

A comprehensive checklist of Estonian myxomycetes

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Abstract

The history of the myxomycetes research in Estonia dates back to the middle of the 19th century, with first data occurring in the H. A. Dietrich's book published in 1856. The current work summarizes all the published reports of Estonian myxomycetes as well as some unpublished data and herbaria revisions. After the assessment of the taxonomic status of published records and bringing in line with currently accepted taxonomy, we present the updated checklist of the myxomycetes of Estonia, comprising 150 species representing 39 genera. Eleven species were excluded from the list as doubtful.

Introduction

Myxomycetes are the group of mostly terrestrial protists of the kingdom Amoebozoa (Adl et al., 2019) possessing a peculiar life cycle. The morphological structure of their fruiting bodies for a long time served as the first and foremost means for

species delimitation before the onset of molecular techniques. The resemblance of myxomycetes fruiting bodies to fungal ones is the reason why, despite the protistean nature of myxomycetes, traditionally they were studied by mycologists.

First data on Estonian myxomycetes were reported in the 19th century by Heinrich August Dietrich, the well-known horticulturist, botanist and mycologist of saxonian origin, who spent most of his life in Estonia. He collected actively in 1850s in the Western and Northern parts of the modern Estonia and his collections resulted in nine volumes of exsiccate *Centuria Plantarum Florae Balticae cryptogamarum (I-IX)* and the subsequent two-volume monograph “Blicke in die Cryptogamenwelt der Ostseeprovinzen” (Dietrich 1856, 1859). In this book he listed 46 species and varieties of myxomycetes. All but one volume of *Centuria* exsiccates have been preserved in at least one copy and are kept in Estonian museums. Eleven specimens of myxomycetes, found in *Centurias* II, IV, V, VII and VIII, were recently revised (Pärtel et al. 2020).

The other historical collection of the 19th century has been recently rediscovered and attributed to the bryologist and teacher Gustav Carl Girgensohn. Upon revision, the collection appeared to include 11 specimens (two with original identifications) that belonged to 6 species of *Myxogastrea* (Pärtel et al. 2020).

In the 20th century, sporadic surveys were carried out by several researchers, such as Jaczewsky (1907), Bucholtz (who used herbaria of Dietrich, Jaczewsky and Naturforschende Verein zu Riga but did not collect material from Estonia himself, (Bucholtz 1908)), Lepik (1938, 1940), Puusepp (1960), Parmasto (1987a, 1987b), Kalamees et al. (1971), Soobik (1984, 1988, 1995), Ing (1990). The first checklist of Estonian myxomycetes that included records from 1856 to 1974 was published in 1980 as a part of the checklist of Estonian fungi (Järva & Parmasto 1980), and comprised 87 species. The second checklist dealing with publications of the years 1975–1990, provided additional 65 species of myxomycetes (Järva et al. 1998). In 1991–1993, myxomycete surveys were carried on the island of Hiiumaa and in the Soomaa National Park (Western Estonia) by the third author of the present article (Kastanje 1994, 1995). They added 32 new species to the list.

In the 21st century, after the surveys conducted

during 14th and 17th Symposia of the Baltic Mycologists and Lichenologists altogether 25 species of myxomycetes new to Estonia were reported (Adamonyte 2000, Adamonyte & Kastanje 2011).

In the present paper, we aim to update and summarize knowledge about the species diversity of Estonian myxomycetes taking into account new collection data and the taxonomic treatments updated since the publication of the last checklist of Estonian myxomycetes.

Material and methods

The checklist was compiled based on all available published myxomycete data till the present day and also includes unpublished material kept in Estonian herbaria: TAAM – Herbarium of the Department of Mycology in the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences; EAA – herbarium of the Estonian University of Life Sciences; TU – herbarium of the University of Tartu. Published sources that were used are listed in the References. Specimens from historical H.A. Dietrich’s exsiccates and G.C. Girgensohn’s collection (22 in total) were recently revised using the conventional techniques of stereoscopic dissecting microscopy and light microscopy (following the methods described in Nannenga-Bremekamp (1991)).

