



# Liverwort flora of Mt. Ko and adjacent areas (middle Sikhote-Alin, south of the Russian Far East)

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Figures with general views of habitats –  
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Table with collection locality descriptions –  
[http://www.geobotanica.ru/bp/2026\\_15\\_02/BP\\_2026\\_15\\_2\\_klimova\\_e\\_suppl1.xlsx](http://www.geobotanica.ru/bp/2026_15_02/BP_2026_15_2_klimova_e_suppl1.xlsx)

Table with bioclimatic indices for collection points –  
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## ABSTRACT

The Ko Mt. is located in the northern part of the middle Sikhote-Alin and is the second-highest peak of this mountain system. It lies 200 km south of the highest peak – Tardoki-Yani Mt. – and also has experienced ancient glaciations, which are evidenced by well-preserved glacial landforms that have influenced the liverwort flora formation. The first data on liverwort flora for this area are presented: 123 species and one form are recorded; five species (*Biantheridium undulifolium*, *Calyptogeia kamchatica*, *Marsupella sprucei*, *Neoorthocaulis binsteadii*, and *Scapania tundrae*) are new to the Sikhote-Alin. Arctic-montane taxa comprise over 20 % of the flora, including *Lejeunea alaskana* and *Scapania tundrae*, which have their southernmost known localities worldwide here, as well as *Gymnomitrium concinatum*, *G. corallioides*, *Marsupella sprucei*, *Nardia insecta*, and *Neoorthocaulis binsteadii*, which have the southernmost occurrences in the Asian mainland within the studied area. Taken together, the above suggests that Mt. Ko and its surroundings, similarly to the Tardoki-Yani Range, may serve as a refugium for arctic-montane flora in eastern Asia.

**Keywords:** Hepaticae, Marchantiophyta, new records, rare species, distribution patterns, phytogeography, taxonomic diversity, East Asia, Pacific Asia, Khabarovsk Territory, Russia

## РЕЗЮМЕ

**Климова К.Г., Бакалин В.А. Флора печеночников горы Ко и прилегающих территорий (средний Сихотэ-Алинь, юг Дальнего Востока России).** Гора Ко находится в пределах северной части среднего Сихотэ-Алиня и является второй по высоте вершиной этой горной страны. Находясь в 200 км южнее наивысшей точки, горы Тардоки-Яни, гора Ко также являлась центром древнего оледенения на Сихотэ-Алине, о чем свидетельствуют хорошо сохранившиеся формы ледникового рельефа, что в свою очередь наложило отпечаток на характер ее флоры печеночников. Сведения о печеночниках этой территории получены впервые: выявлено 123 вида и одна форма; из них 5 видов (*Biantheridium undulifolium*, *Calyptogeia kamchatica*, *Marsupella sprucei*, *Neoorthocaulis binsteadii* и *Scapania tundrae*) являются новыми для Сихотэ-Алиня. Арктогорные таксоны во флоре печеночников этого района составляют более 20 %, из которых *Lejeunea alaskana* и *Scapania tundrae* имеют здесь самые южные местонахождения в мире, а некоторые виды (*Gymnomitrium concinatum*, *G. corallioides*, *Marsupella sprucei*, *Nardia insecta*, *Neoorthocaulis binsteadii*) – самые южные местонахождения в материковой Азии. Вышеперечисленное дает основание полагать, что гора Ко и ее окрестности, так же как и хребет Тардоки-Яни, могут являться рефугиумом арктогорной флоры востока Азии.

**Ключевые слова:** Hepaticae, Marchantiophyta, новые находки, редкие виды, таксономическое разнообразие, фитогеография, Восточная Азия, Хабаровский край, притихоокеанская Азия, Россия

The interpenetration of East Asian and Circumboreal floras in the Pacific Asian mainland is a vital feature of the Sikhote-Alin Mts., as we discussed previously (Klimova & Bakalin 2025). Mt. Ko (2004 m a.s.l.) is located in the middle part of the Sikhote-Alin (Fig. 1) and is the second-highest peak in this mountain system. It is only 86 meters lower than the highest point of these mountains – Mt. Tardoki-Yani (2090 m a.s.l.). Its considerable elevation range and proximity to deep river valleys provide a distinct altitudinal zonation – from hemiboreal foothill communities to mountain tundra near the summits. Pronounced altitudinal gradients over short distances are few in the Sikhote-Alin. Only two have been studied, both incompletely: one in the

north – the Tardoki-Yani Range (Bakalin 2015) and one in the south – Mt. Oblachnaya in Zov Tigra National Park (Klimova et al. 2024).

Like Mt. Tardoki-Yani, Mt. Ko is located on the western macroslope, lies away from the main watershed ridge, and shows clear traces of Quaternary glaciations (Varfolomeeva 1957, Gotvansky & Makhinov 1983). This may also be reflected in the enrichment of the Mt. Ko flora with relics of cold epochs. Thus, Mt. Ko may serve as an outpost for northern species in the Pacific Asia mainland.

We have previously discussed the conventional subdivision of the Sikhote-Alin into southern, middle, and northern parts, as accepted in Far Eastern botanical literature

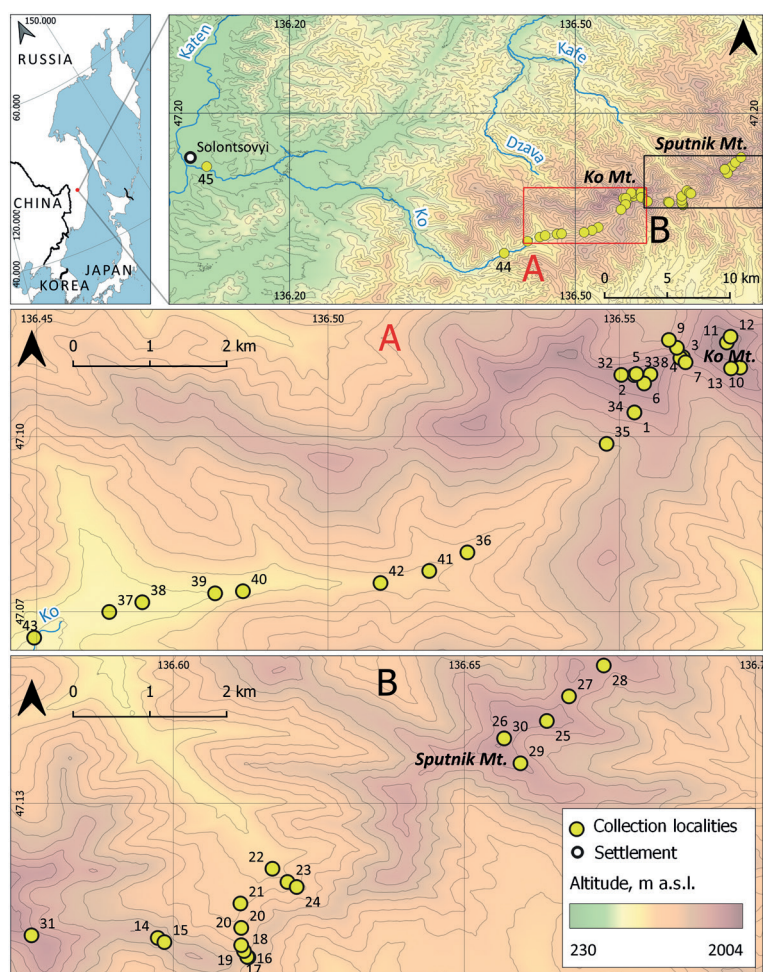


**Figure 1** The map of study area with indicated collecting localities of liverworts

(Klimova & Bakalin 2025). According to this division, most authors assign Mt. Ko to the middle Sikhote-Alin (Sochava 1946, Vasilyev & Kurentsova 1960, Kolesnikov 1969, Vyshin 1990, Krestov 2000, etc.). Therefore, the present work provides a substantial update to the “Liverworts of the middle Sikhote-Alin (south of the Russian Far East)” (Klimova & Bakalin 2025). In a broader sense, it also aims to contribute to a phytogeographic problem – determining the position of the boundary between the Circumpolar and East Asian floristic regions within the Sikhote-Alin.

The goal of the present account is to present the first data on the liverwort flora of the second highest peak of the Sikhote-Alin (Mt. Ko) and its adjacent territories, and to assess the position of the studied flora within the system of local floras of the Sikhote-Alin.

## MATERIAL AND METHODS

### Study area

#### Relief and geology

Mountain Ko, together with Mt. Sputnik (1806 m a.s.l.) and Mt. Ostraya (1789 m a.s.l.), forms a separate mountain massif in the middle part of the Sikhote-Alin (47°N), about 160 km west of the Sea of Japan coast (Figs 1, S1–S4 [here and after, index 'S' before figure number refers the figures in electronic supplement]). It extends from southwest to northeast for approximately 20 km and is separated from

the surrounding ridges and peaks by the well-developed valleys of the Katen, Kafe, and Chuken rivers. All of them belong to the Khor River basin, which flows further into the Amur River. Like the Tardoki-Yani Range, this mountain massif has pronounced evidence of extensive Quaternary glaciation. This is manifested in well-preserved glacial landforms on its slopes, including corries, arêtes, short troughs, moraine deposits, and glacial lakes (Figs S1:E,F,H; S3:G). Glacial forms are most abundant on Mt. Ko, considerably fewer are present on Mt. Sputnik, and only one half-ruined corrie has been recorded on Mt. Ostraya (Ganeshin 1959, Vasilyev & Kurentsova 1960, Gotvansky & Makhinov 1983).

At least two glacial events are recorded in the study area. Moraine characteristics indicate an older and more extensive glaciation that preceded the last glaciation. The older glaciation created the rugged topography that favored snow accumulation during the last glaciation. In addition to shaping the glacial relief in the valleys and their upper reaches, the glaciers promoted the development of periglacial landforms and distinctive denudation processes in the upper mountain belt on flat watersheds, summits, and steep slopes (Gotvansky & Makhinov 1983). This was likely a key factor in the formation and modern composition of the liverwort flora of the Ko–Sputnik–Ostraya massif.

Most of the western macroslope of the massif is composed of Late Cretaceous dacites (including Mt. Sputnik). The exceptions are Mt. Ko itself and the uppermost reaches of the Ko River, where the rocks are Late Cretaceous granites and granitoids. The mouth of the Ko River is composed of Early–Middle Jurassic deposits: siltstones, sandstone interlayers, cherty siltstones, basalts, and their tuffs (Rybalko et al. 2011).

#### Climate

As in the entire Sikhote-Alin, the climate of the study area has monsoonal characteristics. According to the Köppen–Geiger climate classification (Beck et al. 2023, GloH2O 2024), the dominant type on the Ko–Sputnik–Ostraya massif is the monsoon-influenced subarctic climate (Dwc). Climatic characteristics depend strongly on local relief and slope exposure; therefore, the Dwc climate affects the axial part of the massif, the northwestern macroslope up to 1800 m a.s.l. on Mt. Ko, up to 800 m a.s.l. in the upper reaches of the Kafe River, and up to 1600 m a.s.l. on Mt. Sputnik. On the southeastern macroslope, the Dwc climate affects the upper reaches of the Ko River up to 650 m a.s.l. and the upper reaches of the left tributaries of the Katen River up to 900–1100 m a.s.l. Below these elevations are areas influenced by the subarctic climate (Dfc). On the southeastern macroslope, at 700 m a.s.l., it is replaced by the warm-summer humid continental climate (Dfb). Small sections of the Ko River valley within the elevation range of 500–700 m a.s.l. fall under the monsoon-influenced

warm-summer humid continental climate (Dwb). The Ko River valley, at elevations below 400 m a.s.l., is influenced by a Dfb climate. Almost all specimen collection sites were located within the Dwc climate, with a few exceptions.

For a brief climatic characterization of the study area, we used several bioclimatic indices important for the altitudinal distribution of liverworts (Klimova et al. 2024). The values of these indices were obtained (Fick & Hijmans 2017, Worldclim 2020–2026) for several collection localities from the lowest to the highest point of the elevational profile. The localities are subdivided into three areas, corresponding to Table 1: the Ko River valley and Mountain Mt. Ko, the watershed between Ko and Sputnik mountains, and Mt. Sputnik.

### Vegetation

Altitudinal vegetation zonation is well pronounced in the study area. However, the altitudinal limits and the extent of vegetation belts depend strongly on slope exposure, topography, winter winds, and associated snow redistribution, as we previously noted for other areas of the middle Sikhote-Alin (Klimova & Bakalin 2025). Vasilyev & Kurentsova (1960) also noted that on Mt. Ko the lower altitudinal limits of vegetation belts on north-facing slopes are, on average, 100 m lower than on south-facing slopes.

The distinct mountain-tundra vegetation belt (= alpine belt) on Mt. Ko is a complex mosaic of tundra and scattered dwarf modifications of subalpine shrub communities (Rozenberg & Vasilyev 1967, Schlotgauer 2011), and rock fields. It occupies all plateau-like summits, adjacent spurs, and upper slopes (Vasilyev & Kurentsova 1960) (Figs S1:G; S2:G,H; S3:D,F). Published estimates of its elevational boundaries vary. According to Vasilyev & Kurentsova (1960), the belt occurs at elevations above 1800 m a.s.l., whereas according to Schlotgauer (2011) it lies within the range of 1700–2000 m a.s.l. These discrepancies arise because subalpine shrubs (mainly *Pinus pumila* (Pall.) Regel) occur from 1300 m a.s.l. upward (Schlotgauer 2011),

forming thickets of varying height and density throughout the elevational profile. The transition to mountain tundra is often diffuse and forms a complex mosaic, allowing for different interpretations of the boundaries between belts. Moreover, our observations on mountains Ko and Sputnik show that tundra fragments occur well below these elevations – as isolated ‘tongues’ and patches penetrating the subalpine shrub belt down to below 1600 m a.s.l., depending on the topography and slope exposure. Similar observations have been reported for this part of the Sikhote-Alin (Rozenberg & Vasilyev 1967: 144) and for the western Okhotsk region (Schlotgauer 1978: 34).

According to Vasilyev & Kurentsova (1960) and our observations, the most common tundra type is dwarf shrub–forb–lichen tundra. It occurs above 1800 m a.s.l. on all plateau-like watersheds. Vasilyev & Kurentsova (1960) reported that fruticose lichens (*Cladonia* Hill ex P. Browne, *Cetraria* Ach.) cover at least 60 % of these tundras. The dwarf shrub layer includes *Salix phlebophylla* Andersson, *Arctous alpina* (L.) Nied., *Vaccinium vitis-idaea* L. s.l., *Ledum decumbens* (Aiton) Lodd. ex Steud., *Vaccinium uliginosum* L., *Rhododendron redowskianum* Maxim., *Diapensia obovata* (F. Schmidt) Nakai, and *Dryas ajanensis* Juz. (Vasilyev & Kurentsova 1960, Rozenberg & Vasilyev 1967) (Figs S1:G; S2:H; S3:D,E,F; S4:A,C). The dominant vegetation component varies with topography and slope aspect. For example, at about 1750 m a.s.l. on a south-west facing slope, we observed tundras with clear forb dominance and only minor contributions of dwarf shrubs and lichens (Fig. S1:C,D). As we observed, within the 1700–1900 m a.s.l. range, bed-rock outcrops and rock fields support communities with *Bergenia pacifica* Kom. and scattered dwarf clumps of *Rhododendron aureum* Georgi and *Pinus pumila*. In this vegetation belt, the most interesting findings of liverworts for the Sikhote-Alin were made on rocks and rocky outcrops covered with lichen-moss-dwarf shrub tundra patches,

**Table 1.** Bioclimatic data from selected collecting localities in the study area (locality numbers correspond to Figure 1).

