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КРАТКИЕ СООБЩЕНИЯ

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FIRST DATA ON NIVICOLOUS MYXOMYCETES IN THE "BITSEVSKY FOREST" NATURAL AND HISTORICAL PARK (MOSCOW, RUSSIA)

© 2023. V. I. Gmoshinskiy[1,*] and N. I. Kireeva[2,]**

[1]*Lomonosov Moscow State University, 119234 Moscow, Russia*

[2]*Independent researcher, 115563 Moscow, Russia*

**e-mail: rubisco@list.ru*

***e-mail: espoir87@mail.ru*

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Preliminary studies in the northern part of the "Bitsevsky forest" natural and historical park resulted in the collection of 79 specimens of nivicolous myxomycetes belonging to 6 species from 3 genera. This is the first record of nivicolous myxomycetes in urban parks in lowlands. Photographs of sporocarps and micromorphological structures are given for each species. *Lamproderma ovoideoechinulatum* var. *microspora*, *L. zonatopulchellum*, and *Meriderma carestiae* var. *carestiae* were found for the first time in Moscow Region. The data indicate that high level of anthropogenic pressure, namely trampling and moderate improvement does not restrict sporulation of nivicolous species.

Keywords: altitudinal distribution of nivicolous myxomycetes, anthropogenic pressure, biodiversity, ecology, recreation activity, urban territories

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Nivicolous myxomycetes are a rather distinct ecological group comprising species capable of forming sporocarps in early spring at the edge of melting snowbanks (Schnittler et al., 2022). Previously, nivicolous myxomycetes were assumed to sporulate only in the mountains or rugged areas. However, recent years have seen isolated data on their occurrence in lowland boreal ecosystems in Moscow (Gmoshinskiy, Kireeva, 2023), Leningrad (Erastova, Novozhilov, 2015), and Tver Regions (Gmoshinskiy, Kireeva, personal data), as well as in Kharkov Region, Ukraine (Yatsiuk, Leontyev, 2020; Yatsiuk et al., 2023) and other regions (Ronikier, Ronikier, 2009). The increase in the number of such works is associated with the understanding of the nivicolous myxomycete ecology. It has been shown that these species can form sporocarps only under a favorable combination of several climatic factors (the absence of severe frost before the establishment of a stable snow cover persisting throughout the winter) (Schnittler et al., 2015). Such conditions in the lowlands are not observed every year. Also, snow melts in the mountains gradually over several weeks or even months. An important factor in the mountains is also the fairly high solar radiation, which, in the presence of a long and thick snow cover, contributes to the heating of the soil surface under the snow (Ishikawa, 2003). Thus, it is possible to discover nivicolous species within a fairly long period. Otherwise, in the lowlands, only 1–2 weeks may elapse between formation of the first thawed patches and complete disappearance of snow cover. In addition, sporocarps of most species are very fragile and almost completely destroy after the first precipitation (Gmoshinskiy, Kireeva, 2023).

The first data on myxomycetes of Moscow Region date back to the beginning of the 19th century, but regular studies of the species diversity began only in the 1960s (Bortnikov et al., 2020). Since then, more than 197 species of myxomycetes have been recorded in Moscow and Moscow Region (Gmoshinskiy, 2013). A study of the species diversity of nivicolous myxomycetes of Prioksko-Terrasny Nature Reserve was initiated in 2022, during which 10 species were registered (Gmoshinskiy, Kireeva, 2023). At the same time, nivicolous myxomycetes have not been noted not only in Moscow but in any large urban agglomeration so far.

The "Bitsevsky forest" natural and historical park is the second largest forest area in Moscow following Losiny Ostrov National Park. It is located in the southeastern part of the Teplostan Upland, in the most elevated part of it (up to 255 m above sea level), which is an isolated natural area formed on preglacial drift. Its modern territory, split by ravines and gullies with steep slopes, is composed of former estates merged together in the Soviet era (Uzkoe, Yasenevo, Biryulevo, Krasnoe, Konkovo, Markovo, Kolchevo, Znamenski Sadki, etc.) and peasant lands marked off from the estates as a result of the 1861 reform. Consequently, there are no continuous forest tracts, but fields and meadows, interspersed with groves. Each plot of land was exploited depending on the owners' needs (Korobko, 2013).

