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THE LIVERWORTS OF THE AVAM TUNDRA (SOUTHERN TAIMYR)

ПЕЧЕНОЧНИКИ АВАМСКОЙ ТУНДРЫ (ЮЖНЫЙ ТАЙМЫР)

NADEZHDA A. KONSTANTINOVA[1], ELENA D. LAPSHINA[2] & GALINA N. GANASEVICH[2]

НАДЕЖДА А. КОНСТАНТИНОВА[1], ЕЛЕНА Д. ЛАПШИНА[2], ГАЛИНА Н. ГАНАСЕВИЧ[2]

Abstract

The annotated list of liverworts, compiled on the basis of identification of specimens collected at three key sites in the Avam tundra (Taimyr Peninsula), has 85 species and two varieties. This is the second richest flora of liverworts of Taimyr. The list includes, along with widespread species, a large number of species rare in the region, including one that in this study is first recorded for the peninsula (*Rudolgaea borealis*) and one known only from records of the 19th century (*Mannia pilosa*). Each species is provided with comments on the presence of reproductive structures, the frequency of occurrence in each of the three studied key territories, a list of accompanying species and a description of the main habitats and plant communities where they occur. The most phytogeographically interesting discoveries are considered separately and the problems of identification of some groups of liverworts in the Arctic are discussed. The data obtained supplement the available information on the diversity of liverworts, their frequency and distribution in the central part of southern Taimyr.

Резюме

Аннотированный список печеночников, составленный на основе идентификации образцов, собранных на трех ключевых участках в Авамской тундре (полуостров Таймыр), насчитывает 85 видов и две разновидности. Это вторая по богатству флора печеночников Таймыра. Список включает наряду с широко распространенными видами большое количество редких в регионе видов, в том числе те, которые в данном исследовании были впервые найдены на полуострове (*Rudolgaea borealis*) и виды, известные только по находкам 19 века (*Mannia pilosa*). Каждый вид снабжен комментариями о наличии репродуктивных структур, частоте встречаемости на каждой из трех изученных ключевых территорий, перечень сопутствующих видов и описание основных местообитаний и растительных сообществ, где он встречается. Отдельно рассматриваются наиболее фитогеографически интересные находки, обсуждаются проблемы идентификации некоторых групп печеночников в Арктике. Полученные данные дополняют имеющиеся сведения о разнообразии печеночников, частоте их встречаемости и особенностях распространения в центральной части южного Таймыра.

KEYWORDS: liverworts, ecology, distribution, phytogeography, flora, southern tundras, Taimyr, Russia

INTRODUCTION

There are numerous publications on the flora of liverworts of Taimyr (Zhukova, 1973, 1974, 1978, 1979, 1981, 1986; Zhukova & Matveyeva, 1986; Blagodatskikh *et al*., 1979a, b; Blagodatskikh & Duda, 1982). Despite this, the diversity of liverworts and, in particular, their distribution on the peninsula and their value in the vegetation cover of the peninsula are insufficiently studied. This is evidenced by the discovery of new species for the peninsula (Konstantinova *et al*., 2022) and adjacent territory (Fedosov *et al.*, 2015), and new data on the distribution and abundance of species that are presented in this paper.

Most well studied are the Arctic part of the peninsula and the subzone of typical tundra (Zhukova & Matveyeva, 2000), as well as the low-mountain areas of the Anabar plateau (Fedosov *et al*., 2015). Data on liverworts in the south lowland of the Taimyr Peninsula are available only for the surroundings of Kresty village (Zhukova,1986). The territory discussed in this paper is situated in the southern lowland part of Taimyr Peninsula in the middle course of the Dudypta River. It is known as the Avam tundra. The list of mosses of this territory was recently published by Lapshina *et al*. (2022).The present paper provides the results of identification of liverworts collected in this area.

STUDY AREA

The study area is located in the south of the North Siberian Lowland in the southern part of the Taimyr Peninsula, north of the Putorana Plateau (Fig. 1) on the border of the forest tundra (subzones of northern open larch

[1] – Polar-Alpine Botanical Garden-Institute of the Kola Science Center of RAS, Kirovsk, Murmansk Province, 184256, Russia. E-mail: nadya50@list.ru ORCID 000-0002-7600-0512
[2] – Yugra State University, Khanty-Mansiysk, Khanty-Mansiysk Autonomous Area, 628012 Russia. E-mail: e_lapshina@ugrasu.ru ORCID (EL) 0000-0001-5571-7787 (GG) 0000-0002-9280-131X

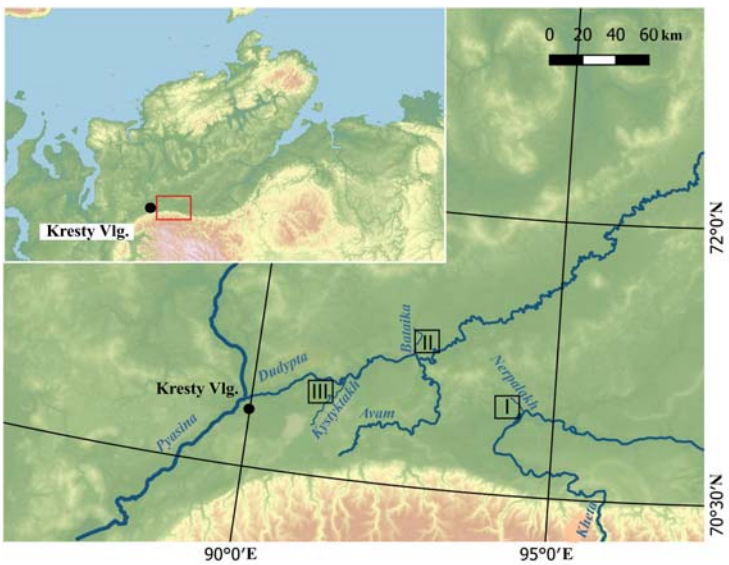

Fig. 1. Study key areas:

I: "Nerpalakh" (71°03'–71°04' N, 93°41'–93°44' E) is located in the upper reaches of the stream Nerpalakh (the basin of the Kheta River) on the watershed between the Kheta and Avam rivers in the larch forest tundra and captures the southern spurs of the Malyi Kamen upland (sand moraine hills with gravelly material accumulated on the surface).

II: "Bataika" (71°12'–71°13' N, 92°35'–92°41' E) is located in the middle reaches of the Dudypta River, between the mouths of the Bataika and Avam rivers in the southern tundra subzone.

III: "Kystyktakh" (70°56'–70°58' N, 91°14'–91°19'E) is located somewhat downstream of the Dudypta River, near the mouth of the Kystyktakh river, in the southern tundra subzone.

woodlands) and the southern tundra of Central Siberia (Lapshina *et al.*, 2022). Administratively, the territory belongs to the Taimyr Dolgan-Nenets Autonomous Okrug, Krasnoyarsk Territory. The climate is harsh, continental. The mean annual air temperature is –12°C, the mean temperature of the coldest month (January) is –30°C. The cold period with stable negative mean monthly temperatures continues about eight months from October to May. The summer is relatively warm, but short. The frost-free period is from 50 to 70 days. The mean temperature of the warmest month (July) is +12°. The mean annual precipitation is 350 mm. The main part falls in summer, the cold period accounts for 20 to 40 mm. The territory is located in an area of continuous permafrost resulting in numerous permafrost landforms.

The relief is hilly-flat (on average 20–60 m a.s.l.) with a dense network of small river valleys. Low-lying alluvial and lacustrine-glacial plains composed of sands and loams, with a large number of thermokarst lakes, drained thermokarst lake areas, called "khasyreys"[1] and shallow peatlands are developed. The relief of the elevated moraine plains is wavy, gently rolling, sometimes ridge-shaped with hill heights in places up to 200 m a.s.l. The continuous permafrost causes widespread forms of cryogenic relief, which is associated with the complexity and mosaic of vegetation cover.

Only in the south of the studied territory there are shrub (*Betula nana*)-moss and shrub-lichen-moss open larch forests. The main areas in the subzone of the southern tundra occupy treeless landscapes. On loamy watersheds, zonal moss-shrub and spotted sedge-dwarf shrub-moss tundra with patches of bare soil are widely represented. Moss-lichen and low-shrub-moss-lichen tundras are developed in well-drained areas.

In low-lying and poorly drained areas on flat watersheds, in lake basins, vast "khasyreys" and valleys of large rivers, polygonal tundra-mire complexes, and flat palsa bogs are developed. Low hills and sand-loamy ridges, bordering or separating vast peatland depressions are occupied by dwarf shrub-moss tussock tundras dominated by *Eriophorum vaginatum*.

On the steep slopes of river valleys and broad gully, thickets of alder – *Duschekia fruticosa* are sporadically found. In the river and stream valleys, in the lower parts of the slopes of watersheds, dense thickets of *Salix lanata* with a height of up to 1.0–1.5 m are developed. In the valleys on the slopes, meadow-like communities with a rich composition of various grasses and thickets of shrubs are widely represented.

Material and Methods

Liverworts were gathered during the geobotanical and landscape-ecological study at three key areas: I – Nerpalakh, II – Bataika, III – Kystyktah (Fig. 1) from July 23 to August 9, 2021 by Elena Lapshina, Galina Ganasevich and Olga Lavrinenko.

