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First data on Myxomycetes of Polistovsky Nature Reserve (Pskov Region)

V. I. Gmoshinskiy, A. V. Matveev

Lomonosov Moscow State University, Moscow, Russia
Corresponding author: V. I. Gmoshinskiy, rubisco@list.ru

Abstract. The first study of species diversity of myxomycetes in Polistovsky National Nature Reserve is presented. It is based on field collections. Sporophores were collected from 28 sites in September 2018. As a result of identification of 227 specimens, 54 species, 1 subspecies and 2 varieties belonging to 21 genera, 9 families, and 5 orders were recorded. Among them 36 species are new for the Pskov Region. Morphology of *Badhamia lilacina, Fuligo muscorum, Lycogala flavofuscum* and *Oligonema flavidum* is illustrated.

Keywords: Amoebozoa, biodiversity, slime molds, Pskov Region, Russia.

Первые данные о биоте миксомицетов государственного природного заповедника «Полистовский» (Псковская область)

В. И. Гмошинский, А. В. Матвеев

Московский государственный университет им. М. В. Ломоносова, Москва, Россия
Автор для переписки: В. И. Гмошинский, rubisco@list.ru

Резюме. Приведены результаты первого исследования видового разнообразия миксомицетов государственного природного заповедника «Полистовский». Сбор материала проводили в сентябре 2018 г. Собрано 227 образцов спорофоров, принадлежащих к 54 видам, 1 подвиду и 2 разновидностям миксомицетов, относящихся к 21 роду, 9 семействам, 5 порядкам. 36 видов впервые выявлены в Псковской области. Приведены иллюстрации морфологии спороношений *Badhamia lilacina, Fuligo muscorum, Lycogala flavofuscum* и *Oligonema flavidum*.

Ключевые слова: Amoebozoa, биоразнообразие, слизевики, Псковская область, Россия.

The species diversity of myxomycetes on the territory of the Pskov Region remains poorly studied (Jaczewski, 1907; Zhulidov *et al*., 2002; Novozhilov, 2005; Lebedev, Sinetenkova, 2013). As a result of previous studies, a species list was created comprising 38 currently recognized taxa (Matveev *et al*., 2016–2018). Jaczewski's monograph (1907) also contains data on myxomycetes from Luzhsky Uezd of Saint Petersburg Governorate based on Grimm's data (Grimm, 1896). A part of this territory is currently located in the Pskov Region. However, the material reported in the original article was collected around Siverskaya railway station (Tsarskoselsky Uezd), which nowadays is located in the Leningrad Region. Apparently, Jaczewski's monograph has

an inaccuracy in location reference for that study. Thus, species collected by Grimm were not taken into account while compiling the total species list of myxomycetes of the Pskov Region (Matveev *et al.*, 2016–2018).

Polistovsky Nature Reserve is located in Bezhanitsky and Loknyansky districts of the Pskov Region. It was established in 1994, simultaneously with Rdeysky Nature Reserve, which is located in the Novgorod Region and has extensional common border with Polistovsky Nature Reserve. The main goals of both nature reserves are protection and study of Polistovo-Lovatskaya raised bog system, which is situated in the southern part of the Priilmen Lowland on the watershed of the Polist and Lovat rivers (Yablokov *et al.*, 2006). It is one of the largest and best-preserved raised bog systems in Europe (Cherevichko, 2008).

The Priilmen Lowland is a flat lowland in the Western European Russia that descends in broad terraces to Lake Ilmen. The formation of the present-day basin of Lake Ilmen is associated with the degradation of the Valdai Ice Sheet and the emergence of periglacial lakes (Nosova *et al.*, 2017). As a result, 85.9% of the territory is represented by mires and only 11.5% by forests, mostly located on islands (Yablokov *et al.*, 2006). The climate of Polistovsky Reserve is moderately continental. The combination of climatic and geomorphological conditions in the area results in high humidity (Reshetnikova *et al.*, 2006; Nosova *et al.*, 2017).

The uplands that surround the Polistovo-Lovatskaya raised bog system and peatland islands located within the reserve boundaries are mainly occupied by small-leaved and mixed forests less than 70 years old, since nearly all areas suitable for agriculture were used as agricultural land and others were unprotected from felling earlier in the mid-twentieth century (Reshetnikova *et al.*, 2006; Nosova *et al.*, 2017).