| Loca-<br>lity                                                   | Coordinates, |               | Elevation,<br>m a.s.l. | Bioclimatic index |      |       |       |       |       |       |       | Climate* |
|-----------------------------------------------------------------|--------------|---------------|------------------------|-------------------|------|-------|-------|-------|-------|-------|-------|----------|
|                                                                 | latitude (N) | longitude (E) |                        | BIO1              | BIO5 | BIO8  | BIO10 | BIO12 | BIO13 | BIO16 | BIO18 |          |
| Ko River valley, Mt. Ko                                         |              |               |                        |                   |      |       |       |       |       |       |       |          |
| 45                                                              | 47°08'38.6"  | 136°06'45.9"  | 268                    | -0.24             | 26.6 | 16.25 | 17.98 | 849   | 165   | 422   | 408   | Dfb      |
| 44                                                              | 47°05'55.6"  | 136°32'52.2"  | 626                    | -2.05             | 24.3 | 14.05 | 15.68 | 933   | 178   | 462   | 449   | Dwb      |
| 40                                                              | 47°04'24.6"  | 136°29'07.5"  | 818                    | -3.56             | 22.6 | 12.53 | 14.13 | 979   | 186   | 485   | 478   | Dwc      |
| 37                                                              | 47°04'11.8"  | 136°27'44.9"  | 730                    | -2.62             | 23.7 | 13.57 | 15.17 | 952   | 181   | 469   | 458   | Dwc      |
| 36                                                              | 47°04'48.6"  | 136°31'26.2"  | 1024                   | -4.03             | 22.3 | 12.17 | 13.75 | 1003  | 190   | 494   | 484   | Dwc      |
| 35                                                              | 47°05'55.5"  | 136°32'52.2"  | 1427                   | -5.03             | 21.1 | 11.08 | 12.65 | 1075  | 200   | 517   | 513   | Dwc      |
| 34                                                              | 47°06'14.9"  | 136°33'09.4"  | 1673                   | -6.03             | 19.7 | 11.38 | 11.38 | 1117  | 206   | 536   | 536   | Dwc      |
| 33                                                              | 47°06'38.7"  | 136°33'10.6"  | 1885                   | -6.11             | 19.5 | 11.23 | 11.23 | 1108  | 208   | 542   | 542   | Dwc      |
| 3                                                               | 47°06'49.1"  | 136°33'39.4"  | 1735                   | -6.03             | 19.6 | 11.32 | 11.32 | 1105  | 206   | 538   | 538   | Dwc      |
| 11                                                              | 47°06'58.1"  | 136°34'06.5"  | 2000                   | -6.38             | 19.1 | 10.87 | 10.87 | 1116  | 209   | 546   | 546   | Dwc      |
| Mountain range between Mt. Ko and Mt. Sputnik, Kafe River basin |              |               |                        |                   |      |       |       |       |       |       |       |          |
| 14                                                              | 47°06'24.8"  | 136°35'50.4"  | 1496                   | -4.67             | 21.1 | 11.23 | 12.78 | 1051  | 197   | 509   | 506   | Dwc      |
| 17                                                              | 47°06'13.1"  | 136°36'45.7"  | 1347                   | -4.47             | 21.2 | 11.35 | 12.90 | 1031  | 195   | 505   | 502   | Dwc      |
| 20                                                              | 47°06'31.0"  | 136°36'42.0"  | 1132                   | -3.94             | 21.9 | 12.02 | 13.55 | 1004  | 190   | 494   | 487   | Dwc      |
| 22                                                              | 47°07'07.6"  | 136°37'01.3"  | 969                    | -3.74             | 22.2 | 12.27 | 13.82 | 992   | 188   | 488   | 481   | Dwc      |
| Mt. Sputnik                                                     |              |               |                        |                   |      |       |       |       |       |       |       |          |
| 25                                                              | 47°08'39.0"  | 136°39'51.0"  | 1737                   | -6.07             | 19.5 | 11.28 | 11.28 | 1097  | 205   | 531   | 531   | Dwc      |
| 28                                                              | 47°09'13.3"  | 136°40'26.2"  | 1660                   | -5.90             | 19.7 | 11.40 | 11.40 | 1086  | 205   | 529   | 529   | Dwc      |
| 30                                                              | 47°08'28.2"  | 136°39'24.6"  | 1762–1782              | -5.99             | 19.7 | 11.42 | 11.42 | 1094  | 205   | 530   | 530   | Dwc      |

\* – climate abbreviation corresponding to the Köppen–Geiger climate maps (Beck et al. 2023): Dfb – Warm-summer humid continental climate, Dwb – Monsoon-influenced warm-summer humid continental climate, Dwc – monsoon-influenced subarctic climate; the transcript of bioclimatic indices abbreviations are: BIO1 = Annual Mean Temperature, BIO8 = Mean Temperature of Wettest Quarter, BIO10 = Mean Temperature of Warmest Quarter, BIO12 = Annual Precipitation, BIO16 = Precipitation of Wettest Quarter, BIO18 = Precipitation of Warmest Quarter

in places at the edge of the contact zone between tundra vegetation and the rocky substratum (Fig. S2:B,C). For example, the NW-facing rocks (Fig. S2:B) are the habitat for *Fuscocephaloziaopsis pleniceps*, *Frullania subarctica*, *Herbertus arcticus*, *Lejeunea alaskana*, etc.; on rocky outcrops covered by lichen–moss–dwarf shrub tundra (Fig. S2:C) we found *Anthelia juratzkana*, *Gymnomitrium commutatum*, *Lejeunea alaskana*, *Mesoptychia heterocolpos*, *Nardia insecta*, *Scapania lingulata*, *Tetralophozia setiformis*, etc. Bare ground spots of cryogenic origin (Figs S2:A; S3:E; S4:J) also host rare species for the Sikhote-Alin, such as *Anthelia juratzkana*, *Gymnomitrium commutatum*, *Nardia insecta*, *Solenostoma rossicum*, and *Gymnocolea inflata*.

Rozenberg & Vasilyev (1967) noted that open, dry, rocky watersheds and slopes support moss-lichen tundras, whereas rock fields and stony screes host lichen tundras of crustose and foliose lichens. Of greatest interest for taxonomic novelties in the Sikhote-Alin are small patches of swampy dwarf shrub–moss–*Carex* tundra found on the southern spur of Mt. Ko, at the foot of the main peak (Fig. S2:D,E,F). These are dominated by green mosses and *Sphagnum* L., with sedges and few dwarf shrubs. In the large saddle on the northern spur of Mt. Sputnik we found swampy *Carex*–*Sphagnum* tundra with hollows and ponds surrounded by *Pinus pumila* and *Rhododendron aureum* thickets (Fig. S4:C,E,H,I). On very steep, rocky north-east facing slopes near Mt. Sputnik, likely fed by groundwater seepage, we observed patches of moist dwarf shrub–moss tundra (Fig. S3:H). These tundra types are very rare in the Sikhote-Alin south of 47°N (the latitude of Mt. Ko). This community type, associated with high elevations, supports several liverwort taxa absent from the Sikhote-Alin south of the Ko and Sputnik mountains, including *Biantheridium undulifolium*, *Calyptogeia kamchatica*, and *Neoorthocaulis binsteadii*. Two other species, *Mylia anomala* and *Calyptogeia sphagnicola*, also occur here; south of this area, they are known only from the Ozyornoe Plateau–Mt. Vysokaya (Klimova & Bakalin 2025).

In sheltered depressions, all authors report mesophilic forb communities (Vasilyev & Kurentsova 1960, Rozenberg & Vasilyev 1967), termed ‘mid-herb alpine lawns’ by Schlotgauer (2011) (Fig. S4:B). They occur in areas with prolonged snow cover, where we observed snow remnants even in late July (Fig. S4:C,D). Besides herbs (*Veronica stelleri* Pall. ex Link, *Trollius riederianus* Fisch. & C.A. Mey., *Veratrum* sp., *Anemonastrum sibiricum* (L.) Holub, *Sibbaldia procumbens* L., etc.), dwarf shrub synusia occur, the most notable being *Phyllodoce caerulea* (L.) Bab. (Fig. S4:F,G), found on the northern spur of Mt. Sputnik. This species often forms continuous carpets in snowbed habitats of the northern Sikhote-Alin (Vyshin 1990) (Fig. S4:F). South of 47°N, we found it only on Mt. Vysokaya (ca. 46°N), as also reported by Grishin et al. (1996). In the Sikhote-Alin Biosphere Reserve, further south, its presence has not been confirmed (Pimenova 2016:241). According to our observations, *Anthelia juratzkana* almost always occurs in the same habitats as *Phyllodoce caerulea*; south of the Ko and Sputnik mountains, the former is known only from Mt. Vysokaya (Klimova & Bakalin 2025). Also found in snowbed habitats were *Barbilophozia hatcheri*,

*Gymnomitrium commutatum*, *Lophozia murmanica*, *Marsupella sprucei*, *Nardia japonica*, and *Pseudolophozia debiliformis*, which are rare for the Sikhote-Alin.

The crooked forest belt (= subalpine belt) consists of two main crooked forest types. According to Vasilyev & Kurentsova (1960), a subalpine shrub belt (subalpine shrubs such as *Pinus pumila*, *Rhododendron aureum*, *Ledum hypoleucum* Kom., *Weigela middendorffiana* C. Koch.) occurs at 1500–1900 m a.s.l. The absolute dominant here is *Pinus pumila*, which forms dense thickets in places with abundant snow accumulation (e.g., at the transition zone with the upper limit of *Betula lanata* (L.) Bab. stands (Fig. S3:C) and *Picea ajanensis*–*Betula lanata* forests). Cover gradually decreases with elevation, and at the tundra boundary *Pinus pumila* becomes scattered. Schlotgauer (2011) places the optimum for *Pinus pumila* crooked forest at 1500–1750 m a.s.l. As with tundra vegetation that extends deep into the subalpine shrubs, the latter reach the summit in dwarf form (e.g., *Rhododendron aureum* on the summit of Mt. Ko) (Fig. S2:G), creating a complex vegetation mosaic (Figs. S2:D,G; S3:D,F; S4:A,C,E) (Vasilyev & Kurentsova 1960, Rozenberg & Vasilyev 1967). On moraine deposits on the bottom of trough valleys, *Pinus pumila* forms dense thickets at 1300 m a.s.l. – below its elevational optimum (Schlotgauer 2011) (Fig. S1:H).

The second type of crooked forest is formed by *Betula lanata* (1200–1500 m a.s.l.) (Figs S1:C; S3:B,C). Unlike the distribution patterns we described for the middle Sikhote-Alin (Klimova & Bakalin 2025), here *Betula lanata* forms a distinct belt 200–300 m in vertical extent (Vasilyev & Kurentsova 1960, Schlotgauer 2011). We visited park-like *Betula lanata* forests with tall herbs on semi-concave steep slopes and gentle spur ridges. The understory is sparse, and the herb layer is dense, polydominant, up to 1.5 m tall, with *Calamagrostis langsdoerffii* (Link) Trin., *Trollius riederianus*, *Filipendula palmata* (Pall.) Maxim., *Dryopteris sichotensis* Kom., *Hemerocallis middendorffii* Trautv. & C.A. Mey., and others. *Betula lanata* forests with fern cover (slopes to Katen River valley) are a variety of the above-mentioned birch forests. Within the contact zone with *Pinus pumila* crooked forest, *Betula lanata* forests occur on more stony areas, with *Pinus pumila* in the understory and *Bergenia pacifica* cover (Vasilyev & Kurentsova 1960). According to Schlotgauer (2011), the northeast-facing slopes host birch forests with the Sikhote-Alin endemic *Microbiota decussata* Kom. Liverwort diversity in *Betula lanata* forests is generally poor. In every *Betula lanata*-dominated community we visited, we found only three species: *Ptilidium pulcherrimum*, *Blepharostoma trichophyllum* s.l., and less often *Lophoziaopsis longidens*. The remaining species collected, which account for more than 80 %, occurred only once in these communities. This may indicate that these species are not natural components of this belt or are accidental occurrences, and also suggests that such communities are poorly suited for liverworts.

Below 1200–1300 m a.s.l., spruce–fir forests (dark coniferous in a broad sense), dominated by *Picea ajanensis* Fisch. ex Carrière and *Abies nephrolepis* (Trautv.) Maxim. occur (Figs S1:A,B; S3:A). According to Vasilyev & Kurentsova (1960), oroboreal spruce–fir forests (termed ‘subalpine’ in Klimova & Bakalin 2025) occupy all slopes and narrow river

valleys at 1000–1300 m a.s.l. Depending on local conditions, there are dark coniferous forests with tall-herb, *Bergenia*, small fern—*Ilex rugosa* F. Schmidt, and low-herb-green-moss cover. Our observations and published data (Rozenberg & Vasilyev 1967, Schlotgauer 2011) show that dark coniferous forests also occur down to 600 m a.s.l. (valley forests). We collected liverworts mostly in small-herb-green-moss (Fig. S3:A) and, to a lesser extent, in small-fern dark coniferous forests (Fig. S1:A). These habitats support the temperate–subtropical *Cololejeunea macounii*, *C. ornata*, *Porella vernicosa*, the temperate *Lejeunea japonica*, and the boreal-temperate *Porella gracillima*. Most liverworts here are epixylous (*Anastrophyllum michauxii*, *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *C. otaruensis*, *Fuscocephalozia lunulifolia*, *F. leucantha*, *Harpanthus scutatus*, *Mylia verrucosa*, *Schistochilopsis cornuta*, *Tritomaria exsecta*, etc.); also *Solenostoma obscurum*, *S. pseudopyriflorum*, *Scapania subalpina*, *Chiloscyphus* spp., *Plagiochila* spp., and others occurring in water-affected sites.

Vasilyev & Kurentsova (1960) reported that larch forests formed by *Larix gmelinii* (Rupr.) Rupr. are nearly absent on Mt. Ko and do not form a separate belt (it was mentioned as *Larix dahurica* Turcz. in l.c.). They noted only one small stand with *Ledum hypoleucum* and *Microbiota decussata* understory occurring at 1000 m a.s.l. in the upper course of the Ko River. As reported by Schlotgauer (2011), larch forests also occur in the upper course of the Dzava River (northern slope of the western spur of Mt. Ko), but we did not visit them.

Vasilyev & Kurentsova (1960) give no data on communities below 1000 m a.s.l. Schlotgauer (2011) only notes that *Pinus koraiensis* Siebold & Zucc.—broadleaved forests occur below 500 m a.s.l. A more detailed account is provided by Rozenberg & Vasilyev (1967), who describe *Pinus koraiensis*–*Picea* and broadleaved-coniferous forests at 400–600 m a.s.l. with *Picea ajanensis*, *Pinus koraiensis*, *Tilia amurensis* Rupr., *Acer mono* Maxim. ex Rupr., and *Ulmus laciniata* (Trautv.) Mayr. Below 400 m a.s.l., broadleaved–*Pinus koraiensis* and broadleaf forests occur, including *Picea ajanensis*, *Larix gmelinii*, *Abies nephrolepis*, *Betula costata* Trautv., *Tilia amurensis*, *Acer mono*, and *Quercus mongolica* Fisch. ex Ledeb. (Rozenberg & Vasilyev 1967).

River valleys also support *Chosenia*–*Populus*, *Populus*, and *Fraxinus*–*Ulmus* forests dominated by *Chosenia arbutifolia* (Pall.) A.K. Skvortsov, *Populus maximowiczii* A. Henry, *Fraxinus mandshurica* Rupr., and *Ulmus japonica* (Rehder) Sarg. *Fraxinus*–*Ulmus* forests commonly contain *Phellodendron amurense* and *Juglans mandshurica*. At elevations of 600 m a.s.l. and below, they form complexes with dark coniferous or coniferous-broadleaved forests, depending on altitude.

As reported by the online resource “High Conservation Value Forests of Khabarovsk Krai”, *Pinus koraiensis* forests occur patchily in the Ko River valley downstream from the Obvalny stream confluence (<https://hcvf.ru/ru/maps/hcvf-khab>). Below 600 m a.s.l., we visited only a deciduous broadleaf forest in the swampy Ko River valley (near Solontsovy Settlement, 268 m a.s.l.), which the online resource (<https://hcvf.ru/ru/maps/hcvf-khab>) classifies as High Conservation Value Forests (HCVF) of the southern Russian Far East. There we collected the rare bo-

real-temperate East Asian *Frullania crispiplicata*, known in Russia from only a few localities (Klimova & Bakalin 2025).

## Specimen collection

The specimens were collected by the first author during fieldwork in the Ko and Sputnik Mountains and the Ko River valley from 16 July to 10 August 2018 (Fig. 1, Table S1). The main expedition walking route started in the Ko River valley upstream of the Obvalny Stream confluence, crossed Mt. Ko summit, then over the ridge between Ko and Sputnik mountains (the watershed of the Kafe and Katen River basins), and ended at the northern spur of Mt. Sputnik in the headwaters of the Pravaya Kafe River (Figs 1, S1–S4). The area of Mt. Sputnik was surveyed in less detail than Mt. Ko, while Mt. Ostraya and its surroundings were not studied. The specimens were collected using the route method; a total of 640 liverwort specimens were collected. During field collection, the following parameters were recorded for each specimen: coordinates and altitude above sea level using a GPS receiver; vegetation community and substrate; light and humidity of the liverwort mats, based on visual observations without specialized measuring equipment. All material was delivered in a living state to the Laboratory of Cryptogamic Biota (Botanical Garden-Institute FEB RAS, Vladivostok) for examination of oil bodies. All identified specimens are kept in the Herbarium of the Botanical Garden-Institute FEB RAS, Vladivostok (VBGI).

## Specimen processing

The collections were identified using microscopes (Olympus CX–31, Zeiss Stemi 2000, Olympus CZX–16) at the Botanical Garden-Institute FEB RAS. Material was studied by anatomical and morphological methods. All material was intended to be studied alive. However, storage conditions were compromised, causing decay and destruction of oil bodies in most specimens, making precise identification of genera such as *Lophozia* and *Calypogeia* impossible without living cells. This explains the few localities reported for *Lophozia* species – we did not use specimens identified under cf. for species annotations. Nevertheless, such specimens were considered when listing accompanying taxa.

## Data analysis

To characterize the flora, we counted floristic elements by latitudinal and longitudinal types. For comparative analysis, we added similar data from selected liverwort floras of the southern Sikhote-Alin (Zov Tigra National Park), the middle Sikhote-Alin (combined flora), its highest surveyed summits (Ozyornoe Plateau– Mt. Vysokaya, Mt. Glukhomanka), and the northern Sikhote-Alin (Tardoki-Yani Range). A some data on these floras are summarized in Table 2. Hereafter, references to Mt. Ko will mean the Ko–Sputnik mountain massif, and the abbreviation KO will denote the liverwort flora of this massif. A classification scheme of floristic elements and area types provided by Bakalin (2009) was used as the basis, with some additions and updates.

