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 The current work summarizes all the published reports of Estonian myxomycetes as well as some unpublished data and herbaria revisions.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 “*Blüecke 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* exsiccate 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).
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 & Kastanje (2011).

*Arcyria affinis* Rostaf.—Kastanje (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—Kastanje (1994).

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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.
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).

Badhamia panicea (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 Ceratium hydnoides Alb. & Schw.—Dietrich (1856) as Ceratiomyxa porioides (Alb. & Schwein.) J. Schröt.—Ing (1990).

Clastoderma debaryanum A. Blytt— Adamonytė (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 leucopodium (Schwein.) Morgan—Adamo¬nyte & Kastanje (2011).

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 rafa (Roth) Rostaf.—Adamonytė (2000).

Cribraria splendens (Schrad.) Pers.—TAAM163151.

Cribraria tenella Schrad.—TAAM163899.

Cribraria violacea Rex—TU109278.

Cribraria vulgaris Schrad.—Kastanje (1994).

Diarchea leucopodia (Bull.) Rostaf.—Kastanje (2000).

Dicytiaethalium 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 Chondroiderma 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 (Batsch) Nann.-Bremek. 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 brooksi 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).
Echinostelium vanderpoelii Nann.-Bremek.—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—Adamonytë (2011).
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 gyrosom 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 virens (Bull.) Pers.—Kastanje (1994).
Reticularia intermedia Nann.-Bremek.—TAAM135019, TAAM135065.
Reticularia lycoperdon Bull. as Reticularia umbrina 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 virginiensis 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.
Willkommlangea 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 exsiccatas 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 Schumach 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 ferrugino-sa (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 fimentarium 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 spumar-oides and related species (Buyck 1988).

Discussion

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