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BRYOPHYTES OF DICKSON AREA, WESTERN TAIMYR – A MODEL BRYOPHYTE FLORA FOR ASIAN ARCTIC TUNDRA
МОХООБРАЗНЫЕ ОКРЕСТНОСТЕЙ ДИКСОНА – МОДЕЛЬНОЙ БРИОФЛОРЫ АЗИАТСКИХ АРКТИЧЕСКИХ ТУНДР

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Abstract

Bryophyte flora of the Dickson village area was studied during five field seasons. The list includes 90 species and 7 infraspecific taxa of liverworts and 249 species and 2 varieties of mosses. This is the greatest number among local floras published for Asian Arctic. It exceeds previously published moss floras of the nearby areas by about hundred species. It is partly caused by application of new species concepts, which appeared as a result of revisions involving molecular phylogenetic data. However, it also demonstrates strong under-exploration, and, consequently, underestimation of bryophyte diversity and need in its conservation. The present study shows that the number of species in local floras does not decrease northward within the tundra zone. Moreover, bryophyte flora of the arctic tundra biome houses the previously neglected or only recently recognized taxonomic diversity. An annotated list of species is provided, along with comments on the problematic taxa and specimens.

Резюме

Бриофлора окрестностей пос. Диксон и расположенной в 17 км южнее бухты Медуза, изученная в течение пяти полевых сезонов, включает 90 видов и 7 внутривидовых таксонов печеночников и 249 видов мхов и по числу выявленных таксонов мохообразных превосходит все ранее опубликованные локальные бриофлоры азиатской Арктики. Представленный список снабжен комментариями к проблемным или интересным с точки зрения фитогеографии таксонам или образцам. Краткое сравнение с ранее опубликованными бриофлористическими исследованиями показывает, что в пределах тундровой зоны разнообразие мохообразных на уровне конкретных флор не уменьшается к северу. Хотя такое большое число выявленных видов, в том числе связанных с высокими широтами, во многом обусловлено таксономическими концепциями, появившимися в последние десятилетия, представляемые данные ставят вопросы сохранения биоразнообразия высокоширотной Арктики и дальнейшего изучения его бриофлоры.

KEYWORDS: arctic tundra subzone, bryophytes, diversity, flora

INTRODUCTION

Arctic biodiversity attracts now an increasing attention as the most sensitive and endangered due to the global warming. According to the results of recent climate modeling, subpolar regions are expected to undergo stronger climatic changes than areas at lower latitudes (Weaver at al., 1998; Intergovernmental Panel on Climate Change:, 2014: https://www.ipcc.ch/site/assets/uploads/2018/05/SYR_AR5_FINAL_full_wcover.pdf).

Among the zonal biomes of the world, Arctic is regarded as the one where bryophytes play the essential role in vegetation (cf. Ogureeva et al., 2020) and this is especially true for high Arctic. In high Arctic, bryophytes in number of species exceeds that of vascular plants; moreover, the arctic tundra biomes are virtually built by bryophytes, which protect permafrost from melting and thus ensure ecosystem stability. Therefore, already first Arctic expeditions have yielded extensive bryophyte collections, which have contributed a lot to knowledge of the biodiversity of the Far North. Further, these data were supplemented by numerous collections, mostly made during phytosociological exploration of tundra commu-

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nities and compiled in regional checklists, while local floras based on collections made by bryologists have remained scanty, and most of them were based on rather short-term, up to one field-season-long exploration. Thus, average estimates of the local pool of species richness, i.e. Whittaker's (1972) ă diversity, for most of Arctic are erroneously low. Moreover, "phytosociological bias" of bryophyte collecting leads to under-representation of the most diverse ecological groups – terrestrial and saxicolous pioneer mosses. Such omission of rare species from large and taxonomically difficult groups led to false impression of poorness and uniformity of Arctic bryophyte flora, while its most interesting and probably endangered fraction remains largely unknown. In particular, this is a case of hard-to-reach regions of Siberian Arctic.

Despite Arctic bryophyte flora is believed to comprise low number of endemic taxa (Longton, 1988), Hedenäs (2019) recently revealed the existence of northern or high mountain infraspecific genetic lineages in eight of ten screened widespread bryophyte species and suggested that a high genetic diversity is characteristic for northern and high mountain areas of Sweden. At the same time, quite a limited number of studies dealt with Asian Arctic populations, essential centre of arctic vascular flora formation (Tolmachev & Yurtsev, 1970). However few such studies conducted with mosses resulted in revealing neglected diversity (Hedenäs et al., 2020; Ignatov et al., 2020). Several previously omitted hybridogeneous species were recently revealed in this area (Ignatova *et al.*, 2016; Kyrkjeeide *et al.*, 2019) indicating ongoing processes of speciation in bryophytes, which is generally regarded as an important source of endemics at high latitude (Dynesius & Jansson, 2000). Due to global warming, arctic biomes are undergoing sufficient changes and zonal boundaries move northward. Therefore, a poorly known diversity of bryophytes is needed to evaluate its risk and develop as efficient acting plan for their conservation. In this context, the surveys of bryodiversity in Asian high Arctic based on integrative taxonomic concepts are especially important.

Dickson village in the northwest of Taimyr Peninsula is an easy to access. Since first Arctic expeditions it has been one of the most visited points of Asian sector of Arctic Ocean shore. Lundström collected here in 1875 and Kjellman in 1878. They collected 63 species that were published later by Arnell (1918). First publications on the Dickson bryophyte flora were published by Jensen (1909) and Brotherus (1910), but these lists included only few widespread species. Extensive collections of hepatics (and likely mosses as well) were made in the area in 1977–1979 by Zhukova, Zanokha and Matveyeva. Hepatics were identified by Zhukova and the list of 64 species was published by Zhukova & Matveyeva (2000). For mosses of this area, however, no sufficient data were published after Arnell (1918). The present study is based on the bryophytes collected inof 2001–2003 by Varlygina in the course of vegetation studies; in 2017 Fedosov and in 2019 Fedosov and Koltysheva conducted strictly bryofloristic exploration of the area.

STUDY AREA

Dickson area is situated on eastern shore of Yenisey River Gulf. Its average annual temperature is ?11.4 °C, positive daily temperature during 3.5 months and average temperatures of July and August +4.6 °C and +4.8 °C correspondingly, Dickson Area is assigned to northern margin of Arctic Tundra subzone (Walker et al., 2005). Despite low annual precipitation rate of ca. 233 mm, environments are rather humid due to permafrost melting and Kara Sea influence. The area studied for bryophytes was briefly characterized by Kannukene & Matveyeva (1996) and Matveyeva & Zanokha (2017). The latter paper deals with vascular plants of Dickson village outskirts, while the former one provides the only sufficient list of mosses (159 species) published for arctic tundra of Taimyr Peninsula, explored ca. sixty kilometers eastward Dickson near Uboynaya River mouth, but since the landscape of northwestern part of Taimyr Peninsula are quite homogeneous, their description might be expanded on Dickson Area as well.

The area belongs to the western foothills of Byrranga Range. There are numerous rocky ridges up to 65 m height, stretched in latitudinal direction and emerging in the sea as capes, separated by gentle 0.5–1.5 km widthway hollows incut in soft quaternary loamy sediments, which form bays. Upper surfaces of rocky ridges are occupied by **dry rockfields** (1) with scattered vascular plants (distribution of vascular plant distribution through the range of characteristic ecotopes is considered in Matveyeva & Zanokha, 2017), partly covered by saxicolous bryophytes and lichens. Although geologically rather homogeneous, these ridges somewhat differs in composition that results in different composition of saxicolous species and local abundance of calciphylous ones. Gentle southern slopes of these ridges are covered by drained ***Dryas* dominated rocky tundra** (2). These communities gradually turn into zonal arctic tundra on gentle convex loamy slopes. **Hummocky or spotty zonal arctic tundra communities** (3) are polydominant due to diverse nanorelief. Concave slopes and interfluvial areas are covered by **boggy cotton-grass dominated communities** (4), which sometimes possess polygonal structure. On sandy sediments poor in mineral nutrition vascular plants are sparse and ground cover is composed by mosses of the genera *Polytrichum, Dicranum* and *Sphagnum*. North faced slopes of rocky ridges are steep, with cliffs and lumpy screes above extensive **snowfields and wet lower slopes below them** (5). Overflooded due to permanent brooks, the latter ecotopes capture fine soil from snowbeds, and therefore are rather rich in mineral nutrition. Creek valleys cross the area along ridge bases or cut quaternary sediments; they have **boggy or pebbly bottom and banks** (6). Creeks cutting loamy hills often

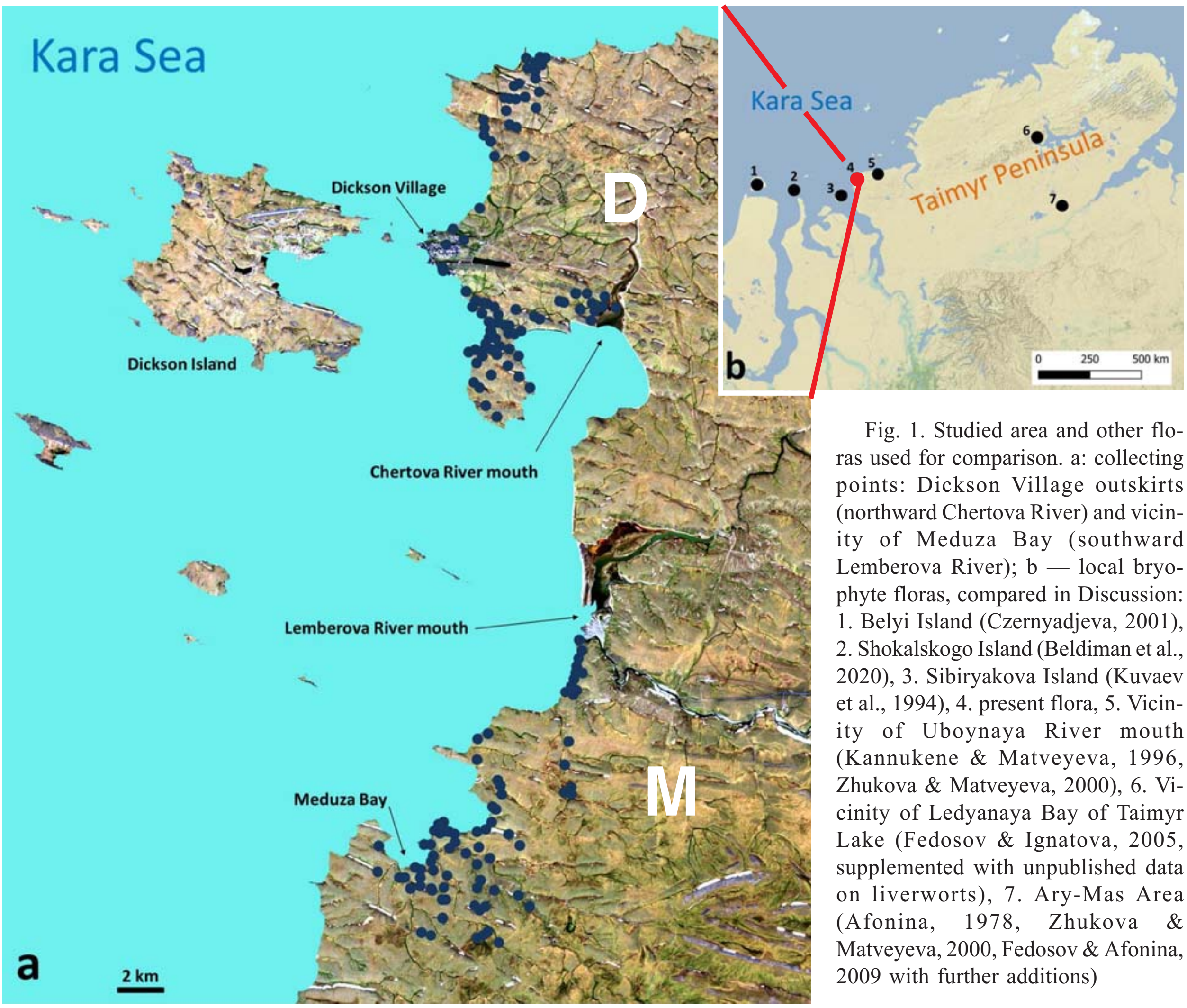

Fig. 1. Studied area and other floras used for comparison. a: collecting points: Dickson Village outskirts (northward Chertova River) and vicinity of Meduza Bay (southward Lemberova River); b — local bryophyte floras, compared in Discussion: 1. Belyi Island (Czernyadjeva, 2001), 2. Shokalskogo Island (Beldiman et al., 2020), 3. Sibiryakova Island (Kuvaev et al., 1994), 4. present flora, 5. Vicinity of Uboynaya River mouth (Kannukene & Matveyeva, 1996, Zhukova & Matveyeva, 2000), 6. Vicinity of Ledyanaya Bay of Taimyr Lake (Fedosov & Ignatova, 2005, supplemented with unpublished data on liverworts), 7. Ary-Mas Area (Afonina, 1978, Zhukova & Matveyeva, 2000, Fedosov & Afonina, 2009 with further additions)