During the Second World War, on the territory of the present park there was a Moscow Line of Defense with a branched network of trenches and bunkers. A significant part of green areas was cut down during its construction and for the needs of local villagers. Therefore, many broad-leaved trees were planted in the 1950–1960s (Anonymous, 2023), but a considerable part of the area is taken up by aspen forests. Most of the conifer stands are also of artificial origin. The oldest ones are oak forests (180–190 years old) and linden forests (90–100 years old), but their area is not large, and the main area is covered by linden forests, represented by 70–90 years old plantations, and birch forests (60–70 years old). The understory is formed by linden and, occasionally, by spruce. The dominant species in the undergrowth is hazel.

Material was collected on April 11, 2023 in four study plots located in the northern part of the park, in the vicinity of the Bitsa Euestrian club:

Loc. 1 – Birch forest with linden: *Betula pendula* Roth, *Malus* sp., *Tilia cordata* Mill.; undergrowth: *Acer platanoides* L., *Cornus sericea* L., *Corylus avellana* (L.) H. Karst., *Sorbus aucuparia* L. (55.64454° N, 37.57774° E). – **Loc. 2** – Mixed forest with birch, acer and linden: *Acer platanoides*, *Betula pendula*, *Tilia cordata*; undergrowth: *Corylus avellana* (55.64450° N, 37.57142° E). – **Loc. 3** – Linden forest with a few birch trees: *Tilia cordata*, *Betula pendula* (55.63901° N, 37.57381° E). – **Loc. 4** – *B. pendula*, *Populus tremula* L., *Quercus robur* L.; undergrowth: *Acer platanoides*, *Corylus avellana* (55.6377° N, 37.57757° E).

We also investigated several sites with dominated by conifers trees, but no sporophores of nivicolous species were found there, so they were excluded from study. Specimens were collected according to the standard methods (Wrigley de Basanta, Estrada-Torres, 2022).

Photographs of sporocarps were taken using a Micromed 3 var. 3LED optical microscope with an E3CMOS06300 digital camera and top illumination. The series of pictures were taken in different focal planes and processed with a Helicon Focus ver. 6.0.18 software. The measurements of spores, capillitium, and sporocarps were obtained via ToupView 3.7 and ImageJ ver. 1.52a. Microscopic measurements and observations were made with the same microscope and software. Microscope slides were prepared with 4% KOH.

The list of recorded species is ordered alphabetically. Authors and concepts of taxa are given according to the *Eumycetozoa* database (Lado 2005–2023).

Dianema nivale (Meyl.) G. Lister (Fig. 1 A–D). – 2 specimens: **Loc. 1** – MYX 22562; **Loc. 2** – MYX 22587. On living *Carex* sp. Colonies are very small and represented by only few sporangia.

The species was previously found in Prioksko-Terrasny natural state reserve (Gmoshinskiy, Kireeva, 2023). Our samples identical for morphological and ecological features of type sample (Singer et al., 2006; Pinheiro Vellosa et al., 2020). The species has been previously recorded ins southern Western Siberia, but sporophores was found in moist chambers conditions on bark of *Salix* sp. and *Populus* sp. (Vlasenko, 2013, 2020).

Lamproderma arcyrioides (Sommerf.) Rostaf. (Fig. 1 E–I). – 23 specimens: **Loc. 1** – MYX 22547; **Loc. 2** – MYX 22563, MYX 22564; **Loc. 4** – MYX 22596–22610, MYX 22614–22616, MYX 22618, MYX 22619. On living *Carex* sp. and on dead small deciduous twigs (less than 3 cm in diam.).

