Myxomycete diversity of the state reserve "Stolby" (south-eastern Siberia, Russia)

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The primary objective of the present study was to obtain taxonomic, ecological, and distributional data on the species of myxomycetes (plasmodial slime moulds) in the mountain taiga and steppe communities of the state reserve "Stolby" (Eastern Sayan mountain ridge, Russia). A total of 977 records representing 123 species of myxomycetes in 33 genera were identified from 371 field collections and 606 collections obtained from 953 moist chamber cultures prepared with samples taken from the bark surface of living plants, decaying plant litter and the weathered dung of herbivorous animals between 2003 and 2006 by the first author. Seventy-six species were collected in the field and 65 species were recorded in moist chamber cultures. Records of taxa obtained from moist chamber cultures and field collections complemented each other in terms of the species represented. Seventy-eight species were determined to be rare (frequency of occurrence below 0.5% of the total of 977 records) and only seven were abundant (exceeding 3% of all records). Taxonomic descriptions and ecological observations of rare and/or tentatively new taxa found in the study area are provided in the annotated checklist. Myxomycete species richness and specificity had different trends on different substrates: bark had the richest but least specific myxomycete assemblages whereas litter and dung were characterized by the poorest, but most specific assemblages. The myxomycete biota of the reserve displayed a high level of similarity to those of other taiga regions of Russia for which data exist, but differed considerably from the biotas of arid regions. Ninety species are herein first reported for the Krasnoyarsk territory and three (*Echinostelium fragile, Physarum penetrale* and *Symphytocarpus amaurochaetoides*) are new records for Russia.

Key words: biodiversity, Krasnoyarsk territory, mountain taiga, slime moulds, species inventory

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Introduction

Myxomycetes (plasmodial slime molds) are a small group of phagotrophic eukaryotes including 880 described taxa (Lado, 2001). These organisms typically inhabit four major substrate types: wood in all stages of decay, the bark surface of living trees and shrubs, the litter of decaying plants, and the dung of herbivorous animals. Although myxomycetes are well known in the boreal forest (taiga) zone of Russia (Novozhilov, 1980, 1987, 1999; Novozhilov and Fefelov, 2000) this vegetation type in eastern Siberia has gone relatively unstudied and few attempts have been made to assess the myxomycete diversity, utilizing local species inventories in Siberia (Taimyr Peninsula: Novozhilov *et al*., 1999; the southern part of the Krasnoyarsk territory: Beglyanova and Katcina, 1973; Kosheleva, 2004, 2006; the northern part of the Sayano-Shushenskiy Biospherical State Reserve: Kutaf'eva and Kosheleva, 2006). Prior to this study only twelve species had been reported from the state reserve "Stolby". The primary objectives of the present study were to assess the biodiversity patterns of myxomycetes in the reserve and to compare these patterns in species diversity to similar studies of well documented myxomycete biotas from Russia (Novozhilov, 1980, 1999; Schnittler and Novozhilov, 1996; Novozhilov and Fefelov, 2000; Novozhilov *et al*., 2006). The second objective was to generate a relatively unbiased data set of myxomycete species abundances with which to estimate the degree of completeness of the present survey.

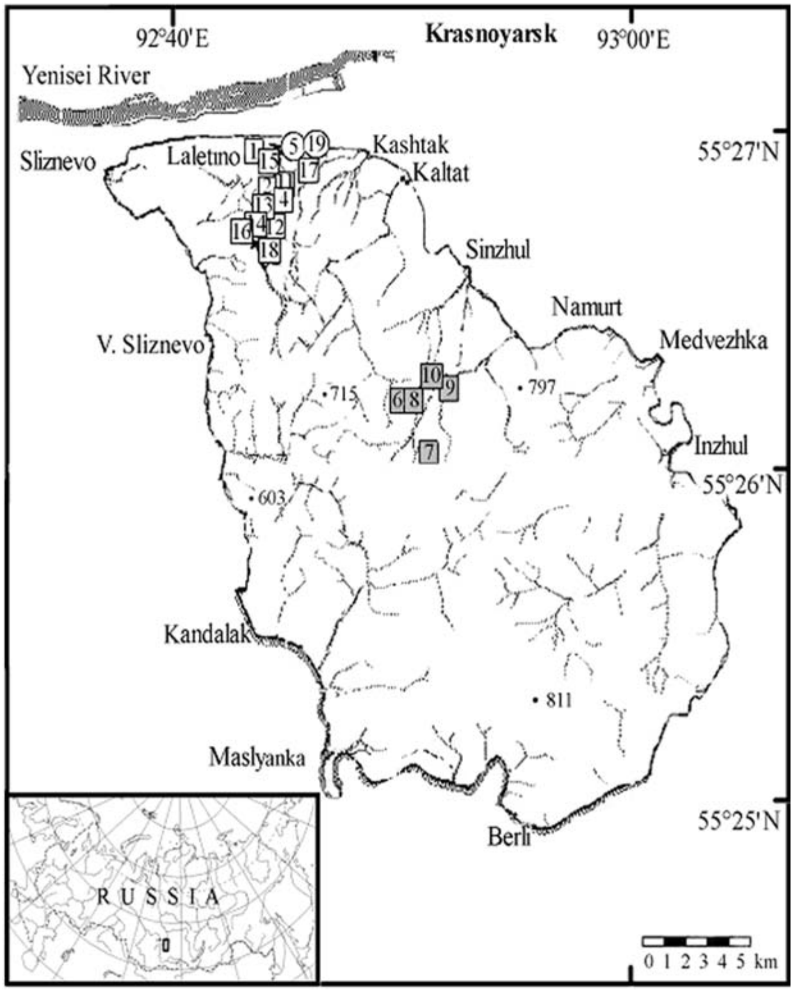


Fig. 1. A map of the "Stolby" State Reserve, with sampling sites indicated by open rectangles: light coniferous forest, grey rectangles: dark coniferous forest, and open circles: mountain steppe. The insert shows the geographical position of the general study area delimited by a rectangle. Source: "Ecological Atlas of the state reserve "Stolby", http://stolby.torins.ru/, 2001-2007, modified.

During several weeks from July to August in 2003-2006, field surveys were conducted across 18 study areas in the state reserve "Stolby" to record and collect myxomycete sporocarps (fruit bodies) as well as to obtain samples of various types of organic substrata for the preparation of moist chamber cultures.

Materials and methods

Study sites

The present study was limited to a rather small area of relatively undisturbed southern mountain taiga encompassing an elevation range of 500 to 1500 m. All microhabitats known to support myxomycetes were examined. Myxomycete fructifications appearing in moist chamber cultures or encountered in the field were recorded.

The state reserve "Stolby" is located between 92°40'-92°55' E and 55°30'-55°38' N, *ca.* 3 km SW of the city of Krasnoyarsk, on the Krasnoyarskiy or Kuysumskiy mountain ridge of northwestern spurs of the Eastern Sayan, adjacent to the right bank of the Yenisei River (Fig. 1). The reserve consists of a total area of 47,200 ha (Shcherbakov and Kirillov, 1962; Kozlov, 1985).

The continental climate is characterized by winter temperatures as low as -45°C, while average January and July temperatures are -16.2°C and +16.8°C, respectively. The mean annual precipitation for this region is 679 mm, with approximately one-third falling as rain between July and August (Andreeva, 2005).

Localities and vegetation types

Within the reserve, forest vegetation replaces the steppe of the Krasnoyarsk steppe depression, and the latter represents the typical mountain taiga of the Eastern Sayan mountain ridge. Locality numbers written (in bold) in the following brief descriptions refer to Fig. 1. The diversity of vegetation across the reserve provides a varying range of conditions with respect to moisture, light exposure and available substrates for myxomycetes.

I. Light coniferous (taiga) forest belt (localities: 1-4, 11-17). The lower elevation belt (elevation 200-500 m) contains forest of intermixed pine (*Pinus sylvestris* L.) and larch (*Larix sibirica* Ledeb.) (localities: 12-14). Spruce (*Picea obovata* Ledeb.), fir (*Abies sibirica* Ledeb.), birch (*Betula pendula* Roth), aspen (*Populus tremula* L.), and alder (*Alnus glutinosa* (L.) Gaertn.) with understories composed of tall perennials, sedges and grasses are associated with the wet depressions of river valleys, (localities: 1, 2, 3, 4, 11, 15, 16, 17). These localities provide numerous favourable habitats for different ecological assemblages of myxomycetes.