form canyons with **eroded soliflunctional slopes and massifs of frost mounds** (7) where meadow spots alternate with eroded turf and mineral ground. Diversity of nanoecotopes including moist shaded niches results in rich bryophyte representations and especially high diversity of liverworts. Along the seashore coastal retreat cause extensive soilslides where pioneer herb aggregations alternates with those, composed of pioneer mosses and bare mineral soil. Composition of the former differs on sandy, loamy including partly salty marine sediments. River deltas are covered by **marshy low grass vegetation** (8) which tolerate marine salt impact with sparse mosses, while along low seashores bryophytes occur mostly on drift wood. Finally, disturbed ecotopes around settlements (9) are covered by ruderal meadows and bryophyte aggregations.

Materials and Methods

The field work was carried out by TV in 2001–2003 and VF & DK in 2019 in vicinity of Willem Barentz field station of Big Arctic Reserve in Meduza Bay (73.359N, 80.537E, ca. 17 km southward from Dickson) northward to Lemberova River mouth (73.405N, 80.653E), and by VF in 2017 and VF & DK in 2019 in vicinity of Dickson village northward to Kurok Cape (73.563, 80.599E) on the northern shore of Taimyr Peninsula and in the vicinity of Meduza Bay (Fig. 1). Collections of TV were identified by EI, and Valery Zolotov (*Bryum*), collections made by VF & DK were identified by VF, VB (Hepatics), EI and AS. NK took care of specimen processing, databasing and species list complining. Liverwort specimen collected by VF were transferred alive (in cryo-anabiosis state) to Vladivostok and therefore were studied in the most cases with the preserved oil bodies in leaf cells. This therefore is one of a few studies of Arctic liverworts that used the information on oil bodies in the identification process and evaluation of taxonomic concept. Specimens are kept in MW, MHA, KPABG and VGBI, specimen voucher information is available in online database of Moss flora of Russia (Ivanov et al., 2017), Moscow Digital Herbarium (Seregin, 2020), Online Herbarium VBGI (liverworts, http://botsad.ru/herbarium/) and CRIS. Several specimens, collected by Matveyeva, Zanokha and Kannukene in 1970s kept in LE were also added.

Fig. 2. Various habitat types in Dikson area (## correspond ecotope numbers in text): A: Meadow near William Barents field station and rocky ridges in the opposite bay shore (## 1,3); B: Arctic tundra and low rocky ridge in the watershed (## 1,3,4); C: Watershed slope in the Meduza Creek upstream (## 3,4,5,6); D: Sedge & cotton grass dominated tundra in the flood plain of Meduza Creek (## 4, habitats of *Tomentypnum nitens*, *Aulacomnium palustre*, *Drepanocladus* spp.); E: Lemberova River in lower course with landslides on right bank and frost mounds along the left bank flood plain edge (## 3,6,7); F: Rocky ridge and snowfield on its north faced slope (# 1, habitats of *Kiaeria blyttii*, *Andreaea* ssp., *Hymenoloma crispulum*); G: Extensive snowfield and brook valley southward Dickson village (## 1,5,6); H: Extensive frost mounds in a creek valley southward Dickson village (# 7, habitat of *Psilopilum cavifolium*, *Pogonatum* spp., *Hennediella heimii* var *arctica*, *Dicranella* spp., *Pohlia* spp.).

List of species

Nomenclature of liverworts and mosses in the list of species follows Konstantinova *et al.* (2009) and Ignatov *et al.* (2006) correspondingly, with further amendments. Frequency of species is provided as follow: Com – common in at least one of widespread ecotopes (1, 3, 4) or in two or more ecotopes; Fr. – common in rarer ecotopes (2, 5-9) or constantly occurs in three or more ecotopes including widespread ones; Sp. – constantly occurs in few rarer ecotopes or rare in wide range of ecotopes; Rar. – few specimens (less then five) from different places or found in a single locality with high abundance; Un. – single locality with low abundance. This system largely corresponds to those accepted in Fedosov & Ignatova (2005) and Fedosov *et al.* (2019). Distribution within studied area, through the range of delimited ecotopes (1-9) and types of substrata are provided as well as accompanying species (for liverworts). Areas are coded as follow: D – Dickson village outskirts, i.e. from Chertova River mouth in the south to Taimyr Peninsula northern shore (Fig. 1); M – vicinity of Willem Barentz field station in Meduza Bay northward to Lemberova River mouth. Ecotopes are coded as follow: 1 – rockfields; 2 – rocky tundra, 3 – zonal Arctic tundra, 4 – wet cotton grass dominated tundra and bogs, 5 – wet lower parts of ridge slopes below snowfields, 6 – creek banks, 7 – eroded slopes and frost mounds; 8 – low deltas and seashore, 9 – rural ecotopes (details are considered above).Substrata are abbreviated as follow: dr – dry or mesic rock, wr – wet or submerged rock, df – dry to moist fine soil, wf – wet fine soil, mg – other mineral ground, dh – dry to mesic humus; wh – wet humus or turf; s – peatmoss hummocks, t – wood or other substrata, not characteristic for the area natural conditions (trash). Most characteristic accompanying species are listed; presence of reproductive structures is reported. Hepatics, referred to the area by Zhukova & Matveyeva are also accounted; however, since no sufficient data about mosses of the area was published, only our data is provided in list below.

Hepatics

Anastrophyllum sphenoloboides – This species was found by Zhukova & Matveyeva, (2000), but is absent in our collections

Aneura pinguis – Zhukova & Matveyeva (2000); Sp. D; 3,7; dh; with *Blepharostoma brevirete, Chiloscyphus pallescens, Mesoptychia rutheana, Odontoschisma macounii, Scapania paludicola, Schljakovianthus quadrilobus, Trilophozia quinquedentata*

Anthelia juratzkana – Zhukova & Matveyeva (2000); Sp. D; 1,5,6; f; with *Aneura pinguis, Blepharostoma brevirete, Cephalozia bicuspidate, Cephaloziella varians, Sphenolobus minutus*

Arnellia fennica – Rar. M; 1,3; dh; with *Barbilophozia barbata, Cephaloziella* sp., *Distichium capillaceum Flexitrichum flexicaule, Tomentypnum* sp., *Sanionia uncinata, Timmia comata*

Barbilophozia barbata – Zhukova & Matveyeva, (2000); Rar. D, M; 3, 6 wt; with *Arnellia fennica, Ptilidium ciliare, Cephaloziella uncinata, Timmia comata, Aulacomnium turgidum, Distichium capillaceum, Pohlia cruda, Polytrichastrum hyperboreum*

B. hatcheri – Zhukova & Matveyeva (2000); Sp. D; 1,2,3,5; f, dh; with *Lophozia sylvicola*

B. lycopodioides – This species was reported by Zhukova & Matveyeva, (2000), but it is absent in our collections

Blepharostoma brevirete – Zhukova & Matveyeva (2000); Fr. M, D; 1,3,4,5,7; f, dh, mg; with *Anthelia juratzkana, Cephalozia bicuspidata, Cephaloziella* cf *varians, Diplophyllum taxifolium, Lophozia ventricosa, Nardia geoscyphus, Scapania parvifolia, Sphenolobus minutus, Trilophozia quinquedentata*

Calycularia laxa – Rar. D, M; 4; wh; with*, Aulacomnium turgidum, Sanionia uncinata, Scorpidium revolvens, Sphagnum squarrosum.*

Cephalozia ambigua – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

C. bicuspidata – Zhukova & Matveyeva (2000); Un. D; 3; mg; with *Sphenolobus minutus*

Cephaloziella arctogena – Zhukova & Matveyeva, (2000); Rar. D, M; 2; ?; with *Lophozia* sp., *Dicranum* cf. *spadiceum, Pohlia cruda, Sanionia uncinata*, *Brachytheciastrum trachypodium*, *Flexitrichum* sp., *Hypnum cupressiforme*, *Tomentypnum* sp., *Rhytidium rugosum*

C. hampeana – Un. D; 4; wh; in pure mats or with *Blepharostoma brevirete*, *Fuscocephaloziopsis leucantha*, *Scapania paludosa*, *Schljakovianthus quadrilobus*, *Trilophozia quinquedentata*

C. spinigera – Zhukova & Matveyeva (2000); Rar. D; 3,5; wh,f; with *Odontoschisma macounii, Scapania paludicola, Trilophozia quinquedentata*

C. uncinata – Rar. M; 3,4,6; wh, t; with *Barbilophozia barbata, Lophoziopsis excisa, Ptilidium ciliare, Sphanolobus minutus, Trilophozia quinquedentata, Timmia comata, Aulacomnium turgidum, Pohlia cruda, Polytrichastrum hyperboreum, Dicranum elongatum, Sphagnum* spp*.*

C. varians – Zhukova & Matveyeva (2000); Sp. D, M; 1,4,5,6; f,wh; with *Anthelia juratzkana, Lophozia* cf. *longiflora*, *L. ventricosa, Lophoziopsis excisa, Scapania hyperborea, Sphenolobus minutus, Trilophozia quinquedentata, Bryum pallens, Polytrichastrum alpinum, Oncophorus* cf. *wahlenbergii, Campylium stellatum, Aulacomnium turgidum, Plagiothecium denticulatum, Sanionia uncinata* and other common mosses

Chiloscyphus polyanthos – Rar. D, M; 6,8; wh,t; with *Ptilidium ciliare, Sanionia uncinata, Campylium stellatum, Calliergon giganteum, Tomentypnum* sp., *Brachythecium mildeanum, Drepanocladus polygamus*

Chiloscyphus pallescens – Zhukova & Matveyeva (2000); Sp. D; 6; wh; with *Aneura pinguis, Blepharostoma* cf *trichophyllum, Scapania paludicola, Trilophozia quinquedentata*

Clevea hyalina – This species was reported by Zhukova & Matveyeva, (2000, as *Athalamia hyalina*), but is absent in our collections

Cryptocolea imbricata – Un. D; 1; dh; with *Kiaeria blyttii, Plagiothecium* cf *denticulatum, Pohlia cruda*

Diplophyllum taxifolium – Zhukova & Matveyeva (2000); Sp. D; 1; dr,f; with *Blepharostoma brevirete*

Frullania subarctica – Zhukova & Matveyeva (2000), as *F. nisquallensis* Sull.; Rar. D; 2; f,wh; with *Radula prolifera*

Fuscocephaloziopsis leucantha – Un. D; 5; wh; with *Blepharos-*

toma trichophyllum var. *brevirete, Cephaloziella hampeana, Orthocaulis quadrilobus, Trilophozia quinquedentata*