It is one of the most widely distributed species. The sporocarps of two specimens (MYX 22598 and MYX 22601) were tinted with gold (Fig. 1 I) apart from the typical violet-blue color (Fig. 1 E–H). This is the feature by which *L. arcyrioides* differs from *L. aeneum* Mar. Mey. et Poulain. Thus, either two different but very similar species formed sporocarps on the same substrate fragment, or the peridium color of *L. arcyrioides* can vary very widely. Further studies are required to establish the limits of the peridium color variability.

L. echinosporum Meyl. (Fig. 1 J–N). – 23 specimens: **Loc. 1** – MYX 22538–22543, MYX 22548–22550, MYX 22552–22554, MYX 22556; **Loc. 2** – MYX 22565, MYX 22566, MYX 22576, MYX 22578–22580, MYX 22582, MYX 22585; **Loc. 3** – MYX 22595; **Loc. 4** – MYX 22617.

On living *Carex* sp. and on dead small twins of deciduous trees (less 3 cm in diam.), rare on fallen leaves of deciduous trees. This is the only species observed in all study areas. Its diagnostic feature is the presence of clearly visible spots on the peridium surface (Fig. 1 J) and echinulate spores (Fig. 1 K). In most specimens, many light spherical bodies with dark warts were observed. These bodies were inside the capillitial filaments and on the spore surface, and were also freely distributed on the slide. Some authors attributed specimens with such characters to *L. echinosporum* f. *liberum* K. Baumann, Nowotny, Kuhnt et Mar. Mey. However, it appears to be a kind of endoparasite related to the genus *Mitosporidium* from Rozellomycota (Yajima et al. 2013; Grossart et al., 2016) (Fig. 1 L–N). Notably, A. Kuhnt (2019) indicates that this phenomenon is typically very rare, but we observed these bodies in 8 of 13 specimens from the Loc. 1, while in Loc. 2 only one such colony was found, and in Loc. 3 and Loc. 4 both specimens were lacking them. Thus, it is possible that the endoparasite lesion may have a local character.

L. ovoideoechinulatum var. *microspora* Mar. Mey et Poulain (Fig. 2 A–D). – 3 specimens: **Loc. 1** – MYX 22545; **Loc. 2** – MYX 22575; MYX 22586. On dead small deciduous twigs (less 3 cm in diam.).

This species has not been previously recorded in the Moscow region. Its most characteristic features are the oval shape of the sporotheca (Fig. 2 A, D) and small spores (11–13 μm in diameter) with unevenly thickened walls and ornamentation of fine warts (Fig. 2 B–C).

L. zonatopulchellum Yatsiuk, Leontyev, Lopez-Vill. et Schnittler (Fig. 2 E–H). – 6 specimens: **Loc. 1** – MYX 22544, MYX 22546; **Loc. 2** – MYX 22577, MYX 22581, MYX 22583, MYX 22584. On small herbaceous shrubs (*Cornus sericea*) and on downside of leaves of living *Carex* sp.

Often sporocarps formed on the same substrate fragments as *L. echinosporum* (MYX 22576–22577; MYX 22581–22582; MYX 22584–22585). This species was not described until 2023. The authors specify that it occupies a middle position between *L. zonatum* Mar. Mey et Poulain and *L. pulchellum* Meyl. It differs from the former primarily by light brown capillitial threads with whitish ends, and from