<u>The issue of the stream “Vtoraya Poperechnaya”</u>. Locality 1: birch forest with rich grass cover, 92°43'30" N 55°27'05" E; 2: aspen forest with rich grass and sedge cover, 92°44'07" N 55°26'57" E; 3: spruce forest with rich grass cover, 31 plot of the forest reserve “Stolbinskoe”, 92°44'52" N 55°26'58" E; 4: alder forest with rich fern and grass cover, 18 plot of the forest reserve “Stolbinskoe”, the Laletina stream, 92°44'48" N 55°26'54" E; 11: birch forest with rich grass cover, 5 plot of the forest reserve “Stolbinskoe”, 92°44'23" N 55°26'48" E; 12: pine forest with rich sedge cover, *ca*. 500 m NE of the rock “Vtoroy Stolb”, plot No. 48 of the forestry “Stolbinskoe”, 92°43'55" N 55°26'53" E; 13: pine forest with rich grass cover, *ca*. 1 km N of the rock “Vtoroy Stolb”, 31 plot of the forest reserve “Stolbinskoe”, 92°43'35" N 55°26'49" E; 14: pine forest with rich grass and sedge cover, ca. 600 m N of the rock “Vtoroy Stolb”, 48 plot of the forest reserve “Stolbinskoe”, 92°43'34" N 55°26'49" E; 15: spruce forest with rich grass and sedge cover, ca. 100 m S of the issue of the stream “Vtoraya Poperechnaya”, 5 plot of the forestry “Stolbinskoe”, 92°44'15" N 55°27'03" E; 16: pine-birch-spruce forest with rich grass cover, ca. 500 m NE of the rock “Vtoroy Stolb”, 48 plot of the forest reserve “Stolbinskoe”, 92°43'55" N 55°26'53" E; 17: pine forest with rich cowberry and sedge cover, ca. 1 km NE of the issue of the stream “Vtoraya Poperechnaya”, 5 plot of the forestry “Stolbinskoe”, 92°44'12" N 55°26'43" E.

II. Dark coniferous forests belt (localities: 6-10). The dark coniferous forest belt is characterized by fir and Siberian pine (*Pinus cembra* L.) and is widespread between 500-800 m elevation, on ridge tops and steep south-facing slopes. The different vegetation communities of this belt contain a rich mixture of grass and moss cover.

<u>The 52 plot of the forest reserve “Stolbinskoe” near the station “Kaltat”</u>. Locality 6: fir forest with rich grass cover, 92°49’57" N 55°26'09" E; 7: Siberian pine-fir forest with rich grass cover, 92°51'15" N 55°25'57" E; 8: fir forest with rich green moss and sedge cover, 92°50'34" N 55°26'09" E; 9: pine forest with rich sedge and grass cover, 92°52'07" N 55°26'11" E; 10: aspen forest with rich grass cover, 92°51'23" N 55°26'15" E.

III. Mountain steppe (localities: 5, 18). The south-facing steep slopes are often dry, rocky or gravel-sand and are characterized by a limited amount of moisture. The mountain shrub steppe occurs among the dark coniferous woodlands as extrazonal vegetation and contains various steppe grasses and shrub species such as *Cotoneaster lucidus* Schltdl. and *Caragana arborescens* Lam. These shrubs grow no higher than 70 cm and initially produce smooth but later furrowed and curly bark which sustains thicker mats of leaf litter, which in turn serves as a suitable microhabitat for myxomycetes.

<u>The 5 plot of the forest reserve “Stolbinskoe”, around the Laletina stream, near the control post</u>. Locality 5: southwestern slope of the rock “Chertov paletc” (“Devil’s finger”), 92°45'16" N 55°27'07" E; 18: southern slope of the rock “Chertov paletc”, 92°46'01" N 55°27'08" E.

Sampling

For each vegetation belt, an effort was made to examine all types of microhabitats upon which sporocarps of myxomycetes could potentially be found. The nomenclature for vascular plants follows that of Czerepanov (1995). Except for the common species of myxomycetes that could be identified in the field - which were recorded but not collected - a collection (voucher specimen) was taken from every fruiting encountered. For the purpose of making determinations, sporocarps were preserved as permanent slides in lacto-phenol and/or glycerol gelatin, to distinguish between limeless and lime-containing structures. Sporocarp structures were studied with a JEOL 35c scanning electron microscope (SEM) at St.-Petersburg. For each species, a voucher specimen was deposited in the fungal herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences, Laboratory of Systematics and Geography of Fungi (LE) and/or in the herbarium of the Krasnoyarsk State Pedagogical University (KRAS).

Moist chamber cultures

Collectively, 953 moist chamber cultures were prepared in the manner described by Härkönen (1977, 1981). Substratum samples were placed in Petri dishes (10 cm diam.) lined with filter paper. These were then moistened with distilled water adjusted to pH 7. After 24 hours, the excess water was poured off and the pH was measured, using an EV-74 pH meter or an Orion 610. The cultures were incubated under diffuse light at room temperature (*ca*. 20-24^{o}C) for up to 60 days and examined under a microscope on eight occasions (days 3, 6, 12, 18, 25, 32, 39, and 46 after excess water was poured off). The occurrence of one species in a Petri dish (i.e., moist chamber culture) was recognized as a single collection.

Data analysis

The data collected from moist chamber cultures and field collections were entered into Excel 2003 spreadsheets. To estimate the extent to which the survey was exhaustive, a species accumulation curve was constructed using the program EstimateS (Colwell, 2006) and subjected to a regression analysis using the hyperbolic function $y = Ax/(B + x)$, where x is the number of samples, y represents the number of species recorded, and the parameter A refers to the maximum number of species to be expected and B is the number of samples needed to reach half of the number of species to be expected (Fig. 35). Species diversity (alpha-diversity) was calculated using Shannon's diversity index H' = - ∑Pi log Pi, where Pi is the relative abundance (the proportion of the total number of individuals or records represented by species) of a particular species (Shannon and Weaver, 1963; Magurran, 2004). To compare myxomycete biotas from different regions, the adjusted incidence-based SØerensen index (Cs) recently developed by Chao *et al*. (2005, 2006) was calculated with Estimate S and used for a cluster analysis as weighted pair-group method (WPGMA) with the program Statistica 5.5.

We used the program PcOrd 4.17 for canonical correspondence analysis (CCA) to assess the relative importance of substrate types for myxomycete associations (MJM Software Design Inc., Gleneden Beach, Oregon, USA; Schnittler, 2001; Schnittler *et al*., 2002). Graphs were created with SigmaPlot 8.0. The calculated eigenvalues, ranged from 0 and 1, and represented a measure of the degree of which the distribution of a particular species could be explained by the respective ordination axis (Ter Braak, 1987). To avoid introducing noise by rare species, only species with a relative frequency > 1.5 % of all records were calculated.

Results

Taxonomy

In the section that follows, all recorded species are listed in alphabetical order. Species were identified according to Martin and Alexopoulos (1969) and various original descriptions from the literature, utilizing a morphospecies concept. Determinations considered as uncertain are denoted as "cf." (compare). Nomenclature follows that of Lado (2001) and Hernández-Crespo and Lado (2005) except for the two genera *Collaria* Nann.-Bremek. and *Stemonitopsis* (Nann-Bremek.) Nann-Bremek. and the conserved names of several other genera (Lado *et al*., 2005) recently approved by the Committee for Fungi of the IAPT (Gams, 2005). Authorities are cited according to Kirk and Ansell (1992). After each name, abbreviations for the names of all the myxomycete species included in CCA and mentioned in Figs 36, 37, an estimate of abundance as described by Stephenson *et al*. (1993) (the proportion of a species in relation to the total number of records (977): R - rare (< 0.5 % of all records), O - occasional (> 0.5-1.5 % of all records), C - common (> 1.5-3 % of all records), A - abundant (> 3 % of all records) and the estimation of abundance and the number of records registered in the field “fc” and in the moist chamber culture “mc” for the species are given in brackets. Next, the occurrence of the species in different vegetation types (indicated by Roman numerals) is listed. The occurrence of the species in different microhabitats (substrate types) and the list of localities where the species were found are given after the brackets. Four species found in the reserve and represented only by older specimens in KRAS without exact locality descriptions on the labels are marked with “Loc.: ?”. Abbreviations for vegetation types are: I -light coniferous forest belt, II -dark coniferous forest belt, III - mountain shrub steppe extrazonal vegetation. Abbreviations for microhabitats are: b - bark of living trees and shrubs; w - coarse woody debris of trees and shrubs; l - ground litter; d - dung of herbivorous animals. Brief taxonomic descriptions are provided for records with uncertain identifications and some rare species. Abbreviations: LM - light microscope, DM - dissection microscope (binocular), SEM - scanning electron microscope.

Annotated species list

Arcyodes incarnata (Alb. & Schwein.) O.F. Cook [R, fc: 1, I: 1] l: 1; Loc.: 3; LE 237043.

Arcyria cinerea (Bull.) Pers. [ARCcin, A, mc: 57, fc: 12, I: 50, II: 18, III: 1] b: 21, l: 30, w: 18; Loc.: 1, 2, 3, 4, 6, 7, 8, 9, 10, 12, 15, 17, 19; LE 229361.

Arcyria denudata (L.) Wettst. [O, fc: 7, I: 6, II: 1] w: 7; Loc.: 1, 6, 12, 17; LE 229261, KRAS 143.

Arcyria helvetica (Meyl.) H. Neubert, Nowotny & K. Baumann [R, fc: 3, I: 3] w: 3; Loc.: 1, 12, 15; LE 229338.

Notes: Our specimens were found on the coarse woody debris of *Betula pendula* and were characterized by large colonies of sporocarps up to 17 cm in total extent. All specimens were typical of this species and could be recognized in the field by the short-cylindrical and slightly curved sporotheca covered by a wine-red iridescent peridium that persisted partly in the upper part, forming a bright red, shining, funnel-shaped to semi-globose calyculus with its margins attached to the flakes of the upper peridium (Fig. 2).

