

LIVERWORTS OF THE SOUTHERN PART OF “KYTALYK” NATIONAL PARK
(TUNDRA ZONE OF REPUBLIC OF SAKHA (YAKUTIA), RUSSIA)

К ФЛОРЕ ПЕЧЕНОЧНИКОВ ЮЖНОЙ ЧАСТИ НАЦИОНАЛЬНОГО ПАРКА
«КЫТАЛЫК» (ТУНДРОВАЯ ЗОНА РЕСПУБЛИКИ САХА – ЯКУТИЯ)

NADEZHDA A. KONSTANTINOVA¹, ELENA D. LAPSHINA² & ILYA V. FILIPPOV²
НАДЕЖДА А. КОНСТАНТИНОВА, ЕЛЕНА Д. ЛАПШИНА², ИЛЬЯ В. ФИЛИПPOB²

Abstract

The annotated list of liverworts, compiled on the basis of identification of specimens collected at three key sites in the “Kytalyk” National Park (Republic of Sakha, Yakutia), counts 72 species, two subspecies and one variety including five species new to the republic and ten new to the arctic of the Republic of Sakha. Each species is provided with comments on the presence of reproductive structures, the frequency of occurrence, a description of the main habitats and plant communities where they occur. The distribution of liverworts by habitats is discussed. The species new for the republic as well as phytogeographically interesting discoveries are considered. The data obtained supplement the available information on the diversity of liverworts, their frequency of occurrence and the peculiarities of the distribution of liverworts in the tundra zone of Yakutia.

Резюме

Аннотированный список печеночников, составленный на основе идентификации образцов, собранных на трех ключевых участках национального парка Кыталык (республика Саха) насчитывает 72 вида, два подвида и одну разновидность, в том числе 5 новых для республики и 10 новых для арктической зоны Якутии видов. Для каждого вида приводятся сведения о наличии репродуктивных структур и перечень основных местообитаний и растительных сообществ, где он встречается. Рассматривается участие печеночников в различных сообществах. Обсуждаются новые для республики виды и наиболее фитогеографически интересные находки. Полученные данные дополняют имеющиеся сведения о разнообразии печеночников, частоте их встречаемости и особенностях распространения печеночников в тундровой зоне Якутии.

KEYWORDS: liverworts, ecology, distribution, phytogeography, flora, Yano-Indigirka lowland, southern tundras, Russia

INTRODUCTION

The “Kytalyk” National Park was established in 2019 in the Allaikhovskiy District of the Republic of Sakha to protect Arctic breeding grounds of migratory birds, including a significant portion of the habitat of the endangered Siberian crane (sterkh). The park is located in the Yana-Indigirka Lowlands, adjacent to the coast of the East Siberian Sea (Figs. 1, 2). The total area of the park is about 1.8 million hectares.

The creation of a new protected area implies a complete inventory of biodiversity within its boundaries. Since the establishment of the park, no specific bryophyte study has been undertaken for this area. Today 55 species of mosses are known in the park based on publications on moss flora of the lower reaches of the Indigirka River and around the Chokurdakh village (Boch & Tsareva, 1974; Afonina, 1986; Stepanova, 1986; Maksimov & Ivanova, 2006) and only two species of liverworts, *March-*

antia polymorpha s.l. and *Ptilidium ciliare* are mentioned in the cited publications. Therefore, we considered it appropriate to publish the results of the study of liverworts gathered during the phytocenological study conducted in 2023 in the southern part of the “Kytalyk” National Park by E.D. Lapshina and I.V. Filippov.

MATERIAL AND METHODS

Study area

“Kytalyk” National Park is situated in the north of Republic of Sakha. The studied southern part of the park is located in northern part in the southern tundra subzone according to Perfil’eva *et al.* (1991). The climate of the area is continental subarctic (Tochyenov, 1986) with a cold, prolonged winter and a short, cold summer. According to data from the Chokurdakh meteorological station, the average temperature in January is –38°C, and in July it ranges from 8 to 12°C. The annual precipitation is 150–250 mm, with 55–60% falling during the

¹ – Polar-Alpine Botanical Garden-Institute of the Kola Science Center of RAS, Kirovsk, Murmansk Province, 184256, Russia E-mail: nadya50@list.ru ORCID (NK) 0000-0002-7600-0512

² – Yugra State University, Khanty-Mansiysk, Khanty-Mansiysk Autonomous Area, 628012 Russia; e-mails: e_lapshina@ugrasu.ru, filip83pov@yandex.ru ORCID (EL) 0000-0001-5571-7787; (IF) 0000-0002-3639-553X

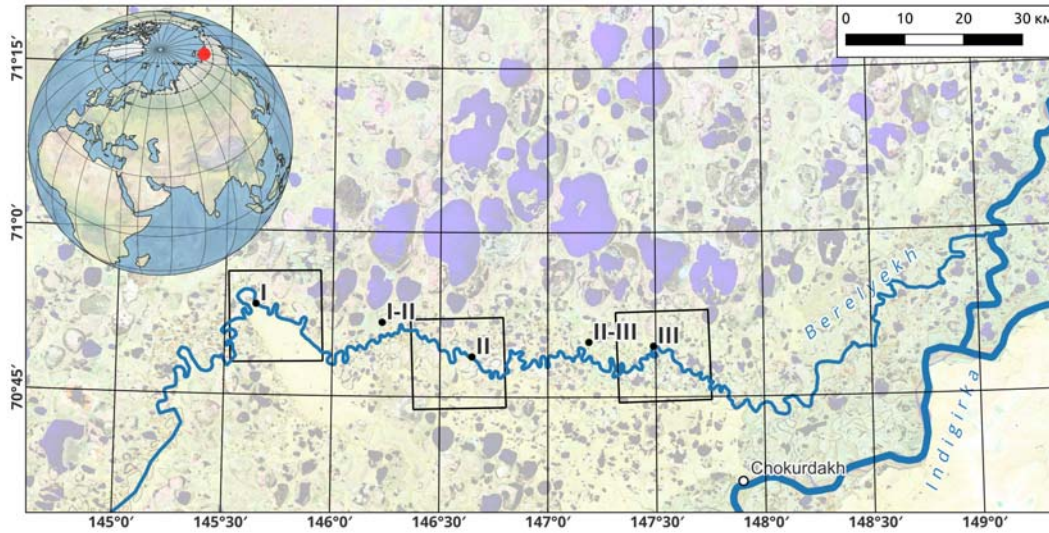


Fig. 1. Study area.

winter period (Smirnova, 1968). Permafrost is continuous throughout the area. The depth of seasonal soil thawing ranges from 0.2 to 1.8 meters.

Rim-polygon mires with a more or less clear polygonal structure predominate in the studied area. They occupy low river terraces and extensive khasyreys (bottoms of deflated thermokarst lakes) of different ages, determining the overall landscape of the Yano-Indigirka lowland, elevated on average 50–80 m above sea level with slight elevation fluctuations. Flat palsa bogs are widespread, forming outside river valleys in the later stages of khasyre development, often creating complex mire systems in combination with rim-polygon mire complexes. Flat areas and lake depressions alternate with elevated landforms such as low ridges and mounds, known in Yakutia as ‘yedoma’ (Popov, 1969), on which zonal *Dryas*-green moss and shrub (*Betula nana* subsp. *exilis*, *Salix* spp.)-lichen-green moss tundras develop. Gentle slopes and flat, poorly drained hilltops (yedoma) are covered by tussock cottongrass (*Eriophorum vaginatum*) tundras and cottongrass-*Sphagnum* (*Sphagnum lenense*, *S. balticum*) bogs. Occasionally there are single domed hills, up to 25–50 m high and 100–300 m wide, called bulgunniakhs



Fig. 2. The Berelyekh River valley in its upper reaches

(frost mounds) and hydrolaccoliths (frost blisters), rising several meters above the surrounding watered tundra. Pioneer bryophyte communities are widespread on bare or slightly turfed soil along the riverbanks, and on sandy-gravel covered outcrops where the river cuts through yedoma hills.

Key areas

The study area (Table 1, Figs. 1–3), includes three key sites: **I** – Okean-Syane, near the upper Park ranger station; **II** – Omuk-Sane in the middle course of Berelyekh river; and **III** – the Central ranger station in the lower course of the river. Additionally, bryophytes were collected between the key sites (I-II, II-III).

I – “Okean-Syane” area (70.889° N, 145.640° E) is located near the southwestern boundary of the National Park. It includes both right and left bank river terraces, a large moraine ridge (the Yelon’ Mountains) rising up to 120 meters above sea level, with sandy-gravelly and clay solifluction outcrops, as well as the adjacent low-lying plain on the left bank of the river with vast khasyreys alternating with drained ridges (edoms) with tundra vegetation adjacent to the left bank of the river.

I-II (70.857° N, 146.225° E). The low-lying plain, adjacent to the north of the river valley, with extensive khasyreys occupied by sedge-hypnum¹ mire complexes with a weakly defined rim-polygonal structure and residual thermokarst lakes.

II – “Omuk-Sane” area (70.812° N, 146.645° E) is located in the middle course of the river. It encompasses diverse rim-polygon complexes (in various stages of development) and oligotrophic flat palsa-hollow bog complexes within and beyond the river valley, as well as plateau-like elevations covered with tussock cottongrass tundras and cottongrass-*Sphagnum* bogs.