Nomenclature is updated following Lado (2005–2020). Names of authors are abbreviated according to Brummit & Powell (1992). In the list currently accepted species name is followed by cited synonyms, if there were any, and a reference where the species was mentioned for the first time. In cases when species are represented only by unpublished herbarium specimen(s), herbarium number(s) is/are provided. Collection data for unpublished specimens are available via the PlutoF platform by the following DOI: <https://dx.doi.org/10.15156/BIO/807449> (Abarenkov et al. 2010).

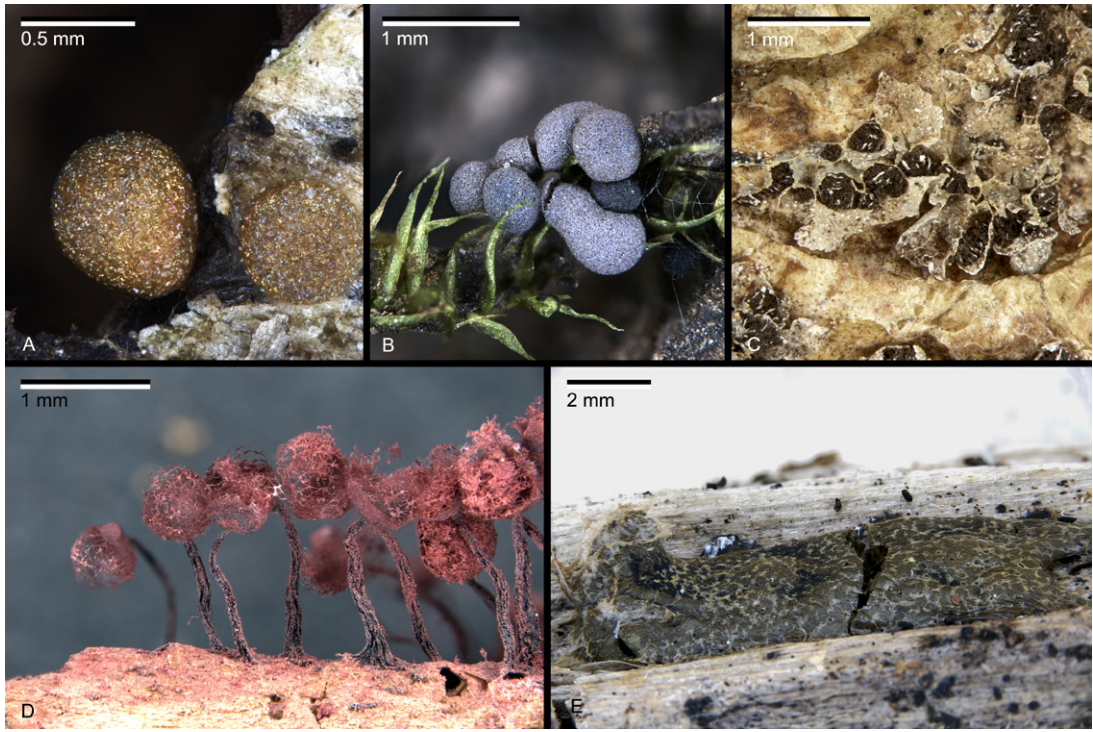


Fig.1. Some of the noteworthy species of Estonian myxomycetes, fruitbodies: **A**—*Calomyxa metallica* (TAAM210509), **B**—*Badhamiopsis ainoae* (TAAM128262), **C**—*Physarum gyrosum* (specimen from H.A. Dietrich's exsiccate, Centuria VII 81), **D**—*Cribraria purpurea* (TU132138), **E**—*Reticularia olivacea* (TAAM210501). Photo: Iryna Yatsiuk.