F. pleniceps – This species was reported by Zhukova & Matveyeva (2000), but is absent in our collections

Gymnomitrion concinnatum – Zhukova & Matveyeva (2000); Sp. M, D; 1,5; f

G. corallioides – Zhukova & Matveyeva (2000); Rar. D; 1; f; with *Sphenolobus minutus*

Jungermannia polaris – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

J. pumila – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

Lophozia longiflora – Zhukova & Matveyeva (2000); Un. D; 5; wh; with *Cephaloziella varians, Lophoziopsis excisa, Scapania hyperborea, Trilophozia quinquedentata*

L. murmanica – Un. M; 1,3; df with *Scapania scandica, Blepharostoma brevirete, Schistochilopsis incisa, Sphagnum balticum, Polytrichum hyperboreum, Dicranum* sp., *Aulacomnium turgidum*

L. savicziae – Zhukova & Matveyeva (2000); Un. D; 3; dh; with *Diplophyllum taxifolium*

L. subapiculata – Rar. D; 3,5; dh, sp; with *Cephaloziella* sp., *Pseudotritomaria heterophylla, Schistochilopsis opacifolia, Lophozia ventricosa* var. *longiflora, Sphagnum squarrosum, S. warnstorfii, Polytrichum hyperboreum, Scorpidium revolvens, Dicranum angustum* [1]

L. sylvicola – Un. D; 1,2,3; dh; with *Gymnomitrion corallioides, Lophozia ventricosa, Sphenolobus minutus, Trilophozia quinquedentata*

L. ventricosa var. *ventricosa* – Zhukova & Matveyeva (2000, without variety identification); Sp. D; 1,3,5,6; f,dh,wh; with *Anthelia juratzkana, Blepharostoma brevirete, Cephalozia bicuspidata, Cephaloziella* spp., *Diplophyllum taxifolium, Lophoziopsis polaris, Nardia geoscyphus, Scapania* cf. *parvifolia, Schistochilopsis opacifolia, Sphenolobus minutus*

L. ventricosa var. *longiflora* – Rar. M; 3; ?; with *Ptilidium ciliare, Calycularia laxa, Blepharostoma brevirete, Tomentypnum nitens, Aulacomnium turgidum, Orthothecium* cf. *chryseon, Dicranum angustum, Campylium stellatum, Polytrichum hyperboreum Sanionia uncinata, Flexitrichum* cf. *flexicaule*

L. ventricosa var. *rigida* – Sp. D; 6; wh; with *Blepharostoma trichophyllum* var. *brevirete, Scapania spitsbergensis, Sphenolobus minutus, Trilophozia quinquedentata* [2]

L. wenzelii – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections. The record most probably based on misidentified *L. murmanica*.

Lophoziopsis excisa – Zhukova & Matveyeva (2000); Rar. D, M; 5,6; wh; with *Cephaloziella uncinata, Schistochilopsis incisa, Trilophozia quinquedentata, Sphagnum teres Cinclidium latifolium, Dicranum* cf. *spadiceum, Polytrichastrum alpinum, Aulacomnium palustre, Polytrichum hyperboreum*

L. pellucida var. *minor* – Un. D; 6; wh; with *Anthelia juratzkana, Blepharostoma brevirete, Cephalozia bicuspidata, Odontoschisma macounii, Trilophozia quinquedentata*

L. polaris – Rar. D; 1,2,3; f,dh; with *Anthelia juratzkana, Diplophyllum taxifolium*

L. polaris var. *sphagnorum* – Sp. D; 1,3,5; f,mg; with *Blepharostoma brevirete, Mesoptychia heterocolpos, Sphenolobus minutus, Trilophozia quinquedentata* [3]

L. propagulifera – Un. D; 3; dh

Mannia gracilis – Zhukova & Matveyeva, (2000, as *Asterella gracilis*), Rar. D; 3; mg

Marchantia alpestris – Zhukova & Matveyeva (2000); Rar. D; 7,9; wh,mg

Marsupella emarginata – Un. D; 1; f

Mesoptychia badensis – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

M. gillmanii – Un. D; 6; wh

M. heterocolpos var. *heterocolpos* – Zhukova & Matveyeva (2000, without variety identification); Sp. D, M; 2,3,5,6,8; wh,mg; with *Blepharostoma brevirete, Cephaloziella varians, Trilophozia quinquedentata*

M. heterocolpos var. *arctica* – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

M. heterocolpos var. *harpanthoides* – Un. D; 5; wh

M. rutheana – Zhukova & Matveyeva (2000); Sp. D; 5,6; wh; with *Aneura pinguis, Trilophozia quinquedentata*

M. sahlbergii – Zhukova & Matveyeva (2000); Sp. M, D; 4,5,6; wh

Moerckia blyttii (Mřrch) Brockm. – Un. D; 7; mg; with *Schistochilopsis opacifolia, Trilophozia quinquedentata*

Moerckia hibernica – This species was reported by Zhukova & Matveyeva, (2000), but in our opinion, this record actually bases on *M. flotoviana*, which for a long time has not been recognized from the previous species

Nardia geoscyphus – Zhukova & Matveyeva (2000); Un. D; 7; mg; with *Moerckia blyttii, Schistochilopsis opacifolia, Trilophozia quinquedentata*

Neoorthocaulis binsteadii – Zhukova & Matveyeva (2000); Un. M; 1; df; with *Neoorthocaulis binsteadii*, *Schistochilopsis incisa, Lophozia murmanica*, *Sphagnum balticum*, *Polytrichum hyperboreum*, species of the genera *Flexitrichum, Dicranum* and *Tomentypnum*

N. hyperboreus – Zhukova & Matveyeva (2000); Un. D; 3; dh; with *Cephaloziella varians, Frullania subarctica, Lophoziopsis excisa*

Odontoschisma elongatum – Un. M; 6?; ?; with *Lophoziopsis excisa*, *Cephaloziella uncinata, Schistochilopsis incisa, Trilophozia quinquedentata, Sphagnum teres Cinclidium latifolium, Dicranum* cf. *spadiceum, Polytrichastrum alpinum, Aulacomnium palustre, Polytrichum hyperboreum*

O. macounii – Zhukova & Matveyeva (2000); Sp. D; 3,4,5,6,7; f,wh,mg; with *Aneura pinguis, Blepharostoma brevirete, Nardia geoscyphus, Scapania paludicola, Schljakovianthus quadrilobus, Solenostoma subellipticum, Sphenolobus minutus, Trilophozia quinquedentata*

Peltolepis quadrata – Un. D; 3; mg

Plagiochila arctica – Zhukova & Matveyeva (2000) as *P. porelloides*; Rar. D, M; 1,3,5; f with *Ptilidium ciliare*, *Racomitrium lanuginosum, Tomentypnum nitens, Dicranum acutifolium, Aulacomnium turgidum*, *Flexitrichum* cf. *flexicaule, Polytrichastrum alpinum*

Prasanthus suecicus – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

Preissia quadrata – Zhukova & Matveyeva (2000); Un. D; 7; mg; with *Blepharostoma trichophyllum* var. *brevirete*

Pseudolophozia sudetica – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections.

Pseudotritomaria heterophylla – Zhukova & Matveyeva (2000); Rar. D; 3; dh; with *Blepharostoma brevirete*

Ptilidium ciliare – Zhukova & Matveyeva (2000); Com. M, D; 2,3,4; dh,wh

Radula prolifera – Zhukova & Matveyeva (2000); Un. D; 3; dh

Sauteria alpina – Zhukova & Matveyeva (2000); Rar. D; 7; mg; with *Aneura pinguis*

Scapania brevicaulis – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

S. crassiretis – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

S. cuspiduligera – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

S. degenii – Rar. D; 5,6; wh; with *Aneura pinguis, Blepharostoma brevirete, Mesoptychia rutheana, Scapania paludicola, Schljakovianthus quadrilobus, Trilophozia quinquedentata*

S. gymnostromophila – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

S. hyperborea – Zhukova & Matveyeva (2000); Un. D; 6; t; with *Cephaloziella* sp.*, Trilophozia quinquedentata*

S. irrigua – Zhukova & Matveyeva (2000); Un. D; 3; dh; with *Lophoziopsis polaris* var. *sphagnorum, Mesoptychia heterocolpos*

S. kaurinii – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

S. lingulata – Un. M; 3; ?; with *Tomentypnum* sp., *Stereodon hamulosus, Aulacomnium palustre, Pohlia cruda, Polytrichastrum alpinum, Oncophorus* cf. *wahlenbergii, Isopterygiella pulchella*

S. obcordata – Zhukova & Matveyeva (2000); Un. M; 6; wh; with *Cephaloziella varians, Schljakovianthus quadrilobus, Sanionia uncinata, Tomentypnum* sp., *Aulacomnium turgidum, Bryum pseudotriquetrum*

S. paludicola – Rar. D, M; 5, 6; wh; with *Blepharostoma brevirete, Cephaloziella spinigera, Cephaloziella varians, Schljakovia kunzeana, Trilophozia quinquedentata, Bryum pseudotriquetrum, Cinclidium latifolium, Aulacomnium turgidum, Sanionia uncinata, Polytrichastrum alpinum, Scorpidium revolvens* and other common march mosses

S. paludosa – Rar. D; 5,6; wh; with *Blepharostoma brevirete, Cephaloziella hampeana, Fuscocephaloziopsis leucantha, Orthocaulis quadrilobus, Trilophozia quinquedentata*

S. parvifolia – Rar. D, M; 1, 3; f; with *Cephalozia bicuspidata, Sphenolobus minutus, Blepharostoma trichophyllum, Polytrichum hyperboreum, Dicranum angustum, Aulacomnium turgidum*. Specimen from Meduza was referred by N.A. Konstantinova to *S. scanica* apparently also represents *S. parviflora* (Konstantibova, pers. comm).

S. scandica – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections. Their record most likely belongs to *S. parvifolia*, before commonly treated as a form within *S. scandica*.

S. simmonsii – Zhukova & Matveyeva (2000); Un. D; 5; wh; with *Blepharostoma brevirete, Tritomaria quinquedentata*

S. spitsbergensis – Sp. D; 3,5,6; dh,wh; with *Diplophyllum taxifolium, Lophoziopsis excisa*

S. subalpina – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

S. uliginosa – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

Schistochilopsis incisa – Zhukova & Matveyeva (2000); Rar. D, M; 3,4,5,6; wh; with *Anthelia juratzkana, Aneura pinguis*, *Blepharostoma brevirete, Diplophyllum taxifolium, Mesoptychia heterocolpos, Moerckia blyttii, Nardia geoscyphus, Sphenolobus minutus, Trilophozia quinquedentata, Dicranum elongatum, Aulacomnium turgdum, Sphagnum* spp., *etc.*

Schistochilopsis opacifolia was reported by Zhukova & Matveyeva (2000) and found in our collection; however, molecular-pylogenetic study of the genus (Bakalin et al., 2020) showed that *S. opacifolia* should be considered as synonym of *S. incisa*. Two specimens from our collection morphologically fit to *S. hyperarctica* and even were tested using molecular phylogenetic data (see Bakalin et al., 2020), but also appeared mixed with morphologically heterogeneous specimens in *S. incisa* s.l. clade.

Schljakovia kunzeana – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

Schljakovianthus quadrilobus – Zhukova & Matveyeva (2000); Rar. D, M; 4,6; wh; with *Blepharostoma brevirete, Cephaloziella hampeana*, *C. varians, Lophoziopsis polaris, Mesoptychia heterocolpos* var. *harpanthoides, Scapania paludicola, Trilophozia quinquedentata, Bryum* spp*., Orthothecium* cf. *chryseon, Sanionia uncinata, Flexitrichum* sp.*, Distichium inclinatum Mnium* cf. *blyttii, Encalypta alpina, Myurella tenerrima*

S. quadrilobus var. *glareosus* – Un. D; 5; wh; with *Aneura pinguis, Chiloscyphus pallescens, Scapania paludicola*

Solenostoma obovatum – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections. Most likely the present record belongs to *S. subellipticum* before commonly not recognized as the species distinct from *S. obovatum*.