II-III (70.830° N, 147.177° E). A flat elevation (yedoma) with tussock cotton-grass-green moss tundras and an extensive khasyreys occupied by a rim-polygon sedge-

¹ – hypnum in mire type names means here mosses other than *Sphagnum*, mostly of Scorpidiaceae, Calliergonaceae, etc.

Table 1. The 15 main types of vegetation in the study area, some with subtypes, showing the diversity of liverworts (number of species is given in parentheses) and liverwort habitats. Abbreviations used: PHB – flat palsa bogs and flat palsa-hollow bog complexes, RPM – rim-polygon mire complexes. Species found only in a particular type of habitat are given in bold.

1 (2 sites). **Zonal low shrub-lichen-moss tundras** on relatively well-drained gentle slopes and flat hilltops of watersheds with clayey soils. Low shrub (*Betula nana* subsp. *exilis*, *Ledum palustre* subsp. *decumbens*, *Salix glauca*)-lichen-moss tundras dominated by *Hylocomium splendens* var. *alaskanum*, *Aulacomnium* spp., *Dicranum* spp., *Tomentypnum nitens* (Fig. 2A–B).

1a (6 species) – scattered among mosses: more or less abundant *Neoorthiscaulis binsteadii*, *Ptilidium ciliare*, and *Sphenolobus minutus* or as small turfs or mats: *Calyptogeia muelleriana*, *Lophozia murmanica*, *L. silvicola*.

1b (3 species) – on clay patches *Arnellia fennica*, *Cephaloziella varians*, and *Pseudotritomaria heterophylla*

2–3. Tussock cottongrass tundras and cottongrass-Sphagnum bogs

on poorly drained gentle slopes and in flat depressions with patches of bare clay in small holes between the tussocks (Figs. 3C–E)

2 (6 sites). **Tussock cottongrass** (*Eriophorum vaginatum*)-lichen-moss and cottongrass-moss tundras dominated by *Hylocomium splendens* var. *alaskanum*, *Aulacomnium* spp., *Dicranum* spp. *Tomentypnum nitens* in moss cover (Fig. 3C)

2a (15 species) – ground cover among mosses;

2b (9 species) – clay patches.

Liverworts are the same as in **3a** and **3b** (see below)

3 (3 sites). **Dwarf shrub** (*Ledum palustre* subsp. *decumbens*)-cottongrass-Sphagnum bogs (Fig. 3D) dominated by *Sphagnum lenense* with *S. balticum*:

3a (13 species) – ground cover scattered among mosses: *Blepharostoma brevirete*, *B. trichophyllum*, *Lophozia murmanica*, *L. silvicola*, *Lophozia polaris*, *Neoorthiscaulis binsteadii*, *Ptilidium ciliare*, *Schljakovia kunzeana*, *Sphenolobus minutus*.

3b (13 species) – on clay patches: *Anthelia juratzkana*, *Cephalozia bicuspidata*, ***Diplophyllum sibiricum***, *Fuscocephaloziopsis pleniceps*, *Marsupella sprucei*, *Mesoptychia* cf. *collaris*, *Nardia geoscyphus*, *Protochilopsis grandiretis*, *Pseudotritomaria heterophylla*, *Riccardia latifrons*, *Scapania parvifolia*, *Sphenolobus minutus* var. *grandis*, *Solenostoma hyalinum*, *S.* cf. *jensenianum*, *S. sphaerocarpum*, etc.

4–5. Flat palsa and palsa-hollow bog complexes (PHB). Frozen peat mounds (palsa)

in flat palsa bogs and flat palsa-hollow complexes on high river terraces, flat watershed areas and on oligotrophic stages of peat bog development in drained thermokarst lakes depressions (khasyres).

4 (20 sites, 16 species). **Drained dome-shaped frozen peat mounds** covered by birch (*Betula nana* subsp. *exilis*)-green moss communities (**4**) with dense turf of *Dicranum* spp., *Polytrichum strictum* in moss layer. Scattered among mosses in small abundance: *Blepharostoma brevirete*, *B. trichophyllum*, *Calyptogeia muelleriana*, ***Lophozia ascendens***, *L. murmanica*, *L. silvicola*, *Lophozia polaris*, *Neoorthiscaulis binsteadii*, *Plagiochila arctica*, *Ptilidium ciliare*, *Scapania paludicola*, *Schljakovia kunzeana*, *Sphenolobus minutus*, *Trilophozia quinquentata*, *Tritomaria exsectiformis*, and ***Scapania kaurinii*** (Fig. 3E)

5 (6 sites, 2 species). **Dwarf shrub** (*Ledum palustre* subsp. *decumbens*)-cloudberry-Sphagnum (*S. lenense*) communities on frozen peat palsa (15–25 cm high). Scattered in dense *Sphagnum* cover: *Calyptogeia sphagnicola* and *Neoorthiscaulis binsteadii*.

6–10. Rim-polygon mire complexes (RPM)

on low river terraces and flat depression of former thermokarst lakes with waterlogged flat or low-centred polygons (10–25 m in diameter) separated by weakly raised rims around their periphery. (Fig. 3F)

6 (55 sites, 11 species). **Willow** (*Salix pulchra*, *S. fuscescens*)-sedge-Sphagnum (*S. squarrosum*) ridges (**6a**) and drained areas (**6b**) of RPM (Fig. 3G). Sporadic in bryophyte mats: ***Barbilophozia barbata***, *Blepharostoma brevirete*, *Cephaloziella spinigera*, *C. uncinata*, *Chiloscyphus pallescens*, *Lophozia polaris*, *Mesoptychia rutheana*, ***Odontoschisma macounii***, *Plagiochila arctica*, *P. porelloides*, *Schljakovia kunzeana*, *Scapania paludicola*, and *Schljakovianthus quadrilobus*, etc.

7 (68 sites, 5 species). **Meso-oligotrophic sedge** (*Carex aquatilis* subsp. *stans*)-Sphagnum (*S. obtusum*) communities in flat or slightly concave polygons in RPM and hollows in flat PHB (Fig. 3F). Rare, only in shallow pools with sparse *Sphagnum* cover: *Cephaloziella uncinata*, ***Lophozia excisa***, ***Rudolgaea fascinifera***, *Scapania paludicola*, *Schistochilopsis incisa*.

8 (32 sites, 10 species). **Sedge** (*Carex aquatilis* subsp. *stans*)-Sphagnum and sedge-hypnum (*Scorpidium*)-Sphagnum communities dominated by *Sphagnum orientale* in hollows and waterlogged concave polygons of RPM (Fig. 3F). Scattered among mosses: *Aneura pinguis*, *Cephaloziella divaricata*, *C. hampeana*, *C. varians*, *Mesoptychia rutheana*, ***Rudolgaea fascinifera***, ***Odontoschisma fluitans***, *Scapania irrigua* subsp. *rufescens*, *S. paludicola*, and *Schljakovianthus quadrilobus*.

9 (55 sites, 16 species). **Waterlogged sedge** (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum (*Scorpidium*, *Meesia*) communities of concave polygons of RPM and lake shore floating mats with high constancy of *Aneura pinguis*, *Cephaloziella divaricata*, *C. hampeana*, *C. spinigera*, *C. uncinata*, ***Chiloscyphus pallescens***, *Marchantia polymorpha* subsp. *ruderalis*, *Mesoptychia rutheana*, *Riccardia latifrons*, *Scapania paludicola*, *Schljakovianthus quadrilobus*, and sporadically *Rudolgaea borealis* and others.

10 (3 sites, 11 species). Tussock sedge (*Carex aquatilis* subsp. *stans*)-moss communities with high (20–25 cm) sedge tussocks in deep concave polygons with variable water level (on slope areas of the rim-polygon mire complexes): *Aneura pinguis*, *Blepharostoma brevirete*, *Cephalozia bicuspidata*, *Cephaloziella divaricata*, *C. uncinata*, *Chiloscyphus polyanthos*, *Mesoptychia heterocolpos*, *M. rutheana*, *Riccardia latifrons*, *Plagiochila arctica* are present among mosses on sedge tussock sides and between them.

Table 1. Diversity of liverworts in main plant communities and liverwort habitats (*cont.*).

- 11** (7 sites, 4 species). **Waterlogged sedge and sedge-cottongrass** (*Carex aquatilis* subsp. *stans*, *Eriophorum angustifolium*) communities in deep low-centred polygons of rim-polygon mire complexes: *Aneura pinguis*, *Cephalozia bicuspidata*, *Cephaloziella uncinata*, *Scapania irrigua*.
- 12** (12 sites, 4 species). **Floodplain mires periodically inundated by river waters**. Herbaceous (*Comarum palustre*, *Polemonium acutiflorum*, *Saxifraga* spp.)-sedge (*Carex aquatilis* subsp. *stans*)-grass (*Calamagrostis* spp., *Arctagrostis latifolia*)-hypnum communities dominated by *Aulacomnium palustre*, *Brachythecium* spp., *Campylium stellatum*, *Hamatocaulis vernicosus* in moss cover: *Aneura pinguis*, *Marchantia polymorpha* subsp. *ruderalis* and *Mesoptychia rutheana*, ***M. sahlbergii*** have been found in such type of habitats.
- 13** (1 sites, 16 species). **Sandy-gravelly hills outcrops** on eroded slopes of moraine hills and elevations (yedoma) (Fig. 3H), on bare fine earth and sand: *Anthelia juratzkana*, *Cephalozia bicuspidata*, *Cephaloziella varians*, ***Cryptocolea imbricata***, ***Iso-paches bicrenatus***, ***Lophozia fuscovirens***, *L. murmanica*, *Marsupella sprucei*, *Nardia geoscyphus*, ***Scapania curta***, ***S. obcordata***, *S. parvifolia*, *Solenostoma sphaerocarpum*, *Sphenolobus minutus*, *S. minutus* f. *grandis*, *Trilophozia quinquedentata*.
- 14** (4 sites, 3 species). **Regularly flooded river and streams banks**, on bare clayey soil: ***Blasia pusilla***, ***Scapania irrigua***, ***Riccia sorocarpa***.
- 15** (4 sites, 7 species). **Regularly flooded floodplain and lakeside reed grass meadows** along the low banks of rivers and lakes: *Blepharostoma trichophyllum*, *Cephaloziella uncinata*, *Chiloscyphus polyanthos*, *Marchantia polymorpha* subsp. *ruderalis*, *Plagiochila porrelloides*, *Scapania irrigua*, *S. paludicola*.

moss mire complex, featuring a sedge-reed regularly flooded lakeshore zone adjacent to a residual lake.