The routes were planned to cover all the diversity of the main vegetation types. Landsat 8 and Sentinel-2 satellite images with a resolution of 15 m were used for this purpose. We paid great attention to all habitats suitable for liverworts which led to a fairly complete identification of the flora. The valleys of small rivers and streams, banks of rivers and lakes, gravelly peaks of moraine hills were studied most thoroughly. In total 1300 specimens were collected from 440 plots located at altitudes from 20 to 130 m. Some species easily recognized in the field (*Anthelia juratzkana, Blasia pusilla, Marchantia polymorpha* subsp. *ruderalis, Ptilidium ciliare, Sphenolobus minutus*, *Tetralophozia setiformis*) were only collected at some sites and most of their localities were just marked in the notes.

[1] – Khasyreys occur in the European North and the north of Western Siberia at the bottoms of drained thermokarst lakes, which are often a subject to secondary waterlogging with the accumulation of peat and the development of swamps in their place.

Fig. 2. Habitats in the Avam Tundra. A: The main diversity of liverworts is concentrated on bare clay spots developing in places poorly protected by snow in open larch woodlands; B: "Spotted" sedge-low shrub-moss tundra; C: The main diversity of liverworts in tundra communities is concentrated on partially overgrown patches of loamy spots; D: Partly drained vast lake depressions ("khasyrey") occupied by sedge-hypnum moss fen; E: Sedge (*Carex rotundata, C. chordorrhiza*)-*Scorpidium scorpioides* forming floats around overgrown thermokarst lakes – the typical habitat of rare species *Rudolgaea borealis*; F: Minerotrophic sedge-hypnum moss fen dominated by *Carex rariflora* at the base of the moraine hill in the groundwater discharge area; G: Snowfields on concave north faced slopes of river valleys; H: Frozen peat palsas dominated by *Sphagnum lenense* in flat palsa bog.

The coordinates and elevations were measured using GPS for all collecting sites. The collected specimens were studied in the laboratory of the Polar-Alpine Botanical Garden-Institute (Kirovsk, Murmansk Province). Some specimens have been studied repeatedly, because the omission of a number of very small species that are scattered in the mats of other mosses is almost inevitable. Repeated thorough examination of specimens from hard-to-reach regions to which the studied territory belongs is important due to the extremely limited possibility of repeated collections. This time-consuming study allowed us to discover a number of rare species that sometimes occur simply in the form of single shoots. It led us to add 12 species to the originally compiled list (i.e., almost 15% of the whole number of species).

Main habitats of hepatics within the study area

The diversity of main hepatics habitats could be reduced to the following groups.

Open larch (*Larix sibirica*) woodlands and thickets of dwarf birch (*Betula nana* or "yernik") located on flat, poorly drained watersheds. Here the main diversity of liverworts is concentrated on bare clay spots developing in places poorly protected by snow in winter time (Fig. 2A). The more common species are *Blepharostoma brevirete, Cephalozia bicuspidata, Nardia* spp., *Protochilopsis grandiretis, Schistochilopsis incisa, Solenostoma confertissimum*. At the base of trunks and on rotting wood and among green mosses *Blepharostoma trichophyllum* s. str., *Lophozia silvicola* occur sporadically.

In the ground floor of larch woodlands the only liverwort found in more or less noticeable abundance is *Ptilidium ciliare*. Sporadically small bundles or single shoots of *Schljakovia kunzeana, Sphenolobus minutus, Neoorthocaulis binsteadii, Trilophozia quinquedentata* are scattered in mats of dominating mosses: *Hylocomium splendens, Pleurozium schreberi, Dicranum* spp.

Tundra. The greatest diversity of liverworts is represented in "spotted" sedge-low shrub-moss tundra with *Dryas* spp. occurring mostly on loamy soils of uplands (Fig. 2B). The ground floor is dominated by *Tomentypnum nitens, Aulacomnium turgidum, Hylocomium splendens, Dicranum* spp., *Ptilidium ciliare* with admixture of *Schljakovianthus quadrilobus*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinquedentata.* But the main diversity of liverworts is concentrated on partially overgrown (Fig. 2C) or bare patches of loamy spots, which occupy 10–40% of the area. *Aneura pinguis, Anthelia juratzkana, Blepharostoma brevirete, Cephalozia ambigua, Nardia* spp. frequently occur here, less common are *Gymnomitrion corallioides, Mesoptychia heterocolpos*, *Protochilopsis grandiretis*. Several species (*Arnellia fennica, Odontoschisma macounii, Scapania brevicaulis, S. gymnostomophila,* and *Cryptocolea imbricata*) were collected in such habitats only.

Sedge (*Carex bigelowii* subsp. *arctisibirica*)-moss-lichen and lichen-moss tundras without spots of bare soil, occurring on soils of lighter mechanical composition, are characterized by a poorer species composition of bryophytes.

Shrub-lichen tundras develop on well-drained and windblown habitats. Bryophytes in such tundras are hardly noticeable (3–10% coverage). Here on spots of sand between sporadically occurring mats of *Racomitrium lanuginosum, Pogonatum dentatum* and *Polytrichum piliferum* some liverworts can be found. The most common in such habitats is *Gymnomitrion corallioides*, often with admixture of *Anthelia juratzkana* and *Prasanthus suecicus*.

Shrub-moss-cottongrass hummocky tundras dominated by *Eriophorum vaginatum* cover huge areas at bases of hills. Cottongrass-dominated communities form in transitional habitats between tundra and palsa bogs, where heavy clay loams underlie the 10–20 cm thick peat layer. The more common and abundant in such habitat are *Sphagnum* spp., *Aulacomnium turgidum, Dicranum* spp., *Hylocomium splendens*, *Polytrichum strictum* with admixture of liverworts, including *Ptilidium ciliare*, which is not rare here, and scattered mats of *Calypogeia muelleriana, Lophozia murmanica, Neoorthocaulis binsteadii, Riccardia latifrons, Sphenolobus minutus*. On scattered spots of bare loamy soil *Dicranella* spp. occur as well, and some liverworts: *Cephalozia ambigua, Nardia geoscyphus, N.* cf. *japonica, Scapania parvifolia, Protochilopsis grandiretis, Solenostoma* cf. *pusillum*.

Mires. The vast areas within the North Siberian Lowland in the southern part of the Taimyr Peninsula are occupied by different mires and peatlands, as well as mire-tundra complexes and wet mossy low-shrubs tundras. These habitats differ in the type of water chemistry gradient which determines the composition of the species found here. Minerotrophic sedge-hypnum moss fens dominated by *Carex rotundata, C. chordorrhiza, C. rariflora* occur in drained lake depressions or forming floats around overgrown thermokarst lakes (Fig. 2D). Moss cover dominated by *Scorpidium revolvens* (50–95%), as co-dominants or admixture can be *Loeskypnum badium, Meesia triquetra*, *Scorpidium scorpioides*, *Sarmentypnum sarmentosum*. In such habitats *Aneura pinguis* often occurs, but mostly as single shoots or small patches among mosses. More rare are found *Gymnocolea inflata, Mesoptychia rutheana, Odontoschisma elongatum, Ptilidium ciliare, Scapania paludicola, S. tundrae*. The poorly known, rare liverwort *Rudolgaea borealis* was recorded only in such habitats growing as single shoots among mosses (Fig. 2E).

At the base of the slopes of moraine hills, sedge (*Carex rariflora*)-hepatic-hypnum moss communities are formed on waterlogged peat and organic-mineral soils in seepages (Fig. 2F). The dominants in such places are *Sarmentypnum sarmentosum, Loeskypnum badium* with admixture (up to 20–40 %) of *Schljakovia kunzeana, Scapania hyperborea* and occurring in a small abundance *Cephaloziella grimsulana, Gymnocolea inflata, Odontoschisma elongatum, Saccobasis polita, Scapania tundrae*.

Moderately rich sedge-*Sphagnum* and shrub (*Salix* spp., *Betula nana*)-sedge-moss fens dominated by *Carex aquatilis* subsp. *stans* develop in lake-side depressions, occupy large areas on the site of drained lakes depressions, and also occur in small fragments in thermokarst depressions among tundra-mire complexes and flat-palsa bogs. In such habitats many liverworts (*Blepharostoma trichophyllum* s. l., *Fuscocephaloziopsis pleniceps*, *Cephaloziella* spp., *Lophozia murmanica, Obtusifolium obtusum, Schljakovianthus quadrilobus, Scapania tundrae, S. paludicola, Schistochilopsis* spp., *Schljakovia kunzeana, Trilophozia quinquedentata*, rarer *Mesoptychia sahlbergii, Lophoziopsis polaris, Lophochaete fryei, Scapania irrigua*) grow on the ground floor and among mosses on sides of small moss hummocks, at bases of sedge stems.

Characteristic species of peatlands of atmospheric nutrition distributed on frozen peat in flat palsa bogs and tundra-mire complexes are *Neoorthocaulis binsteadii, Sphenolobus minutus, Ptilidium ciliare* frequently occurring mixed with *Sphagnum lenense*, *S. balticum* (Fig. 2H). In such habitats *Lophozia murmanica* can sporadically be found, more rarely *Calypogeia muelleriana.*

Obtusifolium obtusum, considered to be rare in Taimyr, can be abundant among *Sphagnum*; it turned out to be not rare and even abundant in *Sphagnum* mats in moist hollow of termokarst origin between palsa. Two species (*Gymnocolea inflata, Odontoschisma elongatum*) can form huge mats in the mode of highly variable water content.

Snowbed communities occur at edges of snowfields on concave north-faced slopes of river valleys where snow often lies until the end of August (Fig. 2G). The most characteristic liverworts of such habitats are *Anthelia juratzkana*, *Blepharostoma brevirete, Lophozia wenzelii, Schljakovianthus quadrilobus*, *Saccobasis polita*. These species occur in pure mats on bare soil or mixed with mosses, e.g. *Sanionia uncinata, Niphotrichum elongatum, Pohlia drummondii*, *Polytrichastrum alpinum*.