S. subellipticum – Rar. D; 5,6,7; wh,mg; with *Anthelia juratzkana, Cephalozia bicuspidata, Cephaloziella varians, Trilophozia quinquedentata*

Sphenolobus minutus – Zhukova & Matveyeva (2000); Com. M, D; 2,3,4,6; dh,wh,mg; with *Anthelia juratzkana, Lophozia ventricosa, Trilophozia quinquedentata*

S. minutus fo. *grandis* – Un. D; 3; dh

S. saxicola – Rar. M, D; 1; dh

Tetralophozia setiformis – Zhukova & Matveyeva (2000); Fr. M, D; 1,2; f,dh

Trilophozia quinquedentata – Zhukova & Matveyeva (2000); Fr. D, M; 1,2,3,4,5,6,7,8,9; f,dh,wh; with *Aneura pinguis, Blepharostoma brevirete*, *Cephalozia bicuspidata, Cephaloziella* cf *spinigera, Cephaloziella varians, Chiloscyphus pallescens, Diplophyllum taxifolium, Lophozia ventricosa, Mesoptychia heterocolpos, Ptilidium ciliare, Scapania paludicola, Schistochilopsis opacifolia, Schljakovianthus quadrilobus, Sphenolobus minutus*

Tritomaria scitula – This species was reported by Zhukova & Matveyeva, (2000), but is absent in our collections

Mosses

Abietinella abietina – Rar. M, D; 1, 2; dh

Aloina brevirostris – Sp. M, D; 7; df; S+

Amphidium mougeotii – Rar. D; 1; dr

Andreaea papillosa – Rar. M; 1; dr, wr

A. rupestris – Fr. M, D; 1, 2; dr, wr; S+

A. sparsifolia – Fr. M; 1, 2; dr, wr; S+

Aplodon wormskjoldii – Fr. M, D; 3, 4; or; S+

Aquilonium plicatulum – Un. M; 1, 3; dh

Arctoa hyperborea – Un. D; 1; df [4]

Aulacomnium palustre – Fr. M, D; 3, 4, 5, 6, 8; wh, s

A. turgidum – Com. M, D; 2, 3, 5, 6, 8; mg, dh, wh, s

Bartramia ithyphylla – Fr. M, D; 1, 5, 7; df, dh; S+

Bartramia pomiformis – Rar. M, D; 3; dh

Blindia acuta – Sp. D; 1, 5; dr, wf
Brachytheciastrum trachypodium – Rar. M; 1,2; dr
Brachythecium cirrosum – Sp. M, D; 3, 4, 5, 6, 7, 8; dh, wh
B. cf. jacuticum – Un. M; 1; dh
B. mildeanum – Rar. M, D; 3, 4, 8; wh
B. turgidum – Rar. D; 5, 6, 8; mg, wh
Bryobrittonia longipes – Rar. M, D; 7; mg
Bryoerythrophyllum ferruginascens – Rar. M, D; 3, 7; mg
B. recurvirostrum – Fr. M, D; 1, 2, 3, 7; wf, df, mg; S+
Bryum algovicum – Un. M; 3; ?; S+
B. amblyodon – Un. M; 1; df; S+
B. archangelicum – Un. M; 3; dh; S+
B. arcticum – Sp. M; 3, 6; dh, mg; S+
B. argenteum – Sp. M, D; 9; mg, r; S+
B. cryophilum – Rar. D; 8; wf
B. cyclophyllum – Fr. M, D; 5, 6; wf, wh
B. elegans – Rar. M, D; 1; dr, dh, or
B. knowltonii – Un. M; 6; wf; S+
B. neodamense – Un. D; 4; wf
B. pallens – Un. M; 6; wf
B. pseudotriquetrum – Fr. M, D; 4, 5, 6, 8; wf, wh
B. purpurascens – Un. M; 2; df; S+
B. rutilans – Sp. M, D; 5, 7; wh, mg
B. salinum – Un. M; 8; mg; S+
B. schleicheri – Un. M, D; 3; dh
B. wrightii – Rar. D; 3; mg; S+
Buckia vaucheri – Rar. M, D; 2; dh
Calliergon cordifolium – Un. M; 4, 6; wh
C. giganteum – Sp. M, D; 4, 5, 6, 8; wh
C. richardsonii – Rar. M, D; 4, 5; wh
Calliergonella lindbergii – Rar. M, D; 6; wh
Campyliadelphus chrysophyllus – Rar. M; 6, 8, 9; wh, t
Campylium bambergeri – Rar. M, D; 2, 3; dh
C. stellatum – Fr. M, D; 3, 4, 5, 6, 7, 8, 0; wf, mg, dh, wh, t
Ceratodon heterophyllus – Un. M; 8; mg
C. purpureus – Sp. M, D; 1, 2, 3, 6, 7, 8, 9; df, mg, dh, wh, t; S+
Cinclidium arcticum – Sp. M, D; 5; wh
C. latifolium – Sp. M, D; 4, 5; wh
C. minutifolium – Rar. M, D; 5; wh
C. stygium – Un. M; 4; wh
C. subrotundum – Rar. M, D; 4; wh; S+
Cnestrum alpestre – Fr. M, D; 1, 2, 3; df, mg; S+
C. glaucescens – Un. M; 3; mg; S+
Conostomum tetragonum – Fr. M, D; 1, 2, 3, 5; df, dh; S+
Cratoneuron curvicaule – Rar. D; 4, 6, 7; mg, wh
C. filicinum – Rar. D; 3, 4, 7, 8; mg, wh
Cynodontium strumiferum – Sp. M; 1, 2; dh, or; S+
C. tenellum – Fr. M, D; 1; dh; S+
Cyrtomnium hymenophylloides – Rar. M; 7; mg, dh
C. hymenophyllum – Rar. M; 7; wh
Dichodontium pellucidum – Sp. M, D; 1, 3, 7; dw, wf, mg
Dicranella cerviculata – Rar. M, D; 7; mg; S+
D. crispa – Sp. M, D; 3, 7; mg; S+
D. schreberiana – Un. M; 3; mg; S+
D. subulata – Fr. M, D; 2, 3, 6; mg; S+
D. varia – Sp. M, D; 7; mg; S+
Dicranum acutifolium – Rar. M, D; 2; dh
D. angustum – Sp. M; 2, 4; dh, wh
D. elongatum – Fr. M, D; 2, 3, 4, 5; wh, dh
D. flexicaule – Un. D; 1, 2; dh
D. groenlandicum – Sp. M, D; 1, 2; dh
D. laevidens – Fr. M, D; 4, 5; wh, s
D. leioneuron – Un. D; 4; wh
D. majus – Rar. D; 2; mg, dh
D. schljakovii – Rar. M; 2; dh
D. septentrionale – Rar. D; 3; dh
D. spadiceum – Rar. M, D; 1, 2, 3; dh
Didymodon ferrugineus – Un. M; 7; mg
D. icmadophillus – Rar. D; 1; df
Distichium capillaceum – Fr. M, D; 1, 2, 3, 4, 7; wf, df, dh, mg; S+
D. hagenii – Un. M; 5; wh; S+
D. inclinatum – Sp. M, D; 2, 3; mg; S+
Drepanocladus aduncus – Rar. M, D; 6, 7; mg, wh, t
D. arcticus – Rar. M, D; 3, 6, 7; mg, wh, t
D. capillifolius – Un. D; 6; wh
D. polygamus – Rar. M, D; 6; t
D. sordidus – Rar. M, D; 7; wt, mg
Encalypta alpina – Fr. M, D; 3, 7; mg, dt, wt; S+
E. brevicollis – Un. M; 1; df; S+ [5]
E. longicollis – Rar. M; 3; mg; S+
E. mutica – Rar. D; 7; mg; S+ [6]
E. procera – Fr. M, D; 1, 7; fs, mg; S+
E. rhaptocarpa – Sp. M; 1, 7; df, dh; S+
E. trachimytria – Sp. M, D; 1, 3; df, dh; S+
Eurhynchiastrum pulchellum – Rar. M, D; 7; dh
Fissidens arcticus – Sp. M, D; 7; mg; S+
F. cf. *bryoides* – Rar. M, D; 1; wf; S+
F. osmundoides – Rar. M; 7, 8; dh
Flexitrichum flexicaule – Fr. M, D; 1, 3, 7; df, wf, mg, dh
F. gracile – Sp. M, D; 1, 2, 4, 5; dh, wh; S+
Funaria arctica – Sp. M, D; 7; mg; S+
F. hygrometrica – Rar. M, D; 7, 9; mg, t; S+
Grimmia incurva – Fr. M, D; 1; r, df
Hamatocaulis vernicosus – Fr. M, D; 4, 5, 6; wh
Hennediella heimii – Fr. M, D; 7, 9; mg; S+
Hygrohypnella polaris – Fr. M, D; 1, 5, 6; wr, wf
Hygrohypum luridum – Un. M; 6; wr, wf
Hylocomium splendens – Com. M, D; 1, 2, 3; df
Hymenoloma crispulum – Fr. M, D; 1; wr, wf; S+
Hypnum cupressiforme – Sp. M, D; 1; dh
Isopterygiella alpicola – Un. M; 1; dr
I. pulchella – Fr. M, D; 1, 2, 3, 5, 7; df, dh; S+
Isopterygiopsis catagonioides – Rar. M; 1; df, dh
Kiaeria blyttii – Fr. M, D; 1, 5; wr, df; S+ [7]
K. glacialis – Rar. D; 5; wh
Leptobryum pyriforme – Rar. M, D; 9; t; S+
Lewinskya cf. *iwatsukii* – Rar. M; 7; dh; S+ [8]
Loeskypnum badium – Rar. M, D; 4; wh
Meesia longiseta – Un. M; 5; wf; S+
M. minor – Sp. M; 2, 3, 7; mg; S+ [9]
M. triquetra – Rar. M, D; 4; wh
M. uliginosa – Rar. M, D; 4, 6; wh; S+
Mnium blyttii – Rar. M; 2,7; mg, dh [10]
M. lycopodioides – Sp. M, D; 7; mg
M. thomsonii – Un. M; 3; dh
Myurella julacea – Fr. M, D; 1, 2, 3, 7; df, mg, dh
M. tenerrima – Fr. M, D; 7; mg, dh
Neckera oligocarpa – Sp. M, D; 1; dr; S+
Niphotrichum canescens – Rar. M; 6; wr
N. ericoides – Sp. D; 1, 2; df
N. panschii – Fr. M, D; 1, 2, 5, 6, 7; df, wf, mg, dh
Oncophorus elongatus – Rar. M, D; 3, 4, 6, 8; dh, wh, t; S+