III – “Central Ranger Station” area (70.828° N, 147.486° E) is located in the lower course of the Berelyekh River. It encompasses a variety of rim-polygon, rim-pool-polygon, and flat palsa-hollow bog complexes situated at different elevation levels and in various stages of development within khasyreys, as well as high ridges (yedoma) covered by zonal tundras.

Vegetation

The primary focus was on the study of the mires vegetation in which 270 plant communities were described and the majority of liverwort specimens were collected. Other habitats including tundra communities, willow thickets, floodplain meadows, as well as clay patches in zonal and boggy tundras, riverbanks, sandy-gravel outcrops are represented by a smaller number of relevés and collected liverworts specimens (Table 1).

Collections

Elena D. Lapshina and Ilya V. Filippov collected bryophytes in the southern part of the “Kytalyk” National Park, within the valley of the Berelyekh River, a left tributary of the Indigirka River, and adjacent areas in 2023 from July 9 to 22. A total of 480 liverwort specimens were gathered from 284 sites at elevations ranging from 20 to 120 meters above sea level. The coordinates 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). Voucher specimens are stored in the Herbarium of Polar-Alpine Botanical Garden-Institute (KPABG) and Biological collection of Yugra State University (YSU).

SPECIES LIST

The annotated list of liverworts includes 72 species, two subspecies and two varieties. The nomenclature of bryophytes generally follows Hodgetts *et al.* (2020) and Sekretareva (2004) for vascular plants. The species in the list are arranged in alphabetical order. Common synonyms are given in square 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). The numbers of key areas where the species was recorded, in accordance with Table 1, are provided in Roman numerals in bold, along with the number of occurrences in Arabic numerals. The habitats (Table 1), are then given in bold and italics in descending order of the number of occurrences, followed by some accompanying species.

The frequency is characterized as: Sp – sporadic (4–6 localities), Fr – frequent (7–15 localities) and Cm – common (more than 15 localities). For species collected from 1–2 (3) localities, labels are given in full and the herbarium numbers of specimens in the Herbarium of Polar-Alpine Botanical Garden-Institute (KPABG) or Biological collection of Yugra State University (YSU) or both are provided. For common and sporadic species at least one reference to a herbarium number in the Cryptogamic Russian Information System – L (CRIS) (https://isling.org/customtable_hepatics?action=showtable&id=230) or the Biological collection of Yugra State University (YSU) or both are cited.

New records for the arctic zone of the Republic Sakha are marked as one asterisk (*), new records for the whole Yakutia – as two asterisks (**).

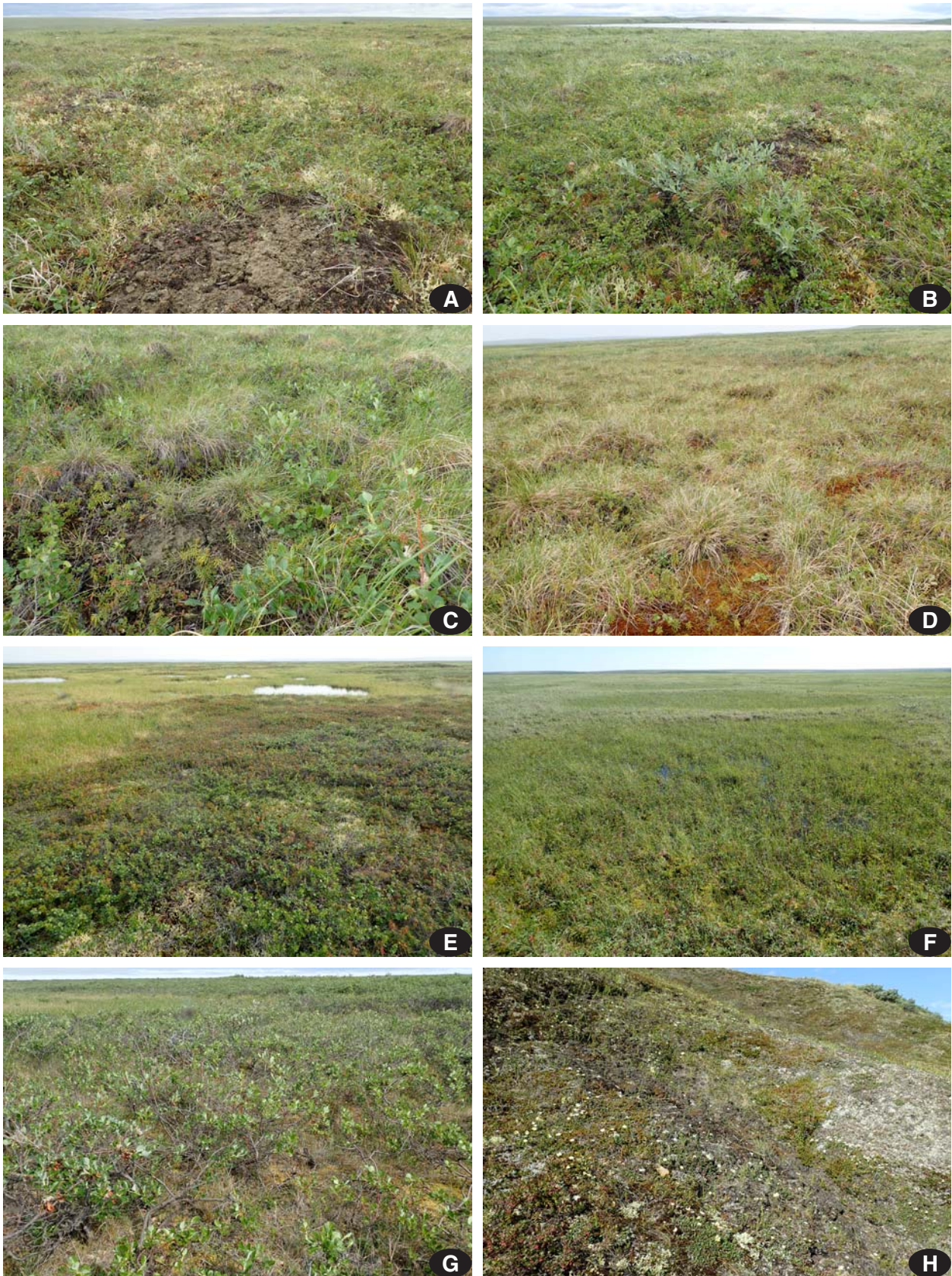


Fig. 3. Main plant communities and liverwort habitats. A: clay patches in zonal low shrub-lichen-moss tundra (1b); B: zonal sedge-low shrub-lichen-moss tundra (1a); C: clay patches in tussock cottongrass-moss tundra (2b); D: tussock cottongrass-*Sphagnum* bog (3a); E: frozen peat mound in flat palsa mire complex (2); F: rim (6a) and waterlogged sedge-moss polygons (7, 8) in rim-polygon mire complex; G: drained willow-*Sphagnum* area in rim-polygon mire (6b); H: sandy-gravelly hill outcrops (13)