Results

The summarized checklist of myxomycetes of Estonia includes 150 species belonging to 39 genera of Myxomycetes *s. l.*, including 149 species of Myxomycetes G. Winter *sensu* Leontyev et al., 2019, and one species of Ceratiomyxomycetes D. Hawksw., B. Sutton & Ainsw. Eleven species are reported as doubtful/invalid taxa or were excluded from the checklist after the specimen revision. Some of the noteworthy species are shown in **Fig. 1**.

List of species

Arcyodes incarnata (Alb. & Schwein.) O.F. Cook—Adamonyte (2000).

Arcyria abietina (Wigand) Nann.-Bremek.—Adamonyte & Kistanje (2011).

Arcyria affinis Rostaf.—Kistanje (1994).

Arcyria cinerea (Bull.) Pers.—Dietrich (1856).

Arcyria denudata (L.) Wettst. as *Arcyria punicea* Rabenh.—Dietrich (1856).

Arcyria ferruginea Saut.—Adamonyte (2000).

Arcyria incarnata (Pers. ex J.F. Gmel.) Pers. as *Arcyria incarnata* Pers. and *A. flexuosa* Rabenh.—Dietrich (1856).

Arcyria insignis Kalchbr. & Cooke—Kistanje (1994).

- Arcyria major* (G. Lister) Ing—Kalamees & Saar (2006).
- Arcyria obvelata* (Oeder) Onsberg as *Arcyria nutans* Greville—Jaczewsky (1907).
- Arcyria oerstedii* Rostaf.—Pärtel et al. (2020)
- Arcyria pomiformis* (Leers) Rostaf.—Jaczewsky (1907).
- Arcyria stipata* (Schwein.) Lister—Adamonyte (2000).
- Badhamia capsulifera* (Bull.) Berk. as *Physarum hyalinum* Pers.—Dietrich (1856).
- Badhamia lilacina* (Fr.) Rostaf.—Kastanje (2000).
- Badhamia macrocarpa* (Ces.) Rostaf.—Jaczewsky (1907).
- Badhamiapanicea* (Fr.) Rostaf.—TAAM163965.
- Badhamia utricularis* (Bull.) Berk.—Parmasto (1987a).
- Badhamiopsis ainoae* (Yamash.) T.E. Brooks & H.W. Keller—Kastanje (1994).
- Calomyxa metallica* (Berk.) Nieuwl.—Kastanje (1994).
- Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr. as *Ceratum hydroides* Alb. & Schw.—Dietrich (1856) as *Ceratiomyxa porioides* (Alb. & Schwein.) J. Schröt.—Ing (1990).
- Clastoderma debaryanum* A. Blytt—Adamonyte (2000).
- Collaria arcyrionema* (Rostaf.) Nann.-Bremek. ex Lado—Ing (1990).
- Collaria lurida* (Lister) Nann.-Bremek.—TAAM184295.
- Collaria rubens* (G. Lister) Nann.-Bremek.—Kastanje (2000).
- Comatricha alta* Preuss—Ing (1990).
- Comatricha elegans* (Racib.) G. Lister as *Collaria elegans* (Racib.) Dhillon & Nann.-Bremek. ex Ing—Ing (1990).
- Comatricha ellae* Härk.—Kalamees & Saar (2006).
- Comatricha laxa* Rostaf.—Ing (1990).
- Comatricha nigra* (Pers. ex J.F. Gmel.) J. Schröt.—Puusepp (1960).
- Craterium aureum* (Schumach.) Rostaf.—TAAM163954, TAAM163955.
- Craterium leucocephalum* (Pers. ex J.F. Gmel.) Ditmar—Kastanje (1994).
- Craterium minutum* (Leers) Fr.—Dietrich (1856).
- Cribraria argillacea* (Pers. ex J.F. Gmel.) Pers.—Dietrich (1856).
- Cribraria aurantiaca* Schrad.—Ing (1990).
- Cribraria cancellata* (Batsch) Nann.-Bremek. as *Dictydium umbilicatum* Schrad.—Dietrich (1856).
- Cribraria intricata* Schrad.—Ing (1990).
- Cribraria microcarpa* (Schrad.) Pers.—Kastanje (1994).
- Cribraria persoonii* Nann.-Bremek.—Ing (1990).
- Cribraria piriformis* Schrad.—Ing (1990).
- Cribraria purpurea* Schrad.—TU132138.
- Cribraria rufa* (Roth) Rostaf.—Adamonyte (2000).
- Cribraria splendens* (Schrad.) Pers.—TAAM163151.
- Cribraria tenella* Schrad.—TAAM163899.
- Cribraria violacea* Rex—TU109278.
- Cribraria vulgaris* Schrad.—Kastanje (1994).
- Diachea leucopodia* (Bull.) Rostaf.—Kastanje (2000).
- Dictydiaethalium plumbeum* (Schumach.) Rostaf.—Ing (1990).
- Diderma asteroides* (Lister & G. Lister) G. Lister—Kastanje (2000).
- Diderma crustaceum* Peck—Kastanje (1994).
- Diderma effusum* (Schwein.) Morgan—Adamonyte & Kastanje (2011).
- Diderma globosum* Pers.—Dietrich (1859).
- Diderma hemisphaericum* (Bull.) Hornem. as *Didymium hemisphaericum* Fr.—Dietrich (1856).
- Diderma niveum* (Rostaf.) E. Sheld. as *Chondrioderma niveum* Rostaf.—Jaczewsky (1907).
- Diderma radiatum* (L.) Morgan as *Leangium stellare* Lk.—Dietrich (1856).
- Diderma spumarioides* (Fr. & Palmquist) Fr.—Dietrich (1856).
- Diderma testaceum* (Schrad.) Pers.—Dietrich (1856).
- Didymium bahiense* Gottsb.—Ing (1990).
- Didymium clavus* (Alb. & Schwein.) Rabenh.—Kastanje (1994).
- Didymium crustaceum* Fr.—Dietrich (1856).
- Didymium difforme* (Pers.) Gray as *Physarum album* Fr.—Dietrich (1856).
- Didymium melanospermum* (Pers.) T. Macbr. as *Didymium lobatum* Nees.—Dietrich (1856).
- Didymium minus* (Lister) Morgan—Kastanje (1994).
- Didymium nigripes* (Link) Fr.—Adamonyte & Kastanje (2011).