Material and Methods

The present study is based on field collections performed according to the standard protocol (Wrigley de Basanta, Estrada-Torres, 2017). Sporophores were collected from twenty eight sites in September 2018 (Table 1). The collecting sites were established within representative examples of different types of forest communities. All sites are located in the Bezhanitsky District of the Pskov Region. Totally 227 specimens of sporophores of myxomycetes were collected.

The specimens were examined using light microscope techniques with Leica DM500 (with a ICC50 HD digital camera) and Leica M80 (with a Leica IC80 HD digital camera) optical microscopes. The sizes of spores, capillitium, and sporophores were calculated by Leica Application Suite ver. 3.0.0 and ImageJ ver. 1.52a. The microscope examination was performed in 10% KOH. Spore surface and structure of capillitium were studied using Camscan-S2 scanning electron microscope (Cambridge Instruments, UK).

All specimens were deposited in the Myxomycetes collection of Department of Mycology and Algology of the Lomonosov Moscow State University (MYX, Moscow, Russia).

We used the ACOR scale of Stephenson *et al.* (1993) for an estimation of species abundance. It is based on the proportion of a species records on the total number of re-

Table 1

Location of collecting sites

No.	Collecting site	Date	Coordinates	Site area, m in diam.
1	Mazurovo area	4 IX 2018	57.044965°N, 30.369351°E	15
2	Forest compartment 14	5 IX 2018	57.158131°N, 30.493145°E	15
3	Forest compartment 14	5 IX 2018	57.158491°N, 30.488823°E	50
4	Forest compartment 15	6 IX 2018	57.166274°N, 30.470525°E	250
5	South part of ecological route “Plavnitskoye Bog”	7 IX 2018	57.098263°N, 30.372753°E	10 × 300 m along trail
6	Tereshikha area	8 IX 2018	57.048046°N, 30.334038°E	50
7	Slepetnoye area	9–10 IX 2018	57.084413°N, 30.511075°E	400
8	Zamostye area	11 IX 2018	57.071356°N, 30.353906°E	50
9	Forest compartment 15	6 IX 2018	57.162824°N, 30.478172°E	5
10	Forest compartment 14	6 IX 2018	57.157658°N, 30.486422°E	5
11	Near Tereshikha area	8 IX 2018	57.045523°N, 30.330933°E	5
12	Near Tereshikha area	8 IX 2018	57.042°N, 30.33°E	300
13	Near Zamostye area	11 IX 2018	57.071768°N, 30.343525°E	5
14	Near Zamostye area	11 IX 2018	57.071896°N, 30.34422°E	5
15	Near Zamostye area	11 IX 2018	57.071969°N, 30.34442°E	5
16	1 km E of Veretye area	10 IX 2018	57.034236°N, 30.382858°E	50
17	Near Mazurovo area	4 IX 2018	57.036218°N, 30.3562°E	5
18	Near Mazurovo area	4 IX 2018	57.036321°N, 30.355898°E	5
19	Near Mazurovo area	4 IX 2018	57.04088°N, 30.359148°E	5
20	Forest compartment 14	5 IX 2018	57.159673°N, 30.486286°E	5
21	Forest compartment 14	5 IX 2018	57.159528°N, 30.485356°E	5
22	Forest compartment 14	5 IX 2018	57.159°N, 30.487°E	150
23	Forest compartment 14	5 IX 2018	57.15887°N, 30.489306°E	5
24	Forest compartment 14	5 IX 2018	57.158746°N, 30.490076°E	5
25	Forest compartment 14	6 IX 2018	57.158991°N, 30.484828°E	5
26	Forest compartment 15	6 IX 2018	57.163236°N, 30.478058°E	5
27	Forest compartment 15	6 IX 2018	57.162882°N, 30.477185°E	5
28	Forest compartment 15	6 IX 2018	57.164149°N, 30.475484°E	5

cords: A — abundant (> 3% of all records, over 6 records for this survey); C — common (1.5–3%, 4–6 records); O — occasional (0.5–1.5%, 2–3 records); R — rare (<0.5%, 1 record).

We used the classification of Lado and Eliasson (2017).

The obtained data were processed in R ver. 3.3.1 (R Core Team, 2018). We used EstimateS 9.1.0 (Colwell, 2013) to estimate the extent to which the survey was exhaustive. In accordance with Unterseher *et al.* (2008), the Chao2 estimator was chosen as the best estimator and calculated with the default settings of EstimateS (bias-corrected formula, 100 randomizations). The proportion of the number of recorded species on the number of expected species according to the Chao2 estimator (S × 100 / Chao2) was used as an estimate for the completeness of a local species inventory.