Banks of rivers and lakes

The most common species along sandy-muddy banks of rivers and streams on rocks covered by alluvium in conditions of regular flooding are *Blasia pusilla, Marchantia polymorpha*, *Pellia neesiana*, *Cephalozia bicuspidata, Lophoziopsis excisa, Nardia geoscyphus*, and *Solenostoma* spp.

SPECIES LIST

The annotated list of hepatics includes 85 species and two varieties. The nomenclature generally follows Söderström *et al*. (2016) for liverworts, Ignatov *et al*. (2006) for mosses, taking into account the latest taxonomic revisions (Ignatov, 2022) and Sekretareva (2004) for vascular plants. The species are arranged in alphabetical order. Common synonyms and synonyms used in old literature on Taimyr liverworts are given in brackets. After the species name the presence of reproductive structures is given in parentheses (and. – androecia; gyn. – gynoecia; per. – perianths or pseudoperianths; spor. – sporophytes; gem. – gemmae). After that the species frequency within each of the 3 key sites (**I** – Nerpalakh, **II** – Bataika, **III** – Kystyktakh), the preferred habitats in descending order of occurrence and some accompanying species are given for sporadic and widespread species. The frequency is characterized as: Un – unique (only 1 locality), R – rare (2–4 localities), Sp – sporadic (5–9 localities), Fr – frequent (more than 10 localities).

For species collected from 1–2 (3) localities, labels are cited in full and the herbarium numbers of specimens in the Herbarium of Polar-Alpine Botanical Garden-Institute (KPABG) and Biological collection of Yugra State University (YSU) are specified. At least one reference to a herbarium number in the Cryptogamic Russian Information System – L. (CRIS) or the Biological collection of Yugra State University (YSU) is cited for sporadic and widespread species. All specimens are kept in the Herbarium of Yugra State University, duplicates in KPABG. Label data of duplicates are entered in the L. (former CRIS – Cryptogamic Russian Information System (kpabg.ru›cris/?q=node/16).

Aneura pinguis (L.) Dumort. (spor.) – Fr I, II; Sp III: sedge-hypnum moss mires and hollows in tundra-mire complexes and drained lake depressions (khasyreys) [YSU-MH-04936, KPABG124515], more rare on loamy mud boils in low shrub-sedge-lichens green moss tundras.

Anthelia juratzkana (Limpr.) Trevis. (spor.) – R I, III; Un II: late snow habitats in hollows [YSU-MH-04883, KPABG124508], on loamy spots and mud boils in low shrub-sedge-lichens green moss tundras.

Arnellia fennica (Gottsche) Lindb. – R II: spotted tundras, on loamy mud boils [YSU-MH-05096]. Often dominating in mats or occurring among mosses with other calciphile liverworts, e.g. *Scapania gymnostomophila.*

Barbilophozia hatcheri (A. Evans) Loeske – Un II: shrub (*Salix glauca, Betula nana*)-green moss community on the slope to the valley of the stream, 71.22513°N, 92.66628°E [YSU-MH-04652].

Blasia pusilla L. – R II; Un III: on bare soil on banks of brooks and rivulets, on loamy spots (mud boils) in willow grass-moss tundra [YSU-MH-05115], in alder (*Duschekia fruticosa*) tickets in flood plains of rivers [YSU-MH-05139].

Blepharostoma trichophyllum (L.) Dumort. (per.) – R I, II; Un III: mud boils in shrub-green moss-lichen open larch woodland, mixed with *Cephalozia bicuspidata* [YSU-MH-05049], shrub-sedge-lichen tundra, *Carex aquatilis* subsp. *stans-Sphagnum* mires, scattered among bryophytes.

B. brevirete (Bryhn et Kaal.) Vilnet et Bakalin [*Blepharostoma trichophyllum* subsp. *brevirete* (Bryhn et Kaal.) R.M. Schust.] (gem., per.) – Fr I; Sp II; R III: on bare soil among mosses in different types of tundra [YSU-MH-04569, KPABG(H) 124514], on loamy mud boils in sedge-hypnum mires, in *Betula nana* moss tickets and in open larch woodlands.

Calypogeia muelleriana (Schiffn.) Müll.Frib. – Un I; R II; Sp III: *Ledum palustre* subsp. *decumbens-Sphagnum lenense* communities of flat palsa bogs [YSU-MH-04794], *Eriophorum vaginatum*-shrub-moss tundra [YSU-MH-04377], sedge-moss mires, scattered among bryophytes, often with *Neoorthocaulis binsteadii, Sphagnum* spp.

Cephalozia ambigua C. Massal. – Sp II: shrub-sedge (*Carex bigelowii* subsp. *arctisibirica*)-moss boggy tundra, scattered in mats of liverworts (*Lophozia* spp., *Sphenolobus minutus*, *Blepharostoma brevirete*, [YSU-MH-04738]; III: shrub-cottongrass-*Sphagnum* tundra, on loamy mud boils scattered in mats of liverworts and shrub-lichen tundra[YSU-MH-05223, KPABG 124538].

C. bicuspidata (L.) Dumort. (per.) – Sp I, II, III: "spotted" low shrub-sedge-lichen-moss tundras, hummocky cotton-grass-tussock-moss tundras, open larch woodlands, on loamy mud boils (spots) [YSU-MH-05222, KPABG 124488].

Cephaloziella arctogena (R.M. Schust.) Konstant. (per., and., clearly paroicous) – R I: shrub-herb-moss meadow in valley of brook, scattered in dying mats of *Tomentypnum nitens*,71.05792°N, 93.70914°E [YSU-MH-04209].

C. grimsulana (J.B. Jack ex Gottsche et Rabenh.) Lacout. – R I: cottongrass (*Eriophorum angustifolium*)-sedge (*Carex rariflora*)-liverwort community in seepage at the base of the hill, not rare in mats with *Odontoschisma elongatum, Gymnocolea inflata, Scapania tundrae*, 71.06120°N, 93.72494°E [YSU-MH-05057, KPABG 124486].

C. spinigera (Lindb.) Warnst. [*Cephaloziella subdentata* Warnst.] (per., and., autoicous) R II: shrub (*Carex aquatilis* subsp. *stans*)-moss community on slightly raised site in a waterlogged lake mire-complex scattered in mats of *Aneura pinguis, Aulacomnium turgidum, Protochilopsis grandiretis, Fuscocephaloziopsis lunulifolia*, 71.20925°N, 92.59513°E [YSU-MH-04801].

C. cf. *uncinata* R.M. Schust. – R I: dwarf shrub (*Andromeda polifolia*)-sedge (*Carex rariflora*)-hypnum moss community, scattered in mats dominated by *Scapania hyperborea*, 71.05026°N, 93.70654 °E[YSU-MH-04248, KPABG 124519]; III: flat palsa bog in huge drained lake depression, sedge (*Carex aquatilis* subsp. *stans, C. chordorrhiza*)-*Sphagnum*-hypnum moss hollow, scattered among *Sphagnum orientale, Scapania tundrae, Gymnocolea inflata, Sarmentypnum exannulatum* 70.96816°N, 91.29525°E [YSU-MH-04924]. Plants with characteristically hooked lobes but without perianth. Thus, the plants cannot be identified accurately.

C. varians (Gottsche) Steph. (per.) – Sp II: shrub-sedge (Carex aquatilis subsp. stans)-*Sphagnum* bump in ridge-pool complex, scattered in mats of bryophytes, in many habitats, 71.22665°N, 92.64687°E [YSU-MH-04291].

Chiloscyphus pallescens (Ehrh. ex Hoffm.) Dumort. – Un III: mesotrophic willow-sedge (*Carex aquatilis* subsp. *stans, C. chordorrhiza*)-*Sphagnum* mire in poorly drained thermokarst lake depressions, mixed with bryophytes,70.96617°N, 91.31231°E [YSU-MH-04927].

Cryptocolea imbricata R.M.Schust. (per.) – R I: bank of lake, on moist loamy soil, mixed with *Solenostoma pusillum, Pogonatum urnigerum, Pohlia proligera*,71.05703°N, 93.68715°E [YSU-MH-05076, KPABG124539]; II: "spotted" sedge (*Carex bigelowii* subsp. *arctisibirica*)-lichen-moss tundra, on mud boils, mixed with *Solenostoma* sp., *Lophozia* sp. 71.21326°N, 92.69042°E [YSU-MH-05103, YSU-MH-05213, KPABG124714].

Fuscocephaloziopsis lunulifolia (Dumort.) Vána et L.Söderstr. [*Cephalozia lunulifolia* (Dumort.) Dumort.] – R I: lake depression between moraine hills, on edge of mires dominated by *Carex rariflora* in mats, mixed with *Neoorthocaulis binsteadii, Mylia anomala, Sphenolobus minutus* 71.05174°N, 93.69656°E [YSU-MH-04425, KPABG 124474]; II: lake-mire complex in partly drained thermokarst lake depression, shrub-sedge (*Carex aquatilis* subsp. *stans*)-moss community on slightly elevated areas mixed with *Aneura pinguis, Aulacomnium turgidum, Protochilopsis grandiretis, Riccardia chamedryfolia*, 71.20925°N, 92.59513°E [YSU-MH-04801].