To quantify floristic similarity between floras (according to Table 2, excluding the combined flora of the middle Sikhote-Alin MSA) using multivariate methods and compare the results, we used several approaches available in PAST 5.3

**Table 2.** Sikhote-Alin floras included in the comparison. The floras are listed from south to north.

| Local flora                            | Local flora abbr. | Geographical subdivision of Sikhote-Alin Mts. | Highest peak, m a.s.l. | Latitude      | Number of taxa | References             |
|----------------------------------------|-------------------|-----------------------------------------------|------------------------|---------------|----------------|------------------------|
| Zov Tigra National park                | ZT                | Southern Sikhote-Alin                         | 1854                   | 43°41'        | 129            | Klimova et al. 2024    |
| Mt. Glukhomanka–Spornyi Stream valley  | GLUKH             | Middle Sikhote-Alin                           | 1595                   | 45°10'        | 111            | Klimova & Bakalin 2025 |
| Ozyornoe Plateau– Mt. Vysokaya         | OZ_VY             | Middle Sikhote-Alin                           | 1745                   | 45°58'        | 96             | Klimova & Bakalin 2025 |
| Total flora of the middle Sikhote-Alin | MSA               | Middle Sikhote-Alin                           | 1745                   | 45°10'–46°48' | 161            | Klimova & Bakalin 2025 |
| Mt. Ko– Mt. Sputnik                    | KO                | Middle Sikhote-Alin                           | 2004                   | 47°06'        | 123            | Present account        |
| Tardoki-Yani Range                     | TARD              | Northern Sikhote-Alin                         | 2090                   | 48°53'        | 107            | Bakalin 2015           |

software (Hammer et al., 2001). The calculations used a binary presence-absence matrix (1/0) of the taxon lists of the compared floras. First, we calculated the Dice similarity index (Sørensen index). Dice is preferred over Jaccard because it is less sensitive to differences in species richness between floras (even though in our dataset the maximum size discrepancy does not exceed 26% taking from maximum). Dice thus effectively emphasizes shared species while de-emphasizing unique ones, helping highlight floristic similarity rather than difference. Dice results were then visualized in a PCoA (Principal Coordinates Analysis) scatterplot. Next, the results of Correspondence Analysis (CA) and Detrended Correspondence Analysis (DCA) were obtained.

Similarity indices like Dice and Jaccard are classic binary tools for assessing floristic similarity. In addition to these quantitative measures, multivariate ordination techniques (CA, DCA) are also commonly used (including by us) to complement the similarity analysis. The latter methods not only allow visual assessment of floristic proximity on scatterplots but also reveal unmeasured environmental gradients that shape the observed distribution. Consequently, this integrative approach helps reveal floristic similarity through ecological factors, even when those factors were not explicitly recorded a priori.

## RESULTS

Conducted research revealed 123 species, and one form in the liverwort flora of the studied area. Among them, 5 taxa are newly reported to Sikhote-Alin Mts.: *Biantheridium undulifolium*, *Calypogeia kamchatica*, *Marsupella sprucei*, *Neoorthocaulis binsteadii*, *Scapania tundrae* (marked with two exclamation marks (!) in the annotated list of species). Rare species included in the last edition of the Red Data Book of Russia (Geltman 2024) are marked with sign ®.

In the annotated list of taxa the names are arranged alphabetically, nomenclature follows Söderström et al. (2016), with the exception for Solenostomataceae, where narrow genus concept was adopted, acceptance of *Pseudolophozia* distinct from *Barbilophozia*, new concept of *Schistochilopsis* according to Bakalin et al. (2020), and new concept of taxa in *Calypogeia* according to Bakalin et al. (2022), *Chiloscyphus* species concept is following to Schljakov (1982).

The annotations in the list made as following: presence and the frequency of occurrence of reproductive structures with the following abbreviations: per. – perianths, ant. – antheridia, arch. – archegonia, spor. – sporophytes, gemm. – gemmae; very common (cc) – more than 65 %, common (c) – 40–65 %, frequent (f) – 20–39.9 %, sporadic (s) – 5–19.9 %, rare (r) – 0.1–4.9 % (if the record is based on a single specimen, the data on the frequency of occurrence

of reproductive structures is not provided); collecting localities according to the Table S1 and in Figure 1 and altitudes in meters above sea level in square brackets (if there are any altitude records in a noticeable gap from others, they are provided after a comma, e. g., “268, 730–1465”); brief description of habitat corresponding to each vegetation belt where the species was recorded, the habitats are listed for each species separately for each belt from upper to lower; accompanying taxa (if any) in alphabetic order; field numbers of the selected specimens examined, three or fewer for each species (in cases, when species was growing intermixed with other taxa and was not detected on the first place during identification, we provide the notice “kept under ...”, which means that the cited specimen is kept under another species in the herbarium); where necessary nomenclatural notes are provided.

## Annotated species list

***Anastrophyllum michauxii* (F. Weber) H. Buch** – (per. – c, ant. – f, gemm. – s); 15, 19, 37, 39, 41 [730–1465]. Barked decaying *Pinus pumila* trunks, humus and rotten wood in *Pinus pumila* crooked forest belt; decaying and partly rotten logs, plant debris covering decaying wood in different types of coniferous forests. In pure mats or with *Bazzania denudata*, *Blepharostoma trichophyllum* s.l., *Crossoclyx hellerianus*, *Fuscocephalozia leucantha*, *Lepidozia reptans*, *Lophozia* cf. *guttulata*, L. cf. *ventricosa*, *Mylia taylorii*, *M. verrucosa*, *Neoorthocaulis attenuatus*, *Novellia curvifolia*, *Riccardia* sp., *Schistochilopsis cornuta*, *Tritomaria exsecta*. Khab-60-12-18, Khab-77-12-18 (under *Mylia verrucosa*), Khab-81-3-18.

***Aneura pinguis* (L.) Dumort.** – (ant. – f, spor. – c); 8, 42, 44, 45 [268, 626–929, 1616]. Humus in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; decorticated decaying logs, rotten wood in floodplain forest with coniferous trees admixture; rotten wood in broadleaved deciduous valley forest. In pure mats or with *Blepharostoma trichophyllum* s.l., *Lophocolea heterophylla*, *Mylia verrucosa*, *Novellia curvifolia*, *Plagioclila porelloides*, *Riccardia palmata*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-51-1-18, Khab-84-11-18, Khab-85-3-18.

***Anthelia juratzkana* (Limpr.) Trevis.** – (per. – s, ant. – s, spor. – s); 3, 4, 5, 7, 10, 25, 28, 32 [1660–1908]. Humus, clayish and sandy-clayish soil covering rocks and boulders in niches, bare soil of cryogenic origin, including that in snowbed habitat in tundra belt. In pure mats or with *Bazzania tricenata*, *Blepharostoma trichophyllum* s.l., *Diplophyllum taxifolium*, *Douinia plicata*, *Frullania subarctica*, *Gymnomitrium commutatum*, *G. concinnatum*, *Herbertus arcticus*, *Lejeunea alaskana*, *Preiszia quadrata*, *Pseudolophozia debiliformis*, *P. sudetica*, *Scapania* cf. *mucronata*, *S. crassiretis*, *Solenostoma obscurum*, *S. rossicum*, *Sphenolobus saxicola*, *Trilophozia quinqueidentata*. Khab-46-14-18, Khab-53-13-18, Khab-68-32-18.

***Barbilophozia barbata* (Schreb.) Loeske** – (spor. – s); 3, 4, 8, 16, 30, 44 [626, 1348, 1616–1762]. Humus and clayish soil covering rocks and boulders in tundra belt; covering

boulder and on plant debris in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; *Betula lanata* trunks and trunk bases, plant debris covering *Betula lanata* roots in *Betula lanata* crooked forest; *Acer* trunk in floodplain forest. In pure mats or with *Lejeunea alaskana*, *Lophozia longidens*, *Mesoptychia heterocolpos*, *Preissia quadrata*, *Ptilidium pulcherrimum*, *Scapania* cf. *crassiretis*, *S. parvifolia*, *Syzygiella autumnalis*, *Tetralopozia setiformis*. Khab-51-14-18, Khab-58-1-18, Khab-84-23-18.

***Barbilophozia hatcheri* (A. Evans) Loeske** – (gemm. – f); 27, 30, 34 [1673–1782]. Humus with plant debris in animal hole in snowbed habitat, humus covering rocks in niches in dwarf shrub-lichen tundra; humus covering boulder in crooked forest belt. In pure mats or with *Calypogeia integristipula*, *Diplophyllum taxifolium*, *Schistochilopsis incisa*, *Sphenolobus minutus*. Khab-67-9-18 (under *Calypogeia integristipula*), Khab-70-28-18 (under *Schistochilopsis incisa*), Khab-74-11-18 (under *Diplophyllum taxifolium*).

***Bazzania denudata* (Torr. ex Gottsche, Lindenb. et Nees) Trevis.** – 3, 15, 19, 30, 34, 37, 45 [268, 626–1762]. Humus, humus with plant debris covering rocks and boulders in niches in tundra belt; bark of *Pinus pumila*, plant debris in *Pinus pumila* crooked forest; decaying and rotten wood, standing decaying tree trunk, *Abies* trunk in different types of coniferous forests; rotten wood in broadleaved deciduous valley forest. In pure mats or with *Anastrophyllum michauxii*, *Bazzania trilobata*, *Blepharostoma trichophyllum* s.l., *Cololejeunea macounii*, *Diplophyllum taxifolium*, *Fuscocephaloziopsis leucantha*, *F. lunulifolia*, *Lepidozia reptans*, *Lophozia* cf. *ventricosa*, *Metacalypogeia cordifolia*, *Metzgeria lindbergii*, *Mylia verrucosa*, *Neoorthocaulis attenuatus*, *Novellia curvifolia*, *Scapania apiculata*, *Tritomaria exsecta*. Khab-60-17-18, Khab-70-1-18, Khab-85-7-18.

***Bazzania paravidentula* Bakalin** – 15, 34, 37 [730, 1465, 1673]. Humus with plant debris, rotten wood in *Pinus pumila* crooked forest; standing decaying tree trunk in coniferous forest. With *Blepharostoma trichophyllum* s.l., *Fuscocephaloziopsis lunulifolia*, *Mylia taylorii*, *M. verrucosa*, *Sphenolobus minutus*. Khab-57-16-18, Khab-74-13-18, Khab-77-10-18.

***Bazzania tricrenata* (Wahlenb.) Trevis.** – 1, 4, 10, 11, 29, 33, 35 [1427–2000]. Humus, humus with plant debris, plant debris covering boulders and rocks in niches and crevices, humus covering vertical surface of rocks in tundra belt; humus covering boulders in rock fields in *Pinus pumila* crooked forest, covering vertical surface of boulders in *Betula lanata* crooked forest. In pure mats or with *Antbelia juratzkana*, *Blepharostoma trichophyllum* s.l., *Diplophyllum taxifolium*, *Doninia plicata*, *Herbertus arcticus*, *Lejeunea alaskana*, *Lophozia longiflora*, *Metzgeria lindbergii*, *Scapania crassiretis*, *S. microdonta*, *Sphenolobus minutus*, *S. saxicola*, *Tetralopozia setiformis*, *Trilophozia quinquedentata*, *Tritomaria exsecta*. Khab-44-18-18, Khab-69-14-18, Khab-75-8-18.

***Bazzania trilobata* (L.) Gray** – 15, 19, 37, 45 [268, 730–1465]. *Pinus pumila* needles and other plant debris in *Pinus pumila* crooked forest belt; plant debris, *Picea* trunk base in coniferous forests; rotten wood in broadleaved deciduous valley forest. In pure mats or with *Bazzania denudata*, *Fuscocephaloziopsis lunulifolia*, *Metacalypogeia cordifolia*. Khab-57-25-18, Khab-60-7-18, Khab-77-22-18.

!!***Biantheridium undulifolium* (Nees) Konstant. et Vilnet** – 10, 13, 28 [1600, 1847, 1862]. *Sphagnum* and its debris, other mosses and plant debris, humus with plant debris in swampy dwarf shrub-moss-*Carex* and *Carex-Sphagnum* tundras with ponds surrounded by lichen-dwarf shrub tundra with spots of dwarf *Pinus pumila* thickets. With *Calypogeia sphagnicola*, *Gymnocolea inflata*, *Neoorthocaulis binsteadii*, *Ptilidium ciliare*, *Scapania paludicola*, *Schliakovia kunzeana*. Khab-53-1-18, Khab-55-9-18 (under *Schliakovia kunzeana*), Khab-68-1-18.

***Blepharostoma trichophyllum* (L.) Dumort.** – 4, 8, 10, 11, 15, 16, 17, 19, 34, 35, 37, 38, 41, 42, 44 [626–2000]. Humus with plant debris, sandy-clayish soil covering boulders in niches, humus and clayish soil covering rocks in crevices and niches in tundra belt; humus with plant debris, humus covering boulder, barked decaying wood, bark of lying *Pinus pumila* trunk in *Pinus pumila* crooked forest, *Betula lanata* trunk bases, partly rotten log, vertical surface of boulder in *Betula lanata* crooked forest; decaying, partly rotten and rotten logs, decaying standing tree trunks, *Abies* trunk base, *Betula* trunk, humus with plant debris, soil covering boulder, sandy-humus soil covering *Populus* root in coniferous forests; soil, sandy soil covering rotten wood, decaying wood in floodplain forest. In pure mats or with *Anastrophyllum michauxii*, *Aneura pinguis*, *Antbelia juratzkana*, *Bazzania denudata*, *B. paravidentula*, *B. tricrenata*, *Calypogeia integristipula*, *Cephalozia bicuspidata*, *C. otariensis*, *Diplophyllum taxifolium*, *Fuscocephaloziopsis leucantha*, *F. lunulifolia*, *Lejeunea alaskana*, *Lepidozia reptans*, *Lophocolea heterophylla*, *Lophozia* cf. *ventricosa*, *L. lantratovae*, *Lophozia longidens*, *Marsupella emarginata*, *Mesoptychia heterocolpos*, *Metacalypogeia cordifolia*, *Metzgeria lindbergii*, *Mylia taylorii*, *M. verrucosa*, *Neoorthocaulis attenuatus*, *Novellia curvifolia*, *Plagiobhila* cf. *ovalifolia*, *Ptilidium ciliare*, *Riccardia palmata*, *Scapania crassiretis*, *S. parvifolia*, *S. subalpina*, *Solenostoma obscurum*, *S. pseudopyriflorum*, *Sphenolobus minutus*, *Syzygiella autumnalis*, *Trilophozia quinquedentata*, *Tritomaria exsecta*. Khab-51-9-18, Khab-60-26-18, Khab-84-17-18.

***Calycularia laxa* Lindb. et Arnell** – (ant. – s, arch. – s); 2, 4, 8, 10, 11, 29, 33, 40 [818, 1616–2000]. Humus covering boulders and rocks, over other bryophytes in niches in rocks and rocky outcrops in different types of tundra; plant debris covering boulder in niche in mossy temporary streambed surrounded by tundra spots in a belt of subalpine shrubs (*Pinus pumila*, *Alnus fruticosa*); soil covering rocks along river in coniferous forest. With *Cephalozia bicuspidata*, *Diplophyllum albicans*, *D. taxifolium*, *Doninia plicata*, *Gymnomitrium concinatum*, *G. parvixetum*, *Lophozia* cf. *ventricosa*, *L. longiflora*, *Marsupella emarginata*, *Pseudolophozia sudetica*, *Scapania crassiretis*, *S. microdonta*, *S. parvifolia*, *Schistochilopsis incisa*, *Solenostoma pseudopyriflorum*, *S. rossicum*, *Sphenolobus minutus*, *Trilophozia quinquedentata*. Khab-45-2-18, Khab-54-30-18, Khab-80-1-18.

***Calypogeia integristipula* Steph.** – 4, 8, 14, 15, 18, 19, 25, 27, 28, 30, 34, 35, 37, 39, 42, 44 [626–1820]. Humus, humus with plant debris in animal holes and covering boulders in niches, humus on animal path across *Carex-Sphagnum* tundra, soil walls in niches in tundra belt; humus-sandy soil covering boulder on animal path, humus, decaying and rotten wood, *Pinus pumila* needles in *Pinus pumila* crooked forest, *Betula* root in *Betula lanata* crooked forest; rotten, partly rotten and decaying wood, humus with plant debris in coniferous forests. In pure mats or with *Barbilophozia hatcheri*, *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *C. otariensis*, *Fuscocephaloziopsis lunulifolia*, *F. pleniceps*, *Harpanthus scutatus*, *Kurzia makinoana*, *Lepidozia reptans*, *Lophozia* cf. *silvicola*, *L. cf. silvicoloides*, *L. cf. ventricosa*, *Metacalypogeia cordifolia*, *Mylia verrucosa*, *Neoorthocaulis attenuatus*, *Plagiobhila ovalifolia*, *Scapania parvifolia*, *Schistochilopsis cornuta*, *Schliakovia kunzeana*, *Sphenolobus minutus*, *S. saxicola*, *Tritomaria exsecta*. Khab-47-52-18, Khab-60-5-18, Khab-68-16-18.