Arcyria incarnata (Pers. ex J.F. Gmel.) Pers. [ARCinc, O, mc: 4, fc: 2, I: 3, II: 3] b: 3, l: 1, w: 2; Loc.: 3, 6, 7, 13; LE 229452.

Arcyria insignis Kalchbr. & Cooke [R, fc: 3, I: 3] b: 1, w: 2; Loc.: 1, 16; LE 229341.

Arcyria obvelata (Oeder) Onsberg [O, fc: 5, I: 4, II: 1] w: 5; Loc.: 7, 14, 16; LE 23710.

Arcyria pomiformis (Leers) Rostaf. [ARCpom, O, mc: 9, fc: 4, I: 3, II: 10] b: 5, l: 4, w: 4; Loc.: 6, 7, 9, 14, 15; LE 229208.

Arcyria stipata (Schwein.) Lister [R, fc: 1, I: 1] w: 1; Loc.: 1; LE 229330.

Badhamia cf. *apiculospora* (Härk.) Eliasson & N. Lundq. [R, mc: 1, III: 1] l: 1; Loc.: 19; LE 237060.

Notes: LE 237060 consists of a few sporocarps collected from a moist chamber. This material does not agree perfectly with the description of this species but cannot be placed elsewhere with more certainly. The wrinkled white peridium together with the dark black spore mass and massive limy pseudocolumella (Fig. 3) appear to be typical of this species. However, the apiculoid structure of the spores was observed only in water under LM (Fig. 4) and was not with SEM (Fig. 5). Typical specimens of *B. apiculospora* have elliptical, smooth, thick-walled spores with 1 or 2 apiculi. The densely verrucose spore ornamentation of the specimen LE 237060 (Fig. 5) differs from the spore ornamentation of either typical form or “morphotypes” found in different arid areas (Novozhilov *et al*., 2003, 2006; western Mongolia, unpublished data).

Badhamia foliicola Lister [R, mc: 2, I: 1, III: 1] l: 2; Loc.: 5, 15; LE 229464.

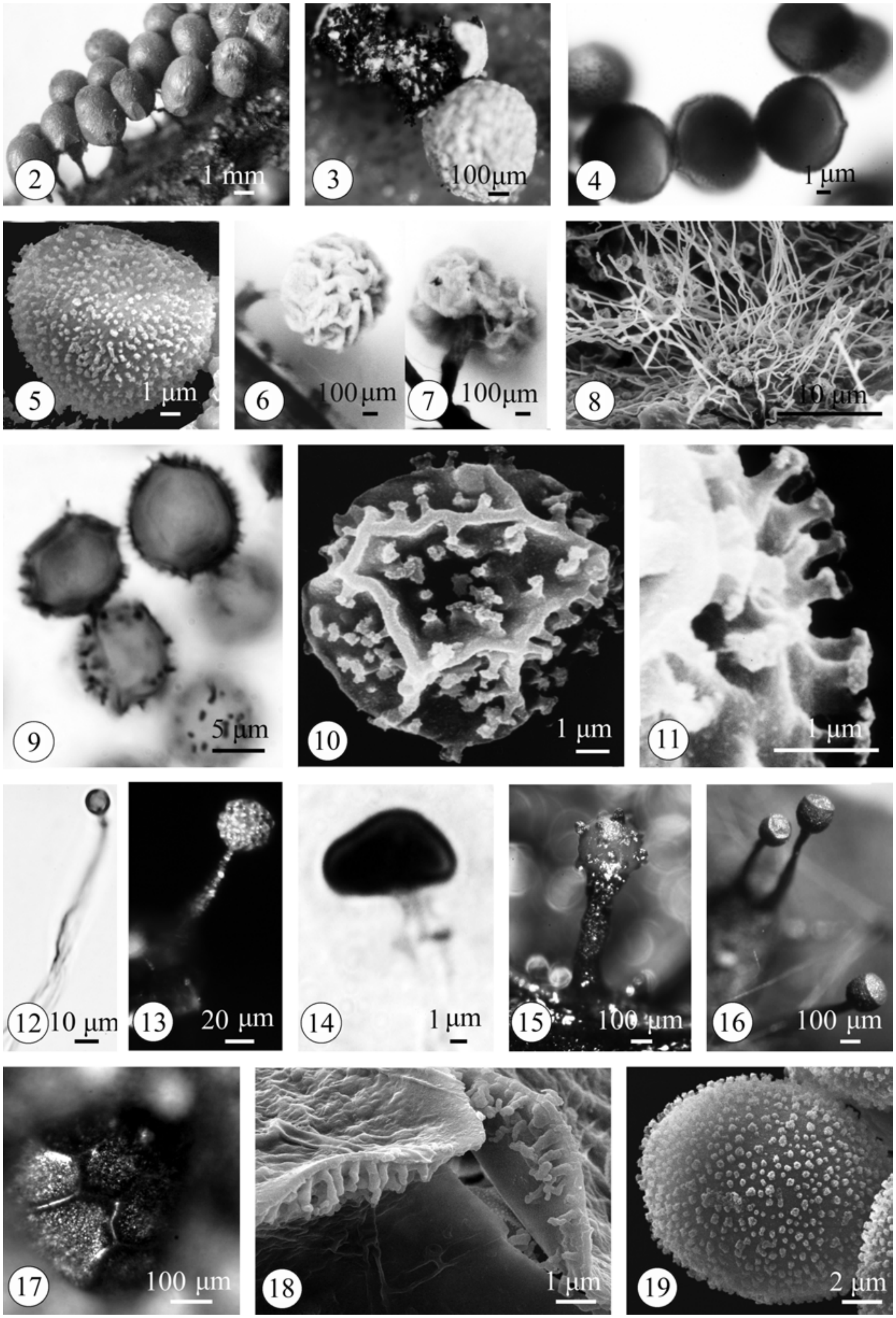


Fig. 2. *Arcyria helvetica* (LE 229338). Sporocarps seen by DM. **Figs 3-5.** *Badhamia* cf. *apiculospora* (LE 237060). **3.** Sporocarps (DM). **4.** Spores (TL). **5.** Spores (SEM). **Figs 6-11.** *DDY* sp. (LE 237070). **6-7.** Sporocarps (DM). **8.** Dehiscing sporocarp (SEM) showing columella and the capillitium remaining as a basal collar. **9.** Spores (TL). **10.** Spore (SEM). **11.** Spore ornamentation (SEM). **Figs 12-13.** *Echinostelium apitectum* (LE 229460). **12.** Sporocarp (TL). **13.** Sporocarp (DM). **Fig. 14.** *Echinostelium brooksii* (LE 229467). Columella (TL). **Fig. 15.** *Hemitrichia pardina* (LE 229225). Sporocarp (DM). **Fig. 16.** *Licea operculata* (LE 229212). Sporocarps (DM). **Figs 17-19.** *Licea tenera* (LE 229495). **17.** Sporocarps (DM). **18.** Spores (TL). **19.** Spores (SEM).

Badhamia panicea (Fr.) Rostaf. [R, fc: 1, I: 1] w: 1; Loc.: ?; KRAS 264.

Badhamia utricularis (Bull.) Berk. [R, fc: 1, I: 1] w: 1; Loc.: 1; LE 237058.

Calomyxa metallica (Berk.) Nieuwl. [R, mc: 4, II: 4] b: 4; Loc.: 6, 8; LE 229297.

Clastoderma debaryanum A. Blytt [R, fc: 1, I: 1] w: 1; Loc.: 1; LE 229388.

Collaria arcyrionema (Rostaf.) Nann.-Bremek. ex Lado [O, fc: 7, I: 6, II: 1] w: 7; Loc.: 7, 14, 15; LE 229250.

Collaria lurida (Lister) Nann.-Bremek. [R, fc: 1, I: 1] w: 1; Loc.: 16; LE229459.

Comatricha elegans (Racib.) G. Lister [O, mc: 10, fc: 2, I: 3, II: 9] b: 10, w: 2; Loc.: 6, 7, 8, 9, 14, 15; LE 229380.

Comatricha nigra (Pers. ex J.F. Gmel.) J. Schröt. [COMnig, C, mc: 14, fc: 4, I: 16, II: 2] b: 11, l: 3, w: 4; Loc.: 1, 2, 3, 4, 6, 9, 13; LE 229445.

Comatricha tenerrima (M.A. Curtis) G. Lister [R, mc: 1, III: 1] l: 1; Loc.: 19; LE 237059.

Notes: Our collection consists of typical dark-brown fusoid sporocarps with long stalks, the latter representing 2/3-3/4 of the total height of the sporocarps.

Craterium aureum (Schumach.) Rostaf. [R, fc: 3, I: 3] w: 3; Loc.: 16; LE 229320.

Notes: Our specimen has the typical characters of this species. The lemon-yellow subglobose or obovoid sporotheca is the distinguishing characteristic of this species.

Craterium leucocephalum (Pers. ex J.F.Gmel.) Ditmar [R, fc: 1, I: 1] l: 1; Loc.: 16; LE 229328.