F. pleniceps (Austin) Váňa et L. Söderstr. [*Cephalozia pleniceps* (Austin) Lindb.] (per., spor.) – R I, II; Un III: sedge (*Carex rariflora*)-moss fens, snow bed communities, on loamy spots in spotted zonal tundra, shaded niches on slopes in river valleys, scattered among bryophytes on bare soil or among mosses [YSU-MH-05122, KPABG 124511].

Gymnocolea inflata (Huds.) Dumort. (per.) – R I; Un II; Sp III: *Carex rotundata*-liverwort hollows in flat palsa bogs, dominates in mats of bryophytes; frozen flat peat mounds in palsa bog on bare peat [YSU-MH-05043, KPABG 124505]; sedge (*Carex aquatilis* subsp. *stans*)-hypnum moss-cottongrass-*Sphagnum* and shrub-sedge-moss mire, scattered among other bryophytes, more rare on loamy frost boils in spotted low shrub-lichens-moss tundras or along streams.

Gymnomitrion corallioides Nees – Sp I; Fr II; R III: shrub-lichen tundras, form crust on bare soil on frost boils [YSU-MH-05175, KPABG 124527]; on bare soil on the tops and slopes of moraine hills [YSU-MH-05177]

Jungermannia polaris Lindb. – II: spotted sedge-lichen-moss tundra on loamy frozen boils, single shoots among *Bryoerythrophyllum* sp., *Distichium capillaceum*, *Meesia uliginosa*, 71.21326°N, 92.69042°E [YSU-MH-05100].

Lophochaete fryei (Perss.) R.M. Schust. [*Pseudolepicolea fryei* (Perss.) Grolle et Ando] – Sp II: shrub-sedge (*Carex aquatilis* subsp. *stans*)-*Sphagnum* and shrub-sedge-moss communities of low hummocks and slightly elevated areas in lake-mire complex, in poorly drained termokarst lake depression, mixed with bryophytes [YSU-MH-04779, KPABG 124496].

Lophozia guttulata (Lindb. et Arnell) A. Evans (per., gem.) – I: dwarf shrub-sedge (*Carex rotundata, C. rariflora*)-moss boggy tundra at the base of hill, in almost pure mats, 71.06071°N, 93.72420°E [YSU-MH-05054]; III: dwarf shrub-cottongrass hillocky tundra, in pure mats, 70.95216°N, 91.25531°E [YSU-MH-04376].

L. cf. *lantratovae* Bakalin – I: loamy mud boils in open *Betula nana*-larch woodlands, scattered in mats with *Solenostoma pusillum*, 71.05714°N, 93.69546°E [YSU-MH-05219].

L. murmanica Kaal. [*Lophozia wenzelii* var. *groenlandica* (Nees) Bakalin] (gem., per.) – Sp I; II, III: shrub-green moss and dwarf shrub-cottongrass-*Sphagnum* (*S. lenense*) boggy tundra, cryogenic hummocks in shrub-mossy yernik (*Betula nana*) thickets, *Betula nana*-hypnum hollow around seepage [YSU-MH-04221, KPABG 124512].

L. silvicola H. Buch (gem.) – Sp I; R II: open larch woodlands, green moss-dwarf shrub community with *Betula nana*, mixed with mosses [YSU-MH-04587, KPABG 124489].

L. savicziae Schljakov (gem., per., spor.) – Un II: *Betula nana*-lichen-moss community on hill, mixed with *Schistochilopsis opacifolia, Trilophozia quinquedentata, Gymnomitrion corallioides, Sphenolobus minutus*, 71.21405°N, 92.60500°E [YSU-MH-05194, KPABG 124526].

L. ventricosa s. l (Dicks.) Dumort. (gem.) – Sp I, III; R II: open larch woodlands, shrub tickets, different types of tundra and mires, on spots of bare soil and among mosses [YSU-MH-05045].

L. wenzelii (Nees) Steph. (gem.) – R I: the concave slope of a creek valley, late snow bed, in turfs of *Dicranum laevidens*, 71.05717°N, 93.69517°E [YSU-MH-04612]; eroded termokarst hollow in larch open woodland, on bare soil [YSU-

MH-04995]. Gray-brown plants with upper part (just the last leaves) green and green gemmae.

Lophoziopsis excisa (Dicks.) Konstant. et Vilnet (gem., per., and., paroicous) – Sp I; Un II, III: bare soil in shrub-herb communities and meadow on eroded steep slopes of river valleys [YSU-MH-05006, KPABG 124501]; loamy mud boils and damp sandy soil on banks of streams in *Larix sibirica-Betula nana* green-moss woodlands.

L. excisa var. *elegans* (R.M. Schust.) Konstant. et Vilnet (gem.) – II: clay spots in willow-yernik (*Betula nana*) tundra in floodplain of Dudypta River, scattered in mats dominated by *Solenostoma* cf. *sphaerocarpum*,71.05303°N, 93.69824°E [YSU-MH-05108, KPABG 124967].

L. jurensis (Meyl. ex Müll. Frib.) Mamontov et Vilnet (gem.) – R I; Un II: sedge-hypnum moss depressions, *Larix sibirica-Betula nana-Equisetum*-moss- and herbs-lichens open woodlands, dwarf shrub green moss tundra [YSU-MH-04405, KPABG 124472].

L. polaris (R.M. Schust.) Konstant. et Vilnet (gem.) – I: moist mud boils in river valley [KPABG 124546] and in willow-*Betula nana* tundra [YSU-MH-05219]; II: willow-*Rubus chamaemorus-Sphagnum-Betula nana* thickets, mixed with bryophytes, 71.22409°N, 92.66481°E [YSU-MH-04828, KPABG 124497; shrub-cottongrass-*Sphagnum* communities, in mats with bryophytes, 71.22357°N, 92.66549°E [YSU-MH-04341, KPABG 124518].

Mannia pilosa (Hornem.) Frye et L. Clark – II: spotted sedge-lichen-moss tundra, on loamy frozen boils, single thalli among *Bryoerythrophyllum* sp., *Distichium capillaceum*, *Meesia uliginosa* and admixture of *Mesoptychia collaris, Jungermannia polaris,* 71.21326°N, 92.69042°E [YSU-MH-05100].

Marchantia polymorpha subsp. *ruderalis* Bischl. et Boissel.-Dub. [*Marchantia latifolia* Gray] female – R I; Un II, III: on bare soil along streams [YSU-MH-05158, KPABG 124487].

Marsupella sprucei (Limpr.) Bernet (per.) – III: low shrub-lichen tundra, single stems in mats dominated by *Nardia geoscyphus* and scattered *Cephalozia bicuspidata*, 70.94761°N, 91.31261°E [YSU-MH-05208].

Mesoptychia collaris (Nees) L. Söderstr. et Váňa – R I: shrub (*Salix pulchra, Betula nana*)-herbs-lichen tundra, single shoots scattered in mats dominated by mosses and *Aneura pinguis* [KPABG 124515]. Plants very small (ca. 2 mm long and 0.3 mm wide), with distinct underleaves and strongly verruculose cuticle of both leaf and stem cells. II: spotted sedge-lichen-moss tundra on loamy frozen boils,71.21326°N, 92.69042°E [YSU-MH-05270], single shoots hidden among mosses, 71.21775°N, 92.67142°E [YSU-MH-05081].

M. gillmanii (Austin) L. Söderstr. et Váňa [*Leiocolea gillmanii* (Austin) A. Evans] (per., and., paroicous) – II: on soil among mosses, scattered in mats dominated by *Blepharostoma brevirete,* 71.21661°N, 92.67673°E [YSU-MH-05273].

M. heterocolpos (Thed. ex Hartm.) L. Söderstr. et Váňa (gem.) – R I: late snow bed in valley of brook, mixed with bryophytes, 71.05717°N, 93.69517°E [YSU-MH-04614, KPABG 124493]; II: spotted low shrub-sedge-lichen-green-moss tundra, mixed with *Oncophorus demetrii, Scapania ligulifolia,*71.21775°N, 92.67146°E [YSU-MH-04726]; shrub (*Betula nana, Salix pulchra*)-herb-lichen tundra, on loamy spots, mixed with brophytes,71.21358°N, 92.68612°E [YSU-MH-05169].

M. heterocolpos var. *harpanthoides* (Bryhn et Kaal.) L. Söderstr. et Váňa – II: shrub (*Betula nana, Salix pulchra*)-herb-lichen tundra, on clay spots, scattered in mats dominated by *Myurella julacea, Distichium capillaceum* and *Marchantia polymorpha* subsp. *ruderalis,* 71.21389°N, 92.68678°E [YSU-MH-05269].

M. rutheana (Limpr.) L. Söderstr. et Váňa [*Leiocolea rutheana* (Limpr.) Müll. Frib.] – R II; Un III: sedge-hypnum moss- and shrub-sedge-moss mires and swampy *Betula nana* dominated communities, single shoots between bryophytes [YSU-MH-04329, KPABG124517].

M. sahlbergii (Lindb. et Arnell) A. Evans – II: shrub-sedge (*Carex aquatilis* subsp. *stans*)-moss community, in pure mats and mixed with *Tomentypnum nitens, Hylocomium splendens, Aulacomnium palustre* [YSU-MH-04661, KPABG 124494]; *Salix* spp.*-Betula nana-Rubus chamaemorus-Sphagnum teres*-shrub tickets, mixed with *Aulacomnium turgidum, Tomentypnum nitens, Sphagnum orientale* [YSU-MH-04826].