!!***Calypogeia kamchatica* Bakalin, A.V. Troitsky et Maltseva** – 13 [1847]. *Sphagnum* debris in swampy dwarf shrub-moss-*Carex* tundra with small ponds. In pure mat. Khab-55-8-18.

***Calypogeia muelleriana* (Schiffn.) Müll. Frib.** – 4, 11, 13, 29 [1743–2000]. *Sphagnum* debris among *Diapensia obovata* on rocks and in swampy dwarf shrub-moss-*Carex* tundra, plant debris in niche, over plant debris and mosses

covering vertical surface of rocks on steep NE-facing slope covered with moist dwarf shrub-moss tundra. With *Lophozia* cf. *silvicoloides*, *L.* cf. *ventricosa*, *Schizakovia kunzeana*. Khab-47-32-18, Khab-55-7-18, Khab-69-31-18 (tested by DNA analysis in Bakalin et al., 2022).

***Calypogeia* cf. *orientalis* Buczk. et Bakalin** – 19 [1225]. Partly rotten log in coniferous forest. With *Cephalozia bicuspidata*, *Fuscocephalozia leucantha*, *Lophozia* cf. *guttulata*, *Mylia verrucosa*. Khab-60-32-18 (under *Lophozia* cf. *guttulata*).

***Calypogeia sphagnicola* (Arnell et J. Perss.) Warnst. et Loeske** – 28 [1600]. Among *Sphagnum* in swampy *Carex-Sphagnum* tundra surrounded by small ponds and dwarf shrub-lichen tundra. With *Biantberidion undulifolium*. Khab-68-14-18 (tested by DNA analysis in Bakalin et al., 2022), Khab-68-13-18 (under *Biantberidion undulifolium*).

***Calypogeia suecica* (Arnell et J. Perss.) Müll. Frib.** – 19, 37 [1225, 730]. Rotten wood in coniferous forests. With *Bazzaniana denudata*, *Fuscocephalozia leucantha*, *Mylia verrucosa*, *Nowellia curvifolia*, *Scapania apiculata*. Khab-60-34-18 (tested by DNA analysis in Bakalin et al., 2022); Khab-77-16-18 (under *Scapania apiculata*).

***Cephalozia bicuspidata* (L.) Dumort.** – (per. – c, ant. – c, arch. – s); 2, 4, 8, 11, 14, 19, 24, 25, 28, 30, 31, 38, 42 [626–2000]. Humus covering rocks and boulders in niches, snowbed habitats, dried temporary streambeds, in animal holes and on animal paths, clayish soil, sandy-clayish soil with plant debris and humus with plant debris in hollows and among other plants in different types of tundra; humus and humus-sandy soil covering boulders on animal path in *Pinus pumila* thickets; humus, partly rotten, rotten and decaying logs, once on soil covering boulder and on sandy soil covering rocks along river bank in coniferous forest; rotten wood in floodplain forest. In pure mats or with *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Calypogeia integrispula*, *Diplophyllum albicans*, *D. taxifolium*, *Fuscocephalozia leucantha*, *F. lunulifolia*, *F. pleniceps*, *Gymnocolea inflata*, *Gymnomitrium parvitextum*, *Kurzia makinoana*, *Lophozia* cf. *ventricosa*, *L. guttulata*, *L. longiflora*, *Marsupella emarginata*, *Mylia taylorii*, *M. verrucosa*, *Nardia insecta*, *Pellia neesiana*, *Ptilidium ciliare*, *Riccardia palmata*, *Scapania crassiretis*, *S. microdonta*, *S. mucronata*, *S. paludicola*, *S. parvifolia*, *S. rufidula*, *S. subalpina*, *Schistochilopsis cornuta*, *S. incisa*, *Schizakovia kunzeana*, *Solenostoma* cf. *pseudopyriferum*, *S. obscurum*, *S. rossicum*, *Sphenolobus minutus*, *S. saxicola*, *Tritomaria exsecta*. Khab-45-3-18, Khab-60-35-18, Khab-78-5-18.

***Cephalozia otaruensis* Steph.** – (per. – f, ant. – f, arch. – c); 19, 37, 39, 41, 42 [730–1225]. Decaying and rotten wood, fine soil covering vertical surface of boulder, decaying branch of *Pinus pumila* in *Pinus pumila* thickets along riverbank in coniferous forest belt. In pure mats or with *Blepharostoma trichophyllum* s.l., *Calypogeia integrispula*, *Fuscocephalozia lunulifolia*, *Harpanthus scutatus*, *Lophozia* cf. *ventricosa*, *L. lantratorae*, *Mylia verrucosa*, *Plagiobolus* cf. *ovalifolia*, *Schistochilopsis cornuta*, *Tritomaria exsecta*. Khab-60-10-18, Khab-77-20-18, Khab-82-16-18.

***Cephaloziella arctogena* (R.M. Schust.) Konstant.** – (per., ant.); 34 [1673]. Bark of lying *Pinus pumila* trunk in *Pinus pumila* thickets on the edge of *Betula lanata* crooked forest. With *Lophozia silvicoloides*. Khab-74-3-18.

***Cephaloziella* cf. *varians* (Gottsche) Steph.** – 25 [1737]. Humus with plant debris among other plants in swampy dwarf shrub-*Carex*-moss tundra with hollows and ponds surrounded by *Pinus pumila* and *Rhododendron aureum* thickets. With *Cephalozia bicuspidata*, *Scapania parvifolia*, *Schizakovia kunzeana*. Khab-66-5-18 (under *Scapania parvifolia*).

***Chiloscyphus fragilis* (Roth) Schiffn.** – (ant.); 38 [753]. Soil covering boulder in a small stream in *Abies* forest with fern cover. In pure mat. Khab-78-10-18.

***Chiloscyphus polyanthos* (L.) Corda** – (per., ant.); 45 [268]. Decaying log in broadleaved deciduous valley forest. In pure mat. Khab-85-8-18.

***Cololejeunea macounii* (Spruce) A. Evans** – (ant. – c, arch. – c); 19, 21, 44 [626, 1060–1225]. *Abies*, *Picea*, *Betula* trunks in different types of coniferous forests. With *Bazzaniana denudata*, *Frullania davurica*, *F. takayuenensis*, *Metzgeria pubescens*, *Radula complanata*, *Tritomaria exsecta*. Khab-60-20-18, Khab-62-3-18, Khab-84-2a-18.

***Cololejeunea ornata* A. Evans** – 4, 37 [730, 1750]. Covering vertical surface of boulder and over the mosses on rocks in tundra belt; *Populus* trunk in coniferous forest. With *Lejeunea japonica*, *Metzgeria pubescens*, *Porcella vernicosa*, *Trilophozia quinqueidentata*. Khab-47-26a-18, Khab-77-31-18 (under *Lejeunea japonica*).

***Conocephalum salebrosum* Szwedk., Buczk. et Odrzyk.** – 17, 19, 37 [730, 1225–1347]. Humus with plant debris in *Betula* crooked forest; humus covering boulder and humus with plant debris in different types of coniferous forests. In pure mats, once with *Plagiobolus ovalifolia*. Khab-59-10-18, Khab-60-4-18, Khab-77-19-18.

***Crossocalyx hellerianus* (Nees ex Lindenb.) Meyl.** – (gemm.); 41 [980]. Decaying wood in coniferous forest. With *Anastrophyllum michauxii*, *Lepidozia reptans*, *Mylia verrucosa*, *Tritomaria exsecta*. Khab-81-3-18 (under *Anastrophyllum michauxii*).

***Diplophyllum albicans* (L.) Dumort.** – (gemm. – s); 2, 4, 11, 12, 29, 32, 33 [1743–2000]. Humus, humus with plant debris covering boulders and rocks in niches, over other bryophytes in tundra belt. With *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum taxifolium*, *Gymnomitrium commutatum*, *G. concinatum*, *G. parvitextum*, *Marsupella emarginata*, *Mylia taylorii*, *Pseudolophozia sudetica*, *Scapania microdonta*, *S. parvifolia*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-47-46-18, Khab-48-4-18, Khab-54-10-18.

***Diplophyllum taxifolium* (Wahlenb.) Dumort.** – (per. – s, gemm. – f); 1, 3, 4, 7, 10, 11, 24, 27, 29, 30, 33, 34, 35, 41 [980–2000]. Humus in niches and crevices, on vertical surface of rocks, on rocks in snowbed habitat, soil with admixture of sand in tundra belt; humus, humus with plant debris covering boulders in niches on rock fields in *Pinus pumila* crooked forest, between *Betula* roots, humus covering boulder in niche in *Betula lanata* crooked forest; humus covering vertical surface of rocky outcrops and boulders in coniferous forests. In pure mats or with *Anthelia juratzkana*, *Barbilophozia hatcheri*, *Bazzaniana denudata*, *B. tricenata*, *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum albicans*, *Doninia plicata*, *Frullania subarctica*, *Gymnomitrium parvitextum*, *Herbertus arcticus*, *Kurzia makinoana*, *Lejeunea alaskana*, *Lophozia* cf. *ventricosa*, *Marsupella emarginata*, *Metacalypogeia cordifolia*, *Metzgeria lindbergii*, *Mylia taylorii*, *Plagiobolus* cf. *porcelloides*, *Preissia quadrata*, *Pseudolophozia sudetica*, *Radula obtusiloba*, *Scapania crassiretis*, *S. mucronata*, *S. parvifolia*, *Solenostoma pseudopyriferum*, *S. rossicum*, *Sphenolobus minutus*, *Trilophozia quinqueidentata*. Khab-44-11-18, Khab-69-10-18, Khab-81-8-18.

***Douinia plicata* (Lindb.) Konstant. et Vilnet** – (gemm. – f); 4, 7, 29, 30 [1704–1782]. Humus, plant debris with humus covering boulders in niches in rocks and rock fields, covering rocks in tundra belt. In pure mats or with *Anthelia juratzkana*, *Bazzaniana tricenata*, *Calycularia laxa*, *Diplophyllum taxifolium*, *Gymnomitrium concinatum*, *G. parvitextum*, *Herbertus arcticus*, *Lejeunea alaskana*, *Scapania crassiretis*, *S. microdonta*, *Sphenolobus minutus*, *S. saxicola*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*. Khab-47-31-18, Khab-50-5-18, Khab-70-10-18.

***Frullania crispiplicata* Yuzawa et S. Hatt.** – (per., ant.); 45 [268]. Living *Acer* trunk, standing died *Acer* trunk in

broadleaved deciduous valley forest. In pure mats. Khab-85-10-18.

**Frullania davurica** Hampe – (per. – s, arch. – s); 37, 38, 44 [626–753]. *Alnus* and *Picea* trunks, *Populus* trunk base, fallen *Betula* trunk in different types of coniferous forests; *Acer* trunk in floodplain forest. In pure mats or with *Cololejeunea macounii*, *Metzgeria pubescens*, *Plagiochila porelloides*, *Tritomaria exsecta*. Khab-77-34-18, Khab-78-1-18, Khab-84-1-18.

**Frullania subarctica** Vilnet, Borovich. et Bakalin – 3, 7 [1683–1745]. Humus and clayish soil covering rocks in niches and crevices, humus with plant debris hanging from rocks, vertical surface of wet rocks in tundra belt. In pure mats or with *Anthelia juratzkana*, *Diplophyllum taxifolium*, *Herbertus arcticus*, *Lejeunea alaskana*, *Mesoptychia heterocolpos*, *Metzgeria lindbergii*, *Plagiochila porelloides*, *Preissia quadrata*, *Ptilidium ciliare*, *Radula obtusiloba*, *Scapania crassiretis*, *Solenostoma obscurum*, *Sphenolobus saxicola*, *Trilophozia quinqueidentata*. Khab-46-15-18, Khab-46-16-18, Khab-50-8-18.

**Frullania takayensis** Steph. – (per. – cc, ant. – cc); 19, 21, 37, 44 [626–1225]. *Abies* and *Betula* trunks, bark of decaying log in coniferous forests. In pure mats or with *Cololejeunea macounii*, *Radula complanata*. Khab-60-24-18, Khab-77-28-18, Khab-84-2-18.

**Fuscocephalozia leucantha** (Spruce) Váňa et L. Söderstr. – (per. – s); 11, 19, 20, 37, 39, 44 [626–2000]. Humus covering rocks in niche in dwarf shrub-lichen stony tundra; decaying, partly rotten and rotten logs (wood) in coniferous forest. With *Anastrophyllum michauxii*, *Bazzania denudata*, *Blepharostoma trichophyllum* s.l., *Calypogeia integristipula*, *Cephalozia bicuspidata*, *C. cf. otaruensis*, *Fuscocephalozia lunulifolia*, *Lepidozia reptans*, *Lophozia cf. guttulata*, *L. cf. ventricosa*, *Metacalypogeia cordifolia*, *Mylia taylorii*, *M. verrucosa*, *Novelia curvifolia*, *Scapania apiculata*, *Schistochilopsis cornuta*, *S. incisa*, *Sphenolobus minutus*, *Tritomaria exsecta*. Khab-54-4-18, Khab-77-7-18, Khab-84-5-18 (under *Calypogeia integristipula*).

**Fuscocephalozia lunulifolia** (Dumort.) Váňa et L. Söderstr. – (per. – f); 8, 14, 15, 18 19, 22, 34, 35, 37, 39, 42, 44, 45 [268, 626–1673]. Humus with plant debris covering boulder in niche in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus-sandy soil covering boulder on animal path, humus, rotten wood, plant debris in *Pinus pumila* crooked forest, *Betula* root in *Betula lanata* crooked forest; partly rotten logs, decaying and rotten wood, humus with plant debris, fine soil covering vertical surface of boulder in different types of coniferous forests; rotten wood in floodplain and broadleaved deciduous valley forests. In pure mats or with *Bazzania denudata*, *B. parabidentula*, *B. trilobata*, *Blepharostoma trichophyllum* s.l., *Calypogeia integristipula*, *Cephalozia bicuspidata*, *C. otaruensis*, *Fuscocephalozia leucantha*, *Harpanthus scutatus*, *Lepidozia reptans*, *Lophocolea heterophylla*, *Lophozia cf. ventricosa*, *L. guttulata*, *Metacalypogeia cordifolia*, *Mylia verrucosa*, *Neoorthocaulis attenuatus*, *Plagiochila cf. ovalifolia*, *Schistochilopsis cornuta*, *Sphenolobus minutus*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-57-11-18, Khab-60-29-18, Khab-79-3-18.

**Fuscocephalozia pleniceps** (Austin) Váňa et L. Söderstr. – (per. – f, ant. – f); 3, 30 [1745–1782]. Humus in niche and in animal hole, humus covering boulder in niche in tundra belt. With *Calypogeia integristipula*, *Cephalozia bicuspidata*, *Lejeunea alaskana*, *Scapania crassiretis*, *S. parvifolia*, *Sphenolobus saxicola*. Khab-46-9-18 (under *Lejeunea alaskana*), Khab-70-12-18, Khab-70-21-18.

**Gymnocolea inflata** (Huds.) Dumort. – (per. – c); 10, 28 [1660–1862]. Sandy-clayish soil, clayish soil with plant debris on a bare ground spot of cryogenic origin, plant debris, humus with plant debris in swampy dwarf shrub-moss–*Carex* and *Carex*–*Sphagnum* tundras. In pure mats or

with *Biantheridium undulifolium*, *Cephalozia bicuspidata*, *Ptilidium ciliare*, *Scapania tundrae*, *S. paludicola*, *Schliakovia kunzeana*. Khab-53-3-18 (under *Schliakovia kunzeana*), Khab-68-19-18, Khab-68-27-18.

**Gymnomitrium commutatum** (Limpr.) Schiffn. – (arch. – s); 1, 4, 5, 7, 10, 11, 27, 29 [1673–2000]. Soil and humus with plant debris between stones, including those on the edge of bare ground spot of cryogenic origin, humus hanging from boulder, stony soil with admixture of sand, rocks in niche in snowbed habitat, open crevices in rocks in tundra belt; humus covering boulder in niche in crooked forest belt. With *Anthelia juratzkana*, *Diplophyllum albicans*, *Pseudolophozia sudetica*, *Solenostoma rossicum*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*. Khab-44-13-18, Khab-50-3-18, Khab-67-15-18.

**Gymnomitrium concinnatum** (Lightf.) Corda – (arch. – s); 30, 32, 33 [1782–1885]. Humus with plant debris covering vertical surface of boulder, humus covering boulders in niches, sandy soil and humus covering rocks and rocky outcrops in tundra belt. With *Anthelia juratzkana*, *Calycularia laxa*, *Diplophyllum albicans*, *Doninia plicata*, *Gymnomitrium parvitextum*, *Marsupella emarginata*, *Nardia insecta*, *Pseudolophozia sudetica*, *Scapania microdonta*, *Sphenolobus minutus*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*. Khab-70-5-18, Khab-72-3-18, Khab-73-1-18.

**Gymnomitrium corallioides** Nees – (arch. – cc, spor. – c); 10 [1830]. Fine soil covering vertical surface of rocky block in forb-dwarf shrub tundra with *Rhododendron aureum* and *Pinus pumila* clumps. In pure mat or with *Gymnomitrium parvitextum*. Khab-53-34-18, Khab-53-35-18 (under *G. parvitextum*).