- Aneura pinguis* (L.) Dumort. (and., gyn., spor.) – **I, II, III** Cm (53): sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*-*Sphagnum orientale* and sedge-hypnum (*Scorpidium*, *Meesia*) polygons and floating mats in rim-polygon mires (**8, 9, 10, 11**) within dry falling lake bottoms (khasyreys) and periodically flooded mires (**12**), found in pure mats or mixed with *Scorpidium revolvens*, *Meesia triquetra*, *Bryum neodamense*, *Cinclidium subrotundum*, *Scapania paludicola*, *Cephaloziella* spp. [YUS-MH-05792; KPABG(H): 126390].
- Anthelia juratzkana* (Limpr.) Trevis. (per.) – **I** (2): sandy-fine-grained outcrop (**13**), on bare soil, many shoots mixed with *Cephaloziella varians*, *Lophozia murmanica*, *Sphenolobus minutus*, *Scapania obcordata*, *S. parviflora* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05494]; steep solifluction slope to the stream, on bare wet soil (**13**), mixed with *Blepharostoma brevirete*, *Trilophozia quinquentata*, *Cephaloziella varians*, *Sphenolobus minutus* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05494; KPABG(H) 126386].
- Arnellia fennica* (Gottsche) Lindb. – **III** (1): zonal dwarf shrub-sedge-lichen-moss frost boils tundra, on clay patches (**1b**), mixed with *Lophozia* sp. (70.76471 N, 147.21767 E), 19.VII.2023, Lapshina [YUS-MH-05986].
- Barbilophozia barbata* (Schmidel ex Schreb.) Loeske – **III** (1): willow-reedgrass (*Calamagrostis holmii*)-*Sphagnum* community in drained area of rim-polygon mire (**6b**), single shoots among *Sphagnum talbotianum* (70.81984 N, 147.49921 E), 20.VII.2023, Lapshina [YUS-MH-06083].
- Blasia pusilla* L. – **II** (1): steep slopes to the river (**14**), on bare loamy soil (70.81178 N, 146.64964 E), 8.VII.2023, Lapshina [YUS-MH-05301; KPABG(H): 126372].
- Blepharostoma brevirete* (Bryhn & Kaal.) Vilnet & Bakalin (per) – **I, II, III** Cm (15): tussock cottongrass (*Eriophorum vaginatum*)-moss tundras and cottongrass-*Sphagnum* bogs (**2a, b, 3a, b**), dwarf birch-*Dicranum* frozen peat mounds (palsa) of the flat palsa-hollow bog complexes (**4**), usually mixed with other bryophytes, rarely in pure mats [YUS-MH-05819; KPABG(H): 126436].
- B. trichophyllum* (L.) Dumort. – **I, II, III** Sp (4): tussock dwarf shrub-cottongrass-moss-lichen tundras (**2a**), in the moss cover, mixed with other bryophytes; dwarf birch-lichen-*Dicranum* and dwarf shrub (*Ledum palustre* subsp. *decumbens*)-cottongrass-lichen-*Sphagnum* frozen peat mounds (palsa) in flat palsa-hollow bogs (**4, 5**), in the cracks on the bare peat; reed grass marshy meadow, on bare soil (**15**) [YUS-MH-06003; KPABG(H) 126425].
- Calypogeia muelleriana* (Schiffn.) Müll. Frib. – **I, II** Sp (6): zonal dwarf shrub-lichen-moss and tussock cottongrass (*Eriophorum vaginatum*)-green moss tundras (**1a, 2a**), and dwarf shrub (*Ledum palustre* subsp. *decumbens*)-cottongrass-*Sphagnum* (*S. lenense*) bogs (**3a**), on the tussock side; dwarf birch-*Dicranum* frozen peat mounds (palsa) of flat palsa-hollow bog complexes (PHB) (**4**), in the cracks on the bare peat [YUS-MH-5473; KPABG(H): 126431].
- C. sphagnicola* (Arnell & J. Perss.) Warnst. & Loeske – **I** (1): dwarf shrub (*Ledum palustre* subsp. *decumbens*)-cloudberry-*Sphagnum* (*S. lenense*, *S. balticum*) community on a low palsa in flat-palsa bog (**5**), minor admixture among *Sphagnum* spp., *Polytrichum strictum*, *Aulacomnium turgidum*, *Neoorthocaulis binsteadii* (70.87344 N, 145.90633 E), 12.VII.2023, Lapshina [YUS-MH-06200].
- Cephalozia bicuspidata* (L.) Dumort. (per., spor.) – **II, III** Fr (7): tussock cottongrass (*Eriophorum vaginatum*)-lichen-moss and cottongrass-green moss tundras (**2b**) and dwarf shrub-cottongrass-*Sphagnum* (*S. lenense*) bogs, on clay patches (**3b**); periodically flooded tussock sedge-moss polygons (**10**) and waterlogged sedge (**11**) in rim-polygon mire, on sides of sedge tussocks [YUS-MH-5555; KPABG(H): 126432]; sandy-gravelly hill outcrops (**13**).
- Cephaloziella divaricata* (Sm.) Schiffn. (spor., per.) – **I-II, II-III, III** Sp (5): sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum moss (*Scorpidium* spp., *Meesia triquetra*) and sedge-*Sphagnum* (*S. orientale*) waterlogged hollows in rim-polygon mire (**8, 9**). Scattered among other bryophytes, less common in loose mats on peat humus and plant litter [YUS-MH-05564; KPABG(H): 126391].
- C. hampeana* (Nees) Schiffn. (spor., per. clearly autoicous) – **II-III, III** Sp (4): sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum moss (*Meesia triquetra*) and sedge-hypnum-*Sphagnum* low-centred polygons in rim-polygon mires (**8, 9**); sedge-reedgrass community on a low flooded lakeshore terrace (**15**) [YUS-MH-6056; KPABG(H): 126438]. Minor admixture among other bryophytes.
- C. spinigera* (Lindb.) Warnst. (spor.) – **I-II, II, III** Sp (4): willow-*Sphagnum* (*S. squarrosum*, *S. fimbriatum*) ridges and riparian drained areas of rim-polygon bogs (**6a, b**) [YUS-MH-5575; KPABG(H): 126392], among other bryophytes; once in waterlogged sedge (*Carex chordorrhiza*)-hypnum-moss hollow (**9**), at the bases of sedge.
- C. uncinata* R.M. Schust. (per., spor.) – **I, I-II, II-III, III** Fr (13): sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum moss (**9**) and waterlogged sedge (**11**) polygons and tussock sedge-moss communities (**10**) periodically flooded by lake waters; rare in willow-sedge-*Sphagnum* (*S. squarrosum*) communities of ridges in rim-polygon mires (**6a**) [YUS-MH-5499; KPABG(H): 126442]. Usually minor admixture among other bryophytes, rarely in loose mats.
- C. varians* (Gottsche) Steph. – **I, II** Sp (5): sandy-fine-grained outcrop (**13**), mixed with *Sphenolobus minutus*, *Trilophozia quinquentata*, *Scapania* spp., *Anthelia juratzkana* [YUS-MH-05494; KPABG(H): 126410]; sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum (*Schljakovianthus quadrilobus*, *Meesia triquetra*, *Scorpidium revolvens*) and sedge-*Sphagnum* (*S. orientale*) hollows in rim-polygon mire complex with frozen flat palsas (**8, 9**); once in high-centered palsa bog on bare peat mixed with *Bryum neodamense*, *Cinclidium subrotundum*, *Scapania kaurinii*, *S. irrigua*, *S. paludicola*.
- Chiloscyphus pallescens* (Ehrh. ex Hoffm.) Dumort. – **II-III** (1): sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum low-centred polygon in the rim-polygon mire (**9**), noticeable admixture among *Scorpidium revolvens* and *Cinclidium subrotundum* (70.82760 N, 147.19104 E), 17.VII.2023, Lapshina [YUS-MH-05846].
- C. polyanthos* (L.) Corda – **II-III, III** Sp (4): waterlogged sedge-reed grass meadow in the river floodplain (**15**); tussock sedge (*Carex aquatilis* subsp. *stans*)-moss community, periodically flooded by lake waters in rim-polygon mire (**10**), scattered among bryophytes on peat humus and plant litter [YUS-MH-5866; KPABG(H): 126437].
- Cryptocolea imbricata* R.M. Schust. – **I** (1): sandy-fine-grained outcrop, on bare ground (**13**), small admixture among *Scapania obcordata*, *Cephaloziella varians*, *Solenostoma sphaerocarpon*, *Marsupella sprucei*, *Anthelia juratzkana*, *Nardia geoscyphus*, *Cephalozia bicuspidata* [YUS-MH-05479]. **I** (1): dwarf shrub-cottongrass-*Sphagnum* bog at the base of a