Cribraria argillacea (Pers. ex J.F.Gmel.) Pers. [O, fc: 12, I: 10, II: 2] w: 12; Loc.: 7, 12, 14, 15, 16; LE 229350.

Cribraria aurantiaca Schrad. [R, fc: 3, I: 3] w: 3; Loc.: 14, 15, 17; LE229358.

Cribraria cancellata (Batsch) Nann.-Bremek. [A, fc: 38, I: 32, II: 6] w: 38; Loc.: 1, 7, 13, 14, 15, 16, 17; LE 237013.

Cribraria intricata Schrad. [R, fc: 3, I: 3] w: 3; Loc.: 13, 15, 16; LE229249.

Cribraria microcarpa (Schrad.) Pers. [R, mc: 1, II: 1] w: 1; Loc.: 9; LE229260.

Cribraria purpurea Schrad. [R, fc: 1, I: 1] w: 1; Loc.: 16; LE 229217.

Cribraria tenella Schrad. [R, fc: 1, I: 1] w: 1; Loc.: 13; LE 229457.

Cribraria violacea Rex [CRIvio, C, mc: 22, I: 4, II: 17, III: 1] b: 2, l: 14, w: 6; Loc.: 2, 3, 4, 6, 9, 10, 19; LE 229315.

Cribraria vulgaris Schrad. [O, mc: 1, fc: 7, I: 6, II: 2] w: 8; Loc.: 1, 6, 9, 16; LE 229475.

Diacheopsis metallica Meyl. [R, mc: 3, I: 3] l: 3; Loc.: 2, 3; LE 229375.

Notes: Our specimens conform well with published description of this species.

Dictydiaethalium plumbeum (Schumach.) Rostaf. [R, fc: 1, II: 1] w: 1; Loc.: 6; LE 229473.

Diderma deplanatum Fr. [R, mc: 1, I: 1] l: 1; Loc.: 3; LE 229462.

Notes: The single specimen of this species was obtained on ground litter (needles) of spruce (*Picea obovata*) in moist chamber culture and consisted of curved plasmodiocarps. These were scattered, pulvinate, sessile, 1-1.5 mm diam., and white. The peridium was double, with the outer layer smooth, crustose, brittle and thick, whereas the inner layer was membranous, iridescent and deep orange below. A columella was lacking. The capillitium consisted of dark purple, simple threads. The spores were dark brown and minutely spinulose, 9.5-10 µm diam.

Diderma effusum (Schwein.) Morgan [R, mc: 1, I: 1] b: 1; Loc.: 1; LE 237046.

Diderma radiatum (L.) Morgan [R, fc: 2, I: 2] w: 2; Loc.: 15; LE 229258.

Notes: The specimen was typical of the species and consisted of short-stalked, slightly flattened, brown sporocarps marked with pale lines. The peridium was double, with the outer layer cartilaginous, brown, limeless and adhering closely to the membranous inner layer. Dehiscence of the peridium was into revolute lobes that reveal the brilliantly white inner peridium. The columella was large, hemispherical to subglobose and reddish-brown. The capillitium was abundant, consisting of brown threads, with these pale at the tips and hardly branching. Spores were purple-brown, densely warted and 10-12 µm diam.

Diderma simplex (J. Schröt.) G. Lister [R, mc: 1, I: 1] l: 1; Loc.: 2; LE 229351.

Didymium anellus Morgan [R, mc: 4, I: 2, III: 2] l: 4; Loc.: 1, 5; LE 229231.

Didymium clavus (Alb. & Schwein.) Rabenh. [R, mc: 3, fc: 1, I: 2, III: 2] l: 3, w: 1; Loc.: 1, 19; LE 229384, KRAS 222.

Didymium difforme (Pers.) Gray [DDYdif, A, mc: 47, I: 18, II: 14, III: 15] b: 3, l: 36, w: 7, d: 1; Loc.: 1, 2, 4, 5, 6, 7, 8, 10, 15, 19; LE 229421.

Didymium melanospermum (Pers.) T. Macbr. [O, mc: 1, fc: 7, I: 8] b: 1, l: 2, w: 4; Loc.: 1, 15, 18; LE 229257.

Didymium nigripes (Link) Fr. [R, fc: 1, I: 1] l: 1; Loc.: 15; LE 237003.

Didymium serpula Fr. [R, mc: 1, I: 1] l: 1; Loc.: 4; LE 229251.

Notes: The single specimen was obtained in moist chamber culture on the leaf litter of *Populus tremula.* It consisted of flat, dark grey plasmodiocarps, 0.1-0.15 mm thick and 2-3 mm long. The hypothallus was inconspicuous. The peridium was membranous and covered with white, stellate crystals. The columella was absent, and the capillitium was made up of slender, yellow-brown threads attached to subglobose vesicles, 30-50 µm diam., filled with yellow granular material. The spores in mass were brown. When viewed under transmitted light, they were pale violet-brown, 8-11 µm diam. and minutely warted.

Didymium sp. [R, mc: 1, II: 1] l: 1; Loc.: 8; LE 237070.

Notes: This taxon was isolated in moist chamber culture on the litter of *Pinus sylvestris* and *Carex* sp., collected in the fir forest. Sporocarps were stalked, gregarious, scattered and had a total height of 0.7-0.8 mm. The sporotheca was subglobose, umbilicate below, white or slightly straw-yellow (60, 34 Petersen, 1996) and 0.5-0.6 mm diam. (Figs 6, 7). The stalk was bright-brown in lower part, pale white in upper part, thin (up to 0.1 mm), calcareous, prominently longitudinally rugose, and 0.2-0.3 mm long. The hypothallus was membranous and light brown (17, Petersen, 1996), whereas the peridium was deeply wrinkled, one-layered, thin, membranous and densely covered with white lime crystals. The columella was mostly absent but sometimes rudimentary, with a dome-like shape and calcareous (Fig. 8). The capillitium was scanty and consisted of slightly undulated, occasionally dichotomously branched threads, these 0.5-1.0 µm in diam. and hyaline in transmitted light (Fig. 8). The spores were black (51, Petersen, 1996) in mass, dark brown to fuscous (3, Petersen, 1996) in transmitted light, globose to ellipsoid and slightly polygonal, with the surface covered by widely-spaced long spines by TL (Fig. 9), 10-12 µm in diam. (including ornamentation), and with an epispore consisting of dark crests (Fig. 10). The spines of the spore ornamentation under SEM were capitate up to 1 µm height, with the caput enlarged to 0.3-0.5 µm, the latter strongly tuberculate with 3-6 small tubercles 0.1-0.2 µm wide (Fig. 11). This is a new taxon which could apparently be referred to *Didymium*; however, to reach any final conclusions about the taxonomic position of this taxon, it will be necessary to examine more material.

Didymium squamulosum (Alb. & Schwein.) Fr. [DDYsqu, C, mc: 23, I: 4, II: 8, III: 11] b: 1, l: 22; Loc.: 1, 2, 5, 6, 8, 10, 19; LE 229275.

Echinostelium apitectum K.D. Whitney [R, mc: 1, I: 1] b: 1; Loc.: 15; LE 229460.

Notes: Our material is quite typical for this species. The distinguishing characteristic is the apex of the stalk, where it projects into the spore-like body for a distance of 1-4 µm (Figs 12, 13).

Echinostelium brooksii K.D. Whitney [O, mc: 5, I: 5] b: 5; Loc.: 15; LE 229467.

Notes: All of our collections were obtained on acidic bark (mean pH of 5.12) of *Pinus sylvestris* in moist chamber culture and exhibit the typical characters of this species (Figs 13, 14).

Echinostelium elachiston Alexop. [R, mc: 1, I: 1] b: 1; Loc.: 3; LE 229469.

Echinostelium fragile Nann.-Bremek. [R, mc: 1, II: 1] w: 1; Loc.: 9; LE 229477.

Notes: This is the first collection of this species reported from Russia. The single specimen of this species was collected from moist chamber culture on the decayed wood fragments of *Pinus sylvestris* and exhibited the typical characters.

Echinostelium minutum de Bary [ECHmin, A, mc: 42, I: 8, II: 34] b: 38, l: 4; Loc.: 6, 7, 8, 9, 15; LE 237019.

Enerthenema papillatum (Pers.) Rostaf. [O, mc: 6, fc: 4, I: 6, II: 4] b: 6, w: 4; Loc.: 6, 8, 9, 13, 14, 15; LE 229307.

Fuligo septica (L.) F.H. Wigg. [FULsep, C, mc: 4, fc: 16, I: 19, II: 1] l: 4, w: 16; Loc.: 1, 3, 4, 8, 12, 13, 14, 15, 16; LE 229281.

Hemitrichia clavata (Pers.) Rostaf. [R, fc: 2, I: 2] w: 2; Loc.: 15, 16; LE 229209.

Hemitrichia pardina (Minakata) Ing [HEMpar, A, mc: 31, I: 29, II: 2] l: 31; Loc.: 1, 2, 4, 9, 10; LE 229225. (Fig. 15).

Hemitrichia serpula (Scop.) Rostaf. ex Lister [R, fc: 1, I: 1] w: 1; Loc.: ?; KRAS 119.