**Gymnomitrium parvitextum** (Steph.) Mamontov, Konstant. et Potemkin – (ant. – s, arch. – f); 1, 3, 4, 10, 11, 27, 29, 30, 33 [1673–2000]. Humus and fine soil covering vertical surfaces of rocks and rocky blocks and their crevices, clayish soil and humus in open crevices, including those in snowbed habitats, humus and humus with plant debris covering boulders in niches in tundra and crooked forest belts. In pure mat or with *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum albicans*, *D. taxifolium*, *Doninia plicata*, *Gymnomitrium concinnatum*, *G. corallioides*, *Marsupella emarginata*, *Mylia taylorii*, *Pseudolophozia sudetica*, *Scapania microdonta*, *Sphenolobus minutus*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*. Khab-53-11-18, Khab-69-18-18, Khab-73-4-18.

**Harpanthus flotovianus** (Nees) Nees – 19 [1225]. Humus in coniferous forest. In pure mat. Khab-60-2-18.

®**Harpanthus scutatus** (F. Weber et D. Mohr) Spruce – 39 [798]. Rotten wood in coniferous forest. With *Calypogeia integristipula*, *Cephalozia otaruensis*, *Fuscocephalozia lunulifolia*, *Mylia verrucosa*, *Schistochilopsis cornuta*, *Tritomaria exsecta*. Khab-79-4-18.

**Herbertus arcticus** (Inoue et Steere) Schliakov – 4, 3, 7 [1683–1750]. Humus, humus with plant debris, plant debris covering rocks in niches of rocky outcrops in tundra belt. With *Anthelia juratzkana*, *Bazzania denudata*, *B. tricrenata*, *Diplophyllum taxifolium*, *Doninia plicata*, *Frullania subarctica*, *Fuscocephalozia pleniceps*, *Lejeunea alaskana*, *Mesoptychia heterocolpos*, *Plagiochila porelloides*, *Ptilidium ciliare*, *Radula obtusiloba*, *Scapania crassiretis*, *Sphenolobus saxicola*, *Trilophozia quinqueidentata*. Khab-46-18-18, Khab-47-31-18 (under *Doninia plicata*), Khab-50-9-18.

**Jungermannia pumila** With. – (per., ant.); 40 [818]. Sandy soil covering N-NW-facing rocks along river in coniferous forest. With *Solenostoma obscurum*. Khab-80-6-18.

**Kurzia makinoana** (Steph.) Grolle – 29, 30 [1743–1782]. Humus, humus with plant debris covering rocks on steep slope covered with moist dwarf shrub-moss tundra, humus in rocky outcrop niches or under boulders in dwarf

shrub-lichen tundra. With *Calypogeia integristipula*, *Cephalozia bicuspidata*, *Diplophyllum taxifolium*, *Lophozia* cf. *ventricosa*, *Mylia taylorii*, *Sphenolobus minutus*, *Trilophozia quinquedentata*. Khab-69-6-18, Khab-69-28-18, Khab-70-16-18.

***Lejeunea alaskana* (R.M. Schust. et Steere) Inoue et Steere** – (per. – s); 3, 4, 29 [1743–1770]. Humus, humus with plant debris covering rocks, sometimes in their niches and crevices, clayish soil covering boulders and rocks in niches in tundra belt. In pure mats or with *Anthelia juratzkana*, *Barbilophozia barbata*, *Bazzania tricenata*, *Blepharostoma trichophyllum* s.l., *Diplophyllum taxifolium*, *Doninia plicata*, *Frullania subarctica*, *Fuscocephaloziaopsis pleniceps*, *Herbertus arcticus*, *Mesophychia heterocolpos*, *Metzgeria pubescens*, *Plagiochila porelloides*, *Preissia quadrata*, *Radula obtusiloba*, *Scapania crassiretis*, *Solenostoma* cf. *rossicum*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinquedentata*. Khab-46-10-18, Khab-47-12-18, Khab-69-23-18 (under *Bazzania tricenata*).

***Lejeunea japonica* Mitt.** – (per. – cc, ant. – cc); 37 [730]. Living *Alnus* and *Populus* trunks, died standing tree trunks in coniferous forest. With *Cololejeunea ornata*, *Frullania* sp., *Metzgeria lindbergii*, *M. pubescens*, *Porella vernicosa*, *Tritomaria exsecta*. Khab-77-29-18, Khab-77-30-18, Khab-77-31-18.

***Lepidozia reptans* (L.) Dumort.** – (per. – f); 19, 37, 41 [730–1225]. Rotten and decaying wood, *Betula* trunk, humus covering boulders in different types of coniferous forests. With *Anastrophyllum michauxii*, *Bazzania denudata*, *Blepharostoma trichophyllum* s.l., *Calypogeia integristipula*, *Fuscocephaloziaopsis leucantha*, *F. lunulifolia*, *Metacalypogeia cordifolia*, *Mylia verrucosa*, *Plagiochila* cf. *ovalifolia*, *Syzygiella autumnalis*, *Tritomaria exsecta*. Khab-60-19-18, Khab-77-15-18, Khab-77-18-18.

***Lioclaena subulata* (A. Evans) Schljakov** – (ant. – c, gemm. – cc); 23, 43 [929–1011]. Rotten wood in coniferous forest; humus with plant debris covering rocks along river in floodplain *Alnus* forest. In pure mats. Khab-64-2-18, Khab-83-2-18.

***Lophocolea cuspidata* (Nees) Limpr.** – (gemm. – f); 35, 37, 44 [626–730, 1427]. Covering vertical surface of boulder in niche in *Betula lanata* crooked forest; *Populus* root in coniferous forest; decaying wood in floodplain forest. In pure mats or with *Metzgeria lindbergii*, *Trilophozia quinquedentata*. Khab-75-3-18, Khab-77-35-18, Khab-84-8a-18.

***Lophocolea heterophylla* (Schrad.) Dumort.** – (per. – c, ant. – c, spor. – f); 22, 37, 42 [730–969]. Decaying wood, including decorticated decaying logs in coniferous forests. In pure mats or with *Aneura pinguis*, *Blepharostoma trichophyllum* s.l., *Fuscocephaloziaopsis lunulifolia*, *Mylia verrucosa*, *Nowellia curvifolia*, *Riccardia palmata*, *Tritomaria exsecta*. Khab-63-2-18, Khab-77-5-18, Khab-82-15-18 (under *Riccardia palmata*).

***Lophozia guttulata* (Lindb. et Arnell) A. Evans** – (per. – f, ant. – f, gemm. – s); 4, 15, 17, 19, 25 [1225–2000]. Humus with plant debris, humus covering boulders and rocks in niches, clayish soil in a hollow in swampy dwarf shrub–*Carex*–moss tundra, hanging plant debris in tundra belt; humus, rotten wood in *Pinus pumila* crooked forest; partly rotten logs in coniferous and *Betula lanata* crooked forests. With *Anastrophyllum michauxii*, *Calypogeia* cf. *orientalis*, *Cephalozia bicuspidata*, *Fuscocephaloziaopsis lunulifolia*, *F. leucantha*, *Mylia taylorii*, *M. verrucosa*, *Neoorthocaulis attenuatus*, *Pseudolophozia sudetica*, *Solenostoma pseudopyriflorum*, *Sphenolobus minutus*, *S. saxicola*, *Tritomaria exsecta*. Khab-47-50-18, Khab-57-19-18 (under *Mylia verrucosa*), Khab-60-35-18 (under *Cephalozia bicuspidata*).

***Lophozia lantratovae* Bakalin** – (per. – c, gemm. – c); 41, 44 [626–980]. Decaying wood in coniferous forest; sandy soil covering rotten wood, soil covering boulder near small pond, decaying wood in floodplain forest with coniferous trees admixture. With *Blepharostoma trichophyllum* s.l., *Cephalozia otaruensis*, *Lophozia* cf. *ventricosa*, *Mylia verrucosa*, *Pellia neesia-*

*na*, *Plagiochila* cf. *ovalifolia*, *Plectocolea ovalifolia*, *Solenostoma pseudopyriflorum*, *Tritomaria exsecta*. Khab-84-15-18, Khab-84-20-18.

***Lophozia longiflora* (Nees) Schiffn.** – (per. – f, ant. – s); 1, 4, 10, 11, 30, 32 [1673–2000]. Humus covering rocks and boulders in niches and in animal holes, humus with admixture of small stones and sand in niche in tundra belt; humus covering vertical surface of boulder in crooked forest belt. With *Bazzania tricenata*, *Calycularia laxa*, *Cephalozia bicuspidata*, *Mylia taylorii*, *Pseudolophozia sudetica*, *Scapania microdonta*, *S. parvifolia*, *Schistochilopsis incisa*, *Solenostoma rossicum*, *Sphenolobus minutus*, *S. saxicola*. Khab-47-55-18, Khab-53-46-18 (under *Schistochilopsis incisa*), Khab-70-14-18.

***Lophozia murmanica* Kaal.** – (gemm. – cc); 28 [1660]. Humus, humus with plant debris in snowbed habitat on SE-facing slope. Khab-68-29-18, Khab-68-33-18.

***Lophozia silvicola* H. Buch** – (per. – f, gemm. – c); 11, 14, 29, 34 [1496–2000]. Humus among mosses in small soil niche, humus covering rocks in tundra belt; humus covering boulder, humus-sandy soil covering boulder on animal path, bark of lying *Pinus pumila* trunk in *Pinus pumila* crooked forest. With *Calypogeia integristipula*, *Cephalozia* sp., *Mylia verrucosa*, *Neoorthocaulis attenuatus*, *Ptilidium ciliare*, *Scapania microdonta*, *Sphenolobus saxicola*. Khab-69-4-18.

***Lophozia silvicoloides* N. Kitag.** – (per. – s); 8, 11, 15, 34 [1465–2000]. Humus with plant debris covering rocks and plant debris in niches in tundra belt; humus with plant debris covering bolder in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; bark of lying *Pinus pumila* trunk, rotten wood in *Pinus pumila* crooked forest. With *Cephalozia arctogena*, *Neoorthocaulis attenuatus*, *Sphenolobus minutus*. Khab-54-27-18 (under *Neoorthocaulis attenuatus*), Khab-74-3a-18.

***Lophozia ventricosa* (Dicks.) Dumort.** – (per. – s, ant. – r); 8, 10, 11, 14, 15, 18, 20, 25, 27, 28, 30, 32, 34, 37, 38, 44 [626–2000]. Humus with plant debris in animal hole and stony soil with admixture of sand in snowbed habitats, humus with admixture of small stones and sand in a big niche under rocky block, humus and plant debris covering rocks and boulders in niches in tundra belt, humus on animal path and clayish soil in *Carex*–*Sphagnum* tundra, plant debris and humus with plant debris in hollows in swampy dwarf shrub–*Carex*–moss tundra; humus covering rocks in temporary mossy streambed in a contact zone with crooked forest belt; humus and humus-sandy soil covering boulder on animal path, decaying (including barked) and rotten wood, humus, plant debris in *Pinus pumila* crooked forest; soil covering boulder and rotten wood on banks of small streams, decaying wood in coniferous forest. With *Anastrophyllum michauxii*, *Bazzania denudata*, *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Calypogeia integristipula*, *C. muelleriana*, *Cephalozia bicuspidata*, *C. otaruensis*, *Diplophyllum taxifolium*, *Fuscocephaloziaopsis leucantha*, *F. lunulifolia*, *Kurzia makinoana*, *Lophozia lantratovae*, *Mylia verrucosa*, *Neoorthocaulis attenuatus*, *Plagiochila* cf. *ovalifolia*, *Ptilidium ciliare*, *Scapania parvifolia*, *S. subalpina*, *Schistochilopsis cornuta*, *S. incisa*, *Schljakovia kuzneana*, *Solenostoma pseudopyriflorum*, *S. rossicum*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinquedentata*, *Tritomaria exsecta*. Khab-53-21-18, Khab-54-34-18.

***Lophoziaopsis excisa* (Dicks.) Konstant. et Vilnet** – (per., ant.); 4 [1750]. Plant debris covering boulder in tundra belt. With *Barbilophozia barbata*, *Tetralophozia setiformis*. Khab-47-34-18 (under *Tetralophozia setiformis*).

***Lophoziaopsis longidens* (Lindb.) Konstant. et Vilnet** – (gemm. – f); 16, 17, 41 [980–1348]. *Betula lanata* trunk bases in *Betula lanata* crooked forest; standing decaying tree trunk in coniferous forest. With *Barbilophozia barbata*, *Blepharostoma trichophyllum* s.l., *Ptilidium pulcherrimum*, *Syzygiella autumnalis*, *Tritomaria exsecta*. Khab-58-7-18, Khab-59-5-18, Khab-81-5-18 (under *Tritomaria exsecta*).

**Mannia gracilis** (F. Weber) D.B. Schill et D.G. Long – (ant., arch., spor.); 43 [929]. Sandy-clayish soil covering E-SE-facing rocks along river in floodplain *Alnus* forest. In pure mat. Khab-83-1-18.

**Marchantia latifolia** Gray – 36 [1024]. Humus among *Chrysosplenium* sp. in coniferous forest. In pure mat. Khab-76-1-18.

**Marsupella emarginata** (Ehrh.) Dumort. – (per. – f, ant. – f); 1, 2, 4, 7, 10, 11, 24, 27, 29, 30, 42 [929, 1046, 1673–2000]. Humus covering vertical surface of rocks and boulders, including those in niches in tundra and *Pinus pumila* crooked forest belt; humus covering vertical surface of rocky outcrops in coniferous forest. In pure mats or with *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum albicans*, *D. taxifolium*, *Gymnomitrium concinnatum*, *G. parvitetum*, *Metacalypogeia cordifolia*, *Pseudolophozia debiliformis*, *P. sudetica*, *Radula* sp., *Scapania crassiretis*, *S. microdonta*, *S. parvifolia*, *S. sphaerifera*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-44-8-18, Khab-54-31-18, Khab-82-12-18.

**Marsupella sprucei** (Limpr.) Bernet – (per., ant.); 27 [1676]. Bare humus soil in snowbed habitat in tundra belt. With *Nardia japonica*, *Pseudolophozia sudetica*. Khab-67-2-18.

**Mesoptychia heterocolpos** (Thed. ex Hartm.) L. Söderstr. et Vána – (gemm. – cc); 3, 8, 38, 41 [753, 980, 1616–1745]. Humus and clayish soil covering rocks in niches in tundra belt; sandy-clayish soil covering vertical surface of boulder in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; decaying wood, sandy-humus soil covering *Populus* root, soil covering vertical surface of boulder near small stream in coniferous forest. With *Barbilophozia barbata*, *Blepharostoma trichophyllum* s.l., *Frullania subarctica*, *Herbertus arcticus*, *Lejeunea alaskana*, *Plagiobhila* cf. *ovalifolia*, *P. porelloides*, *Preissia quadrata*, *Ptilidium ciliare*, *Radula obtusiloba*, *Scapania crassiretis*, *Solenostoma pseudopyriflorum*, *Sphenobolus saxicola*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-46-24-18, Khab-78-8-18 (under *Trilophozia quinqueidentata*), Khab-81-2-18.

**Metacalypogeia cordifolia** (Stephani) Inoue – 24, 37, 45 [268, 730–1046]. Decaying and rotten wood, humus covering vertical surface of rocky outcrops in coniferous forests; rotten wood in broadleaved deciduous valley forest. With *Bazzania denudata*, *B. trilobata*, *Blepharostoma trichophyllum* s.l., *Calypogeia integristipula*, *Diplophyllum taxifolium*, *Fuscocephalozia leucantha*, *F. lunulifolia*, *Lepidozia reptans*, *Marsupella emarginata*, *Mylia verrucosa*, *Plagiobhila ovalifolia*, *Trilophozia quinqueidentata*. Khab-65-3-18 (under *Diplophyllum taxifolium*), Khab-77-17-18, Khab-85-5-18.

**Metzgeria furcata** (L.) Corda – (per.); 19 [1225]. Thin decaying *Betula* trunk in coniferous forest. With *Metzgeria* cf. *lindbergii*, *Radula* cf. *obtusiloba*. Khab-60-16-18.

**Metzgeria lindbergii** Schffn. – (ant. – c, arch. – c); 7, 19, 35, 37, 44. [626–1683]. *Betula* root, boulders in niche and among grasses in *Betula lanata* crooked forest; *Picea* root, *Alnus* trunk, decaying wood with plant debris, vertical surface of rocks and boulders in different types of coniferous forests; soil covering boulder near small pond in floodplain forest. With *Bazzania denudata*, *B. tricenata*, *Blepharostoma trichophyllum* s.l., *Diplophyllum taxifolium*, *Frullania subarctica*, *Lejeunea japonica*, *Lophocolea cuspidata*, *Metzgeria pubescens*, *Plagiobhila* cf. *ovalifolia*, *Porella faurieri*, *Radula constricta*, *R. obtusiloba*, *Trilophozia quinqueidentata*. Khab-60-13-18, Khab-75-12-18, Khab-77-21-18.