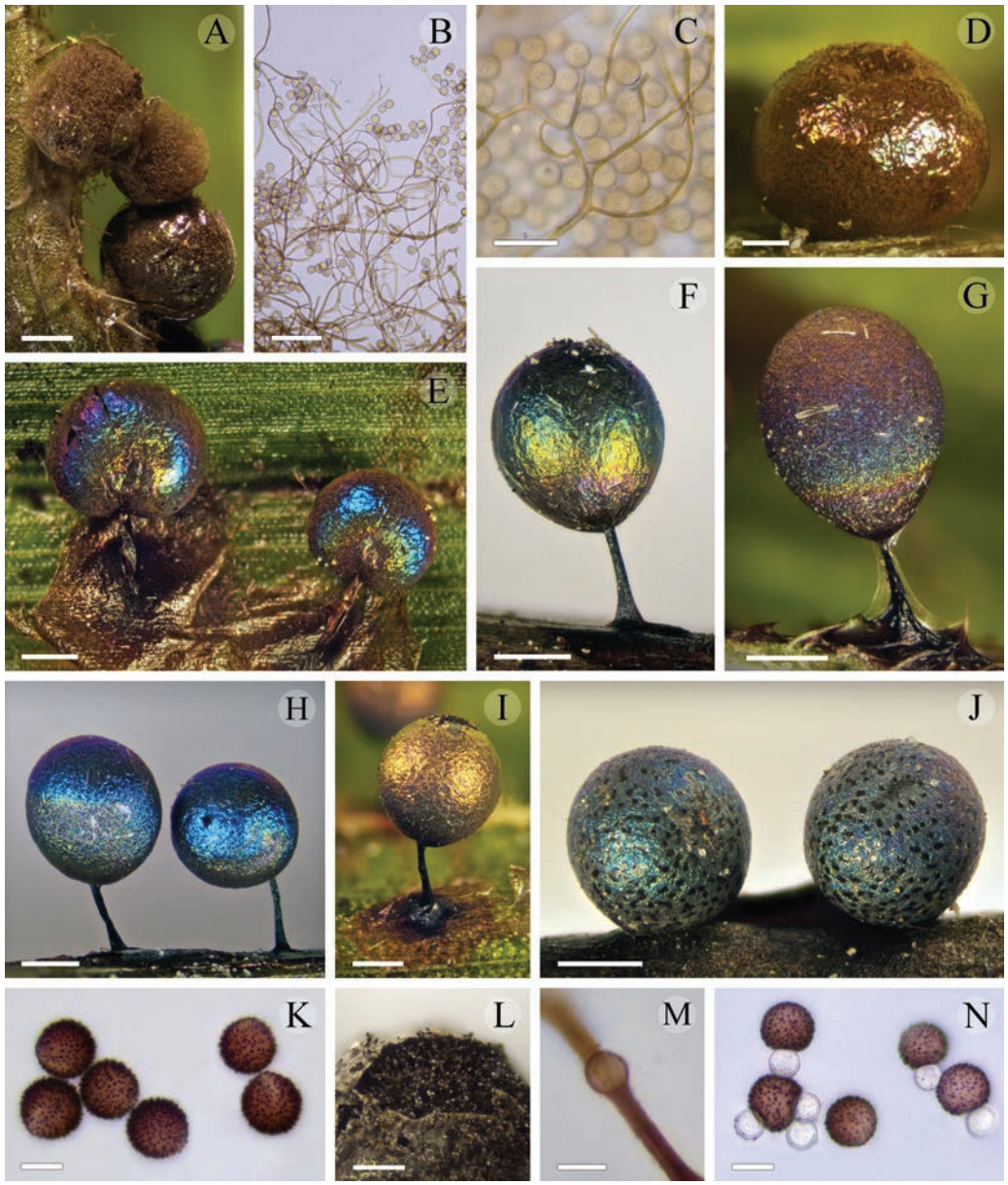

Fig. 1. Sporocarps of myxomycetes from the genera *Dianema* and *Lamproderma*: A–D – *Dianema nivale* (A – MYX 22562, B, C – capillitium and spores in transmitted light, D – MYX 22587, mature sporangia); E–I – *Lamproderma arcyrioides* mature sporangia (E – MYX 22602, F – MYX 22607, G – MYX 22563, H – MYX 22609, I – sporangium with golden reflection, MYX 22601); J–K – *L. echinosporum* MYX 22578 (J – mature sporangia, K – spore ornamentation, TL); L–N – *L. echinosporum* f. *liberum* MYX 22538 (L – sporangium with endoparasite, M – spherical bodies in the capillitium, TL, N – spores and light spherical bodies, TL). Scale: 10 μm (K, M, N); 20 μm (C); 50 μm (B); 200 μm (D, L); 400 μm (E–I); 500 μm (A, J).