Lamproderma arcyrioides (Sommerf.) Rostaf. [R, fc: 1, I: 1] w: 1; Loc.: 1; LE 229370.

Leocarpus fragilis (Dicks.) Rostaf. [O, fc: 8, I: 6, II: 2] b: 2, l: 2, w: 4; Loc.: 1, 6, 10, 15, 16, 18; LE 237030.

Lepidoderma tigrinum (Schrad.) Rostaf. [R, fc: 1, I: 1] l: 1; Loc.: 1; LE 229481.

Licea biforis Morgan [R, mc: 2, II: 2] w: 2; Loc.: 10; LE 229267.

Licea castanea G. Lister [R, mc: 2, I: 1, II: 1] l: 1, w: 1; Loc.: 4, 9; LE 229395.

Licea kleistobolus G.W. Martin [LICkle, C, mc: 24, I: 22, II: 1, III: 1] b: 22, l: 1, w: 1; Loc.: 1, 2, 4, 6, 15, 19; LE 229465.

Licea minima Fr. [R, mc: 4, I: 1, II: 3] b: 1, l: 1, w: 2; Loc.: 6, 9, 15; LE 229277.

Licea operculata (Wingate) G.W. Martin [LICope, C, mc: 15, I: 15] b: 6, l: 8, w: 1; Loc.: 2, 3; LE 229212. (Fig. 16).

Licea parasitica (Zukal) G.W. Martin [LICpar, C, mc: 16, I: 12, II: 4] b: 16; Loc.: 1, 6, 7; LE 229374.

Licea pusilla Schrad. [R, mc: 1, II: 1] b: 1; Loc.: 6; LE 229480.

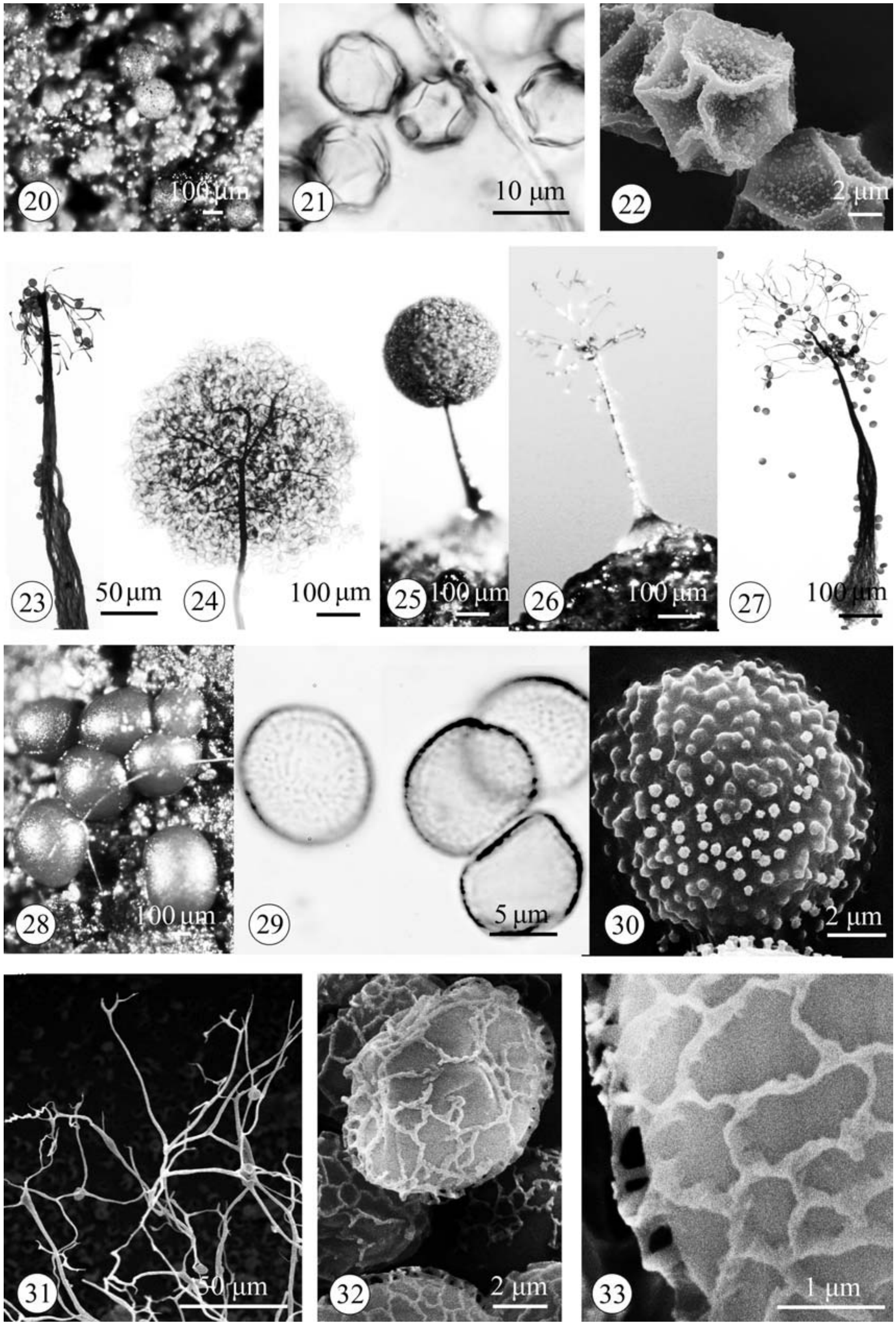
Licea tenera E. Jahn [LICten, O, mc: 7, I: 6, III: 1] b: 1, l: 5, d: 1; Loc.: 2, 4, 19; LE 229495. (Figs 17-19)

Licea testudinacea Nann.-Bremek. [LICtes, A, mc: 37, I: 7, II: 30] b: 34, l: 2, w: 1; Loc.: 6, 7, 8, 9, 15; LE 229290. (Figs 20-22).

Lycogala epidendrum (L.) Fr. [A, fc: 44, I: 43, II: 1] w: 44; Loc.: 1, 2, 3, 9, 14, 15, 17; LE 229311, KRAS 294.

Lycogala flavofuscum (Ehrenb.) Rostaf. [R, fc: 1, I: 1] w: 1; Loc.: ?; KRAS 85.

Metatrichia vesparia (Batsch) Nann.-Bremek. ex G.W. Martin & Alexop. [O, mc: 1, fc: 5, I: 4, II: 2] w: 6; Loc.: 1, 8, 10, 12, 14, 17; LE 237022.



Figs 20-22. *Licea testudinacea* (LE229290). **20.** Sporocarps (DM) **21.** Detail of peridium (SEM). **22.** Spore (SEM). **Fig. 23.** *Paradiacheopsis fimbriata* (LE 229497). Sporocarp (TL). **Fig. 24.** *Paradiacheopsis rigida* (LE 229498), sporocarp (TL). **Figs 25-27.** *Paradiacheopsis solitaria* (LE 229300). **25.** Sporocarp (DM). **26.** Sporocarp (DM) without spores. **27.** Sporocarp (TL). **Figs 28-30.** *Perichaena liceoides* (LE 229489). **28.** Sporocarps (DM). **29.** Spores (TL). **30.** Spore (SEM). **Figs 31-33.** *Symphytocarpus amaurochaetoides* (LE 229354). **31.** Capillitium (SEM). **32.** Spore (SEM). **33.** Detail of spore ornamentation (SEM).

Mucilago crustacea F.H. Wigg. [R, fc: 1, I: 1] w: 1; Loc.: 14; LE 229500.

Paradiacheopsis fimbriata (G. Lister & Cran.) Hertel ex Nann.-Bremek. [PARfim, C, mc: 26, I: 26] b: 26; Loc.: 15; LE 229497. (Fig. 23).

Paradiacheopsis rigida (Brândză) Nann.-Bremek. [R, mc: 1, II: 1] w: 1; Loc.: 9; LE 229498. (Fig. 24).

Paradiacheopsis solitaria (Nann.-Bremek.) Nann.-Bremek. [PARsol, A, mc: 70, I: 4, II: 66] b: 70; Loc.: 6, 7, 8, 9, 15; LE 229300. (Figs 25-27).

Perichaena chrysosperma (Curr.) Lister [PERchr, O, mc: 11, I: 1, II: 10] l: 9, w: 2; Loc.: 4, 7, 8, 10; LE 229235.

Perichaena corticalis (Batsch) Rostaf. [R, mc: 1, II: 1] w: 1; Loc.: 10; LE 229309.

Perichaena depressa Lib. [R, mc: 3, II: 2, III: 1] b: 1, l: 2; Loc.: 6, 10, 19; LE 229490.

Perichaena liceoides Rostaf. [R, mc: 4, III: 4] d: 4; Loc.: 19; LE 229489. (Figs 28-30).

Notes: This represents the only species collected exclusively on dung from the reserve.

Perichaena vermicularis (Schwein.) Rostaf. [PERver, C, mc: 16, I: 4, II: 1, III: 11] b: 2, l: 14; Loc.: 1, 5, 10, 19; LE 229202.