Results and Discussion

The alphabetical species list is annotated by the following data for every taxon name: abundance according to the ACOR scale, followed by relative abundance (in percent) and under slash number of records in brackets, afterwards collecting sites numbers in boldface (Table 1) and then the number of records in every site and herbarium numbers in MYX in brackets. An asterisk (*) indicates the species recorded as new for the Pskov Region. Myxomycete nomenclature follows Lado (2005–2019), except some varieties and subspecies, which are not accepted in this information system, and *Stemonitis lignicola* Nann.-Bremek. recognized by us as a separate species.

Annotated species list of Myxomycetes of Polistovsky Nature Reserve

*__Arcyria affinis__ Rostaf. — A (6.6%/15); **2**: 1 (MYX 9839); **3**: 1 (MYX 9189); **4**: 1 (MYX 9396); **5**: 1 (MYX 9409); **6**: 1 (MYX 9532); **7**: 7 (MYX 9551, MYX 9573, MYX 9578, MYX 9597, MYX 9608, MYX 9849, MYX 9853); **8**: 1 (MYX 9844); **9**: 1 (MYX 9403); **17**: 1 (MYX 9151).

*__A. cinerea__ (Bull.) Pers. — C (2.6%/6); **1**: 2 (MYX 9836, MYX 9838); **7**: 1 (MYX 9604); **13**: 1 (MYX 9854); **23**: 1 (MYX 9195); **26**: 1 (MYX 9841).

__A. denudata__ (L.) Wettst. — C (2.6%/6); **4**: 1 (MYX 9391); **6**: 1 (MYX 9529); **7**: 2 (MYX 9563, MYX 9852); **11**: 1 (MYX 9528); **16**: 1 (MYX 9614).

__A. incarnata__ (Pers. ex J. F. Gmel.) Pers. — C (2.2%/5); **6**: 1 (MYX 9843); **7**: 3 (MYX 9541, MYX 9548); **16**: 1 (MYX 9611).

*__A. obvelata__ (Oeder) Onsberg — O (0.9%/2); **7**: 1 (MYX 9542); **16**: 1 (MYX 9615).

*__A. pomiformis__ (Leers) Rostaf. — O (0.9%/2); **5**: 1 (MYX 9406); **7**: 1 (MYX 9540).

*__Badhamia lilacina__ (Fr.) Rostaf. (Plate I: *1*, *2*) — C (2.6%/6); **7**: 6 (MYX 9546, MYX 9625, MYX 9626, MYX 9589, MYX 9590, MYX 9627–9632). Watery, yellow plasmodia on surface of *Sphagnum* L. and *Polytrichum* Hedw. were observed everywhere (Plate I: *2*). This type of substrate is typical of *Badhamia lilacina*. The plasmodia migrate from the wet bottom layer of mosses upwards to live moss and grass stems, as well as various plant litter where form lilac-grey clumps of small, calcareous sporangia (Plate I: *1*) (Ing, 1999). This species is considered as relatively rare. However, this year the number of records of this species was significantly higher than usual. According to our observations, *B. lilacina* formed sporophores everywhere