the latter – by concentric reddish and yellowish zones on the peridium and smaller spores (12–14 μm in *L. pulchellum* vs. 10.3–12.6 μm in *L. zonatopulchellum*) (Yatsiuk et al., 2023). In addition, most of sporangia in our colonies were short-stalked (Fig. 2 E, F), while sporangia of *L. zonatum* are always sessile. Also, Yatsiuk et al. report that *L. zonatopulchellum* is most likely quite widespread in the lowlands. To note, in the original paper specimens MYX 8431 and MYX 8437 were referred to the erroneous location. They were actually found in Central Forest Nature Reserve (Tver Region) and not in Nizhnesvirsky Reserve (Leningrad Region).

Meriderma carestiae var. *carestiae* (Ces. et De Not.) Mar Mey. et Poulain (Fig. 2 I–K). – 22 specimens: **Loc. 1** – MYX 22551, MYX 22555, MYX 22557–22561; **Loc. 2** – MYX 22567–22574; **Loc. 3** – MYX 22588–22594. On small living broad-leaved shrubs, small fallen twigs, and leaves of living *Carex* sp.

The main distinguishing feature of this species is subreticulate ornamentation of spores (Fig. 2 I).

Even the most superficial studies of the species diversity of nivicolous myxomycetes in Moscow park showed strong chance of their discovery. Most likely,