O. virens – Sp. M, D; 4, 5, 6; wh, mg
O. wahlenbergii – Fr. M, D; 1, 6; wr, wf
Orthothecium chryseon – Rar. M, D; 1, 3; wf, mg, wh – for comments see Ignatov *et al.* (2020).
O. remotifolium – Un. D; 3, 4, 5, 6; mg, wh – for comments see Ignatov *et al.* (2020).
O. retroflexum – Fr. M, D; 1; df – for comments see Ignatov *et al.* (2020)
O. strictum – Sp. M, D; 1, 3, 6; df, mg
Paludella squarrosa – Rar. D; 4; wh
Philonotis tomentella – Fr. M, D; 3, 4, 6, 8; mg, dh, wh; S+
Plagiobryum demissum – Rar. D; 7; mg; S+
Plagiomnium curvatulum – Sp. M, D; 1, 4, 6, 7, 8; wh; S+
P. ellipticum – Rar. M, D; 4; wh
Plagiothecium berggrenianum – Sp. M, D; 1, 3, 4; dr, dh, wh
P. cavifolium – Rar. M, D; 1; dh
P. denticulatum var. *obtusifolium* – Fr. M; 1; dh [11]
P. svalbardense – Sp. D; 1; dh – for comments see Ignatova et al. 2019
Platidyctya jungermannioides – Rar. M, D; 1; dr, df
Platyhypnum alpestre – Sp. M, D; 6; wr
Pogonatum dentatum – Fr. M, D; 1, 7; df, mg
Pogonatum urnigerum – Fr. M, D; 1, 6, 7, 8, 9; df, mg, dh
Pohlia andrewsii – Fr. M, D; 1, 3, 7; df, mg
P. atropurpurea – Rar. M, D; 7; mg; S+
P. beringiensis – Un. M, D; 1; wf; P+
P. cruda – Fr. M, D; 1, 2, 3, 7, 9; df, dh; S+
P. crudoides – Un. M; 1; df
P. drummondii – Fr. M, D; 1, 7; wf, mg; P+
P. ludwigii – Un. M; 1, 5; wf
P. nutans – Sp. M, D; 1, 2, 3, 7, 8, 9; dh; S+
P. proligera – Rar. M, D; 7; mg; P+
P. wahlenbergii – Sp. D; 6; wh
Polytrichastrum alpinum – Com. M, D; 1, 2, 3, 5, 7, 8, 9; df, dh; S+
P. fragile – Rar. M, D; 6; wh
P. septentrionale – Sp. D; 1, 5; df
Polytrichum hyperboreum – Fr. M, D; 3, 4, 5, 7; wf, mg, dh, wh, s; S+
P. jensenii – Sp. M, D; 6, 8; wh
P. juniperinum – Fr. M, D; 1, 2, 7; df, mg, dh; S+
P. longisetum var. *anomalum* – Rar. M; 7; dh
P. piliferum – Sp. M, D; 1; df
P. strictum – Fr. M, D; 4; wh, s
Pseudobryum cinclidioides – Rar. D; 6; wh
Pseudocalliergon brevifolium – Sp. M; 5; wf, wh
P. cf. *angustifolium* – Sp. M, D; 4, 5; wf, wh [12]
P. turgescens – Fr. M, D; 4, 5, 6, 8; wf, wh
Pseudoleskeella papillosa – Rar. M, D; 1; dr, df
P. rupestris – Rar. M, D; 1; dr, df
P. tectorum – Rar. M; 1; dr, df
Pseudostereodon procerrimus – Rar. D; 2; dh
Psilopilum cavifolium – Sp. M, D; 1, 5, 7; wf, mg; S+
P. laevigatum – Un. D; 7; mg
Pterigynandrum filiforme – Sp. M, D; 1; dr, df
Pterygoneurum sp. – Rar. M; 7; mg; S+ [13]
Racomitrium lanuginosum – Com. M, D; 1, 2, 3, 5; dr, df, wf, dh
Rhizomnium andrewsianum – Rar. M, D; 3, 5, 7; wh
Rhytidium rugosum – Fr. M, D; 1, 2, 3; dh
Roaldia revoluta – Sp. M, D; 1; dr, df
Saelania glaucescens – Fr. M, D; 1, 5, 7; df, wf, dh; S+
Sanionia cf. orthothecioides – Rar. M; 8; dr, dh [14]
S. uncinata – Com. M, D; 1, 2, 3, 4, 5, 6, 7, 8, 9; r, df, dh, wh, t; S+
Schistidium abrupticostatum – Rar. D; 5; wf; S+
S. agassizii – Rar. M, D; 6; wr
S. andreaeopsis – Rar. D; 2; dh
S. cf. *flexipile* – Un. D; 1; dr; S+
S. cf. *scandicum* – Un. D; 1; dr; S+
S. frigidum – Fr. M, D; 1; dr; S+
S. grandirete – Un. M; 1; wf; S+
S. obscurum – Un. D; 1; dr; S+
S. papillosum – Fr. M, D; 1, 5; dr, wr, wf; S+
S. platyphyllum – Fr. M, D; 6; wr, dr; S+
S. pulchrum – Rar. M, D; 1; dr; S+
S. rivulare – Un. M; 3; wr
S. venetum – Un. D; 6; wr; S+
Scorpidium cossonii – Sp. M, D; 4, 5; wh
S. revolvens – Com. M, D; 4, 5, 6; wh; S+
Sphagnum aongstroemii – Un. M; 6; wh, s
S. arcticum – Un. M; 6; wh, s
S. balticum – Sp. M, D; 4, 6; wh, s
S. beringiense – Rar. M, D; 4, 5; wh
S. capillifolium – Sp. M, D; 4, 6; wh, s
S. concinnum – Sp. M, D; 6; wh, s [15]
S. fimbriatum – Rar. M; 6; wh, s
S. girgensohnii – Rar. M; 4, 5, 6; wh, s [16]
S. lenense – Rar. M; 4, 6; wh, s
S. orientale – Rar. M, D; 5, 6; wh, s
S. squarrosum – Sp. M, D; 6; wh, s
S. teres – Sp. M, D; 6; wh, s
S. tundrae – Rar. M; 6; wh, s
S. warnstorfii – Sp. M, D; 5, 6; wh, s [17]
Splachnum vasculosum – Rar. M, D; 4, 6; or; S+
Stegonia latifolia – Rar. M; 7; mg; S+
S. hamulosus – Rar. M; 1, 7; dh
S. holmenii – Sp. M, D; 1, 4, 7; dh
S. pratensis – Un. D; 6; wh
S. subimponens – Rar. M, D; 3; dh
Straminergon stramineum – Rar. M, D; 4, 6; dh
Syntrichia norvegica – Rar. M; 1; df
S. ruralis – Sp. M, D; 1, 8; dh
Tetraplodon mnioides – Fr. M, D; 1, 2, 3, 4, 5; or; S+
Timmia austriaca – Sp. M, D; 1, 3; df, mg
T. comata – Fr. M, D; 3, 6, 7; df, mg, dh
T. norvegica – Fr. M, D; 6, 7; mg, dh
T. sibirica – Rar. D; 6, 7; mg
Tomentypnum involutum – Un. M; 3, 4; wh – for comments see Hedenäs et al. 2020
T. nitens – Com. M, D; 3, 4, 5, 6, 7, 8, 9; wf, wh
Tortella arctica – Fr. M, D; 3, 5, 7; mg, dh
T. fragilis – Rar. M, D; 1; df
T. tortuosa – Rar. M; 5; mg
Tortula cf. *cernua* – Sp. M, D; 7; mg; S+ [18]
T. cf. *laureri* – Rar. M, D; 7; mg; S+ [19]
T. leucostoma – Sp. M, D; 7; mg; S+
T. mucronifolia – Rar. M, D; 1, 2, 7; df, mg; S+
Trichodon cylindricus – Rar. D; 7; mg; S+
Warnstorfia exannulata – Sp. M, D; 4, 8; wh
W. fluitans – Rar. M, D; 4; wh
W. pseudostraminea – Un. M; 4; wh
W. sarmentosa – Com. M, D; 1, 4, 5, 6, 8, 9; wh; S+
W. tundrae – Sp. M, D; 4, 6; wh
Weissia cf. *brachycarpa* – Un. M; 3; mg [20]

Comments on remarkable species

1. *Lophozia subapiculata* was neglected from the time of its description: it is regarded as the synonym of *L. ventricosa* in the revision of *Lophozia* worldwide (Bakalin, 2005) and regarded as doubtful (one asterisk) in the World checklist of liverworts (Söderström *et al.*, 2016). We cannot evaluate the true status for this taxon prior to integrative revision of the genus and include it here provisionally, rather with the purpose to attract attention to this poorly known taxon. Due to data in hand this is the first record of the species in Asia if even the plants in type (arisen from West Greenland) actually represent in molecular-genetic sense the same taxon with the present record. One specimen collected in zonal tundra has smaller leaf cells and not so prominently acute lobe apices.

2. World liverwort checklist (Söderström et al., 2016) does not include infraspecific taxa within *L. ventricosa* treating most of them as the independent taxa of species rank. Var. *rigida* is one of the taxa within '*Lophozia ventricosa* s.l.' whose status is not definetely known and the taxon is neglected in the recent literature. This may be high-Arctic derivate of *L. ventricosa* or even a taxon that needs to be evaluated in the species rank.

3. The undoubtful segregation of *Lophoziopsis polaris* var. *sphagnorum* from *L. polaris* is only possible in the presence of botryoidal oil bodies in leaf cells those were present in alive material of the taxon.

4. The specimen referred here to *Arctoa hyperborea* was sterile and its identification is based on DNA sequence data. Nuclear ITS as well as plastid markers rps4 and trnL and mitochondrial Nad5 from this specimen were nearly identical to specimens of *A. hyperborea* from Novaya Zemlya Archipelago (see Fedosov *et al.*, 2020). Gametophyte morphology meets this species as well, therefore we refer our specimen to *A. hyperborea*. This rare species and its differences from *A. fulvella* are likely misunderstood. Partial revision of the genus *Arctoa* in LE revealed several specimens from Kola Peninsula and one specimen from Chukotka, which morphologically fit *A. hyperborea* rather than *A. fulvella.* On the other hand, in phylogenetic tree in Fedosov *et al* (2020), *A. hyperborea* forms a clade nested within *A. fulvella*. Additional sequencing and revision is needed to confirm the status and clarify distribution of this critical taxon.

5. *Encalypta brevicollis* is widespread in inland part of Taimyr but here it is reported for peninsular one for the first time.

6. *Encalypta mutica* is widespread in inland part of Taimyr but here it s reported for peninsular one for the first time.

7. *Kiaeria blyttii* is very abundant within the studied area and very diverse morphologically: along with the plants with short mamillose upper leaf cells (which are rather rare), plants with falcate leaves and elongate upper leaf cells occur and are especially abundant. Morphologically these plants rather resemble *K. starkei*, and based on such plants *Kiaeria starkei* was listed for Anabar Plateau (Fedosov *et al.*, 2011) and likely also for Novaya Zemlya Archipelago (Vekhov & Kuliev, 1998). However, two DNA-barcoded specimens are identical to one of haplotypes of *K. blyttii.*

8. The identity of large Arctic plants of *Lewinskya* needs in further study. Unpublished results of the first author show that plants recently assigned to *L. iwatsukii* actually are not homogeneous, and several different haplotypes, which do not form a separate clade, occur in Arctic. At the same time, high Arctic plants have a unique haplotype. However, this regularity, as well as morphological identity of high Arctic plants should be checked with broader selection of samples.

9. *Meesia minor* for a long time has been considered as a synonym of *M. uliginosa* until Hedenäs (2020) resurrected it based on the results of molecular phylogenetic analysis; it was consequently found to be rather common in Russia. In studied area these two species differ in ecology: *M. minor* colonizes spots of bare loamy soil in spotty tundra, while *M. uliginosa* occurs in closer bryophyte communities in tundra bogs or along brooks.

10. Several specimens from vicinity of Meduza Bay and from Dickson are referred herein to *Mnium blyttii* were originally identified as *M. stellare* due to lack of any cell differentiation along leaf margin. At the same time, according to Ignatov *et al.* (2018), the latter species does not occur in Taimyr, so these strange plants nevertheless represent a marginal phenotype of *M. blyttii*. Additional study is needed to check its identity.

11. Arctic plants of *Plagiothecium denticulatum* from the vicinity of Meduza Bay resemble other saxicolous collections of this species from Taimyr in having broadly acute to obtuse, rarely hook like pointed leaves with recurved margins. Status of this taxon needs in further study.