- slope on the top of a hill, on clay patches, scattered among *Blepharostoma brevirete*, *Cephalozia bicuspidata*, *Scapania parviflora*, *Protocliopsis grandiretis*, *Sphenolobus minutus* var. *grandis*, *Sphenolobus minutus*, *Solenostoma sphaerocarpum*, *Pseudotritomaria heterophylla* (70.81434 N, 145.81543 E), 11.VII.2023, Lapshina [YUS-MH-05442; KPABG(H): 126379].
- ***Diplophyllum sibiricum*** Vilnet & Bakalin (per.) – I (1): dwarf shrub-cottongrass-*Sphagnum* bog at the base of a slope on the top of a hill, on clay patches, a rare admixture among *Blepharostoma brevirete*, *Cephalozia bicuspidata*, *Scapania parviflora*, *Protocliopsis grandiretis*, *Sphenolobus minutus* var. *grandis*, *Sphenolobus minutus*, *Solenostoma sphaerocarpum*, *Pseudotritomaria heterophylla* (70.81434 N, 145.81543 E), 11.VII.2023, Lapshina [YUS-MH-05442; KPABG(H): 126379]. II (1): dwarf shrub (*Ledum decumbens*, *Betula nana* subsp. *exilis*)-cottongrass-*Sphagnum* (*S. lenense*) boggy tundra, on clay patches, a minor admixture among *Cephalozia bicuspidata*, *Fuscocephaloziopsis pleniceps*, *Lophozia murmanica*, *Solenostoma sphaerocarpum* (70.79839 N, 146.45679 E), 15.VII.2023, Lapshina [YUS-MH-05745; KPABG(H): 126397].
- Fuscocephaloziopsis pleniceps*** (Austin) Vána & L.Söderstr. [*Cephalozia pleniceps* (Austin) Lindb.] – II-III (1): tussock dwarf shrub-cottongrass-green moss tundra, on clay patches, minor admixture among *Pseudotritomaria heterophylla*, *Blepharostoma brevirete*, *Anthelia juratzkana*, *Sphenolobus minutus* (70.82639 N, 147.17346 E), 17.VII.2023, Lapshina [YUS-MH-05835; KPABG(H): 126397]. II (1): dwarf shrub-cottongrass-*Sphagnum* (*S. lenense*) wet tundra, on clay patches in a mix with *Cephalozia bicuspidata*, *Lophozia murmanica*, *Scapania parviflora* (70.79839 N, 146.45679 E), 15.VII.2023, Lapshina. [KPABG(H): 126435]
- Gymnocolea inflata*** (Huds.) Dumort. (per.) – I (1): waterlogged thermokarst depression on frozen peat mound (palsa) in flat palsa bog (4), mixed with *Scapania paludicola* (70.87348 N, 145.90805 E), 12.VII.2023, Lapshina [YUS-MH-05521; KPABG(H): 126388].
- Isopaches bicrenatus*** (Schmidel ex Hoffm.) H. Buch – I (1): sandy-fine-grained outcrop (13) on bare ground, minor admixture among *Anthelia juratzkana*, *Cephalozia bicuspidata*, *Lophozia murmanica*, *Scapania obovata*, *S. parviflora* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05484; KPABG(H): 126383].
- ***Lophozia fuscovirens*** Bakalin & Vilnet (gem.) – I (1): sandy-fine-grained outcrop (13), on bare ground, noticeable admixture among *Sphenolobus minutus*, *Trilophozia quinquedentata*, *Anthelia juratzkana*, *Cephaloziella varians*, *Sanionia uncinata* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05486; KPABG(H): 126384].
- L. longiflora*** (Nees) Schiffn. (*sensu* Schljakov) [*Lophozia ventricosa* subsp. *longiflora* (Nees) Macoun] (per.) – II (1): dwarf shrub (*Ledum palustre* subsp. *decumbens*)-cottongrass-*Sphagnum* (*S. lenense*) bog (3b), mixed with *Dicranum elongatum*, *D. laevidens*, *Blepharostoma brevirete*, *Neoorthocaulis binsteadii* (70.77608 N, 146.73721 E), 16.VII.2023, Lapshina [YUS-MH-05769].
- L. murmanica*** Kaal. [*Lophozia wenzelii* subsp. *groenlandica* (Nees) Bakalin] (gem., per., spor.) – I, II, III Cm (20): zonal dwarf shrub-sedge-lichen-green moss (1a, b), wet tussock cottongrass-lichen-moss tundras (2a, b) and cottongrass-*Sphagnum* (*S. lenense*) bogs (3a, b), dwarf birch (*Betula nana* subsp. *exilis*)-green moss (*Dicranum* spp.) covered palsa in flat palsa bogs (4), and on bare clay spots; sandy-fine-grained outcrop (13), mixed with other bryophytes [YUS-MH-05972; KPABG(H): 126423].
- **L. silvicola*** H. Buch (gem., per.) – I, II, III Fr (13): drained dwarf birch (*Betula nana* subsp. *exilis*)-green moss (*Dicranum* spp.)-lichen palsa in flat palsa bogs (4), in pure mats or mixed with other mosses and liverworts: *Plagiothecium svalbardense*, *Pohlia nutans*, *Ptilidium ciliare*, *Sphenolobus minutus* [YUS-MH-05771; KPABG(H): 126399].
- L. ventricosa*** (Dicks.) Dumort. var. *ventricosa* (Dicks.) Dumort. (per., gem.) – II (1): sedge (*Carex aquatilis* subsp. *stans*)-cottongrass (*Eriophorum russeolum*)-*Sphagnum* (*S. balticum*) hollow in palsa-hollow mesooligotrophic bog complex (7), mixed with *Calypogeia muelleriana*, *Tritomaria exsectiformis*, *Trilophozia quinquedentata* (70.77249 N, 146.74301 E), 16.VII.2023, Lapshina [YUS-MH-05807; KPABG(H): 126408].
- L. wenzelii*** (Nees) Steph. (gem., per., spor.) – II Sp (5): zonal dwarf shrub-sedge-lichen-green moss tundras (1a), willow-moss community at the drained edge of rim-polygon mire (6b), sedge (*Carex aquatilis* subsp. *stans*)-cottongrass (*Eriophorum russeolum*)-*Sphagnum* hollow (7) in palsa-hollow bog complex [YUS-MH-05808; KPABG(H): 126406]. Usually mixed with other bryophytes, rare in pure mats.
- Lophoziopsis excisa*** (Dicks.) Konstant. & Vilnet (ant., per.) – I (1): flat palsa-hollow bog complex (7), on old reindeer droppings among *Sphagnum* mosses, with *Pohlia nutans* and *Tetraplodon mnioides* (70.81647 N, 145.83517 E), 11.VII.2023, Lapshina [YUS-MH-05438].
- L. longidens*** (Lindb.) Konstant. & Vilnet [*Lophozia longidens* (Lindb.) Macoun] mod. *alboviridis* (gem.) – II (1): dwarf birch (*Betula nana* subsp. *exilis*)-lichen-*Dicranum* palsa in the palsa-hollow bog complex (4), mixed with *Sphenolobus minutus* (70.77255 N, 146.73479 E), 16.VII.2023, Lapshina [YUS-MH-05798; KPABG(H): 126404].
- L. polaris*** (R.M. Schust.) Konstant. & Vilnet – II, II-III Sp (4): hummocky cottongrass-green moss tundras (2a), dwarf shrub-*Polytrichum* frozen mounds (palsa) in flat palsa-bog (4); drained willow-*Sphagnum* areas in rim-polygon mire complex (6a) [YUS-MH-05740; KPABG(H): 126412], single shoots among other bryophytes.
- Marchantia polymorpha*** subsp. *montivagans* Bischl. & Boissel.-Dub. (gem.) – III (1): willow thickets on steep slopes to the river (14), on moist clay soil among mosses *Bryum* sp., *Ceratodon purpureus*, *Dicranella obtusifolia*, *Leptobryum pyriforme*, *Pohlia atropurpurea*, *Pottia heimii* var. *obtusifolia* (70.76530N, 147.22272E), 19.VII.2023, Lapshina [YUS-MH-05995].
- M. polymorpha*** subsp. *ruderalis* Bischl. & Boissel.-Dub. (gyn.) – II (3): periodically flooded sedge-reed grass meadow along the lakeshore (15), sedge (*Carex aquatilis* subsp. *stans*, *C. chondorrhiza*)-hypnum (*Scorpidium* spp., *Meesia*) community in rim-polygon mire (9) and herb-sedge-hypnum floodplain mire (10), in pure mats and mixed with *Cinclidium stygium*, *Bryum neodamense*, *B. pseudotriquetrum*, *Meesia triquetra* [YUS-MH-05651].
- ***Marsupella sprucei*** (Limpr.) Bernet (per., and.) – I (2): dwarf shrub-cottongrass-*Sphagnum* bog (3b), on clay patches, single admixture among other liverworts *Blepharostoma brevirete*, *Cephalozia bicuspidata*, *Sphenolobus minutus*, *Scapania parviflora*, *Protocliopsis grandiretis*, *Solenostoma hyalinum*, *S. sphaerocarpum*, *Pseudotritomaria heterophylla* (70.81434 N, 145.81543 E), 11.VII.2023, Lapshina

