New data on Myxomycetes of Lazovsky State Nature Reserve (Far East, Russia)

Vladimir I. Gmoshinskiy 1*, Fedor M. Bortnikov 1, Andrey V. Matveev 1 & Yuri K. Novozhilov 2

ABSTRACT

We summarize all available data on the diversity of myxomycetes of the Lazovsky Nature Reserve and its surroundings, including 494 newly collected specimens. Myxomycete biota of the Lazovsky Nature Reserve consists of 90 species. Fifteen species were added to the checklist of myxomycetes from Primorye Territory. Two rare species, Stemonitis marjana Y. Yamam. and Clastoderma pachypus Nann.-Bremek., are illustrated and discussed.

Keywords: Amoebozoa, biodiversity, checklist, Primorye Territory, Myxomycetes, rare species

INTRODUCTION

Myxomycetes are a group of plasmodial slime molds included in Amoebozoa (Adl et al. 2019). Their life cycle combines three stages: mononuclear phase (amoeboid or flagellated), multinuclear phase (plasmodium), and fruiting bodies (sporophores) that contain spores. They live in almost all terrestrial ecosystems and are particularly abundant in temperate and tropical forests (Novozhilov et al. 2017a). Myxomycete diversity in Russia has been unevenly studied. Over 420 species of myxomycetes are reported for Russia (Matveev et al. 2016–2019). Despite the fact that over 187 species were found in the Far East, this region remains understudied. There was only one regular research on species diversity of myxomycetes in Russia (Novozhilov et al. 2017b). In addition, one local species inventory was compiled in Ussuriysky State Nature Reserve, Kedrovaya Pad’ Nature Reserve, and the vicinity of the city of Vladivostok (Bunkina & Koval 1967, Bunkina & Nazarova 1978). The only study of myxomycetes in Lazovsky State Nature Reserve was performed by Novozhilov & Krusanova in 1986. They studied nullah of Benevka (Sandagou) River, where broad-leaved and mixed broad-leaved forests are predominant, and the vicinity of Preobrazeniye urban locality, where oak forests are predominant. In this study, 33 species from 17 genera and 7 families were discovered (Novozhilov & Krusanova 1989). In 2015, Antonov collected about 60 specimens near Valentine and Lazo settlements and Oblachnaya mountain (Gmoshinskiy & Antonov 2016). The results of previously studies are included in this checklist.

Lazovsky State Nature Reserve (hereinafter referred to as Lazovsky Nature Reserve) is located on the southeastern slopes of the Sikhote-Alin mountain range, down towards the coast of the Sea of Japan, located within Lazovsky district of Primorye Territory (Russian Far East) between 42°45’ and 43°40’N and 133°35’ and 134°15’E. The reserve occupies an area of 1210 km², including small Petrov and Beltsov islands (1370 km² including its partly protected buffer zone).

The general features of the climate of the reserve are determined by the proximity of the sea; however, there are significant climatic contrasts on its territory due to the Zapovedny Ridge acting as a barrier to air masses. The winter is cold in northern part of the reserve. The mean temperature in January is from -19 to -20°C. Snow normally covers the ground in the end of October or in the first part of November and reaches a depth 50–60 cm. The spring starts in the second part of March. The summer is warm, mean temperature of July and August is 19–20°C. First frosts are observed from the first half of September. The mean annual precipitation is 700–800 mm. On seaside of reserve the winter is not so cold. The mean temperature of January ranges from -11 to -12°C, temperature minimum -30°C. In the sea-faced part of
the reserve, spring starts earlier, but temperature increases not as fast as in the continental part. Cool and humid summers with frequent fogs are determined by the influence of the sea cooling during the winter. The mean August temperature is 16–18°C; the annual precipitation is 750–850 mm and can reach 1000–1200 mm in some years. Typhoons have been observed from the second half of August, when monthly precipitation falls during the day. The soil cover is represented by brown forest soils (Vasilyev et al. 1985).