Physarum album (Bull.) Chevall. (= *Physarum nutans* Pers.) [PHYalu, A, mc: 10, fc: 35, I: 44, II: 1] b: 9, l: 1, w: 31; Loc.: 1, 3, 4, 6, 12, 13, 14, 15, 16, 17; LE 229441.

Physarum auriscalpium Cooke [R, mc: 2, I: 2] l: 1, w: 1; Loc.: 3; LE 234049.

Physarum bethelii T. Macbr. ex G. Lister [R, fc: 1, I: 1] w: 1; Loc.: 16; LE 229249.

Physarum bivalve Pers. [PHYbiv, O, mc: 5, I: 5] b: 1, l: 4; Loc.: 3, 4; LE 229492.

Physarum conglomeratum (Fr.) Rostaf. [R, fc: 1, II: 1] w: 1; Loc.: 10; LE 237037.

Physarum decipiens M.A. Curtis [R, mc: 4, I: 2, III: 2] b: 3, l: 1; Loc.: 3, 4, 19; LE 229221.

Physarum flavicomum Berk. [O, fc: 6, I: 6] w: 6; Loc.: 13, 14, 15, 16; LE 229228.

Physarum globuliferum (Bull.) Pers. [R, mc: 1, I: 1] l: 1; Loc.: 4; LE 229432.

Physarum leucophaeum Fr. [R, fc: 2, I: 2] w: 2; Loc.: 12; LE 229389.

Physarum notabile T. Macbr. [PHYnot, O, mc: 5, fc: 3, I: 8] b: 4, l: 1, w: 3; Loc.: 4, 12, 14, 15; LE 229331.

Physarum penetrale Rex [R, fc: 2, I: 2] w: 2; Loc.: 12, 16; LE 229377.

Notes: This collection is the first known for Russia. The distinguishing characteristic of this species is the dull yellow, non-calcareous stalk, acuminate (or sometimes enlarged at the tip) columella that is a continuation of the stalk.

Physarum psittacinum Ditmar [O, fc: 5, II: 5] w: 2; Loc.: 7, 8; LE 237041.

Physarum pusillum (Berk. & M.A. Curtis) G. Lister [R, mc: 1, II: 1] b: 1; Loc.: 6; LE 229298.

Physarum rubiginosum Fr. [R, fc: 1, I: 1]; Loc.: 18; LE 229239.

Notes: Our collection consists of a single specimen collected from the field on living mosses. This specimen exhibits the set of typical characters for this species. These are the orange-red subglobose sporotheca up to 0.8 mm diam. and the numerous small reddish nodes of capillitium.

Physarum sulphureum Alb. & Schwein. [R, fc: 1, I: 1] w: 1; Loc.: 16; LE 229247.

Physarum vernum Sommerf. [R, mc: 3, fc: 1, I: 1, II: 3] w: 3; Loc.: 6, 12; LE 229488.

Physarum virescens Ditmar [R, fc: 1, I: 1] w: 1; Loc.: 12; LE 229378.

Physarum viride (Bull.) Pers. [O, fc: 9, I: 8, II: 1] w: 9; Loc.: 7, 14, 15, 16; LE 229487.

Reticularia intermedia Nann.-Bremek. [R, fc: 1, I: 1] w: 1; Loc.: 14; LE 229219.

Reticularia splendens Morgan [R, fc: 2, I: 2] w: 2; Loc.: 1; LE 237057, KRAS 298.

Stemonitis axifera (Bull.) T. Macbr. [C, fc: 18, I: 14, II: 4] w: 18; Loc.: 1, 2, 3, 6, 7, 12, 13, 14, 15, 16, 17; LE 229451, KRAS 213.

Stemonitis flavogenita E. Jahn [R, fc: 1, I: 1] w: 1; Loc.: 14; LE 229387.

Stemonitis fusca Roth [O, mc: 2, fc: 12, I: 9, II: 5] w: 14; Loc.: 6, 8, 10, 12, 15, 16, 17; LE 237006.

Stemonitis herbatica Peck [R, mc: 1, II: 1] w: 1; Loc.: 6; LE 237062.

Stemonitis pallida Wingate [STEpal, O, mc: 3, fc: 3, I: 4, II: 2] l: 3, w: 3; Loc.: 2, 7, 10, 12; LE 229415.

Stemonitis smithii T. Macbr. [R, fc: 3, I: 3] w: 3; Loc.: 12, 15; LE 237064.

Stemonitis splendens Rostaf. [R, fc: 2, I: 2] w: 2; Loc.: 4, 15; LE 229363.

Stemonitopsis hyperopta (Meyl.) Nann.-Bremek. [R, fc: 1, I: 1] w: 1; Loc.: 17; LE 229360.

Stemonitopsis typhina (F.H.Wigg.) Nann.-Bremek. [O, fc: 5, I: 1, II: 4] w: 5; Loc.: 6, 8, 16; LE 237000.

Symphytocarpus amaurochaetoides Nann.-Bremek. [R, fc: 1, I: 1]; Loc.: 1; LE 229354.

Notes: This collection represents the first report from Russia. The single specimen was collected in the field on the hymenophore of *Fomes fomentarius* at a height of 2 m. The thick and dark capillitial threads that form a wide-meshed reticulum with some expanded axils and with short stiff free ends at the periphery represent a distinguishing feature of this species (Fig. 31). The reticuloid spore ornamentation is the other typical characteristic of this species. (Figs 32, 33).

Symphytocarpus flaccidus (Lister) Ing & Nann.-Bremek. [R, fc: 2, I: 2] w: 2; Loc.: 12, 13; LE 229387.

Trichia botrytis (J.F. Gmel.) Pers. [TRIbot, C, mc: 15, fc: 1, I: 12, II: 4] l: 15, w: 1; Loc.: 2, 3, 4, 7, 8, 9, 15; LE 229225.

Trichia contorta (Ditmar) Rostaf. [R, mc: 1, III: 1] b: 1; Loc.: 19; LE 237065.

Trichia decipiens (Pers.) T. Macbr. [TRIdec, O, mc: 2, fc: 8, I: 7, II: 3] l: 2, w: 8; Loc.: 1, 6, 9, 15, 16; LE 229401, KRAS 295.

Trichia favoginea (Batsch) Pers. [R, fc: 3, I: 3] w: 2; Loc.: 12, 15; LE 229319, KRAS 98.

Trichia flavicoma (Lister) Ing [TRIfla, O, mc: 5, I: 4, II: 1] l: 5; Loc.: 7, 15; LE 237066.

Trichia floriformis (Schwein.) G. Lister [R, fc: 1, I: 1] w: 1; Loc.: 4; LE 229463.

Trichia scabra Rostaf. [R, fc: 3, II: 3] w: 3; Loc.: 10; LE 237027.

Trichia subfusca Rex [R, fc: 1, I: 1] w: 1; Loc.: 17; LE 237067.

Trichia varia (Pers. ex J.F. Gmel.) Pers. [R, fc: 1, I: 1] w: 1; Loc.: 1; LE 229210.

Trichia verrucosa Berk. [R, fc: 2, I: 2] w: 2; Loc.: 1; LE 229491, KRAS 230.

Tubulifera arachnoidea Jacq. [O, fc: 9, I: 9] w: 9; Loc.: 12, 14, 15, 17; LE 237068.

Willkommlangea reticulata (Alb. & Schwein.) Kuntze [R, fc: 2, I: 2] w: 2; Loc.: 1, 16; LE 229411.

Discussion

The species list given above was compiled from 977 records of myxomycetes. Of these, 371 were collected in the field, whereas the other 606 records were obtained from 953 moist chamber cultures. In total, 123 species representing 33 genera were identified. This figure is high when compared to other studies in temperate (Lado *et al*., 2007) and tropical regions (Novozhilov *et al*., 2001; Schnittler *et al*., 2002; Lado *et al*., 2003; Tran *et al*., 2006). Seventy-six species were collected in the field and 65 species were recorded in moist chamber cultures. Fifty-nine species in 24 genera were recorded only in the field and 47 species in 15 genera were obtained only from moist chamber cultures. Eighteen species in 11 genera were collected in both the field and from moist chamber cultures.

Records from the field and from moist chamber cultures largely complemented each other (Fig. 34). Seventy-nine species were found to be rare (< 0.5 % of all records) for our study area, eleven species were common (> 1.5-3 % of all records), while *Arcyria cinerea*, *Cribraria cancellata*, *Didymium difforme*, *Echinostelium minutum*, *Hemitrichia pardina*, *Licea testudinacea*, *Lycogala epidendrum*, *Paradiacheopsis solitaria* and *Physarum album* were determined to be abundant (>3 % of all records). Among the species determined to be common, *D. difforme*, *E. minutum, H. pardina* and *L. testudinacea* were observed exclusively from moist chamber cultures. Three species (*E. fragile, Physarum penetrale* and *Symphytocarpus amaurochaetoides*) were new for Russia, and 90 species were new for the Krasnoyarsk territory.

One of the methodological aims was to generate a relatively unbiased data set of the abundances of all myxomycete species to estimate the degree of completeness of this survey so as to compare these results with other datasets from other well studied regions.