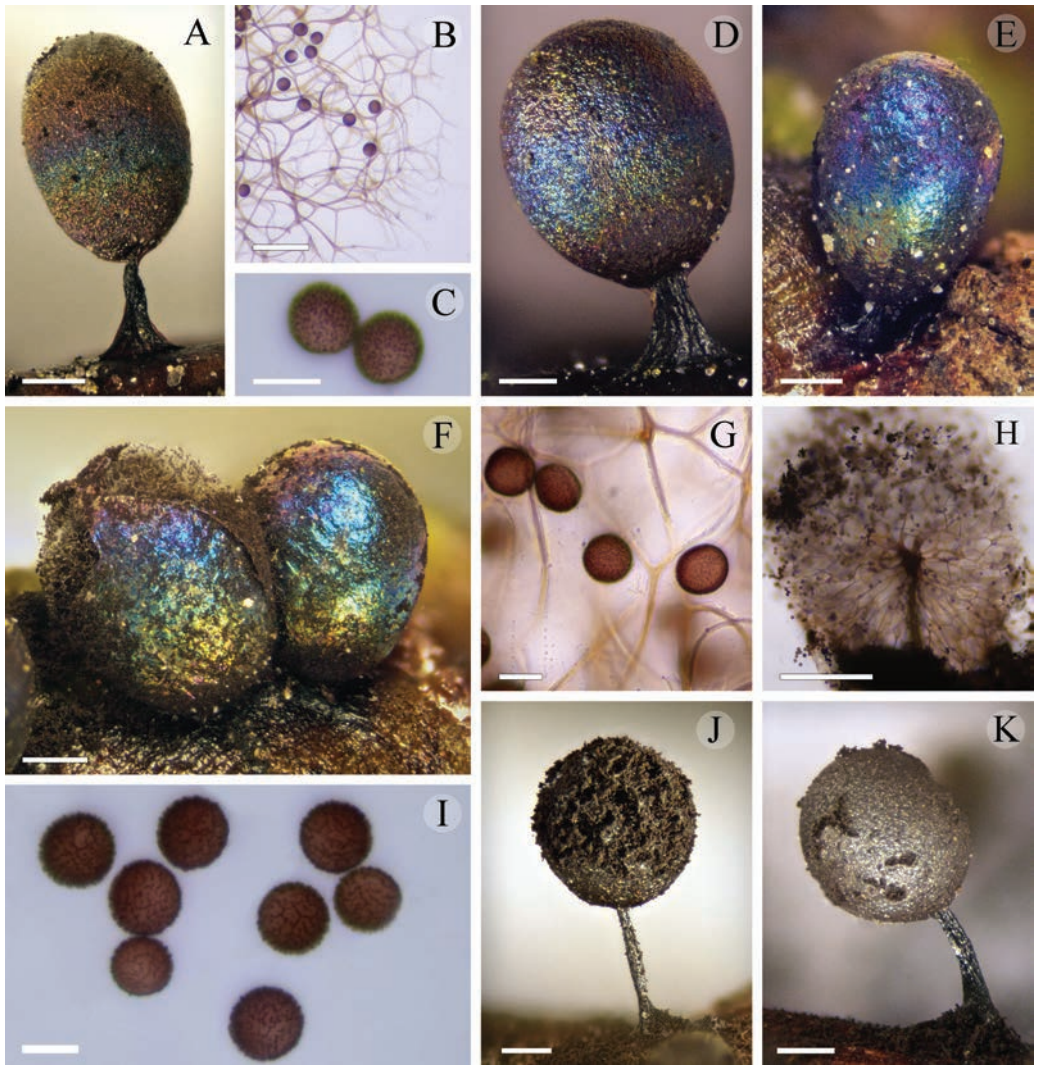

Fig. 2. Sporocarps of myxomycetes from the genera *Lamproderma* and *Meriderma*: A–D – *Lamproderma ovoideoechinulatum* var. *microspora* (A, D – MYX 22575, mature sporangia, B – MYX 22545, capillitium and spores, TL, C – MYX 22575, spore ornamentation, TL); E–H – *L. zonatopulchellum* MYX 22546 (E, F – mature sporangia, G – capillitium and spore ornamentation, TL, H – capillitium and columella, TL); I–K – *Meriderma carestiae* var. *carestiae* MYX 22588 (I – spore ornamentation, TL, J, K – mature sporangia). Scale bars: 10 μm (G, I); 50 μm (B, C); 200 μm (D); 300 μm (A, E, F, H, J, K).

the significant anthropogenic pressure to which the ecosystem in urban parks is subjected is not a limiting factor for nivicolous myxomycete populations. As in the case of vascular plants (Istomina et al., 2014), myxomycetes completely disappear only on the paths, where all other forest myxomycete species cannot form, too. The main reason for the disappearance of myxomycetes as well as vascular plants (Polyakova, Melankholin, 2007), in the park is a significant change in habitat, rather than trampling itself. Thus, in order to preserve biodiversity within the city, it is important to implement a balanced regulation of improvement activities. It should be emphasized that the ecosystem of the city has a very complex and, as this study shows, insufficiently studied multi-component structure. Changes in the natural resource management policy, transformation of native forests into parks – replacement of topsoil with rolled lawns and destruction of the shrub layer and forest floor – entail an irreversible change in the structure of this ecosystem, and consequently the potential disappearance of various organisms. That is why it is so important to preserve small forest areas that are still left on the territory of the European largest city.

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REFERENCES

Anonymous. Retromap. German aerial photography 1939–1943 years. 2023. http://retromap.ru/061942_55.644552,37.578005. Accessed 07.05.2023.

Bortnikov F.M., Matveev A.V., Gmoshinskiy V.I. et al. Myxomycetes of Russia: a history of research and a checklist of species. Karstenia. 2020. V. 58 (2). P. 316–373. https://doi.org/10.29203/ka.2020.502

Erastova D.A., Novozhilov Yu.K. Nivicolous myxomycetes of the lowland landscapes of the Northwest of Russia. Mikologiya i fitopatologiya. 2015. V. 49 (1). P. 9–18.