- [YUS-MH-05444; KPABG(H): 126380]; sandy-fine-grained outcrop (**13a**), on bare ground, minor admixture among *Anthelia juratzkana*, *Cephalozia bicuspidata*, *Cephaloziella varians*, *Cryptocolea imbricata*, *Nardia geoscyphus*, *Scapania obcordata*, *Solenostoma sphaerocarpum* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05479].
- Mesoptychia** cf. **collaris** (Nees) L. Söderstr. & Vána [*Leiocolea collaris* (Nees) Schljakov] – **II-I** (1): tussock dwarf shrub-cottongrass-green moss tundra (**2b**), on clay patches, minor admixture among other liverworts *Protochilopsis grandiretis*, *Fuscocephaloziopsis pleniceps*, *Sphenolobus minutus*, *Pseudotritomaria heterophylla* (70.82636 N, 147.17443 E), 17.VII.2023, Filippov [YUS-MH-05863; KPABG(H): 126435].
- M. gillmanii** (Austin) L. Söderstr. & Vána [*Lophozia gillmanii* (Austin) R.M.Schust., *Leiocolea gillmanii* (Austin) A.Evans] – **II** (1): willow-sedge-hypnum ridge community in rim-polygon mire complex (**9**), scattered among *Philonotis tomentella*, *Cinclidium latifolium*, *Campylium stellatum* (70.79646N, 146.54707E). 14.07.2023, Lapshina [YUS-MH-05672; KPABG(H): 126394].
- M. heterocolpos** (Thed. ex Hartm.) L. Söderstr. & Vána [*Leiocolea heterocolpos* (Thed. ex C. Hartm.) H. Buch] (gem.) – **III** (1): polygon tussock sedge-moss community (**10**) in a flat depression between hills, mixed with *Blepharostoma brevirete*, *Cinclidium subrotundum*, *Drepanocladus polygamus*, *Fissidens osmundoides*, *Scapania irrigua* (70.79604 N, 147.84700 E), 21.VII.2023, Lapshina [YUS-MH-06131; KPABG(H): 126429].
- M. rutheana** (Limpr.) L. Söderstr. & Vána [*Leiocolea rutheana* (Limpr.) Müll.Frib.] (per.) – **I, II, III** Cm (23): waterlogged sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum (*Scorpidium revolvens*, *Cinclidium subrotundum*, *Meesia triquetra*) and sedge-*Sphagnum* (*S. orientale*)-hypnum polygons (**8, 9**), and periodically flooded mires (**12**), occasionally low willow-sedge-moss rims (**6a**) on rim-polygon mires, among hypnum mosses or in pure mats [YUS-MH-05587; KPABG(H) 126422].
- M. sahlbergii** (Lindb. & Arnell) A. Evans – **II** (2): periodically flooded herbaceous-sedge (*Carex aquatilis* subsp. *stans*)-reed grass-hypnum floodplain mire (**12**), mixed with *Brachythecium* spp., *Campylium stellatum*, *Meesia triquetra*, *Bryum pseudotriquetrum*, *Warnstorfia pseudostraminea* (70.79958 N, 146.55977 E), 14.VII.2023, Lapshina [YUS-MH-05628; KPABG(H): 126422]; *ibidem*, sedge-hypnum mire, in pure mats or mixed with *Bryum pseudotriquetrum*, *Marchantia polymorpha* subsp. *ruderalis*, *Meesia triquetra*, *Campylium stellatum* (70.79417 N, 146.56979 E), 14.VII.2023, Filippov [YUS-MH-05701].
- Nardia geoscyphus** (De Not.) Lindb. (per. spor.) – **I** (1): Sandy-gravelly hills outcrops (**13**), on bare ground, minor admixture among *Anthelia juratzkana*, *Cephalozia bicuspidata*, *Cephaloziella varians*, *Cryptocolea imbricata*, *Marsupella sprucei*, *Scapania obcordata*, *Solenostoma sphaerocarpum* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05479]. **II-III** (1): tussock dwarf shrub-cottongrass-green moss tundra (**3b**), on clay patches (70.82639 N, 147.17346 E), 17.VII.2023, Lapshina [YUS-MH-05836; KPABG(H): 126416].
- Neoorchocaulis binsteadii** (Kaal.) L. Söderstr., De Roo & Hedd. [*Orthocaulis binsteadii* (Kaal.) H.Buch] (gem., per.) – **I, II, III** Cm (36): tussock cottongrass-green moss, dwarf shrub-cottongrass-lichen-moss tundras (**2a**) and cottongrass-*Sphagnum* (*S. lenense*) bogs (**3a**); frozen dwarf birch-green moss (*Dicranum* spp.) peat palsa in palsa-hollow bog complexes (**4**), in pure mats or mixed with other bryophytes [YUS-MH-05511; KPABG(H) 126407].
- ****Odontoschisma fluitans** (Nees) L. Söderstr. & Vána [*Cladopodiella fluitans* (Nees) H. Buch] – **I** (1): sedge (*Carex aquatilis* subsp. *stans*)-*Sphagnum* polygon community in rim-polygon mire (**8**), minor admixture among *Sphagnum obtusum*, *S. orientale* (70.81647 N, 145.83517 E), 11.VII.2023, Lapshina [YUS-MH-05433].
- O. macounii** (Austin) Underw. – **III** (1): willow-sedge (*Carex aquatilis* subsp. *stans*)-*Sphagnum* (*S. squarrosum*) rim in rim-polygon mire (**6a**), mixed with *Blepharostoma brevirete*, *Fissidens osmundoides*, *Scapania paludicola* (70.82755 N, 147.19233 E), 7.VII.2023, Lapshina [YUS-MH-05866].
- ****Neoorchocaulis attenuatus** (Mart.) L. Söderstr., De Roo & Hedd. [*Orthocaulis attenuatus* (Mart.) A.Evans] (gem.) – **II** (1): willow-herbaceous-green moss tundra (**6b**) at the edge of rim-polygon mire, mixed with *Lophozia silvicola* (70.81230 N, 146.64589 E), 08.VII.2023, Lapshina [YUS-MH-05262; KPABG(H): 126371].
- Plagiochila arctica** Bryhn & Kaal. – **I, I-II, III** Sp (5): periodically flooded sedge tussock-hypnum low-centred polygons rim-polygon mires (**10**), on the side of sedge tussocks, mixed with other bryophytes [YUS-MH-05335; KPABG(H): 126374]; recorded once in flat palsa-hollow bog complex on frozen peat mound (palsa) (**4**), in frost-breaking cracks on bare peat.
- P. porelloides** (Torr. ex Nees) Lindenb. – **II-III, III** (3): sedge-reed grass community on low lake terrace, reed grass meadow in the river floodplain (**15**) [YUS-MH-06007; KPABG(H): 126443], periodically flooded tussock sedge-moss polygon in rim-polygon mire complex (**10**), always mixed with bryophytes *Bryum pseudotriquetrum*, *Chiloscyphus polyanthos*, *Drepanocladus polygamus*, *Warnstorfia pseudostraminea*, *Pseudobryum cibliclioides*.
- Protochilopsis grandiretis** (Lindb. ex Kaal.) A.V. Troitsky, Bakalin & Fedosov [*Schistochilopsis grandiretis* (Lindb. ex Kaal.) Konstant.] – **II-III** (1): tussock dwarf shrub-cottongrass-green moss tundra (**2b**), on clayey patches, some shoots with *Fuscocephaloziopsis pleniceps*, *Pseudotritomaria heterophylla*, *Sphenolobus minutus* (70.82636 N, 147.17443 E), 17.VII.2023, Filippov [YUS-MH-05863]; **III** (1): dwarf shrub-cottongrass-*Sphagnum* bog (**3b**), on clayey patches, some shoots with *Diplophyllum sibiricum*, *Pseudotritomaria heterophylla*, *Marsupella sprucei*, *Solenostoma sphaerocarpum* (70.81434 N, 145.81543 E), 11.VII.2023, Lapshina [YUS-MH-05442; KPABG(H): 126435].
- Pseudotritomaria heterophylla** (R.M. Schust.) Konstant. & Vilnet [*Tritomaria heterophylla* R.M. Schust.] (gem., per.) – **I, II-III** Sp (5): zonal dwarf shrub-sedge-lichen-green-moss (**1b**) and tussock dwarf shrub-cottongrass-green moss tundras (**2b**), dwarf shrub-cottongrass-*Sphagnum* (*S. lenense*, *S. balticum*) bogs (**3b**), on clay patches, in pure mats and mixed with *Anthelia juratzkana*, *Blepharostoma brevirete*, *Fuscocephaloziopsis pleniceps*, *Sphenolobus minutus*, *Protochilopsis grandiretis* [YUS-MH-05458; KPABG(H): 126435].
- Ptilidium ciliare** (L.) Hampe – **I, II, III** Cm (25): zonal and tussock dwarf shrub-cottongrass-green moss and cottongrass-moss-lichen tundras (**1a, 2a**), cottongrass-*Sphagnum* (*S. len-*