12. According to the key to the genus *Pseudocalliergon* in Flora of North America (Hedenäs & Miller, 2014), *P. brevifolium* should have acute to short acuminate leaves, while most of our plants have longer acuminate ones, unlike plants from vicinity of Ledyanaya Bay or from Anabar Plateau. At the same time, according to this key, *P. angustifolium* usually has prorate laminal cells, while in our plants cells are not prorate. According to Hedenäs & Miller (2014), these species differ in ecology: *P. brevifolium* usually occurs in rich arctic fens, while *P. angustifolium* grows in medium rich fens. Despite of northern locality, in the studied area rich arctic fens are very rare (and short-leaved plants occur there), while in other mire ecotopes *Pseudocalliergon* species with falcate leaves either absent or are represented by longer leaf form, thus attributed to *P. angustifolium*.

13. Identity of this arctic *Pterygoneurum* species remains unclear. This plant is rather frequent in salty sediments throughout Taimyr; it was first considered by Abramova *et al.* (1973), and due to unknown reason re-

ferred to *P. lamellatum*. At the same time, this European species differs from most congeneric ones in having peristomate capsules, while capsules in plants from Arctic Taimyr are eperistomate. From widespread *P. ovatum*, which occurs in southern part of Taimyr Area and often grows together with "Arctic *P.* cf. *lamellatum*", the latter species differs in having larger plants with longer sporophytes, short to nearly absent hyaline hair points and shape of leaf cells. Unpublished molecular data by Jan Kučera and VF suggest that this plant differs from other Eurasian species of the genus *Pterygoneurum*, but several older names are to be checked before describing it as a new species.

14. Large *Sanionia* morphotype with strongly plicate leaves, which occur along a seashore is morphologically nearly identical to the plants from Kola Peninsula referred to *S. orthothecioides*. At the same time, leaves are somewhat longer acuminate in plants from Dixon area, therefore we are uncertain if they belong to *S. orthothecioides*.

15. One *Sphagnum* specimen represented by green plants, which superficially resembled *S. fimbriatum,* had less conspicuous tin bud, and its stem leaves have lower width\length ratio than *S. fimbriatum* usually has; it also demonatrate strong border at the base, apex lacerated rather to 1/3 – 1/2 of leaf length that is characteristic for *S. concinnum*.

16. Two specimens of *Sphagnum* cf. *girgensohnii* combine characters of *S. girgensohnii* and *S. russowii* and therefore could be determined as *S. russowii*. These plants have rather long stem leaves and external cells of hyalodermis with only one medium-sized pore, which is characteristic for the latter species. However, these plants have more lacerate stem leaf apex (from 1/2 to whole leaf width) and less abundant pores on concave surface of branch leaf, which better fit *S. tescorum* or some morphs of *S. girgensohnii*.

17. Specimens referred to *Sphagnum warnstorfii* differ from typical populations of this species which grow in taiga zone in having more ovate branch leaves with larger free ringed pores on the first quarter of convex side of leaf as it was pointed for "high arctic *S. warnstorfii*" by Yousefi *et al.* (2019).

18. Although morphologically plants referred to *T. cernua* fit this species well, unpublished data by Jan Kučera and VF suggest that it is slightly different genetically and may represent a separate arctic (?) species.

19. Although, formally plants from vicinity of Dickson village fit *T. laureri*, position of capsule is a variable trait, while gametophytically plants referred to *T. laureri* do not differ from the previous species.

20. The specimen is represented by plants without capsules; it is identical to one from the vicinity of Ladyanaya Bay (Fedosov & Ignatova, 2005), referred to *W. brachycarpa* due to lack of reddish coloration, which is characteristic to *Trichostomum crispulum*. In addition, the latter usually grows in the areas with limestone outcrops, which are absent in studied area.

Discussion

With its limited area of exploration (in general ca. 100-150 sq. km), uniform relief, homogeneous bedrock composition and climate, ease to access and long history of the bryophyte flora exploration, Dickson area deserves to be considered as kind of a model object of ã - diversity study according to Tolmachev (1974) approach. Therefore we present the studied flora as a reference for comparison with other high Arctic bryophyte moss floras. In studied collections we revealed 69 liverwort and ca. 249 moss species; combined with the previously published data by Zhukova and Matveyeva (2000), list of Hepatics includes 90 species and 7 infraspecific taxa, 339 species of bryophytes are referred to the area – nearly 2.5 times more than flora of vascular plants, know from this area (Kuvaev & Vaschenkova, 1994 with further additions; Matveyeva & Zanokha, 2017). Although only 88 species of hepatics were hitherto known from arctic tundra subzone of Taimyr, each third liverwort species collected by non-hepaticologist (VF) was new for the area; therefore, our data about their diversity cannot be considered as complete. Therefore, the comparative account below is mostly concentrated on mosses. The bryophyte flora of the vicinity of Uboynaya River mouth comprises 159 species of mosses (Kannukene & Matveyeva, 1996) and nearly the same number of moss species were published for the local moss floras of Chukotka Peninsula (Afonina, 1974).

Although the studied area and Uboynaya River lower course represent the same biome and nearly the same landscape, the difference in revealed species is unexpectedly high. Several species of mosses found in vicinity of Uboynaya River mouth are absent in our list. Among them, eleven species, *Arctoa fulvella, Brachythecium udum, Catoscopium nigritum, Didymodon rigidulus, Pohlia filum, Pseudocalliergon trifarium, Sphagnum compactum, S. obtusum, S. russowii, Splachnum sphaericum,* and *Thuidium assimile* occur in similar landscapes in Arctic and Hypoarctic zones and may occur in the studied area, but have not been found. Five species, *Bryum teres, Didymodon asperifolius* var. *gorodkovii*, *Blindiadelpus polaris, B. subimmersus* (originally reported as *Seligeria diversifolia*, but further this specimen was reidentified) and *Trichostomum crispulum* are calcicolous species, which are absent due to lack of suitable substrates.

Circumscription of several species have changed since 1996: *Orthothecium rufescens*, reported for the lower course of Uboynaya River, according to Ignatov *et al*. (2020) does not occur in Arctic; all specimens, previously referred to this species they transferred to *O. chryseon*, while many specimens identified as *O. chryseon* were referred to the newly described *O. retroflexum*. Likewise, specimens from Uboynaya River identified as *Hypnum callichroum*, actually belong to *Stereodon holmenii* (for details see Afonina, 2004)*; Plagiothecium laetum* var. *densum* likely represents *P. svalbardense* (for details see Ignatova *et al.*, 2019); most collections of *Drepanocladus sendtneri* from Asian Arctic actually represent *D. sordidum, etc*. In general, 31 moss taxa from our list have started been recognized after 1996 and therefore could not be reported by Kannukene and Matveyeva, but several species appeared in their paper under other names and ca. 80 moss species from our list could appear in their paper, but either do not occur in the vicinity of Uboynaya River mouth or were omitted.

Only three species of Splachnaceae were revealed in the studied flora; this might be explained by low abundance a reindeer due to high human population. At the same time, two of three species, *Tetraplodon mnioides* and *Aplodon wormskjoldii,* are quite frequent in the area, which could be explained by their ability to colonize different types of organic remnants. In addition to a list of "not found species", *Grimmia elatior, G. longirostris, G. funalis*, *G. jacutica*, *Pseudohygrohypnum subeugyrium,* and *Encalypta brevipes* in central Byrranga (Ledyanaya Bay) occur exactly in the same environments which are widespread in Dickson area, but have not been found in the latter despite of special search and also despite the fact that in Central Byrranga at least three of them are frequent. *Lewinskya* cf. *iwatsukii* is common in Central Byrranga, but was found only in one place in Dickson area. Instead, *Kiaeria blyttii* is common on rock outcrops throughout studied area; this species was referred for vicinity of Ledyanaya Bay (Fedosov & Ignatova, 2005), but this record based on misidentification. Since *Kiaeria blyttii* generally occurs in more humid environments than other above mentioned species (which usually grow together), this difference in composition of saxicolous moss communities might be caused by mesoclimatic conditions, which are more humid in studied area due to seashore influence appearing as a misty summer weather. The same reason could explain uneven distribution of several other species. In particular, within studied area, *Amphidium mougeotii* occurs only along northern seashore of Taimyr Peninsula. On the opposite, both species of *Cynodontium* are rather frequent in vicinity of Meduza Bay, but do not occur in Dickson village outskirts.

Although the area of ă - diversity inventory should be rather homogeneous and species are supposed to be distributed rather homogeneously in all suitable habitats within it, in the studied area this is not always true. An impact of ground/bedrock composition likely supplies probable differences in mesoclimatic conditions between seashore and inland localities, especially ones associated with S-faced slopes resulting in mosaic pattern of bryodiversity on a local scale. In particular, *Amphidium mougeotii* is common on dolerite rocks near northern seashore, but has not been found in other places, although rock outcrops of similar composition are widespread throughout the area. *Buckia vaucheri*, *Pseudostereodon procerrimus, Schistidium andreaeopsis* and *Frullania subarctica* occur in small patch in rocky tundra near the top of one rocky ridge; apparently, here composition of dolerite rock is somewhat different, with higher calcium content. Although high Arctic environments are usually considered as eutrophic and base rich, rich fens are rather rare in studied area and cover quite limited places, therefore species of the genera *Pseudocalliergon, Cinclidium,* and *Meesia* are rather rare (and likely also occur in places with more basic rocks). Instead, *Scorpidium cossonii, S. revolvens, Warnstorfia sarmentosa, Bryum pseudotriquetrum, Hamatocaulis vernicosus,* species of the genera *Calliergon* and *Sphagnum* are common. Composition of pioneer mosses is also uneven. Most interesting species such as *Aloina brevirostris, Stegonia latifolia, Pohlia atropurpurea,* and *Pterygoneurum* sp. are mostly concentrated on eroded slope of seashore terrace southward the mouth of Lemberova River. Only here *Cnestrum glaucescens* and *Lewinskya* cf. *iwatsukii* were found, as well as several vascular plant species.

The same factor (i.e. ground or bedrock composition) works in larger scales as well. For instance, moss flora of sandy Sibiryakova Island situated nearby includes only 74 species (Kuvaev *et al.*, 1994). Similar plain landscapes of Arctic Yamal and Gydan largely formed by sandy sediments house even poorer floras, which, according to the available data, include: Belyi Island – 73 species (Czernyadjeva, 2001); whole arctic tundra zone of Yamal Peninsula – 133 species (Czernyadjeva, 2001), Shokalskogo Island – 79 species (Beldiman *et al.*, 2020).

On the other hand, large scale latitudinal gradient seemingly has a little impact on the bryophyte flora composition within tundra zone. With outstanding latitudinal extension of the area northward timberline and isolation from influence of both Atlantic and Pacific oceans, Taimyr Peninsula is considered as a useful area for studies of zonal trends in composition of arctic flora and vegetation (Matveyeva, 1998). Although with insufficient data available to that time, Matveyeva (l.c.) concluded that bryophyte diversity decreases northward. According to amended data, ca. 210 species of mosses occur in the vicinity of Ary-Mas area, situated in south tundra subzone of Taimyr Peninsula (Afonina, 1978, Fedosov & Afonina, 2009 with further additions). Ca. 233 species were found in the vicinity of Ledyanaya Bay in the typical tundra subzone, among which numerous saxicolous species could not occur in Ary-Mas Area due to lack of rock outcrops. Formally, comparing moss flora of Ary-Mas area (48 species of liverworts, 210 species of mosses), vicinity of Ledyanaya Bay (52 liverworts and 233 mosses) and present flora (97 liverworts and 251 mosses) one could suggest that the bryophyte diversity increases northward, while in fact other factors, including taxonomic concepts used for specimen identification, recall ratio etc. matter rather than a temperature gradient.

