucor 51, 52, 54, 57 hirculus, Inocybe 107 hirsuta, Trametes 21, 22, 138, 139, 148 hirsutum, Stereum 21, 23, 139, 148 Hohenbuehelia 144 holmii, Gibbera 40, 47 hudsoniana, Omphalina 157 Hydropus 160 Hygrocybe 154, 155, 159, 160 Hygrophorus 138, 155 Hymenochaete 21, 22, 72, 143, 144, 145 hyperborea, Scleropleella 45 Hyphoderma 69, 72, 73, 138, 143 Hyphodontia 68, 73, 74, 138, 143, 144, 145 Hypochnicium 144 Hypoderma 41, 47

# I

igniarius, Phellinus 21, 22, 76, 144, 149 incarnata, Arcyodes 101, 102 incarnata, Arcyria 101, 102

#### Index

Inocybe 106, 107, 108, 109, 112, 114, 116, 117, 118, 119, 120, 125, 126, 160 Inonotus 21, 22, 74, 143, 149 investiens, Vararia 80 ionophyllus, Cortinarius 26, 29, 36 Irpex 21, 23 Isothea 41, 47

# J

johansonii, Cainiella 39, 47

# K

kleistobolus, Licea 101 kuehneri, Cortinarius 124 kuehneri, Hebeloma 86, 87, 89, 91

# L

Laccaria 36, 124, 125, 126 laccata, Laccaria 124, 125, 126 lacera, Inocybe 106,107,108,116,118,119,120 lacerata, Athelopsis 68 laceratum, Amylocorticium 68 Lachnum 41, 47 Lactarius 107, 124, 125, 155, 156, 159, 160 lacteus, Irpex 21, 23 Laetiporus 74 laeve, Crucibulum 85 laeve, Cylindrobasidium 21, 22, 23, 144 laevigatus, Phellinus 21, 22 laevis, Phanerochaete 76, 144 laevis, Trechispora 79 lambertii, Naemacyclus 43, 47 Lamproderma 101, 103 lanceolatus, Lactarius 155, 159 lapponicus, Lactarius 155, 159, 160 laricinum, Trichaptum 80, 138 lateritia, Clitocybe 154 latispora, Gibbera 40 laurentii, Peniophora 67, 76 Laurilia 74 laxa, Comatricha 101 Laxitextum 21, 22, 74

Leccinum 138, 156, 159, 160 lecideopsoidea, Melaspilea 43, 47 leiocephala, Inocybe 106, 107, 108, 117, 119, 120 Lenzites 21, 22, 23 Lentinellus 144 Leocarous 101 Lepidoderma 101, 103 Lepiota 128, 129, 132, 133, 134 lepidotus, Lactarius 157, 160 Lepista 125 leptophylla, Inocybe 120 Leptosphaeria 42 Leptosphaerulina 42 leucocephalum, Craterium 101 leucoxanthum, Gloeocystidiellum 75, 143,145, 146, 147 leucoxanthum, Megalocystidium 75 Licea 101, 102 liceoides, Perichaena 101 lilacina, Gliophorus 155 lilacina, Hygrocybe 155 Litschauerella 75 littoralis, Arrhenia 153, 160 lividocoeruleus, Aleurodiscus 138 Lophiostoma 42 Lophium 42 lucorum, Hygrophorus 138 luna, Chaetoderma 70 luna, Chaetodermella 70 lundellii, Phellinus 144 lutescens, Trichia 101 Lycoperdon 82, 85 Lyophyllum 125

### Μ

Macbrideola 101 macrostomum, Lophiostoma 42 Macroventuria 40 maculata, Russula 158 Marasmius 157 martinii, Coprinus 154 Massarina 43, 47 Megalocystidium 75 Melanomma 42 melanospermum, Didymium 101 Melaspilea 43, 47 Merismodes 75, 143 mesenterica, Tremella 144, 149 metallica, Prototrichia 101 microfastigiata, Inocybe 118 microspora, Trechispora 79 minima, Licea 101, 102 minor, Dacryomyces 144 minus, Hebeloma 91 minutum, Echinostelium 101 minutum, Sphaerobasidium 78 mollis, Datronia 21, 22, 23 mollusca, Trechispora 79 Mucilago 101 Mucor 51, 52, 54, 57 multiformis, Lepista 157 munda, Trichia 101, 102 Mycena 157, 158, 159, 160 Mycosphaerella 43, 47