Completeness of survey

A regression analysis utilizing a simple saturation hyperbolic function and bootstrap analysis provided an estimate that 77 species were to be expected from the moist chamber cultures (Fig. 35). In comparing the actual numbers of species recovered to the estimations obtained by the bootstrap method, the survey was determined to have recovered 84% of all species predicted for moist chamber cultures, 85% for bark, 65% for litter, 50% for wood, and 33% for dung-inhabiting species. Twenty-two of the 65 species recorded from moist chamber cultures each represented more than 1.5% of a total number of records and were included in a canonical correspondence analysis to assess the relative importance of substrate types on the myxomycete assemblages (Figs 36, 37). Many species, especially common litter-inhabiting species, were found in both moist chamber cultures and in the field, providing evidence that moist chamber cultures do reflect the myxomycete assemblages actually occurring in a region. The moist chamber cultures prepared with litter had a high proportion (71 of 534 records or 13%) of plasmodia that failed to produce sporocarps during the three months that the cultures were maintained.

These data suggest that the number of moist chamber cultures utilized was sufficient to recover all of the more common species occurring on bark and litter but insufficient for the wood and dung substrates. The seasonality associated with the fructification of various myxomycete species poses a problem that can be addressed only with repeated surveys. This factor is very important in the boreal and temperate forests, where there are pronounced environmental differences throughout the year. Due to the logistical problems associated with visiting our study sites throughout the year, the myxomycete species that develop fruiting bodies in the late autumn were not been estimated in the present study. Another source of error contributing to the underestimation of species richness was the insufficient number of moist chamber cultures prepared from wood and dung substrates. We plan to address these sources of error with future investigations.

Substrate-species relationships

Both species richness and diversity varied considerably within groups of substrates and decreased from coarse woody debris (85 species, H' = 3.73) and litter (45 species, H' = 3.06), to the bark of living plants (36 species, H' = 2.76) and dung (3 species, 0.87). The observed trend was different when we considered records obtained only from moist chamber cultures: litter (39 species, H' = 2.96), bark of living plants (34 species, H' = 2.72), wood coarse debris (20 species, H' = 2.69) and dung (3 species, 0.87). This result indicates that utilizing the moist chamber technique in the absence of field surveys underestimates the diversity of the myxomycete assemblages with respect to coarse woody debris in boreal forests.

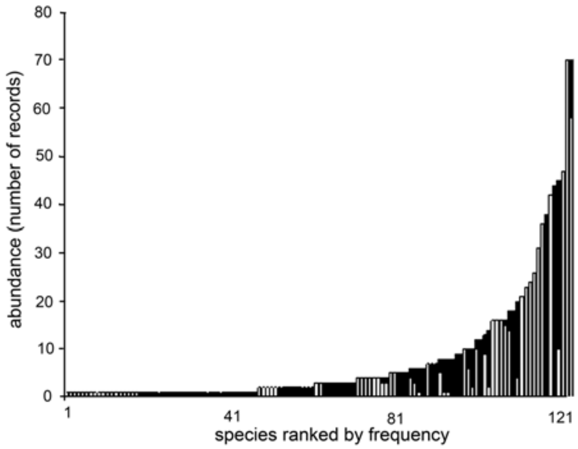


Fig. 34. Frequency distribution of all 977 records of myxomycetes (records from the field and from moist chamber cultures) for the state reserve "Stolby". Black sectors of bars represent field observations, gray sectors indicate records collected only from moist chamber cultures.

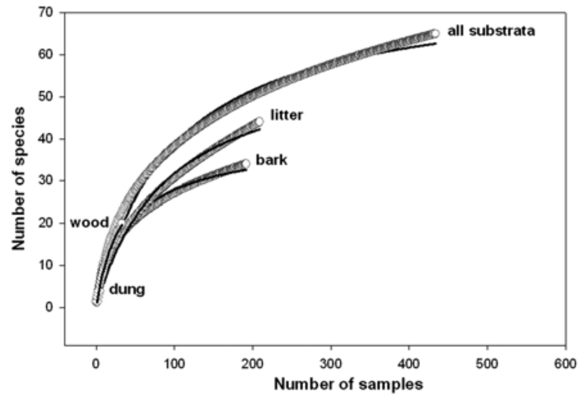


Fig. 35. Species accumulation curves of samples versus cumulated species numbers (circles). Solid lines show the results of regression analysis using a saturation function *y=Ax/(B + x)*, where *A* is the maximum number of species to be expected and *B* is the number of samples needed to reach half of the number of species to be expected.

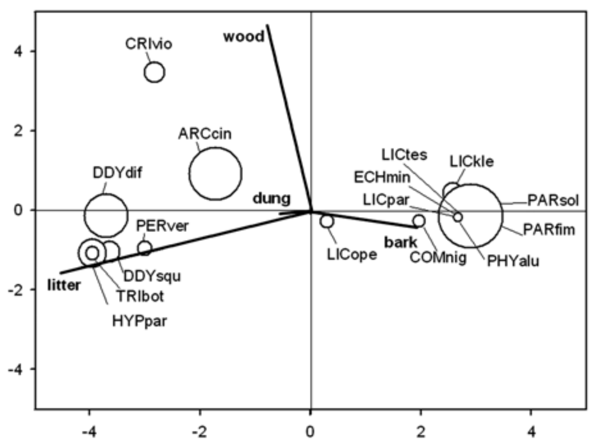


Fig. 36. Biplot of a canonical correspondence analysis (CCA) computed for the occurrences of the 16 common species (> 1.5-3% of 977 records) of myxomycetes collected on four different classes of substrates in moist chamber cultures. The size of each circle is proportional to the frequency of the respective species. Abbreviations for species are indicated in the annotated species list.

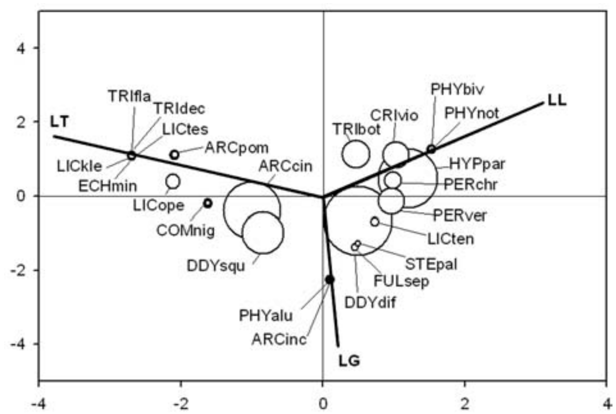


Fig. 37. Biplot of a canonical correspondence analysis (CCA) computed for occurrences of the 23 common species (> 1.5-3% of 977 records) of myxomycetes collected on three different subclasses of litter from moist chamber cultures. The size of each circle is proportional to the frequency of the respective species. Abbreviations for species are indicated in the annotated species list; LL = leaf litter, LG = litter of grasses, LT = needle litter and small coniferous twigs.

The mean value for the number of species per moist chamber culture revealed the same trend (Table 1). The number of dominant species classified as abundant (>3% of the 977 records) was rather low, these nine species represent 45% of all records in the present survey (Fig. 34). The species specificity increased from bark (21 species) to litter (36 species) to woody debris (61 species). The canonical correspondence analysis (CCA, Fig. 36) revealed three distinctive ecological groups of myxomycetes. The most abundant corticolous species were *Licea kleistobolus* (22 records of 317 registered on bark), *Paradiacheopsis fimbriata* (26), *L. testudinacea* (34), *Echinostelium minutum* (38) and *P. solitaria* (70). Only *Leocarpus fragilis* and *Arcyria insignis* (3 records) were found in field on the bark of living trees. The dominant litter-inhabiting forms were species of *Perichaena vermicularis* (14 records of 252 registered on litter), *Trichia botrytis* (15), *Didymium squamulosum* (22), *Hemitrichia*

Table 1. Statistical data for the assemblages of myxomycetes recorded from different vegetation types across the state reserve "Stolby" (south-eastern Siberia, Russia).

	Mc	PMc	S/Mc ± SE	R		S		G		S/G	H´
				mc	Fc	mc	fc	mc	fc		
I	540	54	0.54 ± 0.03	284	324	42	71	17/31	26/31	3.03	3.911
II	290	56	0.92 ± 0.06	266	46	37	24	15/20	13/20	3.06	3.152
III	123	50	0.45 ± 0.06	56	-	16	-	9/9	-	1.78	2.185
All study area	953	54	0.64 ± 0.03	606	371	65	76	13/33	27/33	3.73	4.004
B	307	67	1.03 ± 0.06	314	3	34	2	13/14	2/14	2.57	2.763
CWDC	53	38	0.43 ± 0.10	22	235	14	46	3/21	20/21	2.76	3.297
CWDD	54	28	0.37 ± 0.1	16	113	7	52	3/20	6/20	2.8	3.717
LG	142	59	0.64 ± 0.05	92	1	25	1	13/14	1/14	1.86	2.830
LL	241	48	0.39 ± 0.04	93	4	19	4	11/13	2/13	1.77	2.514
LT	151	40	0.41 ± 0.05	59	2	19	2	11/11	-	1.9	2.741
D	5	80	1.2 ± 0.37	6	-	3	-	3	-	1	-
Mosses	-	-	-	-	11	-	6	-	3	2	-
Fungi	-	-	-	-	1	-	1	-	1	1	-

Notes: I = light coniferous forest; II = dark coniferous forest; III = steppe; B = bark of living trees; CWDC = coarse woody debris of coniferous trees; CWDD = coarse woody debris of deciduous trees; LG = litter of grasses; LT = litter of coniferous needles and small twigs; LL = leaf litter, D = dung of herbivorous animals; Mc = number of moist chamber cultures; PMc = proportion of positive cultures (%); R = number of records, excluding non-fruiting plasmodia; S/Mc = mean number species per culture ± SE; S = number of species; G = number of genera, in denominator the total number for group is given; S/G = species/genus ratio, calculated for all records; H´ = Shannon's diversity index.

pardina (31) and *Didymium difforme* (36).