- ense) bogs (3a), and dwarf birch-lichen-green moss (*Dicranum*) frozen peat mound (palsa) in flat palsa-hollow bogs (4) [YUS-MH-05505; KPABG(H): 126385].
- Riccardia latifrons*** (Lindb.) Lindb. – I, III Fr 7): tussock dwarf shrub-cottongrass-green moss tundras (2b), sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum (*Scorpidium* spp., *Meesia triquetra*) polygons in rim-polygon mire complexes (9), periodically flooded tussock sedge-hypnum mire communities (10), on the slopes of sedge tussocks, mixed with other liverworts and mosses [YUS-MH-06137; KPABG(H): 126430].
- ***Riccia sorocarpa*** Bisch. (spor.) – I (1): regularly flooded riverbank (14), on bare clay soil (70.81178 N, 146.64964 E), 08.VII.2023, Lapshina [YUS-MH-05302; KPABG(H): 126736].
- ***Rudolgaea borealis*** (Frisvoll & Moen) Potemkin & Vilnet [*Gymnocolea borealis* (Frisvoll et Moen) R.M.Schust.] – I, I-II, II Fr (7): waterlogged sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum polygons in rim-polygon mire complexes (9), single shoots among *Scorpidium revolvens*, *S. scorpioides*, *Meesia triquetra*, *Bryum neodamense*, *Cinclidium subrotundum*, *Drepanocladus brevifolius*, *Loeskygnum badium*, and liverworts *Cephaloziella* spp., *Scapania paludicola* [YUS-MH-05964; KPABG(H): 126410]. The species was collected in three mire massifs far apart from each other (Sofronova et al., 2024).
- ***R. fascinifera*** (Potemkin) Potemkin & Vilnet (*Gymnocolea fascinifera* Potemkin) – I (2): small waterlogged depression among sedge (*Carex aquatilis* subsp. *stans*)-*Sphagnum* (*S. obtusum*) hollow in the rim-polygon mire complex (8), with admixture of *Scapania paludicola*, *Sphagnum orientale*, *Cinclidium subrotundum*, *Cephaloziella uncinata* (70.90298 N, 145.53897 E), 10.VII.2023, Lapshina [YUS-MH-05328, 05329; KPABG(H): 126373]; *ibidem*, willow (*Salix saxatilis*)-sedge-*Sphagnum* (*S. obtusum*) mire, subdominant in the ground cover (70.88191 N, 145.56611 E), 09.VII.2023, Filippov [YUS-MH-05328].
- Scapania curta*** (Mart.) Dumort. – I (1): sandy-fine-grained outcrop (13), on bare ground, some shoots among *Cephalozia bicuspidata*, *Cephaloziella varians*, *Lophozia murmanica*, *Scapania obcordata*, *Trilophozia quinqueidentata* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05482].
- S. degenii*** Schiffn. ex Müll. Frib. (gem.) – III (2): willow-sedge (*Carex aquatilis* subsp. *stans*)-*Sphagnum* (*S. squarrosum*) community on rim-polygon mire (6b), dominates in mats with admixture of *Aneura pinguis*, *Aulacomnium palustre*, *Plagiothecium berggrenianum*, *Sanionia uncinata*, *Sphagnum obtusum* (70.80574 N, 147.84622 E), 21.VII.2023, Lapshina [YUS-MH-06106; KPABG(H): 126427]. willow-sedge-moss margin of small lake (9), mixed with *Scapania paludicola* and *Schljakovianthus quadrilobus* (70.85951 N, 147.44875 E), 18.VII.2023, Filippov [YUS-MH-05940; KPABG(H): 126440].
- S. irrigua*** (Nees) Nees (gem.) – Sp II, III (5): deep low-centred polygons in sedge-polygon mires (II), regularly flooded sedge-reed grass meadows in river floodplains and along the lake shores (14, 15) [YUS-MH-06005; KPABG(H): 126429].
- S. irrigua*** subsp. *rufescens* (Loeske) R.M. Schust. – III (1): willow-sedge (*Carex aquatilis* subsp. *stans*, *C. chordorrhiza*)-hypnum-*Sphagnum* (*S. orientale*)-hypnum community (8) in the rim-polygon-pool mire complex, minor admixture to other bryophytes: *Drepanocladus brevifolius*, *Meesia triquetra*, *Sphagnum orientale*, *Scorpidium revolvens*, *Aneura pinguis*, *Mesoptychia rutheana*, *Scapania paludicola* (70.84599 N, 147.46989 E), 18.VII.2023, Lapshina [YUS-MH-05934; KPABG(H): 126421].
- **S. kaurinii*** Ryan (per.) – I (1): high-centered palsa bog complex at the base of the moraine ridge on Yelon' mountain, frozen peat mound (4), on bare peat, mixed with *Scapania irrigua*, *S. paludicola*, *Cephaloziella varians*, *Bryum neodamense* [YUS-MH-05430; KPABG(H): 126378].
- S. obcordata*** (Berggr.) S.W. Arnell – I (1): sandy-fine-grained outcrop (13), on bare ground, mixed with *Anthelia juratzkana*, *Cephalozia bicuspidata*, *Cephaloziella varians*, *Marsupella sprucei*, *Solenostoma sphaerocarpum* (70.86790 N, 145.73860 E), 12.VII.2023, Lapshina [YUS-MH-05484; KPABG(H): 126383].
- S. paludicola*** Loeske & Müll. Frib. (gem.) – I, II, III Cm (38): low-centred polygons and ridges in rim-polygon mires (6, 7, 8), tussock dwarf shrub-green moss tundras (2a) and cottongrass-*Sphagnum* (*S. lenense*, *S. balticum*) bogs (3a), ground-water outcrops on the hill slopes; once found on drained frozen peat mound (palsa) in flat palsa-hollow complex (4) and in flooded reed grass meadow in the river floodplain (15), usually in pure mats or with admixture of other bryophytes [YUS-MH-05421; KPABG(H): 126403].
- S. parvifolia*** Warnst. (gem., per., spor.) – I, II Sp (4): sandy-fine-grained outcrop (13), on bare ground, scattered among *Anthelia juratzkana*, *Cephaloziella varians*, *Scapania obcordata*, *S. curta*, *Trilophozia quinqueidentata*; dwarf shrub-cottongrass-*Sphagnum* (*S. lenense*) bogs, on clay patches (3b), single shoots among *Blepharostoma brevirete*, *Cephalozia bicuspidata*, *Fuscocephalozopsis pleniceps*, *Lophozia murmanica*, *Sphenolobus minutus* [YUS-MH-05747, 05457; KPABG(H): 126383].
- Schistochilopsis incisa*** (Schrad.) Konstant. [*Lophozia incisa* (Schrad.) Dumort.] – II (2): sedge (*Carex aquatilis* subsp. *stans*)-cottongrass (*Eriophorum russeolum*)-*Sphagnum* hollow in a meso-oligotrophic flat palsa-hollow bog complex (7), minor admixture to *Sphagnum balticum* (70.77249 N, 146.74301 E), 16.VII.2023, Lapshina [YUS-MH-05803; KPABG(H): 126405].
- S. opacifolia*** (Culm. ex Meyl.) Konstant. (spor. per.) – III (1): at the edge of sedge (*Carex aquatilis* subsp. *stans*)-cottongrass (*Eriophorum russeolum*)-*Sphagnum* hollow in rim-polygon mire complex (7), minor admixture among *Cephalozia bicuspidata*, *Lophozia wenzelii*, *Neoorthocaulis binsteadii*, *Scapania paludicola*, *Tritomaria exsectiformis* (70.86518 N, 147.43411 E), 18.VII.2023, Lapshina [YUS-MH-05907; KPABG(H): 126418].
- Schljakovia kunzeana*** (Huebener) Konstant. & Vilnet – I, II, III Cm (15): tussock dwarf shrub-cottongrass-green moss tundras (2a) and cottongrass-*Sphagnum* (*S. lenense*, *S. balticum*) bogs (3a), willow-sedge-*Sphagnum* (*S. squarrosum*, *S. fimbriatum*) ridges and drained areas of rim-polygon mires (6a, b), drained dwarf birch-lichens-*Dicranum* peat mounds (palsa) (4), periodically flooded tussock sedge-hypnum moss communities (10), in pure mats or mixed with other bryophytes [YUS-MH-05737; KPABG(H): 126417].
- Schljakovianthus quadrilobus*** (Lindb.) Konstant. & Vilnet – II Fr (7): willow-sedge (*Carex chordorrhiza*, *C. aquatilis* subsp. *stans*)-*Sphagnum* (*S. orientale*)-hypnum and sedge-hypnum polygons (8, 9) in rim-polygon mire complexes, shrub

- (*Salix* spp., *Betula nana* subsp. *exilis*)-moss communities (6), tussock dwarf shrub-cottongrass-green moss tundras (2a) [YUS-MH-05781, 05785; KPABG(H): 126440]
- **Solenostoma hyalinum* (Lydell) Mitt. [*Plectocolea hyalina* (Lydell) Mitt.] (per.) – I (1): dwarf shrub-cottongrass (*Eriophorum vaginatum*)-*Sphagnum* bog, on clay patches (3b), a single shoots with *Marsupella sprucei*, *Protochilopsis grandiretis*, *Solenostoma sphaerocarpum* (70.81434 N, 145.81543 E), 11.VII.2023, Lapshina [YUS-MH-05444; KPABG(H): 126380].
- **S. sphaerocarpum* (Hook.) Steph. (per.) – I, II (3): dwarf shrub (*Betula nana* subsp. *exilis*, *Ledum decumbens*)-cotton-grass-*Sphagnum* bogs, on clay patches (2b), minor admixture to *Cephalozia bicuspidata*, *Lophozia murmanica*, *Marsupella sprucei*, *Scapania parviflora* [YUS-MH-05747; KPABG(H): 126398]; sandy-fine-grained outcrop (13), on bare ground, single shoots among *Anthelia juratzkana*, *Cephalozia bicuspidata*, *Cephaloziella varians*, *Marsupella sprucei*, *Nardia geoscyphus*, *Scapania obcordata*, *Trilophozia quinqueidentata*.
- S. cf. jensenianum* (Grolle) Bakalin – I (1): dwarf shrub-cottongrass-*Sphagnum* (*S. lenense*, *S. balticum*) bog, on clay patches (3b), minor admixture among *Marsupella sprucei*, *Protochilopsis grandiretis*, *Solenostoma sphaerocarpum*, *S. hyalinum* (70.81434 N, 145.81543 E), 11.VII.2023, Lapshina [YUS-MH-05444; KPABG(H):126380].
- Sphenolobus minutus* (Schreb.) Berggr. (per.) – I, II, III Cm (25): zonal dwarf shrub-sedge-lichens-green moss (1a, b), and tussock dwarf shrub-cottongrass-green moss tundras (2a, b) and cottongrass-*Sphagnum* bogs, in the moss cover and on clay patches (3a, b); frozen peat mounds (palsa) in flat palsa bog complexes (4, 5), sandy-gravel outcrops (13) [YUS-MH-05776; KPABG(H): 126414]. In pure mats or mixed with other bryophytes.
- S. minutus* var. *grandis* (Gottsche ex Lindb.) Jørg. (per.) – I (3): dwarf shrub-cottongrass-*Sphagnum* bog, on clay patches (3b), mixed with *Blepharostoma brevirete*, *Cephalozia bicuspidata*, *Pseudotritomaria heterophylla*, *Scapania parviflora*, *Protochilopsis grandiretis*, *Sphenolobus minutus*, *Solenostoma sphaerocarpum* [YUS-MH-05457; KPABG(H): 126382]; sandy-fine-grained outcrop (13), on bare ground, with *Anthelia juratzkana*, *Cephaloziella varians*, *Trilophozia quinqueidentata*.
- Tritomaria exsectiformis* (Breidl.) Loeske (gem.) – II (1): dwarf birch (*Betula nana* subsp. *exilis*)-green moss (*Dicranum* spp.) community on frozen peat mound (palsa) (4), minor admixture among *Dicranum laevidens*, *Lophozia murmanica*, *Blepharostoma brevirete* (70.77658 N, 146.72211 E), 16.VII.2023, Lapshina [YUS-MH-05775]. III (1): at the edge of sedge (*Carex aquatilis* subsp. *stans*)-cotton-grass (*Eriophorum russeolum*)-*Sphagnum* hollow in flat palsa-hollow complex (7), mixed with *Schistochilopsis opacifolia*, *Lophozia wenzelii*, *Scapania paludicola* (70.86518 N, 147.43411 E), 18.VII.2023, Lapshina [YUS-MH-05907; KPABG(H): 126419]
- Trilophozia quinqueidentata* (Huds.) Bakalin [*Tritomaria quinqueidentata* (Huds.) H. Buch] –I, II-III, III Fr (11): tussock dwarf shrub-cottongrass-green moss tundras (2a) and cottongrass-*Sphagnum* (*S. lenense*) bogs (3a, b) [YUS-MH-05907; KPABG(H): 126436], frozen peat mounds (palsa) in flat palsa bog complexes (4), sandy-fine-grained outcrop (13), on bare ground.