Recent concepts, often improved by use integrative taxonomic approach, managed to reveal high arctic element in moss flora, which was neglected before. Among high arctic taxa, *Sphagnum concinnum*, "arctic *S. warnstorfii*", *Orthothecium remotifolium* and several other distinct, though weakly delimited taxa worth mentioning, while the identity of several species from our list need further studies. Among predominantly Arctic species, *Aplodon wormskjoldii, Bryum purpurascens, Ceratodon heterophyllus, Drepanocladus arcticus, Funaria arctica, Plagiothecium berggrenianum, Pterygoneurum* sp., *Schistidium andreaeopsis, S. holmenianum,* and

Tortula cf. *cernua* might be listed. One more recently revealed phytogeographycally interesting element, neglected before, includes species largely associated with Asian cryolithozone and widespread in Arctic: *Lewinskya* cf. *iwatsukii*, *Orthothecium remotifolium, Plagiothecium svalbardense,* and *Tomentypnum involutum*.

Since Arctic biomes have appeared rather recently, i.e. in early Pleistocene (Yurtsev & Tolmachev, 1970), quite a limited number of vascular plants might be considered as high arctic endemics, and slowly evolving bryophytes unlikely could form well morphologically distinctive arctic species. In large scale retrospective trend to high extinction rate in higher latitudes is shown by e.g. Dynesius & Jansson (2000) and formulated as the Rapoport' rule (Rapoport, 1982). Due to a shift of the vegetation latitudinal boundaries northward with increasing temperatures, strong decrease of the areas covered by high Arctic biome in continental areas is predicted (Liljedahl *et al.*, 2016, Hobbie *et al*., 2017), associated with quick loss of biodiversity due to the high Arctic taxa extinction. Moreover, a sufficient change in landscape of Dickson area over last 30 years has already been noticed (Matveyeva & Zanokha, 2017). Likely, high arctic bryophytes may survive in Arctic Islands, if they manage to colonize them. Recently Zanatta *et al.* (2020) highlighted a role of dispersal ability in survival of bryophytes behind the climate change, and in case of Arctic bryophytes, this would be of especial importance, since they are generally known to produce sporophytes seldom (Longton, 1988) and in several groups where high arctic taxa were recently revealed sporophytes occur especially rare. Obviously, a sufficient portion of high arctic bryophyte diversity can disappear before being discovered and described, therefore the aim of the present account is to encourage bryologists to pay special attention to this very interesting phytogeographical group.

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LITERATURE CITED

[ABRAMOVA, A.L., L.S BLAGODATSKIKH, & CHEREPANOVA, L.A.] АБРАМОВАА.Л., Л.С. БЛАГОДАТСКИХ, Л.А. ЧЕРЕПАНОВА. 1973. Обзор рода Pterygoneurum Jur. (Musci) в СССР. – [Overview of genus Pterygoneurum Jur. (Musci) in USSR] *Новости Систематики Низших Растений* [*Novosti Sistematiki Nizshikh Rasteniy*] **10:** *305–316*.

[AFONINA, O.M.] АФОНИНА О.М. 1974. Характеристика некоторых конкретных бриофлор Чукотского полуострова. – [Characteristic of some moss floras of Chukotka Peninsula] *Ботанический журнал* [*Botanicheskij Zhurnal*] **59**(2): *192–205*

[AFONINA, O.M.] АФОНИНА О.М. 1978. Флора листостебельных мхов – [Flora of leaf-stemmed mosses] *В кн.: Ары-Мас. Природные условия, флора и растительность самого северного в мире лесного массива (п/ред. Б.Н. Норина), Л.* [*In: Norin, B.N. Ary-Mas. Enviromental conditions, flora and vegetation of the northernmost forest massif in the world. Leningrad*]: *87–96*. Available at http://byrranga.ru/docs/015.pdf

[AFONINA, O.M.] АФОНИНА О.М. 2004. Виды Hypnum секции Hamulosa (Musci, Hypnaceae) в России. – [The Hypnum species sect. Hamulosa (Musci, Hypnaceae) in Russia] *Arctoa* **13**: *9–28*. doi 10.15298/arctoa.13.03

ARNELL, H.W. 1918. Die Moose der Vega-Expedition. – *Arkiv Bot*. **15**(5): *1–111*.

[BAKALIN, V.A.] БАКАЛИН В.А. 2005. Монографическая обработка рода Lophozia (Dumort.) Dumort. s. str. [Monograph of the genus Lophozia (Dumort.) Dumort. s. str.] *Наука, Москва* [*Nauka, Moscow*], *240 pp*.

BAKALIN, V., V. FEDOSOV, YU. MALTSEVA, I. MILYUTINA, K. KLIMOVA, H.M. NGUYEN & A. TROITSKY. 2020. Overview of Schistochilopsis (Hepaticae) in Pacific Asia with the description of Protochilopsis gen. nov. – *Plants* 9070850. https://doi.org/10.3390/plants9070850

[BELDIMAN, L.N., I.N. URBANAVICHENE, V.E. FEDOSOV & E.YU. KUZMINA] БЕЛЬДИМАН Л.Н., И.Н. УРБАНАВИЧЕНЕ, В.Э. ФЕДОСОВ, Е.Ю. КУЗЬМИНА. 2020. Мхи и лишайники о-ва Шокальского (Карское море, Ямало-ненецкий автономный округ). – [Mosses and lichens of Shokalsky Island (Karskoe Sea, Yamalo-Nenetzky Autonomous District)] *Новости систематики низших растений* [*Novosti Sistematiki Nizshikh Rasteniy*] **54**(2): *497–513*. https://doi.org/10.31111/nsnr/2020.54.2.497

BROTHERUS, V.F. 1910. Die Moose des arctischen Kustengebietes von Sibiriennach der Sammlung der russischen Nordpolar Expedition 1900-1903. – *Mem. Acad. Sci. Petersb., ser. 8* **27**(2): *1–15*.

CZERNYADJEVA, I.V. 2001. Moss flora of Yamal Peninsula (West Siberian Arctic). – *Arctoa* **10**: *121–150*. doi 10.15298/arctoa.10.13

DYNESIUS, M. & R. JANSSON. 2000. Evolutionary consequences of changes in species' geographical distributions driven by Milankovitch climate oscillations. – *PNAS*. **97**: *9115–9120*. https://doi.org/10.1073/pnas.97.16.9115

[FDOSOV, V.E. & O.M. AFONINA] ФЕДОСОВ В.Э., О.М. АФОНИНА. 2009. Дополнения к флоре мхов урочища «Ары-Мас» (Восточный Таймыр). – [Addition to the moss flora of Ary-Mas (East Taymyr)] *Ботанический Журнал* [*Botanicheskij Zhurnal*] **94**(9): *11–23*.

FEDOSOV, V.E., E.YU. CHURAKOVA, S.S. KHOLOD, L.N. BELDIMAN, V.A. BAKALIN, D.A. ZAKHARCHENKO & O.M. AFONINA. 2019. Bryophytes of Zhelanija Cape, Severny Island, Novaya Zemlya Archipelago. – *Nordic Journal of Botany* **34**(4): *1–7*. DOI: 10.1111/njb.02186

FEDOSOV, V.E., A.V. FEDOROVA, J. LARRAÍN, M. BONFIM-SANTOS, M. STECH, J. KUИERA, J.C. BRINDA, D.JA. TUBANOVA, M. VON KONRAT, E.A. IGNATOVA & M.S. IGNATOV. 2020. Unity in diversity: Phylogeny and taxonomy of Rhabdoweisiaceae (Dicranales, Bryophyta). – *Botanical Journal of the Linnean Society* **20**: *1–23*. https://doi.org/10.1093/botlinnean/boaa087

FEDOSOV, V.E. & E.A. IGNATOVA. 2005. Bryophyte flora of Key plot "Ledyanaja Bay" (Central Taimyr, Byrranga range). – *Arctoa* **14**: *71–94*. doi 10.15298/arctoa.14.07

FEDOSOV, V.E., E.A. IGNATOVA, M.S. IGNATOV & A.I. MAKSIMOV. 2011. Rare species and preliminary list of mosses of Anabar Plateau (Subarctic Siberia). – *Arctoa* **20**: *153–174*. doi 10.15298/arctoa.20.11

HEDENÄS, L. & N.G. MILLER. 2014. *Pseudocalliergon. – In: Flora of North America Editorial Committee (eds.) Flora of North America North of Mexico.* ***28.*** *Oxford University Press, New York, pp. 297–300.*

HEDENÄS, L. 2019. On the frequency of northern and mountain genetic variants of widespread species: essential biodiversity information in a warmer world. – *Botanical journal of the Linnean society* **191**(4): *440–474*. https://doi.org/10.1093/botlinnean/boz061

HEDENÄS, L. 2020. Disentangling Scandinavian species hidden within Meesia uliginosa Hedw. s.l. (Bryophyta, Meesiaceae). – *Lindbergia* **2020**(1): doi 10.25227/linbg.01125

HEDENÄS, L., O.I. KUZNETSOVA & M.S. IGNATOV. 2020. A revision of the genus Tomentypnum (Amblystegiaceae) in northern Eurasia. – *The Bryologist* **123**(3): *377–395*. doi 10.1639/0007-2745-123.3.377

HOBBIE, J.E., G.R. SHAVER, E.B. RASTETTER, J.E. CHERRY, S.J. GOETZ, K.C. GUAY, W.A. GOULD & G.W. KLING. 2017. Ecosystem responses to climate change at a Low Arctic and a High Arctic long-term research site. – *Ambio* **46**(Suppl. 1): *160–173*. DOI 10.1007/s13280-016-0870-x.

IGNATOV, M.S, O.M. AFONINA, E.A. IGNATOVA, A. ABOLINA, T.V. AKATOVA, E. Z. BAISHEVA, L.V. BARDUNOV, E.A. BARYAKINA, O.A. BELKINA, A.G. BEZGODOV, M.A.BOYCHUK, V.YA. CHERDANTSEVA, I.V. CZERNYADJEVA, G.YA. DOROSHINA, A.P. DYACHENKO, V.E. FEDOSOV, I.L. GOLDBERG, E.I. IVANOVA, I. JUKONIENE, L. KANNUKENE, S.G.KAZANOVSKY, Z.KH. KHARZINOV, L.E. KURBATOVA, A.I. MAKSIMOV, U.K. MAMATKULOV, V. A. MANAKYAN, O.M. MASLOVSKY, M.G. NAPREENKO, T. N. OTNYUKOVA, L.YA. PARTYKA, O.YU. PISARENKO, N.N. POPOVA, G.F. RYKOVSKY, D.YA. TUBANOVA, G.V. ZHELEZNOVA & V.I. ZOLOTOV. 2006. Check-list of mosses of East Europe and North Asia. – *Arctoa* **15**: *1–130.* doi 10.15298/arctoa.15.01

[IGNATOV, M.S., E.A. IGNATOVA, V.E. FEDOSOV, V.I. ZOLOTOV, T. KOPONEN, I.V. CZERNYADJEVA, G.YA. DOROSHINA, D.YA. TUBANOVA & N.E. BELL] ИГНАТОВ М.С., Е.А. ИГНАТОВА, В.Э. ФЕДОСОВ, В.И. ЗОЛОТОВ, Т. КОПОНЕН, И.В. ЧЕРНЯДЬЕВА, Г.Я. ДОРОШИНА, Д.Я. ТУБАНОВА, Н.Э. БЕЛЛ. 2018. Флора мхов России. Том 4. Bartramiales – Aulacomniales. – [The moss flora of Russia. Vol 4. Bartramiales – Aulacomniales] *М., КМК* [*Moscow, KMK*], *543 pp.*

IGNATOV, M.S., J. KUČERA, L. HEDENÄS, O.I. KUZNETSOVA & E.A. IGNATOVA. 2020. A revision of the genus Orthothecium (Plagiotheciaceae, Bryophyta) in northern Eurasia. – *Arctoa* **29**(1): *10–48*. doi 10.15298/arctoa.29.02

IGNATOVA, E.A., O.I. KUZNETSOVA, & M.S. IGNATOV. 2016. Grimmia beringiensis sp. nova (Grimmiaceae, Bryophyta), a putative case of intrageneric hybridization. – *Arctoa* **25**: *69–79*. DOI: 10.15298/arctoa.25.03

IGNATOVA, E.A., A.V. FEDOROVA, O.I. KUZNETSOVA & M.S. IGNATOV 2019. Taxonomy of Plagiothecium laetum complex (Plagiotheciaceae, Bryophyta) in Russia. – *Arctoa* **28**(1): *28–45*. doi 10.15298/arctoa.28.05

IVANOV, O.V., M.A. KOLESNIKOVA, T.V. AKATOVA, O.M. AFONINA, E.Z. BAISHEVA, A.G. BEZGODOV, O.A. BELKINA, I.V. CZERNYADJEVA, S.V. DUDOV, V.E. FEDOSOV, E.I. IVANOVA, E.A. IGNATOVA, M.N. KOZHIN, E.D. LAPSHINA, A.A. NOTOV, O.YU. PISARENKO, N.N. POPOVA, A.N. SAVCHENKO, V.V. TELEGANOVA, D.YA. UKRAINSKAYA & M.S. IGNATOV. 2017. The database of the moss flora of Russia. – *Arctoa* **26**(1): *1–10*. doi 10.15298/arctoa.26.01

JENSEN, C. 1909. Musci Asiae Borealis. Beschreibung der von den Schwedischen Expeditionen nach Sibirien in den Jahren 1875 und 1876 gesammelten Moose mit Beriicksichtigung allerfruheren bryologischen Angaben fur das russische Nord-Asien. 3. Torf- moose. – *Kungliga Svenska vetenskapsakademiens handlingar* **44**(5): *1–18*.