The reserve is 95% forested, including the largest yew grove (Taxis cuspidata Siebold et Zucc.) in Russia on Petrov island. The most widespread forests are Quercus mongolica Fisch. ex Turcz. dominated forests, mixed broadleaf-Korean pine forests (with Pinus koraiensis Siebold et Zucc.), fir-spruce, birch, and aspen forests. Broadleaved forests are located in the valleys of the rivers. Riparian forests of Chosenia arbutifolia (Pall.) A.K. Skvortsov and species of Salix are situated in the thin band along the river path. Populus maximowiczii are occupied by alder forests. Upper timberline is partially mined and photographed with a JEOL JSM-6380LA scanning electron microscope.

We used classification proposed by Lado & Eliasson (2017) and terms for taxonomic descriptions according to Lado & Pando (1997) and Poulain et al. (2011a).

List of collection sites

Collection sites studied in 2016

1: Petrov Island, grove of Taxis cuspidata, 42.86578°N 133.80510°E (21.06; 29.06; 07.07).

2–3: Petrov Island. Mixed forest. 2: 42.86345°N 133.80544°E (21.06; 07.07); 3: 42.86572°N 133.80802°E (04.07).

4: 12; 23–34: Mongolian oak forest (Quercus mongolica), 4: 42.87667°N 133.78458°E (09.07); 12: 42.87683°N 133.79358°E (29.06); 23: 42.87461°N 133.79922°E (15.06); 24: 42.87767°N 133.79908°E (21.06); 25: 42.87683°N 133.80003°E (04.07); 26: 42.87575°N 133.80450°E (02.07); 27: 42.87725°N 133.80628°E (28.06); 28: 42.87399°N 133.80514°E (30.06); 29: 42.87978°N 133.80269°E (02.07); 30: 42.89375°N 133.82644°E (13.06); 31: 42.89519°N 133.82753°E (20.06); 32: 42.89408°N 133.83003°E (13.06); 33: 42.89267°N 133.83017°E (20.06); 34: 42.89982°N 133.84883°E (13.06).

5–11; 13; 18–22; 35–40: forest with Alnus, Populus, Fraxinus, Betula, Carpinus, and Acer. 5: 42.87533°N 133.78492°E (07.06); 6: 42.87636°N 133.79911°E (06.07); 7: 42.87681°N 133.79089°E (06.07); 8: 42.87742°N 133.79100°E (06.06); 9: 42.87744°N 133.79142°E (06.06); 10: 42.87756°N 133.79250°E (22.06); 11: 42.87656°N 133.79244°E (22.06); 13: 42.87597°N 133.79442°E (07.06); 18: 42.87287°N 133.79317°E (17.06); 19: 42.87311°N 133.79353°E (17.06); 20: 42.87356°N 133.79553°E (15.06); 21: 42.87447°N 133.79651°E (17.06); 22: 42.87560°N 133.79644°E (07.06); 18.06; 19.06; 35: 42.89906°N 133.83042°E (14.06); 36: 42.88931°N 133.85208°E (10.07); 37: 42.88911°N 133.85531°E (14.06); 38: 42.89896°N 133.85817°E (14.06); 39: 42.90072°N 133.85844°E (13.06); 40: 42.90369°N 133.86025°E (14.06).

14: wood house, 42.87120°N 133.79318°E (07.06).

15: waterlogged area near ambit of cordon, 42.87169°N 133.79316°E (05.06; 13.06).

16–17: meadow at the cordon, 16: 42.87151°N 133.79444°E (05.06); 17: 42.87245°N 133.79447°E (12.06).

List of collection sites studied in 2015 (Gmoshinskiy & Antonov 2015)

41–42, 53, 55: Near Valentin locality: 41: 43.12572°N 134.28922°E (13.08); 42: 43.12533°N 134.28932°E (13.08); 53: 43.12422°N 134.31507°E (13.08); 55: 43.12671°N 134.29173°E (13.08).