Mylia anomala (Hook.) Gray (gem.) – I: *Carex rariflora*-moss community along edge of a lake, 71.05174°N, 93.69656°E, mixed with *Fuscocephaloziopsis lunulifolia, Neoorthocaulis binsteadii, Sphenolobus minutus* [YSU-MH-04422, KPABG124474]; dwarf shrub (*Andromeda polifolia*)-sedge (*Carex rariflora*)-moss mire,71.05165°N, 93.69642°E, [YSU-MH-04196].

Nardia geoscyphus (De Not.) Lindb. (per., and.) – Sp I; R III: bank of Nerpalakh River, bare soil in shrub-green moss-lichen larch open woodland, and in termokarst hollow [YSU-MH-04995, KPABG124539]; hummocky shrub-cottongrass boggy tundra, on loamy mud boils [YSU-MH-05221]; low shrub-lichen tundra, on spots of bare soil [YSU-MH-05217, KPABG 124549].

N. japonica Steph. (per., ant., dioicous) – III: low shrub-cottongrass-*Sphagnum* hummocky tundra, mixed with *Cephalozia bicuspidata,* 70.95216°N, 91.25531°E [YSU-MH-05222]; dwarf shrub-lichen tundra, on spot of bare soil with admixture of *Prasanthus suecicus,*70.94761°N, 91.31261°E [YSU-MH-05209]; boggy shrub-cottongrass-*Sphagnum* tundra, on loamy spots, mixed with *Solenostoma hyalinum, Scapania parvifolia, Cephalozia ambigua,* 70.95215°N, 91.25641°E [YSU-MH-05223, KPABG 124538]. Plants slightly smaller than described but that is probably explained by the habitat on bare soil in tundra, which isn't characteristic for the species.

Neoorthocaulis binsteadii (Kaal.) L. Söderstr., De Roo et Hedd. [*Orthocaulis binsteadii* (Kaal.) H. Buch] (gem., per.) – Fr I, II, III: low shrub-*Sphagnum* community on frozen peat mounds in flat palsa bogs and tundra-mire complexes; shrub (*Carex bigelowii* subsp. *arctisibirica*)-cottongrass bogs, boggy tundra and *Betula nana* tickets, between *Sphagnum* spp., with other bryophytes, e.g. *Calypogeia muelleriana* [YSU-MH-04438].

Obtusifolium obtusum (Lindb.) S.W. Arnell – Un I; R II, III: meso-oligotrophic *Eriophorum russeolum-Carex chordorrhiza-Sphagnum obtusum* communities [YSU-MH-04598, KPABG 124490], shrub-sedge (*Carex aquatilis* subsp. *stans*)-cottongrass-moss and sedge (*Carex rotundata*)-moss communities in waterlogged depressions between permafrost hillocks, in pure mats or mixed with *Sphagnum* spp., *Scapania tundrae, Warnstorfia fluitans, W. pseudostraminea* [KPABG 124522].

Odontoschisma elongatum (Lindb.) A. Evans – Sp I, II; Un III: liverwort hollows and waterlogged sedge-hypnum communities in palsa bogs, scattered among mosses *Scorpidium revolvens, Sarmentypnum sarmentosum, Cinclidium subrotundum, Oncophorus demetrii, Sphagnum orientale* and liv-

erworts *Aneura pinguis, Cephaloziella spp., Gymnocolea inflata, Scapania tundrae*, sometimes dominating in mats [YSU-MH-05057, KPABG 124713].

O. francisci (Hook.) L. Söderstr. et Váňa [*Cladopodiella francisci* (Hook.) Jørg.] – III: boggy shrub-cottongrass-*Sphagnum* tundra, on loamy spots, mixed with *Solenostoma hyalinum, Scapania parvifolia, Cephalozia ambigua*, 70.95215°N, 91.25641°E, [YSU-MH-05223, KPABG 124538].

O. macounii (Austin) Underw. – R I, II; Un III: loamy mad boils in "spotted" low shrub sedge-lichen-green moss tundras, on spots of bare soil mixed with other bryophytes [YSU-MH-05084, KPABG124514].

Pellia neesiana (Gottsche) Limpr. (and.) – R I; Un II: willow stands along streams, banks of streams, on bare soil in pure mats or mixed with *Calliergonella lindbergii* [YSU-MH-05183] or other liverworts, e.g. *Nardia geoscyphus, Cephalozia bicuspidata,* etc. [KPABG124488].

Prasanthus suecicus (Gottsche) Lindb. (per., spor.) – R I; Un II, III: sparse plant communities on gravelly-sandy soils on tops of moraine hills, spotted sedge-moss tundra, on bare soil, often mixed with *Gymnomitrion corallioides, Anthelia juratzkana, Blepharostoma brevirete, Sphenolobus minutus* [YSU-MH-05197].

Protochilopsis grandiretis (Lindb. ex Kaal.) A.V. Troitsky, Bakalin et Fedosov [*Schistochilopsis grandiretis* (Lindb. ex Kaal.) Konstant.](per., gem.) – R I, II, III: "spotted" shrub-sedge-lichen-moss and boggy cottongrass-*Sphagnum* tundras, on loamy spots; shrub-sedge-moss mires and yerniks (dwarf shrub with *Betula nana*) [YSU-MH-04851, KPABG124498], on the dead mosses and plant debris; larch open woodlands, on moist loamy spots, in small pure mats or among mosses.

Pseudotritomaria heterophylla (R.M. Schust.) Konstant. et Vilnet (per., and., spor., gem.) – R II: spotted sedge (*Carex bigelowii* subsp. *arctisibirica*)-lichen-moss tundra, dominated in several mats with admixture of *Sphenolobus minutus*, and single shoots of *Arnellia fennica, Cryptocolea imbricata, Scapania brevicaulis*, etc. [YSU-MH-05084].

Ptilidium ciliare (L.) Hampe (per.) – Fr I, II, III: open *Larix sibirica* woodlands, various tundra communities, mossy bogs, very commons in ground cover [YSU-MH-04753, KPABG 124476].

Riccardia chamedryfolia (With.) Grolle – II: lake-mire complex in partly drained thermokarst lake depression, shrub-sedge (*Carex aquatilis* subsp. *stans*)-moss community on slightly elevated areas, mixed with *Fuscocephaloziopsis lunulifolia, Aneura pinguis, Aulacomnium turgidum, Protochilopsis grandiretis*, 71.20925°N, 92.59513°E [YSU-MH-04801].

R. latifrons (Lindb.) Lindb. – Un I, Un II, R III: dwarf shrub-moss tundra at the base of sandy hill, dwarf shrub-sedge (*Carex bigelowii* subsp. *arctisibirica*)-moss boggy tundra at the base of the river terrace in the floodplain, hummocky shrub-cottongrass-*Sphagnum* boggy tundra with spots of mineral soil, boggy shrub-cottongrass-*Sphagnum* tundra, on spots of mineral soil, on side of mats dominated by *Solenostoma hyalinum, Odontoschisma francisci* [YSU-MH-05223, KPABG 124538].

Riccia sp. – II: on bare loamy soil in floodplain of Dudypta River, 71.21517°N, 92.65224°E[YSU-MH-05116, KPABG 124495].

Rudolgaea borealis (Frisvoll et Moen) Potemkin et Vilnet [*Gymnocolea borealis* (Frisvoll et Moen) R.M. Schust.] – Un I, Sp II, R III: sedge (*Carex aquatilis* subsp. *stans, C. chordorrhiza, C. rotundata*)-hypnum moss (*Scorpidium revolvens, Sarmentypnum sarmentosum*) mires in the bottoms of slightly drained thermokarst basins and floating fens adjacent to thermokarst lakes. Always occurs scattered in mats dominated by *Scorpidium revolvens, Sarmentypnum sarmentosum* with admixture of *Oncophorus demetrii, Scorpidium scorpioides, Pseudocalliergon trifarium, Aneura pinguis, Scapania paludicola, S. tundrae* [YSU-MH-05216, KPABG 125157, YSU-MH-04865]. One of specimens was sequenced (Kuznetsova *et al*., 2022) and the obtained results confirmed our identification.

Saccobasis polita (Nees) H. Buch – I: sedge (*Carex rariflora*)-hypnum moss (*Scorpidium revolvens, Sarmentypnum sarmentosum*) mire in the hollow between two moraine hills, mixed with *Odontoschisma elongatum, Aneura pinguis*, 71.05174°N, 93.69656°E [YSU-MH-04419, KPABG 124473] and in mats of *Mylia anomala* [YSU-MH-04427]; III: rocky base of hill, late snow site, in mats with admixture of *Anthelia juratzkana, Cephaloziella* sp., 70.94500°N, 91.24667°E [YSU-MH-04884].

Scapania brevicaulis Taylor (gem.) – II: several collections on loamy spots in spotted sedge (*Carex bigelowii* subsp. *arctisibirica*)-lichen-moss tundra, scattered in mats with *Sphenolobus minutus, Pseudotritomaria heterophylla, Cryptocolea imbricata, Cephaloziella* sp., 71.21326°N, 92.69042°E [YSU-MH-05101, KPABG 124540].

S. crassiretis Bryhn – I: *Ledum palustre-Betula nana*-sedge (*Carex rariflora*)-*Sphagnum* bog on slope of moraine hill, mixed with *Odontoschisma macounii, Blepharostoma brevirete, Scapania tundrae, Schljakovia kunzeana*, 71.05319°N, 93.69778°E [YSU-MH-04203, KPABG 124411].