The species composition of litter was relatively distinct (Fig. 37), with the most specific myxomycete assemblage occurring on the leaf litter (needles) of conifers. This group of species included typical litter-inhabitants such as *Trichia flavicoma* (4 records of the 61 records), and some common lignicolous species which are known to tolerate a wide range of ecological amplitude and can sometimes utilize litter, such as *Arcyria cinerea* (12), *A. pomiformis* (3), *Echinostelium minutum* (4), *Licea operculata* (3), *Trichia botrytis* (7) and *Trichia decipiens* (2). Another typical lignicolous species (*Fuligo septica*) was found three times on grass litter.

Wood-inhabiting (lignicolous) myxomycetes represented the largest myxomycete assemblage in the reserve. In general, these species were only encountered in the field on coarse woody debris (CWD) and a few ubiquitous species are known to commonly occur in moist chamber cultures such as; *Arcyria cinerea* (6 records of the 57 records) and *Cribraria violacea* (6 records of the 22 records). Myxomycete richness and diversity were found to differ between the coarse woody debris of conifers (CWDC) and the coarse woody debris of deciduous trees (CWDD). Species richness was similar between CWDC (58 species of the 258 records) and CWDD (56 species of the 131 records). Species diversity (Shannon's diversity index H') was slightly different between these groups; 3.30 for CWDC and 3.71 for CWDD. The number of species found in moist chamber cultures from CWDC and CWDD revealed a more distinct difference. Fifteen species were recovered from CWDC, while only seven species were recovered from CWDD. In contrast, 45 species were recorded on CWDC and 51 on CWDD in the field. The dominant lignicolous species (>3 % of the total records) were found to exhibit a different frequency of occurence between CWDC and CWDD in the field. On CWDC dominants were, *Cribraria cancellata* (35 specimens on CWDC and only two specimens on CWDD), *Lycogala epidendrum* (30/4), *Physarum album* (23/7) and *Fuligo septica* (12/3). The dominant species on CWDD in the field was *Arcyria cinerea* (0/12), while in the moist chamber culture it was *Didymium difforme* (0/7).

Due to the insufficient number of culturees prepared from dung, the preference of myxomycetes with respect to this substrate was not determined across the reserve. Only one species (*Perichaena liceoides*) was found exclusively on dung in moist chamber cultures. Typically, this species forms fruiting bodies in moist chamber cultures after 30-40 days.

Table 2. Pairwise comparisons of myxomycete biotas among four taiga and five treeless, arid study regions. The total numbers of all specimens observed in the field as well as in moist chamber cultures were used for the calculation of the adjusted incidence-based Chao-SØerensen similarity index. Both the similarity index (upper right) and number of species shared (lower left) are given.

	KA	LE	SV	ST	MO	MP	CP	CL	CH
KA	-	0.830	0.770	0.770	0.284	0.204	0.264	0.388	0.197
LE	92	-	0.840	0.800	0.202	0.139	0.184	0.376	0.130
SV	72	91	-	0.840	0.127	0.084	0.105	0.347	0.104
ST	72	83	85	-	0.320	0.281	0.235	0.441	0.168
MO	13	13	11	14	-	0.730	0.568	0.654	0.192
MP	9	12	9	11	10	-	0.530	0.675	0.139
CP	11	12	9	8	9	7	-	0.556	0.320
CL	27	35	27	30	18	16	15	-	0.179
CH	11	11	11	13	7	4	3	9	-

Notes: Study regions are abbreviated as KA = Russian northern Karelia (Schnittler and Novozhilov, 1996); LE = Leningrad region (Novozhilov, 1980; 1999); SV = Sverdlovsk region (Novozhilov and Fefelov, 2000); ST = this study (reserve "Stolby"); MO = depression of the Great Lakes (western Mongolia) (Novozhilov and Schnittler, in review); MP = Mangyshlak peninsula, treeless desert zonal communities (Schnittler and Novozhilov, 2000; Schnittler, 2001); CP = Colorado Plateau, sagebrush communities with *Artemisia tridentata* (Novozhilov *et al*., 2003); CL = Caspian Lowland, treeless zonal dry steppe and desert communities (Novozhilov *et al*., 2006); CH = arid areas of Chile (Lado *et al*., 2006).

Surprisingly, in our survey the first plasmodia were observed after 7 days and the first matured sporocarps were recorded after 14-20 days of culturing (Figs 28-30).

Distribution patterns of myxomycetes within vegetation types of the state reserve "Stolby"

Overall, the myxomycete diversity and species richness from the reserve "Stolby" were found to be relatively high (H´ = 4.00, 123 species). Considering the species observed in the field and in those recovered from moist chamber cultures, the alpha-diversity and species richness, in both cases, increased significantly (Table 1) across the steppe over light coniferous forest (LCF) to dark coniferous forest (DCF). Additionally, the species/genus (S/G) ratio was rather low in the steppe community (1.78) when compared with those calculated for the myxomycete biotas of LCF and DCF, where the S/G values ranged from 3.03 and 3.06, respectively (Table 1).

As would be expected, many corticolous and lignicolous myxomycetes were found predominantly on the bark surface of living trees and coarse woody debris in the taiga communities. However, several lignicolous species were able utilize other microhabitats within the steppe vegetation, therefore increaseing the total species richness in the steppe portion of the reserve up to 16 species. Examples for this are *Cribraria violacea* and *Physarum decipiens*, which were found on grass litter. Interestingly, *Badhamia apiculo-spora*, which was found only once in the reserve "Stolby" (on a southern steppe slope on grass litter), was recently reported from the dry steppe and desert regions of Russia, Kazakh-stan and Mongolia (Novozhilov *et al*. 2006; Novozhilov and Schnittler, 2008). This observa-tion may support our hypothesis that the distributional peak for this species in Eurasia is associated with arid regions. Despite the difference in the number of moist chamber cultures prepared with substrata from LCF and DCF, we could not detect a noticeable difference in species richness between these two types of taiga (42 species of 17 genera in LCF and 37 species of 15 genera in DCF). The similarity between myxomycete biotas of these vegetation types was also very high (Chao-SØerensen similarity index is 0.96). In contrast, the relatively low average value (0.48) of similarity between the myxomycete biotas of the taiga forests and the steppe communities reflects a high level of dissimilarity with respect to the myxomycete biotas between these vegetation types within the reserve.

Myxomycete biota of the reserve "Stolby" in comparison with other taiga myxomycete biotas in Russia and those from treeless arid regions of the World

A comparison based on the adjusted incidence-based Chao-SØerensen similarity index Cs (Table 2) revealed that the myxomycete biota of the reserve "Stolby" exhibited a considerable similarity to the myxomycete biotas of other taiga regions of Russia (average value of Cs = 0.81 ± 0.01). In contrast, the average value (Cs = 0.29 ± 0.04) of similarity between the myxomycete biota of the reserve and other arid regions including the temperate and warm deserts of western North America (Novozhilov *et al*., 2003) and South America (Lado *et al*., 2006) revealed a high level of dissimilarity among the myxomycete biotas of the reserve and the biotas of these arid regions. The majority of the species recovered from the reserve exhibited polyzonal areas and were widely distributed. Sixteen of the 20 common species recorded in this study were also reported from four well studied taiga regions in Russia (Table 2) and can be regarded as regularly occurring in the taiga zone.

Prominent examples include most of the reported species of *Trichia*, which included 10 species from the reserve. The boreal zone is relatively rich in members of the *Trichiaceae* (29 species of the total 52 species known in the taiga zone of Russia), while members of the *Physaraceae* are relatively depauperate (24 species of the total known 62 species). One explanation for this phenomenon may be the dominance of coniferous woodlands in the reserve that supply a large amount of CWDC that represents a suitable substrate for the *Trichiaceae*. This pattern has also been observed in other well studied coniferous communities of the taiga zone throughout Russia. In addition, many species of the Trichiales develop on CWDD and litter. For the ten species of *Trichia* recorded in the present study, two species (*Trichia botrytis* and *T. flavicoma*) exhibited a preference for litter substrates, while the other eight were typically wood inhabitants.

As was expected, a hierarchical cluster analysis based on Cs values revealed that the myxomycete biotas of the taiga regions were most similar to one another, forming a homogenous cluster that also included the biotas from other well studied regions in boreal zone of Russia. These boreal zone biotas formed a distinct cluster away from the biotas associated with arid regions (Fig. 38) emphasizing the distinct assemblages of myomycetes associated with each ecological region.

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