43–46, 56: Near Lazo locality: 43: 43.37797°N 133.90797°E (15.08); 44: 43.36683°N 133.90677°E (15.08); 45: 43.37510°N 133.90882°E (15.08); 46: 43.37533°N 133.90897°E (15.08); 56: 43.37228°N 133.896738°E (15.08).

47–53: Oblachnaya Mountain. 47: 43.68536°N 134.29753°E (17.08); 48: 43.68118°N 134.21081°E (17.08); 49: 43.68341°N 134.29753°E (17.08).
134.20018°E (17.08); 50: 43.69190°N 134.19630°E (17.08); 51: 43.69808°N 134.20029°E (17.08).
54: South spur of Snezhnaya Mountain, 43.725587°N 134.43771°E (18.08).

List of collection sites, studied in 1986 (Novozhilov & Krusanova 1989).

L1–L3: Cordon Sandagou, Benevka river. L1: floodplain broad-leaved forest (01.10; 03.10); L2: pine-broad-leaved forest (29.09; 01–03.10; 08.10); L3: broad-lived forest (29.09; 01.10; 3.10).
L4: Near Preobrazheniye urban locality, oak forest (05.10; 09.10).

RESULTS

The following annotated checklist was compiled from our quantitative survey of 456 field specimens and 38 collections from moist chambers and literature data (Novozhilov & Krusanova 1989). The abbreviations for these data are given in Table 1.

†Arcyria affinis Rostaf., FC: 4; 4 (MYX 7153); 6: 4 (MYX 7193); 7: 2 (MYX 7209); 36: 1; 46: 1; 56: 1 (MYX 6367).
†Arcyria cinerea (Bull.) Pers., FC: 4; 2 (MYX 7152); 6: 4 (MYX 7192); 7: 3 (MYX 7215); 10: 1 (MYX 7238); 11: 1 (MYX 7251); 25: 7 (MYX 7324); 36: 2; 42: 1 (MYX 6368); 43: 1 (MYX 6370); 45: 1; 46: 2 (MYX 6365); 54: 2 (MYX 6382). MC: 1: 5 (MYX 8146, MYX 8147, MYX 8148, MYX 8149, MYX 8172).
†Arcyria denudata (L.) Wettst., FC: 6: 1 (MYX 7191); 27: 1; 36: 2; 41: 1 (MYX 6377).
†Arcyria ferruginea Saut., FC: 22: 1.
Arcyria incarnata (Pers. ex J.F. Gmel.) Pers., FC: 6: 1; 10: 1 (MYX 7239); 25: 2 (MYX 7321, MYX 7325); L1.
*Arcyria cf. magna Rex., FC: 1: 1 (MYX 7131); 22: 1.
*Arcyria oerstedii Rostaf., FC: I: 1 (MYX 7130).
†Arcyria pomiformis (Leers) Rostaf., FC: 4: 1 (MYX 7150); 7: 2 (MYX 7216); 25: 1; 50: 1. MC: 1: 2 (MYX 8166, MYX 8173).
Arcyria stipata (Schwein.) Lister, FC: L1.
*Badhamia affinis Rostaf., FC: 7: 1 (MYX 7227); 24: 1 (MYX 7310).

Badhamia capsulifera (Bull.) Berk., FC: 18: 1 (MYX 7274).
†Badhamia folicola Lister, FC: 20: 1 (MYX 7280).
†Badhamia utricularis (Bull.) Berk., FC: 23: 3 (MYX 7305, MYX 7306, MYX 7307). All specimens were found on fruiting bodies of polyporoid fungi.
†Calomyxa metallica (Berk.) Nieuwl., MC: 1: 1 (MYX 8174).
†Ceratyonia fruticulosa var. flexuosa (Lister) G. Lister, FC: 1: 1 (MYX 7135); 3: 1 (MYX 7141); 4: 3 (MYX 7148); 6: 4 (MYX 7184); 7: 5 (MYX 7206); 8: 1 (MYX 7230); 10: 6 (MYX 7234); 12: 2 (MYX 7259); 22: 1 (MYX 7287); 25: 2; 26: 2; 28: 2; 35: 1; 36: 1.
†Ceratyonia fruticulosa var. porioides (Alb et Schwein.) G. Lister, FC: 1: 1 (MYX 7132); 6: 1 (MYX 7185); 7: 4 (MYX 7205, MYX 7238); 10: 1 (MYX 7232); 11: 2 (MYX 7249); 12: 1 (MYX 7258).
Cladostereum debaryanum A. Blytt., FC: L1, L2, L4. MC: I: 1 (MYX 8175).