- Didymium serpula* Fr.—Dietrich (1856).
Didymium squamulosum (Alb. & Schwein.) Fr. & Palmquist—Jaczewsky (1907).
Didymium trachysporum G. Lister—Kastanje (1994).
Echinostelium apitectum K.D. Whitney as *Echinostelium vanderpoelii* Nann.-Bremek. et al.—Kastanje (2000).
Echinostelium brooksii K.D. Whitney—Ing (1990).
Echinostelium colliculosum K.D. Whitney & H.W. Keller—Ing (1990).
Echinostelium fragile Nann.-Bremek.—Ing (1990).
Echinostelium minutum de Bary—Ing (1990).
Enerthenema papillatum (Pers.) Rostaf.—Ing (1990).
Fuligo intermedia T. Macbr.—Kastanje (1994).
Fuligo megaspora Sturgis—TAAM163465.
Fuligo muscorum Alb. & Schwein. as *Reticularia muscorum* Fr.—Dietrich (1856).
Fuligo leviderma H. Neubert, Nowotny & K. Baumann—Adamonyte (2000).
Fuligo septica (L.) F.H. Wigg. as *Aethalium septicum* Fr.—Dietrich (1856); as *Fuligo candida* Pers.—Adamonyte & Kastanje (2011); as *Fuligo septica* var. *flava* (Pers.) Lázaro Ibiza—Adamonyte & Kastanje (2011); as *Fuligo rufa* Pers.—Ing (1990).
Hemitrichia abietina (Wigand) G. Lister as *Arcyria abietina* (Wigand) Nann.-Bremek.—Adamonyte & Kastanje (2011).
Hemitrichia calyculata (Speg.) M.L. Farr—TU118865.
Hemitrichia clavata (Pers.) Rostaf.—Jaczewsky (1907).
Hemitrichia serpula (Scop.) Rostaf. ex Lister—Kastanje (1994).
Lamproderma arcyrioides (Sommerf.) Rostaf.—TU118862.
Lamproderma columbinum (Pers.) Rostaf. as *Physarum columbinum* Pers.—Dietrich (1856).
Lamproderma gulielmae Meyl.—Kastanje (2000).
Leocarpus fragilis (Dicks.) Rostaf. as *Leocarpus vernicosus* Lk.—Dietrich (1856).
Licea inconspicua T.E. Brooks & H.W. Keller—Ing (1990).
Licea kleistobolus G.W. Martin—Ing (1990).
Licea minima Fr.—Adamonyte & Kastanje (2011).
Licea operculata (Wingate) G.W. Martin—Adamonyte & Kastanje (2011).
Licea parasitica (Zukal) G.W. Martin—Ing (1990).
Licea pusilla Schrad.—Ing (1990).
Licea variabilis Schrad.—Kastanje (2000).
Lycogala epidendrum (L.) Fr. as *Lycogala epidendron* Fr. and *L. terrestre* Fr.—Dietrich (1856).
Lycogala exiguum Morgan—Parmasto (1987b).
Lycogala flavofuscum (Ehrenb.) Rostaf.—TU117486.
Macbrideola cornea (G. Lister & Cran) Alexop.—Ing (1990).
Macbrideola macrospora (Nann.-Brem) Ing—TAAM163488.
Metatrichia floriformis (Schwein.) Nann.-Bremek.—Adamonyte (2000).
Metatrichia vesparia (Batsch) Nann.-Bremek. ex G.W. Martin & Alexop. as *Hemitrichia vesparium* (Batsch) T. Macbr.—Puusepp (1960).
Mucilago crustacea P. Micheli ex F.H. Wigg. as *Spumaria alba* DC.—Dietrich (1856).
Oligonema flavidum (Peck) Peck—Adamonyte (2000).
Paradiacheopsis cribrata Nann.-Bremek.—Ing (1990).
Paradiacheopsis fimbriata (G. Lister & Cran) Hertel. ex Nann.-Bremek.—Ing (1990).
Paradiacheopsis solitaria (Nann.-Bremek.) Nann.-Bremek.—Ing (1990).
Perichaena chrysosperma (Curr.) Lister—Ing (1990).
Perichaena corticalis (Batsch) Rostaf.—Ing (1990).
Physarum album (Bull.) Chevall. as *Physarum nutans* Pers.—Jaczewsky (1907).
Physarum auriscalpium Cooke—Ing (1990).
Physarum bivalve Pers.—Jaczewsky (1907).
Physarum cinereum (Batsch) Pers. as *Didymium cinereum* Fr.—Dietrich (1856).
Physarum compressum Alb. & Schwein.—Dietrich (1856).
Physarum gyrosum Rostaf.—Pärtel et al. (2020)
Physarum leucophaeum Fr. & Palmquist—Ing (1990).
Physarum contextum (Pers.) Pers.—Kastanje (1994).
Physarum leucophaeum Fr. & Palmquist—Ing (1990).