Gmoshinskiy V.I. Myxomycetes of Moscow and Moscow region. PhD Thesis, Moscow, 2013 (in Russ.).

Gmoshinskiy V.I., Kireeva N.I. The first data on nivicolous myxomycetes (*Amoebozoa*) of the Prioksko-Terrasny Reserve (Moscow Region, Russia). Phytotaxa. 2023 (in press).

Grossart H.-P., Wurzbacher C., James T.Y. et al. Discovery of dark matter fungi in aquatic ecosystems demands a reappraisal of the phylogeny and ecology of zoosporic fungi. Fungal Ecol. 2016. V. 19. P. 28–38. https://doi.org/10.1016/j.funeco.2015.06.004

Ishikawa M. Thermal regimes at the snow–ground interface and their implications for permafrost investigation. Geomorphology. 2003. V. 52. P. 105–120. https://doi.org/10.1016/S0169-555X(02)00251-9

Istomina I.I., Pavlova M.E., Terechin A.A. Population structure of *Corydalis intermedia* (L.) Merat in the "Bitsevsky forest" natural and historical park. Vestnik RUDN, seriya agroecologia i zhivotnovodstvo. 2014. Issue 4. P. 14–29 (in Russ.).

Korobko M.Yu. Findings in Bittsevo Forest: Some results of the latest historical and local history research in Moscow. Moskovskiy zhurnal. 2013. Issue 1. P. 68–79 (in Russ.).

Kuhnt A. Bemerkenswerte Myxomycetenfunde: Neue Arten, Neukombinationen und Nachweise seltener Arten, Teil 2. Bayerischen Botanisch. Gesellschaft. 2019. V. 89. P. 139–222.

Lado C. 2005–2023. An online nomenclatural information system of *Eumycetozoa*. http://www.nomen.eumycetozoa.com. Accessed 15.05.2023.

Pinheiro Velloso J.R., Putzke J., Schmitz et al. Dianema nivale – A myxomycete (*Amoebozoa*) new to the Antarctic. Polar Science. 2020. V. 26. 100598. https://doi.org/10.1016/j.polar.2020.100598

Polyakova G.A., Melanokhin P.N. Problems of preserving rare species in the natural park of Bitza Forest. Aktualnye problemy lesnogo kompleksa. 2007. Issue 19. P. 148–151 (in Russ.).

Ronikier A., Ronikier M. How 'alpine' are nivicolous myxomycetes? A worldwide assessment of altitudinal distribution. Mycologia. 2009. V. 101. P. 1–16. https://doi.org/10.3852/08-090

Schnittler M., Dagamac N.H.A., Woyzichovski J. et al. Biogeographical patterns in myxomycetes. In: *C. Rojas, S.L. Stephenson* (eds). Myxomycetes: biology, systematics, biogeography and ecology. Academic Press, Oxford, 2022, pp. 377–416.

Schnittler M., Erastova D.A., Shchepin O.N. et al. Four years in the Caucasus – observations on the ecology of nivicolous myxomycetes. Fungal Ecol. 2015. V. 14. P. 105–115. https://doi.org/10.1016/j.funeco.2015.01.003

Singer H., Moreno G., Illana C. Mountainous and nivicolous myxomycetes described by Charles Meylan. A SEM-study. Österreichische Z. Pilzkunde. 2005. V. 14. P. 11–29.

Vlasenko A.V. Species diversity and taxonomic structure of slime molds in the intrazonal and zonal habitats plains area south of West Siberia. Rastitelnyy mir aziatskoy Rossii. 2013. V. 2 (12). P. 3–11 (in Russ.).