KANNUKENE, L. & N.V. MATVEYEVA. 1996. Mosses from the Arctic tundra of the Taimyr Peninsula, Siberia. – *Proceedings of the Estonian Academy of Sciences: Biology* **45**: *51–67.*

KONSTANTINOVA, N.A., V.A. BAKALIN, E.N. ANDREJEVA, A.G. BEZGODOV, E.A. BOROVICHEV, M.V. DULIN & YU.S. MAMONTOV. 2009. Checklist of Liverworts (Marchantiophyta) of Russia. – *Arctoa* **18**: *1–64*. doi 10.15298/arctoa.18.01

KOPONEN, T., E.A. IGNATOVA, O.I. KUZNETSOVA & M.S. IGNATOV. 2012. Philonotis (Bartramiaceae, Bryophyta) in Russia. – *Arctoa* **21**: *21–62.* doi 10.15298/arctoa.21.02

[KUVAEV, V.B. & E.N. VASCHENKOVA] КУВАЕВ В.Б., Е.Н. ВАЩЕНКОВА. 1994. О флоре сосудистых растений окрестностей бухты Медуза (биологическая станция «Виллем Баренц», Северо-Западный Таймыр). – [On flora of vascular plants on Medusa Bay area (Villem-Barentz biological station, North-Western Taymyr)] *В кн.: Арктические тундры Таймыра и островов Карского моря. Т. II., М.* [*In: Arctic tundra of Taymyr and islands of Karskoe Sea. V. II., Moscow*]: *97—120*. Available at http://byrranga.ru/docs/046.pdf

[KUVAEV, V.B., V.B. KOZHEVNIKOVA, S.V. GUDOSHNIKOV, M.P. ZHURBENKO & E.L. NEZDOYMINOGO] КУВАЕВ В. Б., А. Д. КОЖЕВНИКОВА, С. В. ГУДОШНИКОВ, М. П. ЖУРБЕНКО, Э. Л. НЕЗДОЙМИНОГО. 1994. Растительный покров острова Сибирякова. Опыт комплексного флористического и геоботанического исследования. – [The vegetation of Sibiryakov Island. The experience of combined floristic and phytosociological research] *М. [Moscow], 138 pp*. Available at http://byrranga.ru/docs/kuvaev_sibiryakov.pdf

KYRKJEEIDE, M.O., K. HASSEL, B. AGUERO, E.M. TEMSCH, O.M. AFONINA, A.J. SHAW, HANS K. STENШIEN & K. I. FLATBERG. 2019. Sphagnum x lydiae, the first allotriploid peatmoss in the northern hemisphere. – *The Bryologist* **122**(1): *38–61*.https://doi.org/10.1639/0007-2745-122.1.038

LILJEDAHL, A. K., J. BOIKE, R.P. DAANEN, A.N. FEDOROV, G.V. FROST, G. GROSSE, L.D. HINZMAN, YO. IIJMA, J.C. JORGENSON, N. MATVEYEVA, M. NECSOIU, M.K. RAYNOLDS, V.E. ROMANOVSKY, J. SCHULLA, K.D. TAPE, D.A. WALKER, C.J. WILSON, H. YABUKI & D. ZONA. 2016. Pan-Arctic ice-wedge degradation inwarming permafrost and its influence on tundra hydrology. — *Nature Geoscience* **9**: *312–318*. https://doi.org/10.1038/ngeo2674

LONGTON, R.E. 1988. Biology of polar bryophytes and lichens. – *Cambridge, 391 pp*.

MATVEYEVA, N.V. 1998. Zonation in plant cover of the Arctic. – *Proceedings of Komarov Botanical Institute 21, St-Petersburg*. *220 pp.* Available at http://byrranga.ru/docs/056.pdf

[MATVEYEVA, N.V. & L.L. ZANOKHA] МАТВЕЕВА Н.В, Л.Л. ЗАНОХА. 2017. Изменения во флоре соудистых растений в окрестностях пос. Диксон (Западный Таймыр). – [Changes in flora of vascular plants on Dikson settlement area (Western Taymyr)] *Ботанический Журнал* [*Botanicheskij Zhurnal*] **102**(6): *812–846*.

[OGUREEVA, G.N, N.B. LEONOVA, I.M. MIKLYAEVA, M.V. BOCHARNIKOV, V.E. FEDOSOV, E.E. MECHNIK, G.P. URBANAVICHUS, L.G. EMELJANOVA, L.A. KHLJAP, V.YU. RUMJANTZEV, I.V. KUZIKOV, O.N. LIPKA, M.V. ARKHIPOVA, E.V. BULDAKOVA & N.G. KADETOV] ОГУРЕЕВА Г.Н., Н.Б. ЛЕОНОВА, И.М. МИКЛЯЕВА, М.В. БОЧАРНИКОВ, В.Э. ФЕДОСОВ, Е.Э. МУЧНИК, Г.П. УРБАНАВИЧЮС, Л.Г. ЕМЕЛЬЯНОВА, Л.А. ХЛЯП, В.Ю. РУМЯНЦЕВ, И.В. КУЗИКОВ, О.Н. ЛИПКА, М.В. АРХИПОВА, Е.В. БУЛДАКОВА, Н.Г. КАДЕТОВ. 2020. Равнинные биомы. – [The plain biomes] *В кн.: Биоразнообразие биомов России. (Под ред. Г.Н. Огуреевой) Москва, ФГБУ ИГКЭ* [*In: Ogureeva, G.N. Russian Biomes Biodiversity*. *Moscow, FGBU IGKE*], *623 pp*.

RAPOPORT, E.H. 1982. Aerography: geographical strategies of species. – *Pergamon, New York, 269 pp*.

SEREGIN, A.P. 2020. Moscow Digital Herbarium: Electronic resource. – *Moscow State University, Moscow*. Available at: https://plant.depo.msu.ru/

SÖDERSTRÖM, L., A. HAGBORG, M. VON KONRAT, S. BARTHOLOMEW-BEGAN, D. BELL, L. BRISCOE, E. BROWN, D.C. CARGILL, D.P. COSTA, B.J. CRANDALL-STOTLER, E.D. COOPER, G. DAUPHIN, J.J. ENGEL, K. FELDBERG, D. GLENNY, S.R. GRADSTEIN, X. HE, J. HEINRICHS, J. HENTSCHEL, A.L. ILKIU-BORGES, T. KATAGIRI, N.A. KONSTANTINOVA, J. LARRAÍN, D.G. LONG, M. NEBEL, T. PÓCS, P.F. FELISA, E. REINER-DREHWALD, M.A.M. RENNER, A. SASS-GYARMATI, A. SCHÄFER-VERWIMP, J.G.S. MORAGUES, R.E. STOTLER, P. SUKKHARAK,

B.M. THIERS, J. URIBE, J. VÁŇA, J.C. VILLARREAL, M. WIGGINTON, L. ZHANG & R.L. ZHU. 2016. World checklist of hornworts and liverworts. – *PhytoKeys* **59**:*1–828*. https://doi.org/10.3897/phytokeys.59.6261

[TOLMACHEV, A.I.] ТОЛМАЧЕВ А.И. 1974. Введение в географию растений. – [Introduction to plant geography] *Л.* [*Leningrad*], *244 pp*. Available at http://byrranga.ru/biblio.htm

[TOLMACHEV, A.I. & B.A. YURTSEV] ТОЛМАЧЕВ А. И., Б.А. ЮРЦЕВ. 1970. История арктической флоры в ее связи с историей Северного Ледовитого океана. – [The history of arctic flora as linked with Arctic Ocean history] *В кн.: Северный Ледовитый океан и его побережье в кайнозое. Л. [In: The Arctic Ocean and it's shore in The Cenozoic, Leningrad]: 87–100*. Available at http://byrranga.ru/docs/122.pdf

VEKHOV, N.V. & A.N. KULIEV. 1998. Lichens, Bryophytes and Vascular plants of polar deserts of Novaya Zemlya Archipelago. – *Bulletin of Moscow Society of Naturalists. Biological series.* **10**: *44–50*.

WALKER, D.A., M.K. RAYNOLDS, F.J.A. DANIJJLS, E. EINARSSON, A. ELVEBAKK, W.A. GOULD, A.E. KATENIN, S.S. KHOLOD, C.J. MARKON, E.S. MELNIKOV, N.G. MOSKALENKO, S.S. TALBOT, B.A. YURTSEV. 2005. The Circumpolar Arctic vegetation map. – *Journal of Vegetation Science* **16**: *267–282*. https://doi.org/10.1111/j.1654-1103.2005.tb02365.x

WEAVER, A.J., M. EBY, A.F. FANNING & E.C. WIEBE. 1998. Simulated influence of carbon dioxide, orbital forcing and ice sheets on the climate of the Last Glacial Maximum. – *Nature* **394**: *847–853*. https://doi.org/10.1038/29695

WHITTAKER, R.H. 1972. Evolution and Measurement of Species Diversity. – *Taxon* **21**, *213–251*. https://doi.org/10.2307/1218190

YOUSEFI, N., N. MIKULÁŠKOVÁ, H.K. STENŘIEN, K.I. FLATBERG, A. KOŠUTHOVÁ, M. HÁJEK & K. HASSEL. 2019. Genetic and morphological variation in the circumpolar distribution range of Sphagnum warnstorfii: indications of vicariant divergence in a common peatmoss. – *Botanical Journal of the Linnean Society* **189:** *408–423*. https://doi.org/10.1093/botlinnean/boy086

ZANATTA, F., R. ENGLER, F. COLLART, O. BROENNIMANN, R.G. MATEO, B. PAPP, J. MUCOZ, D. BAURAIN, A. GUISAN & A. VANDERPOORTEN. 2020. Bryophytes are predicted to lag behind future climate change despite their high dispersal capacities. – *Nature Communications* **11**: *5601*. https://doi.org/10.1038/s41467-020-19410-8

[ZHUKOVA, A.L. & N.V. MATVEYEVA] ЖУКОВАА А.Л., Н.В. МАТВЕЕВА. 2000. Печеночники Таймыра. – [The liverworts of the Taymyr Peninsula] *Ботанический журнал* [*Botanicheskij Zhurnal*] **85**(11): *42–62*.