**Metzgeria pubescens** (Schränk) Raddi – 3, 4, 37, 44, 45 [268, 626–730, 1745–1750]. Covering vertical surface of rocks and boulders in niches, over mosses, humus with plant debris covering vertical surface of boulder in niche, stony soil with plant debris in niche in tundra belt; humus with plant debris covering *Picea* trunk base, *Abies*, *Alnus*

and *Picea* trunks in different types of coniferous forests; trunk of deciduous tree in broadleaved deciduous valley forest. In pure mats or with *Bazzania denudata*, *Cololejeunea macounii*, *C. ornata*, *Frullania* cf. *subarctica*, *F. davurica*, *Lejeunea alaskana*, *L. japonica*, *Metzgeria lindbergii*, *Plagiobhila* cf. *porelloides*, *P. ovalifolia*, *Ptilidium pulcherrimum*, *Radula* cf. *obtusiloba*, *R. complanata*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-47-26-18, Khab-77-26-18, Khab-85-13-18.

**Mylia anomala** (Hook.) Gray – (gemm.); 28 [1600]. *Sphagnum* and its debris in *Carex–Sphagnum* tundra with small ponds surrounded by dwarf thickets of *Pinus pumila*, *Rhododendron aureum* and dwarf shrub-lichen tundra. With *Neoorthocaulis binsteadii*, *Schizakia kunzeana*. Khab-68-12-18 (under *Neoorthocaulis binsteadii*).

**Mylia taylorii** (Hook.) Gray – (per. – r, ant. – s, gemm. – r); 1, 4, 8, 11, 19, 29, 30, 34, 39 [798–2000]. Humus and humus with plant debris covering rocks and boulders in niches in tundra belt; plant debris covering boulder in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus with plant debris covering boulder in crooked forest belt; decaying log, plant debris covering decaying wood in different types of coniferous forests. In pure mats or with *Anastrophyllum michauxii*, *Bazzania paravidentula*, *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *Diplophyllum albicans*, *D. taxifolium*, *Fuscocephalozia leucantha*, *Gymnomitrium parvitetum*, *Kurzia makinoana*, *Lophozia* cf. *guttulata*, *Lophozia* cf. *longiflora*, *Mylia verrucosa*, *Scapania microdonta*, *Sphenobolus minutus*, *S. saxicola*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*. Khab-47-37-18, Khab-70-15-18, Khab-79-1-18.

**Mylia verrucosa** Lindb. – (per. – s, ant. – f); 11, 14, 15, 17, 19, 22, 34, 37, 39, 41, 42, 44 [626–1673, 2000]. Humus covering rocks in niche in dwarf shrub-lichen stony tundra; humus and humus-sandy soil covering boulders, bark of lying *Pinus pumila* trunk, barked decaying wood, rotten wood, humus and humus with plant debris in *Pinus pumila* crooked forest, partly rotten log in *Betula lanata* crooked forest; decaying and partly rotten logs, rotten wood, decaying standing tree trunk, humus covering boulder in coniferous forests; rotten wood in floodplain forest. In pure mats or with *Anastrophyllum michauxii*, *Aneura pinguis*, *Bazzania denudata*, *B. paravidentula*, *Blepharostoma trichophyllum* s.l., *Calypogeia integristipula*, *Cephalozia bicuspidata*, *C. otariensis*, *Fuscocephalozia leucantha*, *F. lunulifolia*, *Harpanthus scutatus*, *Lepidozia reptans*, *Lophocolea heterophylla*, *Lophozia* cf. *silvicola*, *L. cf. silvicoloides*, *L. cf. ventricosa*, *L. guttulata*, *L. lantratorae*, *Metacalypogeia cordifolia*, *Mylia taylorii*, *Neoorthocaulis attenuatus*, *Novellia curvifolia*, *Plagiobhila ovalifolia*, *Scapania apiculata*, *Schistochilopsis cornuta*, *Solenostoma pseudopyriflorum*, *Sphenobolus minutus*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-54-1-18, Khab-59-2-18, Khab-77-12-18.

**Nardia insecta** Lindb. – (per. – f, ant. – c, arch. – f); 3, 4, 25, 26, 28, 29, 31, 32 [1660–1861]. Sandy-clayish soil on bare ground spot of criogenic origin, sandy-clayish soil covering boulder in niche, humus in open crevice, humus and sandy soil covering rocks, clayish soil in a hollow in swampy dwarf shrub–*Carex*–moss tundra, humus covering rocks near snowbed habitat in tundra belt. With *Cephalozia bicuspidata*, *Gymnomitrium concinnatum*, *Pseudolophozia sudetica*, *Scapania parvifolia*, *Solenostoma pseudopyriflorum*, *S. rossicum*, *Sphenobolus minutus*. Khab-47-61-18, Khab-66-16-18, Khab-69-13-18.

**Nardia japonica** Steph. – 25, 27 [1676–1737]. Humus in swampy dwarf shrub–*Carex*–moss tundra, bare humus soil, humus covering boulder in snowbed habitat in tundra belt. With *Marsupella sprucei*, *Pseudolophozia debiliformis*, *P. sudetica*. Khab-66-2-18, Khab-67-6-18.

**Neoorthocaulis attenuatus** (Mart.) L. Söderstr., De Roo et Hedd. – (gemm. – c); 11, 15, 34 [1465–2000]. Humus with plant debris covering rocks in niche in dwarf shrub-

lichen stony tundra; barked decaying and living *Pinus pumila* trunks, decaying and rotten wood, plant debris, humus in *Pinus pumila* crooked forest. In pure mats or with *Anastrophyllum michauxii*, *Bazzania denudata*, *Blepharostoma trichophyllum* s.l., *Calyptogeia integristipula*, *Fuscocephalozia lunulifolia*, *Lophozia* cf. *silvicola*, *L.* cf. *ventricosa*, *L. guttulata*, *L. silvicoloides*, *Mylia verrucosa*, *Sphenolobus minutus*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-54-27-18, Khab-57-14-18, Khab-74-4-18.

**!!*Neoorthocaulis binsteadii* (Kaal.) L. Söderstr., De Roo et Hedd.** – 28 [1600]. Plant debris, *Sphagnum* and its debris in *Carex-Sphagnum* tundra with small ponds surrounded by dwarf thickets of *Pinus pumila*, *Rhododendron aureum* and dwarf shrub-lichen tundra. With *Biantheridium undulifolium*, *Mylia anomala*, *Scapania paludicola*, *Schliakovia kunzeana*. Khab-68-11a-18, Khab-68-12-18.

***Nowellia curvifolia* (Dicks.) Mitt.** – (per. – s); 19, 22, 37, 42 [730–1225]. Decorticated decaying logs, rotten wood in different types of coniferous forests. In pure mats or with *Anastrophyllum michauxii*, *Aneura pinguis*, *Bazzania denudata*, *Blepharostoma trichophyllum* s.l., *Cephalozia* cf. *bicuspidata*, *Fuscocephalozia leucantha*, *Lophocolea heterophylla*, *Mylia verrucosa*, *Riccardia palmata*, *Scapania apiculata*. Khab-63-1-18, Khab-77-9-18, Khab-82-15-18 (under *Riccardia palmata*).

***Pellia neesiana* (Gottsche) Limpr.** – (per. – f, ant. – f, arch. – f); 19, 39, 44 [626–1225]. Humus, soil covering rocks in coniferous forests; soil and soil covering boulder near small pond in floodplain forest. In pure mats or with *Blepharostoma* sp., *Cephalozia bicuspidata*, *Lophozia lantratorvae*, *Plagiochila* cf. *ovalifolia*, *Solenostoma pseudopyriflorum*, *Tritomaria exsecta*. Khab-60-1-18, Khab-79-5-18, Khab-84-18-18.

***Plagiochila ovalifolia* Mitt.** – (ant. – s); 17, 19, 37, 38, 40, 41, 44, 45 [268, 730–1347]. Humus with plant debris in *Betula lanata* crooked forest; rotten wood, humus covering boulder, humus with plant debris covering *Picea* trunk base, soil covering rocks in coniferous forests; barked decaying wood in broadleaved deciduous valley forest. In pure mats or with *Calyptogeia integristipula*, *Conocephalum salebrosum*, *Metacalyptogeia cordifolia*, *Metzgeria pubescens*, *Mylia verrucosa*. Khab-77-24-18, Khab-80-7-18, Khab-85-9-18.

***Plagiochila porelloides* (Torr. ex Nees) Lindenb.** – (per. – s, ant. – s); 3, 8, 19, 37, 41, 42, 43 [730–1745]. Humus with plant debris in a hole, humus covering rocks in tundra belt; humus in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; decaying standing tree trunk, *Populus* trunk, sandy soil covering *Abies* root and rocky blocks along river bank in coniferous forests; humus, humus with plant debris covering rocks along river in floodplain *Alnus* forest. In pure mats or with *Aneura pinguis*, *Frullania davurica*, *F. subarctica*, *Herbertus arcticus*, *Lejeunea alaskana*, *Mesoptychia heterocolpos*, *Porella gracillima*, *Ptilidium ciliare*, *Radula obtusiloba*, *Scapania crassiretis*, *S. rufidula*, *Schistochilopsis incisa*, *Solenostoma obscurum*, *Sphenolobus saxicola*, *Trilophozia quinqueidentata*. Khab-60-18-18, Khab-81-6-18, Khab-83-3-18.

***Plectocolea ovalifolia* (Amakawa) Bakalin et Vilnet** – (per.); 44 [626]. Decaying wood in floodplain forest. With *Lophozia lantratorvae*. Khab-84-7-18.

***Porella faurieri* (Steph.) S. Hatt.** – 35 [1427]. Covering vertical surface of boulders in *Betula lanata* crooked forest on SW-facing slope. With *Metzgeria lindbergii*. Khab-75-7a-18.

***Porella gracillima* Mitt.** – 37 [730]. *Populus* trunk in coniferous forest. With *Frullania davurica*, *Plagiochila porelloides*. Khab-77-33-18 (under *Plagiochila porelloides*).

***Porella vernicosa* Lindb.** – 37, 45 [268, 730]. *Populus* trunk in coniferous forest; *Betula* trunk in broadleaved deciduous valley forest. With *Cololejeunea ornata*, *Frullania* sp., *Lejeunea japonica*. Khab-77-23-18, Khab-85-12-18.

***Preissia quadrata* (Scop.) Nees** – (spor. – c); 3 [1745]. Humus in niche, clayish soil and clayish soil with plant debris covering rocks in niches in tundra belt. With *Anthelia juratzkana*, *Barbilophozia barbata*, *Blepharostoma* sp., *Diplophyllum taxifolium*, *Frullania subarctica*, *Lejeunea alaskana*, *Mesoptychia heterocolpos*, *Plagiochila* sp., *Radula* sp., *Scapania crassiretis*, *Solenostoma obscurum*. Khab-46-11-18, Khab-46-20-18, Khab-46-21-18.

***Pseudolophozia debiliformis* (R.M. Schust. et Damsh.) Konstant. et Vilnet** – (gemm. – cc); 10, 27, 28, 42 [929–1830]. Stony soil with admixture of sand, bare humus soil and humus in snowbed habitats in tundra belt; vertical surface of rocky blocks covered with *Pinus pumila* thickets along river bank in coniferous forest belt. In pure mats or with *Anthelia juratzkana*, *Marsupella emarginata*, *Nardia japonica*, *Scapania crassiretis*. Khab-53-15-18, Khab-67-3-18, Khab-68-28-18.

***Pseudolophozia sudetica* (Nees ex Huebener) Konstant. et Vilnet** – (per. – s, ant. – r, gemm. – cc); 4, 10, 11, 14, 25, 27, 29, 30, 32 [1496–2000]. Humus covering boulders and rocks in niches and in snowbed habitats, humus in crevices and animal holes, stony and sandy soil, bare humus soil, humus-sandy soil, sandy-clayish and clayish soil in a hollows in swampy areas in tundra belt; humus-sandy soil covering boulder on animal path in *Pinus pumila* crooked forest on a ridge. In pure mats or with *Anthelia juratzkana*, *Calycularia laxa*, *Diplophyllum albicans*, *D. taxifolium*, *Gymnomitrium commutatum*, *G. concinatum*, *G. parvitextum*, *Lophozia* cf. *guttulata*, *Lophozia* cf. *longiflora*, *Marsupella emarginata*, *M. sprucei*, *Nardia insecta*, *N. japonica*, *Scapania crassiretis*, *S. microdonta*, *S. parvifolia*, *Schistochilopsis incisa*, *Solenostoma pseudopyriflorum*, *S. rossicum*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinqueidentata*. Khab-53-44-18, Khab-66-19-18, Khab-72-5-18.

***Ptilidium californicum* (Austin) Underw. et O.F. Cook** – 14 [1496]. Living and dead branches of *Pinus pumila* on a top of the ridge covered with *Pinus pumila* crooked forest and spots of tundra. With *Ptilidium pulcherrimum*. Khab-56-8a-18.

***Ptilidium ciliare* (L.) Hampe** – (gemm. – s); 3, 6, 8, 10, 14, 25, 29 [1496–1870]. Soil, plant debris, sandy-clayish soil with plant debris, humus with plant debris in hollows in swampy dwarf shrub-moss-*Carex* tundra, humus covering rocks in niche in tundra belt; humus with plant debris covering boulder in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus and *Pinus pumila* needles in *Pinus pumila* crooked forest on a ridge. In pure mats or with *Biantheridium undulifolium*, *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *Frullania subarctica*, *Gymnocolea inflata*, *Herbertus arcticus*, *Lophozia* cf. *ventricosa*, *L. silvicola*, *Mesoptychia heterocolpos*, *Plagiochila porelloides*, *Radula obtusiloba*, *Scapania crassiretis*, *S. microdonta*, *S. mucronata*, *S. parvifolia*, *Schliakovia kunzeana*, *Sphenolobus saxicola*, *Trilophozia quinqueidentata*. Khab-46-1-18, Khab-51-5-18, Khab-69-2-18.

***Ptilidium pulcherrimum* (Weber) Vain.** – (per. – f); 4, 14, 15, 16, 17, 19, 34, 35, 37 [730, 1225–1820]. Died *Rhododendron aureum* trunk in niche in tundra belt; living and dead branches of *Pinus pumila*, living *Pinus pumila* trunk in *Pinus pumila* crooked forest, *Betula lanata* and *Acer* trunk bases, *Betula* root in *Betula lanata* crooked forest; thin decaying *Betula* and *Abies* trunks in coniferous forests. In pure mats or with *Barbilophozia barbata*, *Lophozia longidens*, *Metzgeria* cf. *furcata*, *M. pubescens*, *Ptilidium californicum*, *Radula complanata*, *Tritomaria exsecta*. Khab-47-51-18, Khab-60-14-18, Khab-77-27-18.

***Radula complanata* (L.) Dumort.** – (per. – cc, ant. – cc, arch. – s, spor. – f); 4, 19, 21, 41, 44 [626–1225, 1750]. Covering vertical surface of boulder and over mosses on

rocky ridge in tundra belt; *Betula* and *Abies* trunks, thin decaying *Betula* trunk, leaning decaying barked *Acer* trunk in coniferous forests. In pure mats or with *Cololejeunea macounii*, *Frullania takayuiensis*, *Metzgeria pubescens*, *Ptilidium pulcherrimum*, *Trilophozia quinquedentata*. Khab-60-22-18, Khab-62-1-18, Khab-81-7-18.

***Radula constricta* Steph.** – (arch. – f, gemm. – f); 27, 35 [1427, 1676]. Covering vertical surface of boulder in temporary stony streambed in snowbed habitat in tundra belt; covering boulders among grasses in *Betula lanata* crooked forest. In pure mats or with *Metzgeria lindbergii*, *Trilophozia quinquedentata*. Khab-67-7-18, Khab-75-4-18, Khab-75-6-18.

***Radula obtusiloba* Steph.** – 3, 4, 7, 19 [1225, 1683–1750]. Humus covering rocks and boulders in niches, humus with plant debris in a hole, covering vertical surface of rocks and rocky outcrops in tundra belt; thin decaying *Betula* trunk in coniferous forest. With *Blepharostoma* sp., *Diplophyllum taxifolium*, *Frullania subarctica*, *Fuscocephaloziaopsis pleniceps*, *Herbertus arcticus*, *Lejeunea alaskana*, *Mesoptychia heterocolpos*, *Metzgeria furcata*, *M. lindbergii*, *M. pubescens*, *Plagiobolus porelloides*, *Ptilidium ciliare*, *Scapania lingulata*, *S. crassiretis*, *Sphenobolus saxicola*, *Tritomaria exsecta*. Khab-46-13-18, Khab-47-23-18, Khab-50-7-18 (under *Metzgeria lindbergii*).

***Riccardia latifrons* (Lindb.) Lindb.** – (ant., arch.); 45 [268]. Rotten wood in broadleaved deciduous valley forest. In pure mat. Khab-85-2-18.

***Riccardia palmata* (Hedw.) Carruth.** – (ant. – f, arch. – c); 19, 37, 42, 44 [626–1225]. Decaying and rotten wood, including decorticated decaying logs in coniferous forests; decaying log over small stream in floodplain forest. With *Aneura pinguis*, *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *Lophocolea heterophylla*, *Nowellia curvifolia*, *Scapania carinthiaca*, *Syzygiella autumnalis*, *Tritomaria exsecta*. Khab-60-33-18, Khab-77-1-18, Khab-82-15-18.