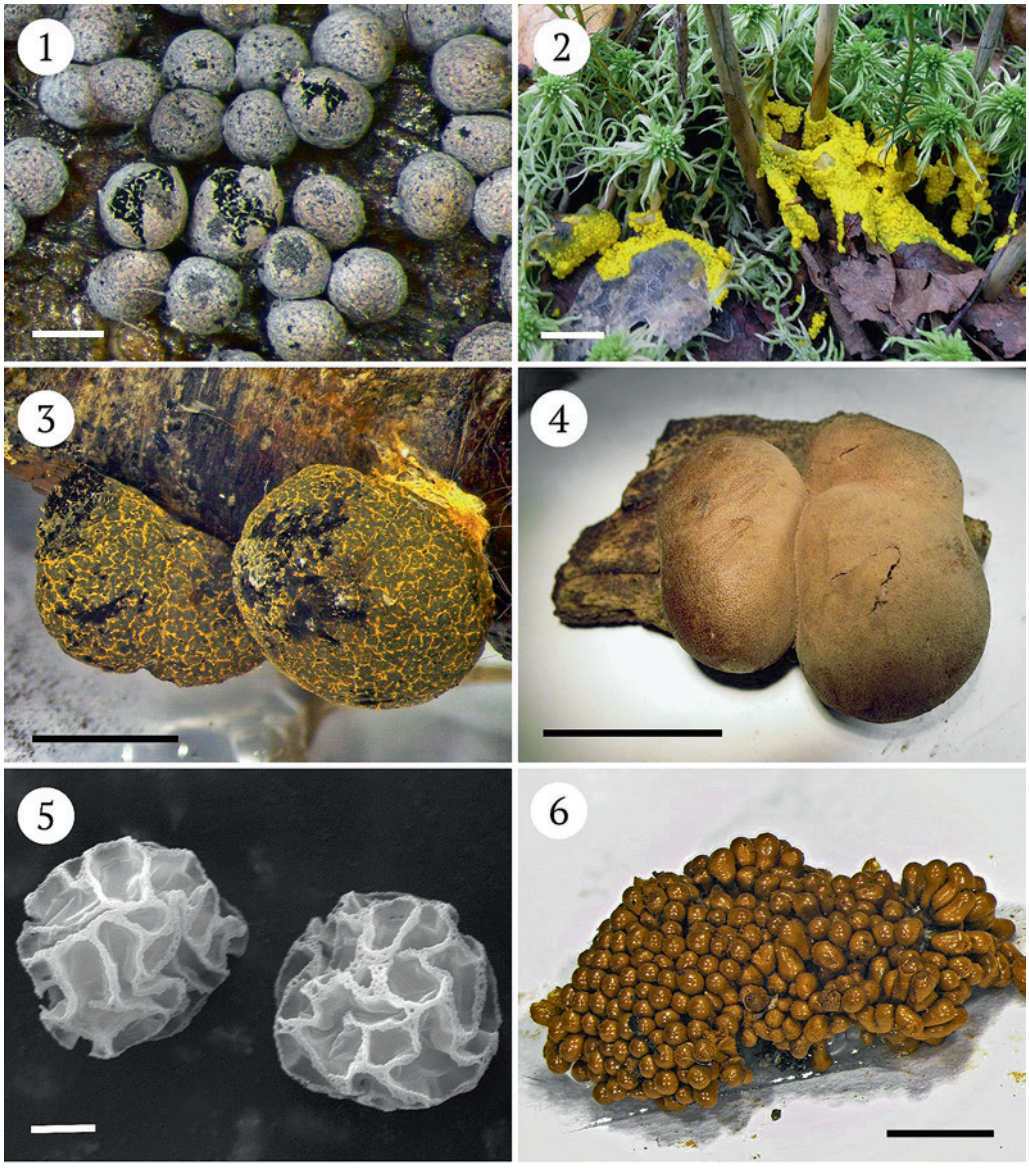

Plate I. *1* — *Badhamia lilacina* (MYX 9546), sporophores; *2* — *B. lilacina*, plasmoduim on *Polytrichum* sp.; *3* — *Fuligo muscorum* (MYX 9623), two aethalia; *4* — *Lycogala flavofuscum* (MYX 9636), two sporophores; *5* — *Oligonema flavidum* (MYX 9612), spores (SEM); *6* — *O. flavidum* (MYX 9612), clustered sporangia.
Scale bars: *1* — 0.5 mm; *2*, *3* — 1 cm; *4* — 1.5 cm; *5* — 3 μm; *6* — 2 mm.

in European part of Russia, e. g., in Central Forest Natural State Reserve of the Tver Region, Nelidovo District, particularly.

***B.** cf. **panicea** (Fr.) Rostaf. — R (0.4%/1); **7**: 1 (MYX 9566–9567). Our specimen has small, rounded sporangia, badhamioid capillitium, free spores with minutely punctate ornamentation, 11–14 μm diam. Thus, it is similar to typical form of *B. panicea* (Martin, Alexopoulos, 1969). The most remarkable feature of this species is a reddish base of sporangium and hypothallus. The base of sporophores in our specimen is reddish-brown, but hypothallus was colorless and inconspicuous. We assume that this is due to the dark color of the substrate.

***Ceratiomyxa fruticulosa** (O. F. Müll.) T. Macbr. — A (3.5%/8); **3**: 1 (MYX 9190); **4**: 3 (MYX 9254, MYX 9289, MYX 9395); **7**: 2 (MYX 9848); **21**: 1 (MYX 9193); **27**: 1.