Table 1. Abbreviations used in the annotated species list

| Example | Data | Description |
|---------|------|-------------|
| †, *    | Status | The species marked with † or * are new records for Lazovsky Nature Reserve and Primorye Territory, respectively |
| Arcyria affinis | Taxon name | According to Lado (2005–2019), unless stated otherwise |
| Rostaf. | Author | |
| FC, MC | Sampling method | FC – field sampling; MC – moist chambers |
| 4 | Collection site | List of collection sites where the species was found (see list of collection sites and Fig. 1) |
| 4 | Record number | Number of records from this locality |
| (MYX 7153) | Specimen | Specimens from Collection of Myxomycetes at the Department of Mycology and Algology (Faculty of Biology, Lomonosov Moscow State University (MYX)). The absence of a herbarium number in the list means that the species was only registered and the specimen has not yet been placed in the herbarium |
Figure 2 Badhamia setispina (Bull.) Berk. (A, B): A – capillitium as seen by scanning electron microscope (SEM) with single spore of *Tubifera* sp., B – clustered spores (SEM); *Clastoderma pachypus* Nann.-Bremek. (C–F): C – sporocarp seen with light microscopy (LM), D – spores (LM), E – collar at the base of sporocyst (SEM), F – plate-like widening at the end of capillitium thread and spores (SEM). G – *Cribaria minutissima* Schwein., sporocarp (SEM). H – *Diderma saundersii* (Berk. et Broome ex Massee) E. Sheld., plasmodiocarp (dissecting microscope, DM). Bars: A = 20 μm, B = 10 μm, C = 50 μm, D = 15 μm, E, F = 3 μm, G = 100 μm, H = 2 mm
**Figure 3** *Hemitrichia abietina* (Wigand) G. Lister (A, B): A – capillitium as seen by SEM, B – spore (SEM); C – *Physarum tenerum* Rex., capillitium (SEM); *Stemonitis marjana* Y. Yamam. (D–G); D – group of sporocarps (dissecting microscope), E – surface net of capillitium (SEM), F, G – spores (SEM). Bars: A, C = 10 μm, B, F, G = 3 μm, D = 2 mm, E = 30 μm
Sporophores are stalked sporangia, scattered, dark-brown when moist and light-brown when dry, 0.15–0.3 mm high, sporangium up to 0.1 mm in diam. Peridium partly remains as a collar at the base after the upper portion has broken away. Hypothallus is absent or inconspicuous. Stalk long, occupying three-quarters of the total height of the sporophore, expanded at the base, translucent light-brown, contain refuse matter, tapering in upper part, in upper quarter is brown, translucent, lack granular material. Columnella short, is a prolongation of the stipe inside the sporangium, divided dichotomously, with the rami forming dicotomously, with plate-like widenings at the end, do not form close net. Spores in mass brown; light-violaceous in transmitted light, globose, uniformly thickened, 12.5–13.5 μm in diam., very finely and regularly warted. Plasmoidium hyaline or pale-brown.

Substrate: on bark of living Taxus cuspidata.

Comparisons with other species with similar morphology of sporophores has been made. C. pachyus has large sporangia, brown spore mass and stalk without the drop-like swelling. If closed net of capillitium is formed, then it is very similar to Echinostelium cribrarioides Alexop., but the latter has yellow spore mass. Clastoderma microcarpum (Meiy.) Cohn., in Cohn., 8167), black stalk base, more compact capillitium without free ends and expanded plates, and large spores (13.5–15 μm in diam.) (Kowalski 1975).