S. curta (Mart.) Dumort. – I: termokarst depression, on bare soil, 71.05717°N, 93.69517°E [YSU-MH-04995].

S. gymnostomophila Kaal. (gem.) – Sp II: loamy mud boils in shrub-sedge-green-moss-lichen tundra, scattered among mosses and liverworts, in mats with *Arnellia fennica, Orthothecium strictum, Distichium capillaceum, Myurella julacea, Encalypta rhaptocarpa, Flexitrichum flexicaule,* 71.21389°N, 92.68678°E [YSU-MH-05191]; loamy mud boils in "spotted" sedge-lichen-moss tundras, mixed with *Orthothecium strictum, Bryum pseudotriquetrum, Tomentypnum involutum*, 71.21661°N, 92.67673°E [YSU-MH-05098].

S. ligulifolia R.M. Schust. – II: "spotted" low shrub-sedge-lichen-green-moss tundra, scattered with *Oncophorus demetrii, Mesoptychia heterocolpos*, 71.21775°N, 92.67146°E [YSU-MH-04726]; willow-*Betula nana* tundra in floodplain of Dudypta River, on eroded sites mixed with *Solenostoma* cf. *sphaerocarpum, Lophoziopsis excisa* var. *elegans, Scapania obcordata, Dicranella heteromalla, Pogonatum urnigerum, Pohlia filum*, 71.21546°N, 92.65854°E [YSU-MH-05108].

S. hyperborea Jørg. (gem. and.) – Sp I; Un II; R III: sedge (*Carex rariflora*)-hypnum moss-liverwort community on waterlogged peat and mineral soil at bases of moraine hills, in pure mats or mixed with *Schljakovia kunzeana, Loeskypnum badium, Sarmentypnum sarmentosum, Ptilidium ciliare, Cephaloziella* cf. *uncinata* [YSU-MH-04502, KPABG 124541].

S. irrigua (Nees) Nees – R I, II; Un III: shrub-sedge-moss fens and shrub tickets, hollow with seepages, in pure mats or mixed with *Bryum pseudotriquetrum, Sarmentypnum exannulatum* [YSU-MH-04961, KPABG 124509].

S. obcordata (Berggr.) S.W. Arnell – I: bank of Nerpalakh River, on moist sandy soil, mixed with *Pellia neesiana, Trilo-*

phozia quinquedentata, Cephalozia bicuspidata, 71.05621°N, 93.71424°E [YSU-MH-05069, KPABG 124488]; II willow-*Betula nana* tundra in floodplain of Dudypta River, on loamy spots, scattered in mats of bryophytes, 71.21546°N, 92.65854°E [YSU-MH-05109].

S. paludicola Loeske et Müll. Frib. (per., spor.) – Sp I, III; Fr II: sedge-hypnum moss- and shrub-sedge-moss fens, in hollows in tundra-mire complexes and drained thermokarst lake depressions [YSU-MH-04361, KPABG 124521]; in boggy shrub-sedge (*Carex aquatilis* subsp. *stans*)-moss tundras.

S. parvifolia Warnst. – Un I; R II: shrub-sedge (*Carex rotundata, C. rariflora*)-moss boggy tundra at the base of moraine hill, sporadic in mats dominated by *Lophozia guttulata* [YSU-MH-05054]; III: boggy shrub-cottongrass-*Sphagnum* tundra, on spots of mineral soil, sporadic, mixed with *Odontoschisma francisci, Solenostoma hyalinum* [YSU-MH-05223, KPABG 124538]; hummocky shrub-cottongrass *Sphagnum lenense* boggy tundra on gentle slope, scattered among *Dicranum laevidens, Aulacomnium turgidum* [YSU-MH-05214, KPABG 124506].

S. scandica (Arnell et H. Buch) Macvicar – Un III: sedge (*Carex rotundata*)-moss community in waterlogged hollow in flat palsa mire complex, single shoots scattered in mats with *Lophozia* cf. *murmanica, Sphagnum balticum, Schistochilopsis incisa, Scapania tundrae,* 70.95573°N, 91.26899°E [YSU-MH-04899, KPABG 124504].

S. tundrae (Arnell) H. Buch (gem.) – Sp I; Fr II, III: sedge (*Carex rotundata, C. chordorrhiza*)-hypnum moss- and shrub-sedge (*Carex aquatilis* subsp. *stans*) moss fens [YSU-MH-04390, KPABG 124512], shrub-sedge (*Carex bigelowii* subsp. *arctisibirica*)-green moss tundras and bush tickets. This is a common species which can occur in pure mats or mixed with other bryophytes.

Schistochilopsis incisa (Schrad.) Konstant. (spor.) – I: larch shrub-green moss-lichen open woodlands, mixed with *Fuscocephaloziopsis pleniceps, Blepharostoma brevirete,* 71.04728°N, 93.71973°E [YSU-MH-05224]; III: sedge (*Carex aquatilis* subsp. *stans*)-moss mire on bank of lake, mixed with *Aulacomnium turgidum, Sphagnum obtusum, S. squarrosum,* 70.94979°N, 91.25771°E [YSU-MH-0489]; sedge (*Carex rotundata*)-moss community in hollow of flat palsa complex, with *Lophozia* cf. *murmanica, Sphagnum balticum, Sarmentypnum exannulatum, Scapania tundrae,* 70.95573°N, 91.26899°E [YSU-MH-04899, KPABG124504].

S. opacifolia (Culm. ex Meyl.) Konstant. (per., spor.) – R I, II, III: different types of mires and mire complexes, boggy tundra and yerniks (dwarf shrub with *Betula nana*), in mats with mosses and liverworts [YSU-MH-04918, KPABG124526].

Schljakovia kunzeana (Huebener) Konstant. et Vilnet (per.) – Fr I, II; R III: sedge-liverwort-hypnum moss bogs at base of moraine hills [YSU-MH-04498, KPABG 124525], shrub-sedge-moss bogs and shrub tickets, more rare shrub-sedge-moss tundras, usually mixed with other bryophytes.

Schljakovianthus quadrilobus (Lindb.) Konstant. et Vilnet (per., spor.) – R I, III; Sp II: sedge-moss and shrub-sedge-moss bogs and shrub tickets, late snowbed habitats at base of hills, more rare in tundra and open larch woodlands, scattered among mosses [YSU-MH-04611, KPABG 124500].

Solenostoma confertissimum (Nees) Schljakov (per., ant., spor.) – R I; Un II: on loamy spots in shrub-hypnum moss-lichen larch open woodlands and *Betula nana*-hypnum moss-lichen tundra, on loamy soil on eroded sites in low willow-moss tundra in floodplain of Dudypta River, mostly scattered among other liverworts characteristic for such sites: *Nardia geoscyphus, Cephalozia bicuspidata, Fuscocephaloziopsis pleniceps, Protochilopsis grandiretis,* etc. [YSU-MH-05048, KPABG 124542].

S. hyalinum (Lyell) Mitt. [*Jungermannia hyalina* Lyell, *Plectocolea hyalina* (Lyell) Mitt.] (per., and. dioicous) – III: boggy shrub-cottongrass *Sphagnum* tundra, on loamy spots, mixed with *Odontoschisma francisci, Scapania parvifolia, Cephalozia ambigua,* 70.95215°N, 91.25641°E [YSU-MH-05223, KPABG 124538].

S. pusillum (C.E.O. Jensen) Steph. (per., ant., spor.) – I: bank of lake, on loamy bare soil, dominated in mats with admixture of *Cryptocolea imbricata, Pogonatum urnigerum, Pohlia proligera,* 71.05703°N, 93.68715°E[YSU-MH-05076, KPABG 124538]; loamy mud boils in open *Betula nana*-larch woodlands dominated in mats with admixture of *Lophozia* cf. *lantratovae,* 71.05714°N, 93.69546°E [YSU-MH-05219], III: hummocky shrub-cottongrass-*Sphagnum* boggy tundra with spots of mineral soil, on bare soil mixed with *Nardia geoscyphus,* 70.95215°N, 91.25641°E [YSU-MH-05221].

S. cf. *rossicum* Bakalin et Vilnet – I: shrub-green moss-lichen larch open woodland, on bare clay spots, with admixture of *Nardia geoscyphus, Solenostoma confertissimum, Cephalozia bicuspidata, Fuscocephaloziopsis pleniceps, Protochilopsis grandiretis,* 71.04603°N, 93.72135°E[YSU-MH-05048, KPABG 124537].

S. sphaerocarpum (Hook.) Steph. – I: termokarst hollow in shrub-green moss-larch open woodland, mixed with *Nardia geoscyphus, Fuscocephaloziopsis pleniceps, Scapania curta,* 71.05717°N, 93.69517°E[YSU-MH-04995]; II: low shrub (*Betula nana, Salix* spp.)-moss tundra in floodplain of Dudypta River, on spots of bare loamy soil, mixed with *Scapania obcordata, Dicranella heteromalla, Pogonatum urnigerum, Pohlia filum, Saelania glaucescens,* 71.21546°N, 92.65854°E [YSU-MH-05109, KPABG 124968]; shrub-green moss-lichen larch open woodland, on clay spots,71.04603°N, 93.72135°E [YSU-MH-05048].

Sphenolobus minutus (Schreb.) Berggr. (per.) – Fr I, II, III: in all types of tundras including low shrub-*Sphagnum* communities on permafrost flat peat mounds in flat palsa bogs and tundra-mire complexes, shrub-sedge-moss fens, shrub tickets, open larch woodlands, in moss cover and spots of bare soil [YSU-MH-04603, KPABG124511].

S. saxicola (Schrad.) Steph. (per.) – R I, III; Fr II: "spotted" shrub-sedge-green-moss-lichen tundra, shrub-sedge (*Carex rotundata, C. rariflora*)-moss boggy tundras [YSU-MH-04568, KPABG 124482], between mosses or on loamy mud boils.