Physarum oblatum T. Macbr.—Ing (1990).
Physarum robustum (Lister.) Nann.-Bremek.—Adamonyte & Kastanje (2011).
Physarum virescens Ditmar—Ing (1990).
Physarum viride (Bull.) Pers.—Kastanje (1994).
Reticularia intermedia Nann.-Bremek.—TAAM135019, TAAM135065.
Reticularia lycoperdon Bull. as *Reticularia umbriana* Fr.—Dietrich (1856); as *Enteridium lycoperdon* (Bull.) M.L. Farr—Kalamees & Saar (2006).
Reticularia olivacea (Ehrenb.) Fr. as *Enteridium olivaceum* Ehrenb.—Kastanje (1994).
Stemonaria irregularis (Rex) Nann.-Bremek., R.Sharma & Y.Yamam.—Adamonyte & Kastanje (2011).
Stemonitis axifera (Bull.) T. Macbr. as *Stemonitis ferruginea* Ehrenb.—Puusepp (1960); as *Stemonitis smithii* T. Macbr.—Kastanje (1994).
Stemonitis flavogenita E. Jahn—Ing (1990).
Stemonitis fusca Roth—Dietrich (1856).
Stemonitis splendens Rostaf.—TAAM163901, TAAM163898.
Stemonitis virginensis Rex—Kastanje (1994).
Stemonitopsis amoena (Nann.-Bremek.) Nann.-Bremek.—Adamonyte & Kastanje (2011).
Stemonitopsis gracilis (G. Lister) Nann.-Bremek.—Ing (1990).
Stemonitopsis hyperopta (Meyl.) Nann.-Bremek.—Ing (1990).
Stemonitopsis typhina (F.H.Wigg.) Nann.-Bremek. as *Stemonitis typhoides* DC—Dietrich (1856).
Symphytocarpus amaurochaetoides Nann.-Bremek.—TAAM181963.
Symphytocarpus flaccidus (Lister) Ing & Nann.-Bremek.—Ing (1990).
Symphytocarpus impexus Ing & Nann.-Bremek.—Ing (1990).
Trichia affinis de Bary—Kalamees & Saar (2006).
Trichia botrytis (J.F. Gmel.) Pers.—Ing (1990).
Trichia contorta (Ditmar) Rostaf. as *Trichia contorta* G.H. Otth—Kastanje (1994).
Trichia decipiens (Pers.) T. Macbr.—Jaczewsky (1907).
Trichia erecta Rex—EAA12928, EAA12929.
Trichia favoginea (Batsch) Pers.—Jaczewsky (1907).