It is a rare species for Asian region and was previously reported only from East coast of China (Liu et al. 2013) and from eastern Tian-Shan (Schnittler et al. 2013). Our specimens consists of 4–6 mature sporocarps with dispersed spores. It has wide ends of capillitium threads and do not form a close net. Original differential diagnosis states that main differences between C. pachyus and C. de-baryanum are small size of sporangium, firm capillitium, and large spores (Nannenga-Bremekamp 1968).

The original description states: “Capillitium lax, violet-brown, consisting of a few, rather rigid, not anastomosing branches; the latter ramifying dichotomously, with the ramifications spreading at an almost right angle and ending at the periphery in the persistent flakes of the peridium”. Therefore, in the original description and illustration (Nannenga-Bremekamp 1968, fig. 3) there is no mention of a closed network of capillitium. However, later papers provides descriptions and illustrations of species with closed large-meshed net of capillitium on the periphery of sporangium (Mitchel 1978: fig. 28; Lado 1985: figs 3–5; Ing 1999: fig. 4; Poulain et al. 2011b: pl. 80). In addition, in some monographs, one of the main identifying features of this species is the presence of a closed peripheral network (Ing 1999, Poulain 2011a).

Interestingly, in some cases, the C. pachyus may have a partially closed capillitium, with a small number of free expanded, plate-like ends, and a practically closed peripheral net (Leontyev et al. 2011: fig. 2). Moreover, the specimens of C. pachyus from the hyperarid regions of China (Schnittler et al. 2013) have small size of sporangia, firm capillitium, and do not form a close net. Original differential diagnosis states that main differences between C. pachyus and C. de-baryanum are small size of sporangium, firm capillitium, and large spores (Nannenga-Bremekamp 1968).
**Stemonitis palida** Wingate, in Macbride., FC: 3: 1 (MYX 7142); 4: 1 (MYX 7157); 7: 3 (MYX 7221); 10: 1 (MYX 7245); 11: 1 (MYX 7255).

**Stemonitis splendens** Rostaf., FC: 1: 1 (MYX 7160); 6: 1 (MYX 7200); 7: 1 (MYX 7210); 10: 1 (MYX 7267).

**Stemonitopsis aequalis** (Peck) Y. Yamam., FC: 4: 1; 7: 1 (MYX 7211).

**Stemonitopsis gracilis** (G. Lister) Nann.-Bremek., FC: 1: 1 (MYX 7156).

**Stemonitopsis hyperopta** (Meyl.) Nann.-Bremek., FC: 1: 1 (MYX 7223); 10: 1 (MYX 7245); 25: 3 (MYX 7316); 28: 1; 47: 1.

**Trichia botrytis** (J.F. Gmel.) Pers., FC: 52: 1; L2.

**Trichia decipiens** (Pers.) T. Macbr., FC: 1: 1 (MYX 7217); 22: 3 (MYX 7280); L2.

**Trichia favoginea** (Batsch) Pers., FC: 2: 1 (MYX 7218); 7: 2 (MYX 7240); 10: 1 (MYX 7245); L1; 14: 1; L2.

**Trichia lutescens** (Lister) Lister, FC: 51: 1.

**Trichia persimilis** P. Karst., FC: 6: 1 (MYX 7195).

**Trichia scabra** Rostaf., FC: 10: 3 (MYX 7240); 22: 1 (MYX 7284); 30: 1.

**Trichia subfuscata** Rex., FC: 50: 1; 52: 1.

**Trichia varia** (Pers. ex J.F. Gmel.) Pers., FC: L2.

**Tabifera fergusina** (Batsch) J.F. Gmel., FC: 1: 1 (MYX 7149); 6: 2 (MYX 7180); 7: 4 (MYX 7208); 10: 1 (MYX 7237); L2.

**DISCUSSION**

In 2015–2016, 494 specimens were obtained for this study including 74 species and 6 varieties from 23 genera, 12 families, and 6 orders. Of these myxomycetes, 456 specimens (55 species) were collected in the field and 38 (23 species) were obtained from moist chamber cultures on substrates collected on Petrov Island. Only four species were simultaneously revealed by both of these methods. This confirms the need for their joint usage for comprehensive studies of Myxomycetes diversity.
Fifty seven species had not been reported from Lazovsky Nature Reserve before this study, and 15 species were described as new for Primorye Territory. One species, *Clastoderma pacchypus*, was recorded for the Russian Far East for the first time.