Tetralophozia setiformis (Ehrh.) Schljakov – R I, Un III: wasteland on slopes of moraine hills, in shrub-lichens tundras, once found in boggy shrub-sedge (*Carex rotundata, C. rariflora*) moss tundra at the base of moraine hill, mixed with *Neoorthocaulis binsteadii, Sphenolobus minutus, Ptilidium ciliare, Sphenolobus saxicola* [YSU-MH-04567, KPABG 124482].

Trilophozia quinquedentata (Huds.) Bakalin [*Tritomaria quinquedentata* (Huds.) H. Buch] (per.) – Fr I, II; Sp III: different types of tundras [YSU-MH-05103, KPABG124475], moss fens, bushes tickets and open larch woodlands, where usually mixed with mosses and liverworts, rarely on loamy mud boils, once on moist sandy soil on bank of stream.

Tritomaria scitula (Taylor) Jørg. (gem.) – II: spotted sedge (*Carex bigelowii* subsp. *arctisibirica*)-lichen-moss tundra,

on mud boils, mixed with *Cryptocolea imbricata, Solenostoma* sp., *Lophozia* sp., 71.21326°N, 92.69042°E [YSU-MH-05213, KPABG124714].

Discussion

We recorded 85 species and two varieties in total. This is significantly more than is given for most of the previously studied liverwort floras of Taimyr. According to Zhukova & Matveyeva (2000), the largest number of species (71) was found for the Rogozhinka River, a little less (64 species) were found in the vicinity of the village of Dixon, and 56 species were recorded both for the vicinity of the villages of Tareya and Kresty. In the remaining areas studied by that time, less than 50 species have been recorded. Two more or less complete lists have already been published in the 21st century. One of these studied the north-western part of Taimyr – the vicinity of the village of Dixon and 90 species were recorded in it (Fedosov *et al*., 2020), while the second one studied the south-east of the peninsula and 66 species were found there (Fedosov *et al.*, 2015). So, the number of species in the local flora of Taimyr Peninsula varies from 14 in Lenivaya River (Zukova & Matveyeva, 2000) to 90 (Fedosov *et al*., 2020). Such large differences are caused not only and not so much by objective reasons, in particular the size of territories and the duration of the study and as result the real diversity of local flora, but by the ability of collectors to recognize liverworts in the field and the completeness of the search and study of all suitable for liverworts habitats and completeness of examination of specimens. Basically, all collections in Taimyr Peninsula were carried out by plant sociologists, who mostly focus on more or less formed plant communities and do not carefully examine habitats with disturbed vegetation cover, e.g. rock fields, rock outcrops, spots of bare soil in spotted tundras, solifluction slopes, niches in steep banks of small rivers or lakes, roadsides and trails, etc., that are, the most appropriate habitats for liverworts. Repeated collecting and expansion of the number of studied sites leads to a significant increase in the list of species. This is very well illustrated by the latest publication on the diversity of liverworts in the Dixon area, where the work has been carried out repeatedly and importantly by different persons, both bryologists and plant sociologists, and specimens were identified by experienced hepaticologists. As result, the largest number of species have been recorded there (Fedosov *et al*., 2020). In terms of the richness of the flora, the territory we studied is closest to the richest of the previously studied – the Dixon area, the essential difference of which is the presence of rock outcrops and rock fields completely absent in areas studied by us.

The flora of liverworts of the studied region well reflects the geographical position of the area in the subarctic plain area of permafrost distribution with a continental climate.

Many of the collected species are widely distributed in the north of the Holarctic. Some of them are more or less abundant and are found in all three areas studied by us. These group include 31 species, the most common are *Aneura pinguis, Blepharostoma brevirete, Fuscocephaloziopsis pleniceps, Gymnocolea inflata, Neoorthocaulis binsteadii, Ptilidium ciliare, Scapania paludicola, Scapania tundrae, Schljakovia kunzeana, Schljakovianthus quadrilobus, Sphenolobus minutus, Trilophozia quinquedentata.* However, many liverworts are found as admixture in cushions or mats of mosses or as single shoots on bare soil. In some cases only a re-examination of the specimens allowed us to discover additional species that occur as scattered shoots in mats of other bryophytes. This has changed our initial ideas on the frequency of occurrence of a number of species in the studied territories, e.g. *Mesoptychia collaris* or *Cephalozia ambigua, Scapania gymnostomophila, etc.* Also some of the rare and phytogeographically interesting species were found in the re-studied specimens.

We believe that a detailed comparison of the floras of the three studied areas and published floras hardly makes sense due to the obvious incompatibility of the known lists, both in terms of the completeness of the study and nature conditions. At the same time, we consider it useful to summarize in tabular form the lists of species of the three studied territories (see Appendix) and will limit ourselves to the most general remarks. The largest numbers of liverworts and mosses were recorded for the Bataika key area, which is quite possibly explained by both the largest number of studied relevés (Appendix 1) and greater diversity of spotted tundra with clay and loamy spots comparing to the other two areas. However, the liverwort flora of the Nerpalakh key area is poorer whereas the moss flora of Kystyktakh is the poorest. These differences are small and may well be explained by random reasons.Meanwhile, we believe that it is important and useful to discuss the most phytogeographically interesting or taxonomically ambiguous species.

Notes on the most noteworthy discoveries and "difficult" taxa

Cephaloziella species. The taxonomy of the genus, especially in the Arctic, is very poorly studied. Interpretations of taxa are ambiguous. In addition, in the collected specimens, species of the genus occur, although in many specimens, but scattered and mostly without perianths and sporophytes. This did not allow us to identify many of the specimens more or less accurately.

Cryptocolea imbricata. This rather worldwide rare species was described from North America where it is rare, it is also known from Greenland, one locality in Scandinavia and one in Svalbard (Damsholt, 2002). In the 21st century the species has been found to occur scattered in Siberia and the Far East (Konstantinova *et al*., 2009). In Taimyr Peninsula the species was recorded previously for Tareya and Rogosinka (Zhukova & Matveyeva, 2000). The species has probably often been overlooked because is very small and often occurs scattered among bryophytes. We found it in two sites in several specimens.

Lophochaete fryei (Perss.) R.M. Schust. was previously collected in Taimyr in the surroundings of Tareya village only (Zhukova & Matveyeva, 2000). The species has mostly arctic distribution (Schuster & Konstantinova, 1996) and is not rare in arctic Alaska, Chukotka Peninsula, in the north of Yakutiya and Yamal Peninsula (Konstantinova, 2000). Recently it was found as well in Greenland and Western Himalaya (Aguero & Hassel, 2020). The species can surely be overlooked in Taimyr especially by less experienced students who with a quick revision of specimens could identify it as *Blepharostoma trichophyllum*. As was recently shown (Aguero & Hassel, 2020), this species belongs to the genus *Lophochaete*, and not *Pseudolepicolea*, by which it was known in all over the world (Söderström *et al*., 2016) and in Russia (Konstantinova *et al*., 2009).

Lophozia species with green gemmae. Identification of species of this group in the Subarctic is extremely difficult both because of the ambiguous interpretation of species and the rapid decomposition of oil bodies necessary for accurate identification. Therefore, we assigned the vast majority of specimens to the aggregate species *Lophozia ventricosa*, which occurs sporadically. Most of the other species of the group are given in cases of greater or lesser certainty correctness of identification, but still with a certain degree of doubt.

Lophozia cf. ***lantratovae.*** One specimen was referred to this species but with great doubt, since the oil bodies have not been preserved and the gemmae are rather darkly brown colored, which does not contradict the description and may be due to growing in the open area in the far north, where the summer insolation is quite high. The basis for attributing these plants to *L. lantratovae* was the characteristic "caps" of gemmae on the tops of shoots and rather large leaf cells (about 23–25 μm in the middle), which does not allow us to attribute these plants to *Barbilophozia sudetica* – the only similar species with rusty brown gemmae.

Lophozia savicziae was recorded for Taimyr for several areas in typical and arctic tundra (Zhukova & Matveyeva, 2020) but with some doubts (as cf.). The discovery in Dixon Area has later been confirmed by Bakalin (Fedosov *et al.*, 2020). The specimen collected by us was referred to this species without doubt based on characteristic appearance of plants with green to mostly reddish-rusty-brown colored leaves which are very wide, and cap-shaped, large leaf cells that are ca. (25–)30–40 μm wide and (30–)35–45(–50) μm long, numerous small oil-bodies that were preserved, and stellate, one-two-celled gemmae with distinctly thickened angles, ca. 23–27 μm in diameter.

Mannia pilosa. Lindberg & Arnell (1889: 11) recorded the species for a location somewhat to the south of Dudinka as occurring "an mehereren Stellen". But we do not know any records of the species for Taimyr Peninsula in recent publications. We just managed to collect several thalli of the species; however, it can be assumed that it occurs sporadically on loamy frost (mud) boils.

Marsupella sprucei is a not rare arctic montane species but it was recorded previously in Taimyr Peninsula only for Koso-Turku area. It is a very small liverwort occurring more often as single shoots on bare soil. We just found several shoots during the re-examination of the specimen. For sure the species is overlooked and is much more widespread in Taimyr Peninsula.

Mesoptychia collaris is a not rare arctic montane species that occurs in the studied area as single shoots in mats of mosses. The species occurs in the studied area as the very small form *pumila* that is morphologically quite similar to *Mesoptychia badensis*. We attributed the studied shoots to this species on the basis of the presence of single small underleaves, rather small cells with distinctly striolate cuticula and small but distinct trigones. It should be emphasized that this species occurs as scattered shoots among mosses and was found only after repeated careful re-examination of specimens from suitable habitats. Previously the species was recorded as *Lophozia collaris* (Nees) Dumort. for the surroundings of Tareya village only (Zhukova & Matveyeva, 2000).