Trichia munda (Lister) Meyl.—Adamonyte & Kastanje (2011).
Trichia persimilis P. Karst.—Ing (1990).
Trichia scabra Rostaf.—Jaczewsky (1907).
Trichia varia (Pers. ex J.F.Gmel.) Pers.—Dietrich (1856).
Tubifera ferruginosa (Batsch) J.F. Gmel. as *Tubulina cylindrica* (Bull.) DC.—Dietrich (1856).
Siphoptychium casparyi Rostaf. as *Tubifera casparyi* (Rostaf.) T. Macbr.—Adamonyte (2000).
Siphoptychium violaceum Leontyev, Schnittler & S.L. Stephenson—TU132132.
Willkommangea reticulata (Alb. & Schwein.) Kuntze as *Cienkowskia reticulata* (Alb. & Schwein.) Rostaf.—Jaczewsky (1907).

Doubtful or invalid species

Arcyria nutans DC—Dietrich (1856). H.A. Dietrich here most probably refers to *Trichia nutans* Bull. from De Candolle and Lamarck, p. 254, where the *T. nutans* is listed within the section Arcyrie (De Candolle & Lamarck 1805). It is confirmed by Dietrich's additional references to "Weinm. 609", and "Rabenh. 2151". Both in Weinmann on p. 609, and in Rabenhorst under the number 2151 there is *Arcyria nutans* Fr. = *Trichia nutans* Bull (Rabenhorst 1844, Weinmann 1836). According to Lado (2005-2020), *T. nutans* Bull. is a synonym for *Arcyria obvelata* (Oeder) Onsberg. However, the revision of poorly preserved herbarium specimen Cent. VII 47 from abovementioned *Centuria* exsiccates suggests that it may represent *A. oerstedii* rather than *A. obvelata*.

Didymium compactum Rostaf.—Soobik (1984, 1988, 1995). Although we could not confidently trace the species name in the relevant literature, it might refer to *Physarum compactum* Ehrenb., mentioned in Rostafinski (1876). If this is the case, it is a synonym of *Physarum citrinum* Schumacher according to Lado (2005-2020). However, we are inclined to treat the species name as doubtful until the revision of P. Soobik's collections is performed.