***Comatricha elegans** (Racib.) G. Lister — R (0.4%/1); **6**: 1 (MYX 9538).

C. nigra (Pers. ex J. F. Gmel.) J. Schröt. — O (1.3%/3); **7**: 1 (MYX 9571); **16**: 1 (MYX 9609); **22**: 1 (MYX 9194).

***Cribraria cancellata** (Batsch) Nann.-Bremek. — A (4%/9); **1**: 4 (MYX 9158, MYX 9173, MYX 9175); **4**: 1; **7**: 3 (MYX 9549, MYX 9583); **21**: 1 (MYX 9192).

***C. microcarpa** (Schrad.) Pers. — O (0.9%/2); **5**: 1 (MYX 9407); **7**: 1 (MYX 9592).

***C. tenella** Schrad. — R (0.4%/1); **1**: 1 (MYX 9176).

Dictydiaethalium plumbeum (Schumach.) Rostaf. — O (0.9%/2); **4**: 1 (MYX 9397); **6**: 1 (MYX 9534).

***Diderma cinereum** Morgan — R (0.4%/1); **7**: 1 (MYX 9559).

***D. radiatum** (L.) Morgan — R (0.4%/1); **7**: 1 (MYX 9581).

***Didymium nigripes** (Link) Fr. — R (0.4%/1); **4**: 1 (MYX 9402).

***Fuligo leviderma** H. Neubert, Nowotny et K. Baumann — C (2.2%/5); **3**: 2 (MYX 9185, MYX 9635); **7**: 2 (MYX 9557, MYX 9598); **10**: 1 (MYX 9405).

***F. luteonitens** L. G. Krieglst. et Nowotny — O (1.3%/3); **7**: 2 (MYX 9568–9569, MYX 9603); **26**: 1 (MYX 9198).

***F. muscorum** Alb. et Schwein. (Plate I: *3*). — R (0.4%/1); **7**: 1 (MYX 9623–9624).

F. septica (L.) F. H. Wigg. var. **candida** (Pers.) R. E. Fr. — R (0.4%/1); **19**: 1 (MYX 9153).

***Hemitrichia calyculata** (Speg.) M. L. Farr — O (0.9%/2); **1**: 1 (MYX 9174); **7**: 1 (MYX 9582).

***H. clavata** (Pers.) Rostaf. — C (1.8%/4); **4**: 2 (MYX 9386, MYX 9393); **6**: 1 (MYX 9533); **7**: 1 (MYX 9599).

H. serpula (Scop.) Rostaf. ex Lister — C (1.8%/4); **7**: 4 (MYX 9562, MYX 9579, MYX 9587, MYX 9607).

Leocarpus fragilis (Dicks.) Rostaf. — R (0.4%/1); **25**: 1 (MYX 9197).

Lycogala epidendrum (L.) Fr. — C (2.6%/6); **1**: 1 (MYX 9157); **3**: 2; **6**: 1 (MYX 9531); **7**: 1 (MYX 9593); **9**: 1 (MYX 9404).

***L. exiguum** Morgan — O (0.9%/2); **1**: 1 (MYX 9156); **4**: 1 (MYX 9400).

***L. flavofuscum** (Ehrenb.) Rostaf. (Plate I: *4*). — R (0.4%/1); **7**: 1 (MYX 9636).

***Metatrichia floriformis** (Schwein.) Nann.-Bremek. — C (2.2%/5); **2**: 1 (MYX 9183); **4**: 1 (MYX 9384); **7**: 3 (MYX 9554, MYX 9555, MYX 9561).

M. vesparia (Batsch) Nann.-Bremek. ex G. W. Martin et Alexop. — A (9.7%/22); **1**: 3 (MYX 9154, MYX 9159, MYX 9837); **2**: 2 (MYX 9840); **4**: 1 (MYX 9842); **7**: 14 (MYX 9544, MYX 9545, MYX 9575, MYX 9577, MYX 9585, MYX 9591, MYX 9600, MYX 9851); **8**: 1 (MYX 9619); **15**: 1 (MYX 9855).