***Scapania apiculata* Spruce** – (gemm.); 37 [730]. Rotten wood in coniferous forest. With *Bazzania denudata*, *Calypogeia suecica*, *Fuscocephaloziaopsis leucantha*, *Mylia verrucosa*, *Nowellia curvifolia*. Khab-77-16-18.

***Scapania carinthiaca* J.B. Jack ex Lindb.** – (per., gemm.); 44 [626]. Decaying log over a small stream in floodplain forest. With *Riccardia palmata*, *Syzygiella autumnalis*. Khab-84-16-18.

***Scapania crassiretis* Bryhn** – (per. – r, gemm. – c); 3, 4, 7, 8, 19, 20, 24, 38, 40, 42 [753–1770]. Humus in niches, humus covering rocks and boulders in niches, sandy-clayish and clayish soil covering rocks, plant debris covering boulders, humus with plant debris in a hole, clayish soil with plant debris in tundra belt; humus with plant debris covering vertical surface of boulder in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus covering decaying log on a stream bank, humus covering vertical surface of rocky outcrops, soil covering rocks and boulders along streams and rivers in coniferous forests. In pure mats or with *Anthelia juratzkana*, *Bazzania tricenata*, *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum taxifolium*, *Doninia plicata*, *Frullania subarctica*, *Fuscocephaloziaopsis pleniceps*, *Herbertus arcticus*, *Lejeunea alaskana*, *Marsupella emarginata*, *Mesoptychia heterocolpos*, *Plagiobolus porelloides*, *Preiszia quadrata*, *Pseudolophozia debiliformis*, *P. sudetica*, *Ptilidium ciliare*, *Radula obtusiloba*, *Scapania lingulata*, *S. parvifolia*, *Solenostoma* cf. *pseudopyriflorum*, *Sphenobolus minutus*, *S. saxicola*, *Trilophozia quinquedentata*, *Tritomaria exsecta*. Khab-51-13-18, Khab-65-4-18, Khab-82-7-18.

***Scapania irrigua* (Nees) Nees** – 13, 23 [1011, 1847]. Humus in lichen-dwarf shrub tundra; sandy-clayish soil in dry streambed in coniferous forest. In pure mats or with *Schizakovia kunzeana*. Khab-55-10-18, Khab-64-1-18.

***Scapania lingulata* H. Buch** – (gemm.); 4 [1750]. Humus covering boulder in open rock crevice in tundra belt. With *Radula obtusiloba*, *Scapania crassiretis*, *Tritomaria exsecta*. Khab-47-23-18.

***Scapania microdonta* (Mitt.) Müll. Frib.** – (gemm. – r); 1, 2, 7, 10, 11, 29, 30, 32, 33 [1673–2000]. Humus covering rocks and boulders in niches in dwarf shrub-lichen stony tundra, humus with admixture of small stones, plant debris and sand covering vertical surface of rocks in niche, soil wall in niche in tundra belt; humus covering boulders in niches on rock fields in *Pinus pumila* crooked forest belt. In pure mats or with *Bazzania tricenata*, *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum albicans*, *Doninia plicata*, *Gymnomitrium concinatum*, *G. parvitetum*, *Lophozia* cf. *longiflora*, *L. silvicola*, *Marsupella emarginata*, *Mylia taylorii*, *Pseudolophozia sudetica*, *Ptilidium ciliare*, *Scapania parvifolia*, *Sphenobolus minutus*, *S. saxicola*, *Tetralophozia setiformis*, *Trilophozia quinquedentata*. Khab-44-15-18, Khab-50-6-18, Khab-69-30-18.

***Scapania mucronata* H. Buch** – (per. – f, gemm. – cc); 4, 25 [1737–1750]. Humus between boulders, humus on rocky shelf in tundra belt, humus with plant debris in a hollow in swampy dwarf shrub–*Carex*–moss tundra. In pure mats or with *Cephalozia bicuspidata*, *Diplophyllum taxifolium*, *Ptilidium ciliare*, *Schizakovia kunzeana*, *Trilophozia quinquedentata*, *Tritomaria exsecta*. Khab-47-15-18, Khab-66-3-18.

***Scapania paludicola* Loeske et Müll. Frib.** – 28 [1600]. Plant debris, *Sphagnum* debris, clayish soil with plant debris in *Carex*–*Sphagnum* tundra with small ponds surrounded by dwarf thickets of *Pinus pumila*, *Rhododendron aureum* and dwarf shrub-lichen tundra. In pure mats or with *Biantheridium undulifolium*, *Cephalozia bicuspidata*, *Gymnocolea inflata*, *Neoorthocaulis binsteadii*, *Schizakovia kunzeana*. Khab-68-3-18, Khab-68-6-18.

***Scapania parvifolia* Warnst.** – (per. – f, gemm. – r); 2, 3, 4, 5, 11, 14, 20, 25, 29, 30, 31, 32, 34 [1132, 1496–2000]. Humus and humus with plant debris covering boulders in niches, humus in crevices, humus and plant debris covering rocks and rocky outcrops, soil walls in niches, soil between small stones and sandy-clayish soil on bare ground spots of cryogenic origin, sandy-clayish soil, sandy-clayish soil with plant debris in tundra belt, humus with plant debris in hollows and plant debris in swampy dwarf shrub–*Carex*–moss tundra; humus and humus-sandy soil covering boulders on animal path in *Pinus pumila* crooked forest; rotten wood on a bank of small stream in coniferous forest. In pure mats or with *Barbilophozia barbata*, *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Calypogeia integrastipula*, *Cephalozia bicuspidata*, *Cephalozia* cf. *varians*, *Diplophyllum albicans*, *D. taxifolium*, *Fuscocephaloziaopsis pleniceps*, *Lophozia* cf. *ventricosa*, *L. longiflora*, *Marsupella emarginata*, *Nardia insecta*, *Pseudolophozia sudetica*, *Ptilidium ciliare*, *Scapania crassiretis*, *S. microdonta*, *Schistochilopsis incisa*, *Schizakovia kunzeana*, *Solenostoma pseudopyriflorum*, *S. rossicum*, *Sphenobolus minutus*, *S. saxicola*, *Tritomaria exsecta*. Khab-46-3-18, Khab-54-9-18, Khab-70-25-18.

***Scapania rufidula* Warnst.** – (gemm. – f); 20, 40, 42 [818–1132]. Humus covering boulder, soil covering N-NW-facing rocks along river, sandy soil covering rocky blocks with *Pinus pumila* thickets along river bank in coniferous forest belt. In pure mats or with *Cephalozia bicuspidata*, *Plagiobolus porelloides*, *Scapania subalpina*, *Solenostoma obscurum*. Khab-61a-5-18, Khab-80-5-18, Khab-82-3-18.

® ***Scapania sphaerifera* H. Buch et Tuom.** – (gemm. – cc); 1, 30 [1673–1782]. Humus covering boulder in niche, fine soil covering upper surface of boulder in dwarf shrub-lichen tundra; covering vertical surface of boulder on a rock field surrounded by *Pinus pumila* crooked forest. In pure mats or with *Marsupella emarginata*, *Tetralophozia setiformis*. Khab-44-21-18, Khab-70-3-18.

***Scapania subalpina* (Nees ex Lindenb.) Dumort.** – (per. – s, ant. – s, gemm. – f); 9, 19, 38 [753–1530]. Sandy-clayish soil covering boulders in streambed surrounded by *Betula lanata* crooked forest; humus covering boulder, soil covering boulders near stream, submerged boulder in streambed in coniferous forests. In pure mats or with *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *Lophozia* cf. *ventricosa*, *Scapania rufidula*, *Solenostoma obscurum*. Khab-52-1-18, Khab-61a-6-18, Khab-78-9-18.

**!!*Scapania tundrae* (Arnell) H. Buch** – 28 [1600]. Plant debris, moss debris in *Carex–Sphagnum* tundra with small ponds surrounded by dwarf thickets of *Pinus pumila*, *Rhododendron aureum* and dwarf shrub-lichen tundra. With *Gymnocolea inflata*. Khab-68-4-18.

***Schistochilopsis cornuta* (Steph.) Konstant.** – (per. – f); 19, 37, 39 [730–1225]. Decaying, partly rotten and rotten wood in coniferous forests. In pure mats or with *Anastrophyllum michauxii*, *Calypogeia integristipula*, *Cephalozia bicuspidata*, *C. otariensis*, *Fuscocephalozia leucantha*, *F. lunulifolia*, *Harpanthus scutatus*, *Lophozia* cf. *ventricosa*, *Mylia verrucosa*, *Tritomaria exsecta*. Khab-60-31-18, Khab-77-3-18, Khab-79-4-18 (under *Harpanthus scutatus*).

***Schistochilopsis incisa* (Schr.) Konstant.** – (per. – s); 4, 7, 10, 11, 19, 29, 30, 32, 43 [929–1132, 1704–2000]. Humus covering boulders and rocks in niches and in rock crevices, clayish soil covering boulder in niche in tundra belt; rotten wood on a bank of small stream in coniferous forest; humus covering vertical surface of rocks along river in floodplain *Alnus* forest. In pure mats or with *Barbilophozia hatcheri*, *Calycularia laxa*, *Cephalozia bicuspidata*, *Fuscocephalozia leucantha*, *Lophozia longiflora*, *L. ventricosa*, *Plagiobhila porelloides*, *Pseudolophozia sudetica*, *Scapania parvifolia*, *Solenostoma rossicum*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-53-40-18, Khab-72-4-18, Khab-83-4-18.

***Schljakovia kunzeana* (Huebener) Konstant. et Vilnet** – (ant. – r, gemm. – s); 10, 13, 25, 28 [1600–1862]. Humus, humus with plant debris, plant debris, moss debris including *Sphagnum* debris, *Sphagnum*, sandy-clayish soil with plant debris and humus with plant debris in hollows in swampy dwarf shrub-moss-*Carex* and *Carex–Sphagnum* tundras. In pure mats or with *Biantheridium undulifolium*, *Calypogeia integristipula*, *C. muelleriana*, *Cephalozia bicuspidata*, *Gymnocolea inflata*, *Lophozia* cf. *ventricosa*, *Neoorthocaulis binsteadii*, *Ptilidium ciliare*, *Scapania irrigua*, *S. mucronata*, *S. paludicola*, *S. parvifolia*, *Sphenolobus minutus*. Khab-53-3-18, Khab-55-1-18, Khab-68-10-18.

***Solenostoma obscurum* (A. Evans) R.M. Schust.** – (per. – s, ant. – c, arch. – s); 3, 9, 22, 38, 40, 42, 44 [626–969, 1530–1745]. Clayish soil covering rocks, humus covering boulder in niche in tundra belt; sandy-clayish soil covering boulder in streambed in *Betula lanata* crooked forest; humus covering boulders near stream banks, sandy soil covering rocks along river in coniferous forests; sandy soil covering rotten wood in floodplain forest. In pure mats or with *Anthelia juratzkana*, *Blepharostoma trichophyllum* s.l., *Cephalozia bicuspidata*, *Frullania subarctica*, *Jungermannia pumila*, *Plagiobhila porelloides*, *Preissia quadrata*, *Scapania* cf. *crassiretis*, *S. rufidula*, *S. subalpina*, *Trilophozia quinqueidentata*. Khab-46-7-18, Khab-63-4-18, Khab-82-2-18.

***Solenostoma pseudopyriflorum* Bakalin et Vilnet** – (per. – cc, ant. – cc, arch. – s); 3, 4, 10, 15, 19, 25, 29, 38, 44 [626–1830]. Humus, sandy-clayish and clayish soil covering boulders in niches, clayish soil in a hollow in swampy dwarf shrub-*Carex*-moss tundra, humus covering rocks and hanging from those, soil between small stones on a bare ground spot of cryogenic origin, stony soil with admixture of sand in snowbed habitat in tundra belt; humus covering boulders in *Pinus pumila* and *Betula lanata* crooked

forests; humus, soil covering boulders near streams in coniferous forests; soil covering boulders near pond in floodplain forest. In pure mats or with *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Diplophyllum taxifolium*, *Lophozia* cf. *guttulata*, *L. cf. ventricosa*, *L. lantratorvae*, *Mesoptychia heterocolpos*, *Mylia verrucosa*, *Nardia insecta*, *Pellia neesiana*, *Plagiobhila* cf. *ovalifolia*, *Pseudolophozia sudetica*, *Scapania parvifolia*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-47-58-18, Khab-60-3-18, Khab-75-1-18.

***Solenostoma rossicum* Bakalin et Vilnet** – (per. – f, ant. – f, arch. – s); 3, 5, 10, 25, 28, 30 [1600–1908]. Sandy-clayish soil at the bottom of a bare ground spot of cryogenic origin, soil between stones and at the edge of a bare ground spot of cryogenic origin, sandy-clayish soil in hollows and covering boulders in swampy dwarf shrub-moss-*Carex* and *Carex–Sphagnum* tundras, humus with admixture of small stones and sand in niche of rocky outcrops in tundra belt. In pure mats or with *Anthelia juratzkana*, *Calycularia laxa*, *Cephalozia bicuspidata*, *Diplophyllum taxifolium*, *Gymnomitrium commutatum*, *Lophozia longiflora*, *L. ventricosa*, *Nardia insecta*, *Pseudolophozia sudetica*, *Scapania parvifolia*, *Schistochilopsis incisa*. Khab-48-3-18, Khab-53-10-18, Khab-70-24-18.

***Sphenolobus minutus* (Schreb.) Berggr.** – (per. – s, ant. – r, spor. – r, gemm. – r); 1, 4, 8, 10, 11, 19, 25, 27, 29, 30, 31, 32, 33, 34, 41, 42 [929–2000]. Humus and humus with plant debris covering rocks and boulders in niches, stony soil with admixture of sand, humus in animal holes and humus covering rocks in snowbed habitats, humus and humus with plant debris in swampy dwarf shrub-*Carex*-moss tundras, plant debris covering rocks in niches of rocks and rocky outcrops in tundra belt; sandy-clayish soil and humus, humus and plant debris covering boulders in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus covering boulders in niches on rock fields, *Pinus pumila* needles, rotten and decaying wood, bark of lying *Pinus pumila* trunk in *Pinus pumila* crooked forest belt; *Picea* trunk and vertical surface of boulder in coniferous forest. In pure mats or with *Bazzania paravidentula*, *B. tricenata*, *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Calypogeia integristipula*, *Cephalozia bicuspidata*, *Diplophyllum albicans*, *D. taxifolium*, *Doninia plicata*, *Fuscocephalozia leucantha*, *F. lunulifolia*, *Gymnomitrium concinnatum*, *G. parvitetum*, *Kurzia makinoana*, *Lejeunea alaskana*, *Lophozia guttulata*, *L. longiflora*, *L. silvicoloides*, *L. ventricosa*, *Mylia taylorii*, *M. verrucosa*, *Nardia insecta*, *Neoorthocaulis attenuatus*, *Pseudolophozia sudetica*, *Scapania crassiretis*, *S. microdonta*, *S. parvifolia*, *Schistochilopsis incisa*, *Schljakovia kunzeana*, *Sphenolobus saxicola*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-47-40-18, Khab-60-28-18, Khab-82-10-18.

***Sphenolobus saxicola* (Schr.) Steph.** – 1, 3, 4, 8, 11, 14, 29, 30, 33 [1496–2000]. Humus covering rocks and boulders in niches, soil among boulders and plants, humus in animal holes, plant debris, plant debris covering boulders in tundra belt, plant debris in *Carex–Sphagnum* tundras; humus in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus with plant debris covering boulders on rock fields, humus covering boulder on animal path in *Pinus pumila* crooked forest belt. In pure mats or with *Anthelia juratzkana*, *Bazzania tricenata*, *Calypogeia integristipula*, *Cephalozia bicuspidata*, *Diplophyllum albicans*, *Doninia plicata*, *Frullania subarctica*, *Fuscocephalozia pleniceps*, *Herbertus dicranus*, *Lejeunea alaskana*, *Lophozia guttulata*, *L. longiflora*, *L. silvicola*, *L. ventricosa*, *Mesoptychia heterocolpos*, *Mylia taylorii*, *Plagiobhila porelloides*, *Pseudolophozia sudetica*, *Ptilidium ciliare*, *Radula obtusiloba*, *Scapania crassiretis*, *S. microdonta*, *S. parvifolia*, *Schistochilopsis incisa*, *Sphenolobus minutus*, *Tetralophozia setiformis*, *Trilophozia quinqueidentata*, *Tritomaria exsecta*. Khab-44-17-18, Khab-54-28-18, Khab-68-17-18.

***Syzygiella autumnalis* (DC.) K. Feldberg, Vána, Hentschel et Heinrichs** – (per. – f, arch. – f); 16, 19, 37, 44

[626–1348]. Plant debris covering *Betula lanata* root, trunk base and trunk on a ridge in *Betula lanata* crooked forest belt; plant debris covering decaying wood, *Betula* trunk in different types of coniferous forests; decaying log over small stream in floodplain forest with coniferous trees admixture. In pure mats or with *Barbilophozia barbata*, *Blepharostoma trichophyllum* s.l., *Lepidozia reptans*, *Lophozia longidens*, *Riccardia palmata*, *Scapania carinthiaca*, *Tritomaria exsecta*. Khab-58-1-18, Khab-60-8-18, Khab-84-16-18 (under *Scapania carinthiaca*).