Tubulina fragiformis DC—Dietrich (1856). Again, this is evidently the reference to De Candolle & Lamarck (1805). In this case, Dietrich probably meant

Tubulina fragiformis (Bull.) Pers. = *Tubifera ferruginosa* (Batsch) J.F.Gmel. The record was not accompanied by the reference to the herbarium specimen.

Physarum sinuosum Fr.—Dietrich (1856). The revised specimen Cent. IV 65 was re-identified as *Physarum bivalve* Pers.

Perichaena strobilina Fr.—Dietrich (1856). The revised specimen Cent. II 79 appeared to be a rust fungus *Pucciniastrum areolatum* (Fr.) G.H. Otth.

Physarum confluens Pers.—Dietrich (1856). The revised specimen Cent. VII 81 was re-identified as *Physarum gyrosum* Rostaf.

Physarum conglobatum Ditmar—Dietrich (1856). Invalid or doubtful name according to Lado (2005–2020). The exsiccate *Centuria* III, where the referenced specimen Cent. III 30 had been kept, has not been preserved.

Physarum fimetarium Schumach. as *Physarum fimetarium* Schumach.—Dietrich (1856). Invalid or doubtful name according to Lado (2005–2020). The record was not accompanied by the reference to the herbarium specimen.

Physarum muscicola Pers.—Dietrich (1856). Invalid or doubtful name according to Lado (2005–2020). The record was not accompanied by the reference to the herbarium specimen.

Didymium physaroides Fr.—Dietrich (1856). If this is *Didymium physaroides* (Pers.) Fr. & Palmquist and not *Didymium physaroides* (Link) Link, then according to Lado (2005–2020) it is a doubtful name “Cited by Martin & Alexopoulos, Myxomycetes 391. 1969, as a synonym of *Didymium melanospermum* (Pers.) T. Macbr., but in p. 369 say that may be *Diderma spumarioides* (Fr.) Fr”. H. A. Dietrich did not refer to any specimen and we have not found the species in the revised part of his collections. However, it is to be mentioned that the substrate described by Dietrich (“on decaying wood, especially birch, in autumn, not rare”) is untypical for *Diderma spumarioides* and related species (Buyck 1988).

Discussion

The number of species provided herein, 150, is comparable to, although less than those reported from ge-

ographically close regions with an extended history of myxomycetes research. As an example, over 211 species of myxomycetes are known from Lithuania, and no less than 188 species from the Leningrad region of Russia (Adamonytė 2007, Erastova & Novozhilov 2015, Popov et al. 2007). On the other hand, in Latvia, which borders both Estonia and Lithuania, only 108 species of myxomycetes have been discovered so far (Adamonytė, 2020). Such differences in a number of species between the regions similar in terms of the area and environmental conditions are most probably caused by the different research efforts applied.

It is worth mentioning that all species reported herein, are in fact morphospecies. The potential cryptic diversity of myxomycetes has not been yet thoroughly evaluated in Estonia, and further barcoding studies may reveal many more species occurring in this country.

Lastly, although the role of myxomycetes as key microbial predators in detrital food webs can hardly be exaggerated (Fukasawa et al. 2018), their conservation status has not yet gained proper attention in Estonia. As compared to fungi, among which 434 species have already been evaluated according to IUCN criteria and 153 declared as threatened, no myxomycetes have been included into the up-to-date Red List of Estonian fungi (Saar et al. 2019). The assessment of the threat status of myxomycetes in Estonia is an important future task, in which the current checklist might prove useful.

Conclusion

In the current study, all the published reports as well as unpublished data and results of revision of the herbarium collections are summarized to provide the updated checklist of the myxomycetes of Estonia that includes 150 morphological species. Further research is needed to assess the hidden biodiversity of this group, as well as to evaluate the frequency and conservation status of the listed species.

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