***Oligonema flavidum** (Peck) Peck (Plate I: *4*, *5*). — R (0.4%/1); **16**: 1 (MYX 9612). This is a rare species in Russia (Matveev *et al.*, 2016–2018). It was reported from the Murmansk (Gmoshinskiy, 2014), Leningrad (Novozhilov, 1999), and Volgograd regions (Zemlyanskaya, 2003). Apparently, this species is widely distributed, but never common.

Physarum album (Bull.) Chevall. — A (4%/9); **2**: 1; **3**: 2 (MYX 9184, MYX 9187); **6**: 2 (MYX 9537); **7**: 3 (MYX 9847); **15**: 1 (MYX 9618).

***P. psittacinum** Ditmar — R (0.4%/1); **2**: 1 (MYX 9181).

***P. viride** (Bull.) Pers. — R (0.4%/1); **7**: 1 (MYX 9594).

***P. viride** var. **aurantium** (Bull.) Lister — O (1.3%/3); **2**: 2 (MYX 9178, MYX 9179); **5**: 1 (MYX 9413).

***Reticularia intermedia** Nann.-Bremek. — R (0.4%/1); **7**: 1 (MYX 9596).

R. lycoperdon Bull. — O (0.9%/2); **4**: 1 (MYX 9398); **14**: 1 (MYX 9616).

***R. splendens** Morgan — R (0.4%/1); **5**: 1 (MYX 9414).

Stemonitis axifera (Bull.) T. Macbr. — A (4.4%/10); **4**: 1 (MYX 9389); **5**: 2 (MYX 9412); **6**: 1 (MYX 9539); **7**: 3 (MYX 9558, MYX 9606); **8**: 1 (MYX 9622); **15**: 1 (MYX 9617); **16**: 1 (MYX 9613).

S. fusca Roth — C (1.8%/4); **7**: 4 (MYX 9547, MYX 9576, MYX 9846).

***S. lignicola** Nann.-Bremek. — O (0.9%/2); **3**: 1 (MYX 9186); **7**: 1 (MYX 9570). This species is sometimes considered as a synonym for *S. splendens* Rostaf. (Lado, 2005–2018), however, it is distinguished by a fine-meshed surface and fairly dense internal network of capillitium. Therefore, we hold the opinion that this species is a separate taxon.

***S. pallida** Wingate — R (0.4%/1); **12**: 1 (MYX 9527).

***Stemonitopsis aequalis** (Peck) Y. Yamam. — O (1.3%/3); **6**: 2 (MYX 9530, MYX 9535); **8**: 1 (MYX 9621).

***S. amoena** (Nann.-Bremek.) Nann.-Bremek. — O (0.9%/2); **1**: 1 (MYX 9177); **16**: 1 (MYX 9610).

***S. hyperopta** (Meyl.) Nann.-Bremek. — C (1.8%/4); **1**: 1 (MYX 9170); **4**: 2 (MYX 9388, MYX 9399); **7**: 1 (MYX 9550).

***S. typhina** (F. H. Wigg.) Nann.-Bremek. — C (2.6%/6); **3**: 1 (MYX 9188); **4**: 2 (MYX 9387, MYX 9390); **5**: 1 (MYX 9411); **7**: 1 (MYX 9595); **18**: 1 (MYX 9152).

***S. typhina** var. **similis** (G. Lister) Nann.-Bremek. et Y. Yamam. — R (0.4%/1); **7**: 1 (MYX 9586). This taxon differs from the type variety in the absence of membranous silver cover on stalk and peridium, but similar in very fine pale warts (oil immersion) and some large, darker clusters of warts.

***Symphytocarpus flaccidus** (Lister) Ing et Nann.-Bremek. — O (0.8%/2); **5**: 1 (MYX 9633), **7**: 1 (MYX 9565).

Trichia decipiens (Pers.) T. Macbr. — A (3.5%/8); **4**: 2 (MYX 9385, MYX 9392); **5**: 1 (MYX 9408); **7**: 5 (MYX 9552, MYX 9572, MYX 9845).

T. favoginea (Batsch) Pers. — A (6.2%/14); **1**: 2 (MYX 9171, MYX 9172); **2**: 1 (MYX 9182); **4**: 2 (MYX 9266, MYX 9284); **5**: 1 (MYX 9410); **7**: 6 (MYX 9543, MYX 9553, MYX 9580); **8**: 2 (MYX 9620).