DISCUSSION

For today 121 species and 10 varieties of liverworts from 27 families are known for the tundra zone of the Republic of Sakha (Sofronova, 2005). As a result of our study of a relatively restricted area within just 10 days we managed to find 70 species, including 5 species new for the Republic. That is more than half of the liverwort flora of the entire Arctic region of the republic and about a third of the liverwort diversity of Yakutia. It is clear that the above list of liverworts cannot claim to be complete because the main goal of this research was to study the diversity of plant communities of mire complexes, but at the same time, the authors paid a lot of attention to the collection of bryophytes.

The greatest diversity of liverworts was found in tussock cottongrass tundras and cottongrass-*Sphagnum* bog communities (there are 26 species in each type of habitat). This is due to the presence of moist clay spots (Table 1), which occupy tiny areas, no more than 1%, but significantly enrich the species composition of liverworts. Relatively large variety of liverworts has been revealed in rim-polygon mire complexes. This is due to both the largest number of relevés of the communities of these complexes and the wide variety of habitats. Many characteristic species of moderately rich fens like *Scapania paludicola*, *Schljakovianthus quadrilobus*, *Mesoptychia rutheana* are restricted mostly to the waterlogged sedge-hypnum communities of these mire complexes. It is in the latter communities that the rare *Rudolgaea borealis* has been found along with widespread species, recorded for the first time in Yakutia (Sofronova *et al.*, 2024). However, in meso-oligotrophic sedge (*Carex aquatilis* subsp. *stans*)-*Sphagnum* (*S. obtusum*) communities of the rim-polygon mire complexes and hollows of flat palsa bogs, despite the very large number of described relevés (68), only four species were found. Liverworts are quite diverse in willow-*Sphagnum* (*S. squarrosum*) communities (11 species) of drained sites and in sedge-hypnum-*Sphagnum* (*S. orientale*) polygon communities (10 species).

High diversity of liverworts (16 species) (including *Scapania kaurinii* and *Lophozia longidens*, found in this type only) was recorded in drained dome-shaped frozen peat mounds covered by dwarf birch (*Betula nana* subsp. *exilis*)-green moss communities (20 relevés) in flat palsa-hollow bog complexes.

The high number of species (16) were found on the only one examined sandy-gravelly hill outcrop. Of these, four species (Table 1) were found only here.

Relatively few species have been found in zonal low shrub-lichen-moss tundras, which is partly explained by the very small number of relevés (only two). At the same time, one species (*Arnellia fennica*) was found only here.

Despite a significant number of relevés (12) in flood-plain mires periodically flooded by river waters very few (four) species have been found, among which none is specific to these habitats. Only four relevés of floodplains have been made, however, of the three species recorded

here, two (*Blasia pusilla* and *Riccia sorocarpa*) have been found only in such habitats.

Some species, e.g. *Lophozia excisa*, were found in very specific habitats, such as old reindeer droppings. Such species have been assigned to the communities in which these habitats have been described.

The species composition of the flora of the studied region is quite characteristic for the tundra zone. Most of the recorded species are widespread in the arctic liverworts with arctic or arctoboreomontane circumpolar distribution. However, almost half of the revealed species have been collected only once or twice in spite of most of them are widespread arctic or arctic montane (e.g. *Anthelia juratzkana*, *Mesoptychia sahlbergii*, *Nardia geoscyphus*, *Odontoschisma macounii*, *Scapania kaurinii*, *Scapania obcordata*), arctoboreomontane (*Barbilophozia barbata*, *Fuscocephaloziopsis pleniceps*, *Gymnocolea inflata*, *Isopaches bicrenatus*, *Lophozia excisa*, *Lophozia longiflora*, *Mesoptychia heterocolpos*, *Mesoptychia collaris*, *M. gillmanii*, *Rudolgaea fasciniifera*, *Odontoschisma fluitans*, *Scapania curta*, *Scapania degenii*, *Solenostoma hyalinum*), and cosmopolitan (*Blasia pusilla*) species. This is obviously due to the specifics of the study, which focused on mire communities and also because of the short duration of the study. The most common in the studied area are species of rich fens and widespread tundra species listed below in decreasing order of the number of records given in parentheses: *Aneura pinguis* (55), *Scapania paludicola* (38), *Neoorthocaulis binsteadii* (36), *Lophozia murmanica* (25), *Ptilidium ciliare* (25), *Sphenobolus minutus* (25), *Mesoptychia rutheana* (23), *Blepharostoma brevirete* (15), *Schljakovia kunzeana* (15), *Trilophozia quinqueidentata* (11), *Lophozia silvicola* (13). Some negative features of the flora, in particular the absence of such species not rare in the tundra and wetlands as *Barbilophozia hatcheri* (A.Evans) Loeske, *Fuscocephaloziopsis lunulifolia* (Dumort.) Vána & L. Söderstr., *Mylia anomala* (Hook.) Gray, *Odontoschisma elongatum* (Lindb.) A. Evans, *Pellia neesiana* (Gottsche) Limpr., *Scapania hyperborea* Jørg., *Scapania tundrae* (Arnell) H. Buch and others are explained by the limitations of the studied area and the time spent studying it, focused mostly on mire communities. The absence of some arctic-alpine species common in the arctic (*Gymnomitrium* spp., *Marsupella* spp.), as well as calciphiles (*Preiszia quadrata*, *Sauteria alpina*, *Scapania gymnostomophila* Kaal., etc.) and others is well explained by the lowland landscape and underlying rocks.

* * *

The most interesting species are those first found in Yakutia and some rare and poorly known species, which we discuss below.

Liverworts new for Sakha (Yakutia) Republic

Rudolgaea borealis, a species described from Norway (Frisvoll & Moen, 1980) and only recently found in Russia (Potemkin & Vilnet, 2021). Kytalyk National Park is the third area in Russia where the species has been found

(Sofronova *et al.*, 2024). It has previously been recorded on the Gydan and Taimyr Peninsulas, where this stenotopic species has been found in similar habitats (l.c.). Most likely, *Rudolgaea borealis* occurs scattered throughout the northern regions, but has been overlooked due to the fact that it grows scattered among mosses in moderately rich sedge-hypnum mires and never occurs in extensive mats.

Lophozia fuscovirens is recently described little-known liverwort. It is a very small species that was described from Magadan Province and so far is known from several localities in Magadan Province (Bakalin & Vilnet, 2019) and in Svalbard (Ellis *et al.*, 2019; Konstantinova & Savchenko, 2020). This species was collected only once on bare soil scattered among other bryophytes.

Marsupella sprucei is a very small arctic-montane species, occurring scattered on bare ground and often overlooked because of very small size, occurrence often as single shoots on soil or mixed with other bryophytes.

Diplophyllum sibiricum. The species was recently described from the Amur region (Bakalin & Vilnet, 2018) and the authors of the description attributed all Siberian records of *Diplophyllum obtusatum* and *D. obtusifolium* to this species. Both latter species are recorded for Sakha (Yakutia) Republic (Sofronova, 2005) but for more southern areas. Records in Katalyk Nature Park is located much to the north of the previously known, and it significantly changes our understanding of the distribution of the species. We referred two studied specimens to this species based on autoicous inflorescences and green-brownish color of leaves without any trace of red-purple pigmentation. Unfortunately, only a few shoots were found in specimens, so we were unable to sequence them.

Riccia sorocarpa. The species occurs scattered on bare soil and has a quite characteristic appearance with knife-like cut apical part of the thallus with ascending sides and collapsed uppermost cells of assimilation tissue, as well as relatively small thalli, ca. 1–1.2 mm wide, and spores ca. (55) 65–70 µm. This cosmopolitan species is one of the few *Riccia* species found in the Arctic with the northernmost record in Greenland at 77°23'N (Damsholt, 2013).

Rare or poorly known liverwort species

Lophozia longidens (Lindb.) Konstant. & Vilnet. The only collected specimen of the species is characterized by colorless gemmae on brightly brownish-colored leaf lobes. Colorless gemmae are noted for this species, but for young plants or in shade. But according to some other features, the intense brown coloration of narrow leaves with hornlike lobes, the larger size of gemmae, and ecology we refer this specimen to *Lophozia longidens*.

Cryptocolea imbricata is a species occurring rather scattered in tundras (Konstantinova *et al.*, 2023). Several shoots of the species mixed with other liverworts were collected only once, on bare ground on sandy-fine-grained outcrop. In the Republic of Sakha the species has been recorded several times. The species has probably often been overlooked because it is very small and often occurs scattered among bryophytes.

Pseudotritomaria heterophylla is a poorly known arctic liverwort, which probably is not uncommon in suitable conditions in northern Siberia. It is possible, however, that the species has been overlooked, since it is often found as single shoots among other bryophytes on patches of bare ground. The identification of such specimens is very time-consuming and presents great difficulties.

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