Odontoschisma francisci occurs scattered on bare soil, shoots are just 0.2–0.35 cm wide, with distinct *Nardia*-like underleaves, large trigones, cells averaging 25 μm, oil-bodies 2–3 per cell, rather large, 8–10 μm. As far as we know, the species was not previously known in Taimyr, but was recorded for the Yamal Peninsula, the Far East and Southern Siberia. Finding this species in Taimyr is not unexpected, given its records in Yamalo-Nenets Autonomous Area (Potemkin, 1993, 2008).

Nardia japonica. Several specimens of dioecious *Nardia* with two-lobed leaves we referred to this species with some doubts. The species was collected several times in crusts on loamy mud boils in spotted tundra. We attributed to this species dioecious plants with two-lobed leaves, large connected with leaves underleaves and homogeneous oil-bodies which have preserved in some specimens. The taxonomic problems associated with this species had recently been discussed in a separate paper (Konstantinova *et al*., 2022).

Obtusifolium obtusum was recorded previously as *Lophozia obtusa* (Lindb.) A. Evans only for Ozhidanie Bay (Zhukova & Matveyeva, 2000). *O. obtusum* occurs in the studied area scattered in different waterlogged habitats where it sometimes can be abundant. It is an arctic boreomontane species that rarely occurs above the timberline (Damsholt, 2002, 2013). The species is near its northern limits in the studied area and almost exclusively restricted to boggy and spring areas. The peculiarity of the studied plants (uncharacteristic for the species) is the warm brown color of some leaves and sometimes almost entire plants that are scattered among the predominant light green plants, and the absence of red pigmentation of the stem. Plants are rather large, 2–2.5 mm wide, but cells rather small, in the middle ca. 20–25×25–30 μm, to the base distinctly larger, ca. 25–30×(30–)37–45(–50) μm, thin-walled, with very small, partly indis-

tinct trigones. Oil-bodies (8–)10–15(–20) per cell, slightly lager than described, ca. 3–5 μm but that probably is because they quickly enlarged immediately after soaking.

Pellia neesiana is a widespread boreomontane species which, however, rarely occurs above the timberline. It has previously been recorded for Taimyr Peninsula for Syrdasay River valley only (Zhukova & Matveyeva, 2000). The species occurs sporadically in the studied area in willow stands and on banks of streams.

Pseudotritomaria heterophylla. This poorly known arctic species was described from Ellesmere Island in the second half of the twentieth century and has subsequently been found in other Arctic regions. Especially many localities have been found in the north of Siberia (Konstantinova, 2000; Sofronova, 2005). It has also been recorded for several sites in Taimyr Peninsula (cf. Zhukova & Matveyeva, 2000).

Rudolgaea borealis was just recently found in Siberia in Gydansky Peninsula (Potemkin *et al*., 2021). The discovery of the species in Taimyr Peninsula confirmed by molecular data (Kuznetsova *et al.*, 2022) is not unexpected and expands the known distribution of the species. Moreover, in the Avam tundra, where suitable moderately rich sedge-hypnum mires are rather common, this species is likely not rare.

Scapania tundrae was described as *Martinellius tundrae* by H. Arnell from Dudinka (citing Buch, 1928) situated somewhat south-west of Taimyr Peninsula. The species was recently recorded in Taimyr Peninsula for Rogozinka River valley and Pronchishsheva Bay (Zhukova & Marveyeva, 2000). The species is not rare in the studied area in fens and boggy tundras. The absence of records of this species from the majority of other territories studied in Taimyr is most likely due to incorrect identifications and attribution to other species (cf. Buch, 1928).

Solenostoma is taxonomically one of the most complicated genera. In spite of numerous attempts to revise the genus both worldwide (Váňa, 1974 a, b; 1975 a,b;) and regional (Schuster 1969, 1988; Schljakov, 1981; Schuster & Damsholt, 1972; Bakalin, 2014), confusion and disagreement in the interpretations of many taxa are numerous. The lack of relevant reliable data in the GenBank precludes the use of molecular data to solve existing problems. In our collection, many specimens from spots in the spotted tundra, as well as from eroded solifluction slopes, included species of this genus. Many such specimens have quite specific appearance and were referred by us to *Solenostoma pusillum.* In this study we prefer not to treat *Solenostoma pusillum* as synonym of *S. sphaerocarpum* as it is accepted in the recent European Checklist of Bryophytes (Hodgetts *et al*., 2020) and consider *Solenostoma pusillum* a distinct species (Schuster, 1969; Damsholt, 2002; Bakalin, 2014).

Our study once again highlights the problems in studying the flora of liverworts in the Arctic regions. As can be seen from the list presented above, many specimens could not be identified with confidence. These are mainly species from the genera *Cephaloziella, Lophozia, Solenostoma,* and *Nardia*. These genera have many unresolved taxonomic problems, despite repeated attempts of revisions (Schuster, 1969, 1980, 1988; Schuster & Damsholt, 1974; Bakalin, 2014;Váňa, 1974 a, b, 1975 a, b). It would seem that the possibilities opened up by the use of new methods, in particular molecular ones, allow us to solve at least some of these problems. However, this is not the case, and so-called integrative floristics does not help here because the use of molecular methods encounters the absence of reference barcodes. Therefore, until monographic treatments of the genera, with the inclusion of all species and specimens from different parts of the species' area, the use of integrative floristics will encounter all the same problems as taxonomy. On the other hand, the revision of these genera requires material that accumulates in studies like the one presented above. Specimens collected in hard-to-reach places and identified even with doubt can be extremely useful in treatments of problematic genera.

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Appendix 1. Liverworts records within key sites

Key areas	I Nerpalakh	II Bataika	III Kystyktakh
Number of relevés	114	168	118
Additional collection sites of bryophytes	18	13	10
Hepatic species in key sites	60	64	54
Moss species in key sites	111	140	125
Aneura pinguis	15	26	7
Anthelia juratzkana	3	1	3
Arnellia fennica		4	
Barbilophozia hatcheri		1	
Blasia pusilla		2	1
Blepharostoma trichophyllum	3	2	1
Blepharostoma brevirete	17	8	4
Calypogeia muelleriana	1	2	5
Cephalozia ambigua		1	2
Cephalozia bicuspidata	3	2	3
Cephaloziella arctogena	1		
Cephaloziella grimsulana	1		
Cephaloziella spinigera		1	
Cephaloziella cf. uncinata			1
Cephaloziella varians		1	
Chiloscyphus pallescens			1
Cryptocolea imbricata	1	1	
Fuscocephaloziopsis lunulifolia	1	1	
Fuscocephaloziopsis pleniceps	3	3	1
Gymnocolea inflata	3	1	9
Gymnomitrion corallioides	7	13	4
Jungermannia polaris		1	
Lophozia cf. *lantratovae*	1		
Lophozia guttulata	1		
Lophozia murmanica	5	6	8
Lophozia savicziae		1	
Lophozia silvicola	7	2	
Lophozia ventricosa	1	4	1
Lophozia wenzelii	1		
Lophoziopsis excisa	5	1	1
Lophoziopsis excisa var. *elegans*		1	
Lophoziopsis jurensis	4	1	
Lophoziopsis polaris	1	3	
Mannia pilosa		1	
Marchantia polymorpha subsp. *ruderalis*	2	1	1
Marsupella sprucei			1
Mesoptychia collaris	1	2	
Mesoptychia gillmanii		1	
Mesoptychia heterocolpos	1	2	
Mesoptychia heterocolpos var. *harpanthoides*		1	
Mesoptychia rutheana		4	1
Mesoptychia sahlbergii		1	
Mylia anomala	2		
Nardia geoscyphus	1		2
Nardia japonica			2
Neoorthocaulis binsteadii	22	17	36
Obtusifolium obtusum	1	1	3
Odontoschisma elongatum	5	5	1
Odontoschisma francisci			1
Odontoschisma macounii	4	2	1
Pellia neesiana	4	1	
Prasanthus suecicus	2	1	1
Lophochaete fryei		5	
Pseudotritomaria heterophylla		2	
Ptilidium ciliare	56	62	39
Riccardia chamedryfolia		1	
Riccardia latifrons	1	1	1
Riccia cavernosa		1	
Rudolgaea borealis	1	6	2
Saccobasis polita	2		1
Scapania brevicaulis		1	
Scapania crassiretis	1		
Scapania curta	1		
Scapania gymnostomophila		3	
Scapania hyperborea	6	1	3
Scapania irrigua	3	2	1
Scapania ligulifolia		2	
Scapania obcordata	1	1	
Scapania paludicola	7	17	6
Scapania parvifolia	1		2
Scapania scandica			1
Scapania tundrae	6	23	18
Schistochilopsis grandiretis	2	3	2
Schistochilopsis incisa	1		2
Schistochilopsis opacifolia	2	2 1	2
Schljakovia kunzeana	24	21	3
Schljakovianthus quadrilobus	4	6	3
Solenostoma confertissimum	1	1	
Solenostoma hyalinum			1
Solenostoma pusillum	1		1
Solenostoma cf. *rossicum*	1		
Solenostoma sphaerocarpum	1	1	
Sphenolobus minutus	48	39	32
Sphenolobus saxicola	2	13	4
Tetralophozia setiformis	3		1
Tritomaria scitula		1	
Trilophozia quinquedentata	21	21	7