Vlasenko A.V. Epiphytic myxomycetes on the bark of *Salix* and *Populus* in the southeast of Western Siberia. Samarskiy nauchnyy vestnik. 2020. V. 9 (4). P. 34–38 (in Russ.). https://doi.org/10.17816/snv202094104

Wrigley de Basanta D., Estrada-Torres A. Techniques for recording and isolating myxomycetes: updated. In: *C. Rojas, S.L. Stephenson* (eds). Myxomycetes: biology, systematics, biogeography and ecology. Academic Press, Oxford, 2022, pp. 417–451.

Yajima Y., Inaba S., Degawa Y. et al. Ultrastructure of cyst-like fungal bodies in myxomycete fruiting bodies. Karstenia. 2013. V. 53 (1–2). P. 55–65. https://doi.org/10.29203/ka.2013.458

Yatsiuk I., Leontyev D.V. Two species of nivicolous myxomycetes that formed fruiting bodies during three spring seasons in the lowlands of the Eastern Ukraine. Phytotaxa. 2020. V. 437 (3). P. 147–155. https://doi.org/10.11646/phytotaxa.437.3.3

Yatsiuk I., Leontyev D.V., López-Villalba Á. et al. A new nivicolous species of *Lamproderma* (*Myxomycetes*) from lowland and mountainous regions of Europe. Nova Hedwigia. 2023. V. 116 (1–2). P. 105–136. https://doi.org/10.1127/nova_hedwigia/2023/0807

Власенко А.В. (Vlasenko) Видовое разнообразие и таксономическая структура миксомицетов зональных и интразональных биотопов равнинной территории юга Западной Сибири // Растительный мир Азиатской России. 2013. № 2 (12). С. 3–11.

Власенко А.В. (Vlasenko) Эпифитные миксомицеты на коре Salix и Populus на юго-востоке Западной Сибири // Самарский научный вестник. 2020. Т. 9 (4). С. 34–38.

Гмошинский В.И. (Gmoshinskiy) Миксомицеты Москвы и Московской области. Дисс. ... к.б.н. М.: МГУ, 2013. 690 с.

Истомина И.И., Павлова М.Е., Терехин А.А. (Istomina et al.) Структура популяции хохлатки промежуточной (Corydalis intermedia (L.) Merat), в природно-историческом парке "Битцевский лес" // Вестник РУДН, серия Агрономия и животноводство. 2014. № 4. С. 14–29.

Коробко М.Ю. (Korobko) Находки в Битцевском лесу: о некоторых итогах новейших историко-краеведческих изысканий в Москве // Московский журнал. 2013. № 1. С. 68–79.

Полякова Г.А., Меланхолин П.Н. (Polyakova, Melankholin) Проблемы сохранения редких видов природного парка "Битцевский лес" // Актуальные проблемы лесного комплекса 2007. № 19. С. 148–151.

Первые данные о нивальных миксомицетах природно-исторического парка “Битцевский лес” (Москва, Россия)

В. И. Гмошинский[a,#], Н. И. Киреева[b,##]

[a]*МГУ имени М. В. Ломоносова, Москва, Россия*

[b]*Независимый исследователь, Москва, Россия*

[#]*e-mail: rubisco@list.ru*

[##]*e-mail: espoir87@mail.ru*

В ходе предварительного исследования в северной части природно-исторического парка “Битцевский лес” было собрано 79 образцов нивальных миксомицетов, принадлежащих к 6 видам из 3 родов. Это первый случай обнаружения нивальных миксомицетов в городских парках. Для каждого вида приводятся фотографии спороношений и микропрепаратов. Впервые для Московского региона отмечены *Lamproderma ovoideoechinulatum* var. *microspora*, *L. zonatopulchellum* и *Meriderma carestiae* var. *carestiae*. Полученные данные свидетельствуют о том, что высокий уровень антропогенной нагрузки (вытаптывание и умеренное благоустройство) не может полностью препятствовать формированию спороношений нивальных видов.

Ключевые слова: антропогенная нагрузка, биоразнообразие, высотное распределение нивальных миксомицетов, городские территории, рекреационная деятельность, экология