# Ν

Naemacyclus 43, 47 nana, Inocybe 118 nana, Russula 125, 158 nanus, Lactarius 124 Nectriella 43, 45 Neurospora 54 nigra, Comatricha 101 nigrescens, Bovista 83, 124, 125, 126 nigrescens, Lycoperdon 85 nigripes, Didymium 101 nigrolimitatus, Ochroporus 76 nigrolimitatus, Phellinus 76 nitidum, Steccherinum 144 nivalis, Amanita 153 nivea, Plicatura 21, 22, 77, 138, 143, 146, 147, 148, 149 nivea, Skeletocutis 21, 22

niveum, Diderma 101 norvegica, Russula 124, 125, 126, 159 nutans, Physarum 101

# 0

oblatum, Physarum 101 obliquus, Inonotus 21, 22, 74 obtusisporum, Botryobasidium 144 obvelata, Arcyria 101 ochracea, Trametes 21, 22, 23, 138, 139 ochraceum, Steccherinum 21 Ochroporus 76 octopetalae, Mycosphaerella 43, 47 octosporum, Sistotrema 78 odoratum, Gloeophyllum 18 Omphaliaster 157, 160 Omphalina 157, 158 omphalodes, Lentinellus 144 operculata, Licea 101 Otthia 45

# ρ

pallidula, Hyphodontia 73 pallidum, Hyphoderma 72 paludosa, Bovista 80, 83 paluster, Boletinus 138 palustris, Hygrophorus 155 papillatum, Enerthenema 101 Paradiacheopsis 101 paragaudis, Cortinarius 26, 31, 33, 36 parasitica, Licea 101 pargamenum, Trichaptum 23 patellaris, Tectella 138, 143, 146, 147, 148. 149 Penicillium 51, 52, 54, 57 penicillus, Pleospora 45 Peniophora 67, 75, 76, 138, 143, 145, 147, 148, 149 Perichaena 101, 102 perlatum, Lycoperdon 85 Phaeosphaeria 45 Phanerochaete 76, 144, 145 Phellinidium 76

Phellinus 21, 22, 76, 77, 79, 138, 139, 144, 149 Phlebia 21, 22, 23, 77, 144 Phlebiella 77 Pholiota 149 Physarum 101, 102, 103 pinicola, Fomitopsis 21, 22, 129, 139, 148 pinophilus, Boletus 148 Piptoporus 21, 22, 23, 139 Pleospora 45 Pleurotus 149 Plicatura 21, 22, 77, 138, 143, 146, 147, 148, 149 polaris, Anthostoma 39 Polyporus 143, 144 pomiformis, Arcyria 101 Porodaedalea 76 Postia 21, 22 praestans, Scytinostroma 77 praetermissum, Hyphoderma 72, 143 Prototrichia 101 protractum, Gloeophyllum 138 oseudogrisella, Mycena 158 pseudogrisella, Omphalina 158 pseudogrisella, Rickenella 158 oseudohelveola, Lepiota 128 pseudotsugae, Phlebiella 77 pseudouvidus, Lactarius 156 pubescens, Trametes 21, 23 pulmonarius, Pleurotus 149 punctata, Fomitiporia 77, 144 ounctatus, Phellinus 76 purpureum, Chondrostereum 21, 22, 23 pusilla, Inocybe 118 pusillum, Hebeloma 86, 88, 89, 91 pusillus, Lactarius 155 puteana, Coniophora 21 putidum, Lyophyllum 125 Pycnoporus 21, 23

# Q

quercina, Hyphodontia 74, 144

## R

racemosus, Mucor 57 radiatus, Inonotus 21, 22, 74, 143, 149 radula, Basidioradulum 69, 143, 145, 146. 147 radula. Hvohoderma 69 Radulomyces 77 regificus, Tubulicrinis 80 remyi, Hebeloma 86, 87, 90 repanda, Exidia 144 reticulata, Ceriporia 69 rhacodes, Inocybe 124, 125, 126 rhytismoides, Isothea 41, 47 Rickenella 158 rimosa, Inocybe 106, 107, 114, 118, 119, 120 rimosa, Scopuloides 144, 145 robertianus, Lactarius 156 rotundifoliae, Leccinum 138, 156, 159, 160 rouxii. Mucor 57 rugosum, Stereum 21, 22, 144, 146, 147 Russula 124, 125, 126, 158, 159 rutilans, Hapalopilus 21, 23, 144

# S

salicis-herbaceae, Lactarius 156 sambuci, Hyphodontia 144, 145 sanguinolentum, Stereum 78 sapinea, Inocybe 107 sauteri, Lamproderma 101 Scleropleella 45 Scopuloides 144, 145 scutellata, Datronia 70, 144, 147 Scytinostroma 77 semiovata, Anellaria 124, 126 sepiarium, Gloeophyllum 21, 23, 72 septentrionalis, Calvatia 82, 84, 85 septentrionalis, Daedaleopsis 70 Septoria 46 serialis, Antrodia 68 serpens, Ceraceomyces 144 setigerum, Hyphoderma 73, 143 simia, Mycena 157, 159, 160