Substrates for the moist chambers cultures were collected only from Petrov Island, from *Tuscar cuspidata* grove. For this reason, only a part of species was revealed, that can be obtained by this method from studied area.

The sampling effort for the field collections were probably sufficient to recover all of the most common species (55 taxa from 457 records, 81 % complete according to the Chao2 estimator). The large majority (44 %) of taxa are rare, representing < 0.5 % of the total abundance (Stephenson et al. 1993). Only eight species are considered abundant, representing 3 % of the total abundance in field collections, including *Hemithrichia calyculata* (48 specimens/10.6 %), *Stemonitis acerifera* (47/10.4 %), *Ceratinocyca fruticulosa* (42/9.3 %), *Lycogala epidendrum* (40/8.8 %), *Conastrichia nigra* (35/7.7 %), *Archiea cinerea* (32/6.9 %), *Physarum viride* (16/3.5 %), and *Stemonitis phylina* (16/3.5 %). Together these eight taxa represent 60 % of the total abundance in field collections.

Consequently, taking into account the literature data (Novozhilov & Krussanova 1988), 90 species from 27 genera, 12 families, and all 6 orders were found on the territory of Lazovsky Nature Reserve and its buffer zone. These records bring the total number of Myxomycetes species reported from Primorye Territory to 187. This number indicates that currently, Primorye Territory (despite almost complete lack of regular studies, except for the Sikhote-Alin Nature Reserve) is one of the regions with the greatest myxomycetes species diversity, inhabited by approximately 43.5 % of all known species cited from Russia (Matveev et al. 2015–2019).

Only 16 previously found species (48 %) are recorded in this study again, three decades later. Such differences can be explained by the seasonality of the sporophore formation in these species: in 1986, studies were performed in late September – early October, while in 2015 and 2016, material was collected from mid June to mid August.

The majority of the species in our study belongs to the order Trichiales (26 species), Physarales (25), and Ste­monitidales (21). Fewer species were recorded in the order Crib­ariales (14). Only three species belong to Echinost­lariales, and a single species to Ceratiomyxales. For well-studied territories, the proportion of the species of Physarales is slightly higher than that from all other orders (Novozhilov & Fefelov 2001, Novozhilov et al. 2010, Vlasenko & Novozhilov 2011a, Gmoshinskiy 2013). On one hand, this is due to the large number of described species in Physar­ales, and on the other hand, some members of this order often have a pronounced seasonality in the formation of sporophores (Vlasenko & Novozhilov 2011b, Gmoshinskiy & Matveev 2016) and relatively fragile fruit bodies, which quickly collapse. At the same time, sporophores of *Trichia­les do not contain lime and remain relatively long in the field conditions. Thus, to obtain an exhaustive species list, research should be conducted during the entire vegetation period, from the moment when snow melts to the time when it falls. In addition, it is preferable that such work is performed during several field seasons, since the species diversity varies from year to year even within the same study area (Barsukova et al. 2012).

**CONCLUDING REMARKS**

The myxomycetes biota of Lazovsky Nature Reserve currently includes 90 species. However, it should be recognized that the species diversity of these organisms is far from being fully studied. When planning further research, special attention should be paid to the core of the reserve and the survey of the mountainous portion of the reserve. In this case, the collection of material should be carried out not only during summer but the whole snowless period. In the course of further research, extensive use of the moist chamber method is also essential, for which the main types of plant substrates should be selected.

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