***T. persimilis** P. Karst. — O (1.3%/3); **6**: 1 (MYX 9536); **7**: 2 (MYX 9556).

T. scabra Rostaf. — O (1.3%/3); **1**: 1 (MYX 9155); **7**: 1 (MYX 9605); **28**: 1 (MYX 9199).

T. varia (Pers. ex J. F. Gmel.) Pers. — A (4.8%/11); **1**: 1; **2**: 1 (MYX 9180); **4**: 1 (MYX 9394); **7**: 7 (MYX 9574, MYX 9579, MYX 9588, MYX 9601, MYX 9602, MYX 9850); **22**: 1.

***Tubifera applanata** Leontyev et Fefelov — R (0.4%/1); **20**: 1 (MYX 9191).

T. ferruginosa (Batsch) J. F. Gmel. — R (0.4%/1); **4**: 1 (MYX 9401).

***T. ferruginosa** subsp. **acutissima** Leontyev, Schnittler et S. L. Stephenson — O (1.3%/3); **7**: 2 (MYX 9560, MYX 9564); **24**: 1 (MYX 9196). It is the first report of *T. ferruginosa* subsp. *acutissima* for Russia. This subspecies was described in 2015. As noted by its authors "...in some localities in Eastern Europe, such as the Gomolsha Forests in Ukraine, it is much more abundant than the type subspecies" (Leontyev *et al.*, 2015). Apparently, this subspecies will be found more frequently on the territory of Russia during the future investigations of species diversity and the revisions of collections.

This study resulted in 227 records representing 57 taxa (54 species, 2 varieties, and 1 subspecies) belonging to 21 genera and 9 families. Among them 36 species (67% of all founded species) are recorded for the first time for the Pskov Region. Thus, species list of this region increased from 38 to 74 species.

The majority of the recorded species belongs to the order Trichiales (17 species or 32% of the total number of species), followed by Physarales (13 species or 24%), Cribrariales (12 species or 22%), Stemonitidales (11 species or 20%), and Ceratiomyxales (1 species or 2%).

There are 16 rare species (30% of the total number), 15 occasional species (28%), 13 common species (24%), and 10 abundant species (19%) according to the ACOR scale (Stephenson *et al.*, 1993).

The sampling effort was probably sufficient to recover all of the most common species on suitable substrates in collecting sites. This study resulted in 54 species from

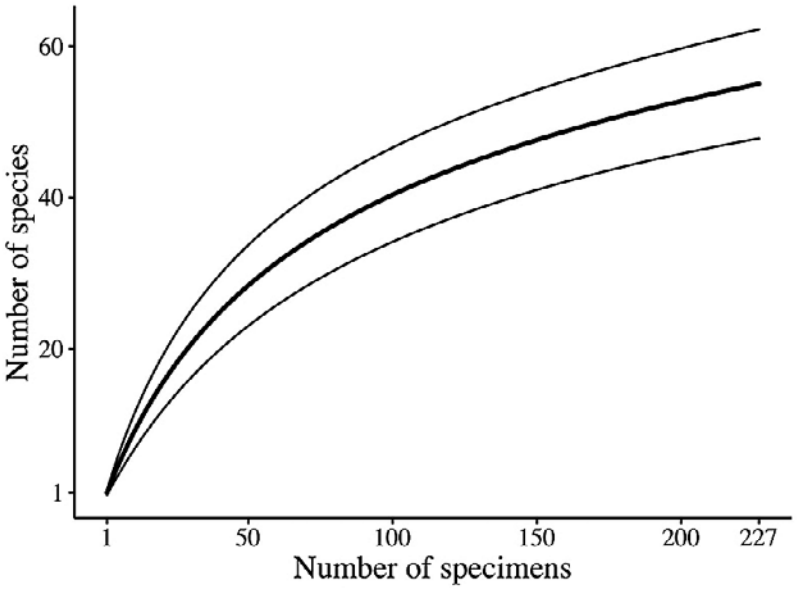

Fig. 1. Individual-based species accumulation curve (thick line) and its lower and upper confidence intervals (thin lines).

227 records (Fig. 1), 83% complete according to the Chao2 estimator, which is 65. Upper and lower borders of confidence interval equal to 57 and 90, respectively.

In the future, the study should be continued using the moist chamber technique. Usually, the use of this method in the Central Russia allows to increase the species list by 15–20%. For example, its use in a well-studied territory of Moscow and the Moscow Region has increased the species list by 16.7% of the total number of species (Gmoshinskiy, 2013).

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