Sistotrema 78 Skeletocutis 21, 22, 78 soluta, Inocybe 120 sordida, Phanerochaete 144, 145 sororius, Tubulicrinis 80 speciosus, Hygrophorus 138 Sphaeria 43 Sphaerobasidium 78 Sphaerotheca 46 spinulosum, Penicillium 51, 52, 54, 57 squalens, Dichomitus 138 squamulosum, Didymium 101 Steccherinum 21, 144 stellae, Skeletocutis 78 stereoides, Datronia 71 Stereum 21, 22, 23, 78, 139, 144, 146, 147.148 Stomiopeltis 46 Stropharia 159 suaveolens, Trametes 139 subaloinus, Lactarius 155 subalutacea, Hyphodontia 74, 144 subbalaustinus, Cortinarius 26, 35, 36 subbrunnea, Inocybe 119 subcaesia, Postia 21, 22 subcarpta, Inocybe 120 subcoronatum, Botryobasidium 69 subhirsuta, Inocybe 108, 118 subtomentosum, Stereum 21, 23 subtorminosus, Lactarius 156 Suillus 137, 138 sulcata, Laurilia 74 sulphureus, Laetiporus 74 Svdowiella 46

# T

tabacina, Hymenochaete 21, 22, 143, 144, 145 tatrensis, Calvatia 84 taxicola, Gloeoporus 21, 22 Tectella 138, 143, 146, 147, 148, 149 tephroleuca, Postia 21, 22 tessulatus, Ceraceomyces 69 Thanatephorus 78 torminosulus, Lactarius 156, 159, 160 traganus, Cortinarius 28 Trametes 21, 22, 23, 138, 139, 148 Trechispora 79 Tremella 144, 149 tremellosa, Phlebia 21, 22, 23 Trichaptum 21, 23, 79, 80, 138 Trichia 101, 102 Tubulicrinis 80 turneri, Calvatia 82, 84

## U

unicolor, Cerrena 21, 22, 23, 70, 149

## V

vagans, Gnomoniella 41, 47 vagum, Botryobasidium 69 Vararia 80 varia, Trichia 101 variabile, Crocicreas 40, 47 varius, Polyporus 144 velutipes, Flammulina 149 venustus, Cortinarius 26, 30, 36 versicolor, Trametes 21, 22, 23, 139, 148 violacea, Cribraria 101 violeipes, Hygrophorus 155 viride, Physarum 101 viticola, Phellinus 77 volkartii, Sphaerotheca 46

## W

Wettsteinina 46 winteri, Lophiostoma 42

# X

xanthochroa, Gliophorus 155 xanthochroa, Hygrocybe 155

# TABLE OF CONTENTS

List of Participants
Goldberg, I. & Romanova, Ye. The Fifth International Symposium on Arcto-Alpine Mycology, Labytnangi, Russia, August 15-27, 1996
Valery M. Shishmaryov Yamal-Nenets autonomous district: NATURAL ENVIRONMENT AND CONDITIONS
Arefyev, S.P. Communities of Xylotrophic fungi in Urban centres of the North of Western Siberia
Borgen, T. Cortinarius subgenus Telamonia in Greenland
Chlebicki, A. Dryadicolous microfungi of the Polar Urals
Ivanova, A.Ye. & Marfenina, O.Ye. The microfungal growth from mycelial fragments and from spores in low temperature conditions
Karatygin, I.V. Results and some aspects of exploration of the Russian Arctic Mycobiota
Kotiranta, H. & Penzina, T.A. Notes on the North Ural Aphyllophorales (Basidiomycetes) 67
Lange, M. Arctic Gasteromycetes III. Additional notes on Bovista and Calvatia from South Greenland and from Tyumen region, Siberia

Miller, O.K.Jr. Hebeloma in the arctic and alpine tundra in Alaska
Novozhilov, Yu.K., Schnittler, M. & Stephenson, S. MYXOMYCETES OF THE RUSSIAN SUBARCTIC AND ARCTIC AREAS (PRELIMINARY REPORT)
Ohenoja, E., Vauras, J. & Ohenoja, M. The Inocybe species found in the Canadian Arctic and West Siberian Sub-Arctic, with ecological notes
Peintner, U. Lead and cadmium contents of basidiomycetes along a heavily trafficated high mountain pass road in the Austrian Alps
Peintner, U. LEPIOTA CORTINARIUS VAR. DRYADICOLA, AN ARCTIC-ALPINE TAXON? 128
Penzina, T.A. & Yakovlev, A.Yu. The peculiarities of macromycete fruiting in mountainous regions of Pribaikalye
Mukhin, V.A. & Knudsen, H. The evolution of high latitudinal and altitudinal biotas of xylotrophic basidiomycetes
Knudsen, H. & Mukhin, V.A. The arctic-alpine agaric element in the Polar Urals and Yamal, Western Siberia
INDEX TO THE LATIN NAMES OF FUNGI
Научное издание

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