***Tetralophozia setiformis* (Ehrh.) Schljakov** – 1, 4, 11, 29, 30 [1673–2000]. Soil among other plants, humus, plant debris and humus with plant debris covering boulders in tundra belt; humus covering open boulders and those in niches on rock fields, once on lying *Pinus pumila* trunk in *Pinus pumila* crooked forest. In pure mats or with *Barbilophozia barbata*, *Bazzania tricenata*, *Douinia plicata*, *Lophozia excisa*, *Marsipella emarginata*, *Myliia taylorii*, *Scapania microdonta*, *Sphenolobus minutus*, *S. saxicola*, *Trilophozia quinquedentata*. Khab-44-1-18, Khab-54-32-18, Khab-70-29-18.

***Tetralophozia setiformis* (Ehrh.) Schljakov f. *alpina* (Hook.) Schljakov** – 1, 11, 29, 30 [1673–2000]. Humus and fine soil covering open rocks and boulders and those in niches in tundra belt; humus covering boulders in niches on rock fields in *Pinus pumila* crooked forest. With *Bazzania tricenata*, *Douinia plicata*, *Gymnomitrium commutatum*, *G. concinnatum*, *G. parvitextum*, *Scapania microdonta*, *S. sphaerijera*, *Sphenolobus saxicola*, *Trilophozia quinquedentata*. Khab-44-9-18 (under *Gymnomitrium parvitextum*), Khab-54-12-18 (under *Scapania microdonta*), Khab-70-9-18.

***Trilophozia quinquedentata* (Huds.) Bakalin** – (per. – s, ant. – r, gemm. – r); 1, 3, 4, 7, 8, 10, 11, 15, 19, 22, 24, 27, 29, 30, 33, 35, 38, 42, 44 [626–2000]. Vertical surface of rocks and boulders, humus and humus with plant debris covering rocks and boulders in niches, humus with plant debris hanging from rocks, over mosses, clayish soil, sandy-clayish soil, stony soil with plant debris in niches, stony-sandy soil and rocks in snowbed habitat, over lichen in tundra belt; clayish soil with plant debris in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; humus with plant debris covering boulders in niches including rock fields, rotten wood in *Pinus pumila* crooked forest, vertical surface of boulder in niche, boulder among grasses in open *Betula lanata* forest; humus with plant debris, humus covering vertical surface of rocky outcrops, soil covering boulder near small stream, humus covering rotten stump, sand covering rocky blocks with *Pinus pumila* thickets along river bank in coniferous forests; decaying wood in floodplain forest. In pure mats or with *Aneura pinguis*, *Anthelia juratzkana*, *Bazzania denudata*, *B. tricenata*, *Blepharostoma trichophyllum* s.l., *Calycularia laxa*, *Cololejeunea ornata*, *Diplophyllum albicans*, *D. taxifolium*, *Douinia plicata*, *Frullania subarctica*, *Fuscocephalozia lunulifolia*, *Gymnomitrium commutatum*, *G. concinnatum*, *G. parvitextum*, *Herbertus arcticus*, *Kurzia makinoana*, *Lejeunea alaskana*, *Lophocolea cuspidata*, *Lophozia* cf. *silvicoloides*, *L.* cf. *ventricosa*, *Marsipella emarginata*, *Mesoptychia heterocolpos*, *Metacalyptopogon cordifolia*, *Metzgeria lindbergii*, *M. pubescens*, *Myliia taylorii*, *M. verrucosa*, *Neoorthocaulis attenuatus*, *Plagiobolus poretoides*, *Pseudolophozia sudetica*, *Ptilidium ciliare*, *Radula complanata*, *R. constricta*, *Scapania crassiretis*, *S. microdonta*, *S. mucronata*, *Schistochilopsis incisa*, *Solenostoma obscurum*, *S. pseudopyriflorum*, *Sphenolobus minutus*, *S. saxicola*, *Tetralophozia setiformis*, *Tritomaria exsecta*. Khab-47-28-18, Khab-69-32-18, Khab-78-8-18.

***Tritomaria exsecta* (Schmidel ex Schrad.) Schiffn. ex Loeske** – (gemm. – cc); 2, 4, 7, 8, 10, 14, 15, 17, 19, 24, 29, 34, 37, 39, 41, 44, 45 [268, 626–1885]. Humus and humus with plant debris covering boulders in niches and crevices, stony and sandy soil among mosses in snowbed habitat, plant debris covering rocks and rocky outcrops in tundra belt; san-

dy-clayish soil and humus in temporary mossy streambed surrounded by tundra spots in a contact zone with crooked forest belt; rotten wood, barked decaying wood, bark of living lying *Pinus pumila* trunk, humus and humus-sandy soil covering boulder on animal path in *Pinus pumila* crooked forest, partly rotten logs in *Betula lanata* crooked forest; *Abies*, *Acer*, *Betula lanata* trunk bases, *Betula* and *Picea* trunks, decaying standing tree trunk, rotten, partly rotten and decaying wood, sandy-humus soil covering *Populus* root in coniferous forests; rotten wood and soil in floodplain forest; rotten wood in broadleaved deciduous valley forest. In pure mats or with *Anastrophyllum michauxii*, *Aneura pinguis*, *Bazzania denudata*, *B. tricenata*, *Blepharostoma trichophyllum* s.l., *Calyptopogon integrispinus*, *Cephalozia bicuspidata*, *C. otariensis*, *Cololejeunea macounii*, *Diplophyllum albicans*, *Frullania davurica*, *Fuscocephalozia leucantha*, *F. lunulifolia*, *Harpanthus scutatus*, *Lejeunea japonica*, *Lepidozia reptans*, *Lophocolea heterophylla*, *Lophozia* cf. *ventricosa*, *L. guttulata*, *L. lantratovae*, *Lophozia longidens*, *Marsipella emarginata*, *Mesoptychia heterocolpos*, *Metzgeria pubescens*, *Myliia verrucosa*, *Neoorthocaulis attenuatus*, *Pellia neesiana*, *Plagiobolus* cf. *ovalifolia*, *Ptilidium pulcherrimum*, *Radula obtusiloba*, *Riccardia palmata*, *Scapania lingulata*, *S. crassiretis*, *S. mucronata*, *S. parvifolia*, *Schistochilopsis cornuta*, *S. incisa*, *Solenostoma pseudopyriflorum*, *Sphenolobus minutus*, *S. saxicola*, *Syzygiella autumnalis*, *Trilophozia quinquedentata*. Khab-47-7-18, Khab-59-1-18, Khab-85-6-18.

## Data analysis

Table 3 summarizes floristic elements and area types of the compared floras. The floras are listed from south to north. Along with local floras, the tables include a generalized flora of the middle Sikhote-Alin (MSA) from Klimova & Bakalin (2025), excluding data on Mt. Ko provided in the present account.

As shown in Table 3, the first three floras (ZT, MSA, GLUKH) are dominated by arctic-boreal, boreal, and boreal-temperate latitudinal type species, which make up 62–67 % of each flora. In the ZT flora, the proportions of boreal, boreal-temperate, and temperate species are equal (15.5 % each, 20 taxa), so the leading group cannot be determined. This does not affect the overall pattern: in MSA and GLUKH, temperate species rank fourth, following boreal-temperate (Table 3). From OZ\_VY flora onward (including KO and TARD floras), the leading groups shift northward: arctic-mountain, arctic-boreal, and boreal taxa dominate, accounting for 72–77 % of these floras.

Longitudinal types possess three main patterns: (1) circumpolar and East Asian taxa dominate in all floras; (2) circumpolar taxa increase with latitude, while East Asian taxa decrease; (3) despite this shift, their combined share remains stable at about 72–76 % of all taxa.

Table 4 shows the Dice similarity index for the five floras compared (ZT, GLUKH, OZ\_VY, KO, TARD). To compare the distribution patterns of floras, we used scatterplots derived from PCoA, CA, and DCA (Fig. 2).

According to the Dice values in Table 4, the floras exhibit similarity levels ranging from high to very high (0.59907834 to 0.76150628). The KO flora shows the highest floristic similarity with OZ\_VY flora (0.73972603), followed by ZT flora (0.67555556). The similarity values of KO with the GLUKH flora (0.66094421) and with the TARD flora (0.66086957) is almost identical. In turn, the flora closest to TARD is KO (0.66086957), followed by OZ\_VY (0.63054187), indicating an asymmetry – TARD's closest

**Table 3.** The composition of the latitudinal elements and area types of liverwort floras involved in the comparison. The leading elements are given in bold.

| Area                                          | Zov Tigra  |             | Middle Sikhote-Alin |             | Glukhomanka |             | Ozyornoe–Vysokaya |             | Ko         |             | Tardoki-Yani |             |
|-----------------------------------------------|------------|-------------|---------------------|-------------|-------------|-------------|-------------------|-------------|------------|-------------|--------------|-------------|
|                                               | Nr of taxa | %           | Nr of taxa          | %           | Nr of taxa  | %           | Nr of taxa        | %           | Nr of taxa | %           | Nr of taxa   | %           |
| <b>Floristic elements (latitudinal types)</b> |            |             |                     |             |             |             |                   |             |            |             |              |             |
| Arctic-montane                                | 10         | 7.7         | 18                  | 11.3        | 6           | 5.4         | 12                | 12.5        | 25         | 20.3        | 30           | 28.0        |
| Arctic-boreal                                 | 42         | <b>32.6</b> | 53                  | <b>33.1</b> | 38          | <b>34.2</b> | 41                | <b>42.7</b> | 47         | <b>38.2</b> | 37           | <b>34.6</b> |
| Boreal                                        | 20         | <b>15.5</b> | 25                  | <b>15.6</b> | 20          | <b>18.0</b> | 17                | <b>17.7</b> | 17         | <b>13.8</b> | 15           | <b>14.0</b> |
| Boreal-temperate                              | 20         | <b>15.5</b> | 21                  | <b>13.1</b> | 16          | <b>14.4</b> | 10                | 10.4        | 15         | 12.2        | 8            | 7.5         |
| Temperate                                     | 20         | <b>15.5</b> | 19                  | 11.9        | 13          | 11.7        | 10                | 10.4        | 12         | 9.8         | 9            | 8.4         |
| Temperate-subtropical                         | 12         | 9.3         | 14                  | 8.8         | 11          | 9.9         | 3                 | 3.1         | 5          | 4.1         | 6            | 5.6         |
| Subtropical                                   | 1          | 0.8         | 3                   | 1.9         | 0           | 0.0         | 1                 | 1.0         | 0          | 0.0         | 0            | 0.0         |
| Tropical-subtropical                          | 1          | 0.8         | 0                   | 0.0         | 0           | 0.0         | 0                 | 0.0         | 0          | 0.0         | 0            | 0.0         |
| Multizone                                     | 3          | 2.3         | 7                   | 4.4         | 7           | 6.3         | 2                 | 2.1         | 2          | 1.6         | 2            | 1.9         |
| <b>Total</b>                                  | <b>129</b> | <b>100</b>  | <b>160</b>          | <b>100</b>  | <b>111</b>  | <b>100</b>  | <b>96</b>         | <b>100</b>  | <b>123</b> | <b>100</b>  | <b>107</b>   | <b>100</b>  |
| <b>Area type (longitudinal types)</b>         |            |             |                     |             |             |             |                   |             |            |             |              |             |
| Circumpolar                                   | 62         | <b>48.1</b> | 86                  | <b>53.8</b> | 58          | <b>52.3</b> | 58                | <b>60.4</b> | 76         | <b>61.8</b> | 65           | <b>60.7</b> |
| Asian                                         | 8          | 6.2         | 9                   | <b>5.6</b>  | 8           | <b>7.2</b>  | 5                 | 5.2         | 5          | 4.1         | 6            | 5.6         |
| Asian-American                                | 4          | 3.1         | 4                   | 2.5         | 3           | 2.7         | 3                 | 3.1         | 4          | 3.3         | 5            | 4.7         |
| East Asian                                    | 34         | <b>26.4</b> | 36                  | <b>22.5</b> | 23          | <b>20.7</b> | 14                | <b>14.6</b> | 17         | <b>13.8</b> | 12           | <b>11.2</b> |
| East Asian-American                           | 1          | 0.8         | 2                   | 1.3         | 1           | 0.9         | 1                 | 1.0         | 1          | 0.8         | 2            | 1.9         |
| Amphi-oceanic                                 | 10         | <b>7.8</b>  | 9                   | <b>5.6</b>  | 5           | 4.5         | 7                 | <b>7.3</b>  | 8          | <b>6.5</b>  | 7            | <b>6.5</b>  |
| Amphi-Atlantic                                | 0          | 0           | 0                   | 0.0         | 3           | 2.7         | 3                 | 3.1         | 0          | 0.0         | 0            | 0.0         |
| Amphi-Pacific                                 | 4          | 3.1         | 4                   | 2.5         | 0           | 0.0         | 0                 | 0.0         | 7          | 5.7         | 5            | 4.7         |
| European-American                             | 0          | 0           | 0                   | 0.0         | 2           | 1.8         | 2                 | 2.1         | 0          | 0.0         | 0            | 0.0         |
| Eurasian                                      | 2          | 1.6         | 2                   | 1.3         | 1           | 0.9         | 0                 | 0.0         | 1          | 0.8         | 1            | 0.9         |
| European                                      | 0          | 0.0         | 1                   | 0.6         | 0           | 0.0         | 0                 | 0.0         | 0          | 0.0         | 0            | 0.0         |
| Multi-area                                    | 4          | 3.1         | 7                   | 4.4         | 7           | 6.3         | 3                 | 3.1         | 3          | 2.4         | 3            | 2.8         |
| Disjunctive                                   | 0          | 0           | 0                   | 0           | 0           | 0           | 0                 | 0           | 1          | 0.8         | 1            | 0.9         |
| <b>Total</b>                                  | <b>129</b> | <b>100</b>  | <b>160</b>          | <b>100</b>  | <b>111</b>  | <b>100</b>  | <b>96</b>         | <b>100</b>  | <b>123</b> | <b>100</b>  | <b>107</b>   | <b>100</b>  |

affinity is with KO, whereas KO is more strongly linked to OZ\_VY and ZT. This asymmetric floristic relationship is well illustrated by the scatterplots in Figures 2a and 2b, where PCoA and CA produced broadly similar clustering of the floras (Figs 2a, b), whereas DCA highlighted a continuous floristic gradient (Fig. 2c).

The clustering observed in PCoA (based on Dice) and CA reflects high floristic similarity within groups of floras that share many common species; the Dice similarity index, being a binary metric, does not account for double absences (i.e., if a species is absent from both floras, it does not increase their similarity), and CA similarly disregards double absences. In contrast, the continuous gradient in DCA suggests underlying ecological or geographical gradients (in our case, broadly speaking, changes in latitude) that are not fully captured by binary similarity metrics such as Dice, nor can they be properly captured by CA, which compresses the middle of the gradient and stretches its ends, thereby creating artificial clusters – the so-called “arch effect”.

Figure 2c shows that TARD, KO, and OZ\_VY floras are quite similar (closely located along all three axes), and the composition and proportion of “northern” latitudinal groups of taxa (mostly arctic-montane) point to common ecological features – maximum elevation, altitudinal zonation, and likely mountain tundra development. By contrast, the ZT flora falls on the periphery of the diagram and differs markedly in the value of the third axis. Its taxonomic composition – enriched in more southern floristic fractions (taxa south of the boreal group) and having both weaker development and a smaller area of tundra communities – points to differences in ecological factors, even though ZT generally shares the same altitudinal and zonation characteristics as the three floras discussed above. The same can be said about GLUKH flora.

## DISCUSSION

The total species richness (123 species in the studied flora) slightly exceeds the average taxonomic diversity reported for local floras of the Middle Sikhote-Alin. By comparison, the floras of Mt. Glukhomanka and Ozyornoe Plateau–Mt. Vysokaya harbour 111 and 96 species, respectively.

The contribution of different floristic elements to species composition differs among the floras compared as described above. Table 3 shows a clear latitudinal trend: the proportion of “northern” taxa (Arctic-montane, Arctic-boreal, Boreal) increase with latitude, while relatively “southern” portion of the floristic spectrum (Boreal-temperate, Temperate, Temperate-subtropical) decrease. This is an expected pattern, consistent with results obtained in other regions for vascular plants (Tolmatchev 1974).

Notably, the combined MSA flora is distinctly similar to the flora of ZT in the southern Sikhote-Alin (Klimova et al. 2024). However, when floras of the highest peaks of the middle Sikhote-Alin (GLUKH, OZ\_VY) are examined separately (Klimova & Bakalin 2025), differences in element proportions (leading floristic groups, their percentage ratios according to Table 3) linked to both elevation and latitude become much more pronounced. We assume that combined MSA flora differ from GLUKH and OZ\_VY floras because “southern” species do not vanish in the middle Sikhote-Alin but may become rarer then southward. Thus, they enter the combined MSA flora (raising its southern share) but occur in fewer species in local floras. In other words, a conditionally northern occurs in all local floras, while an conditionally southern one occurs in only one. Smoothed frequencies in MSA flora hide real differences, which emerge when comparing individual local floras like GLUKH and OZ\_VY in Table 3.

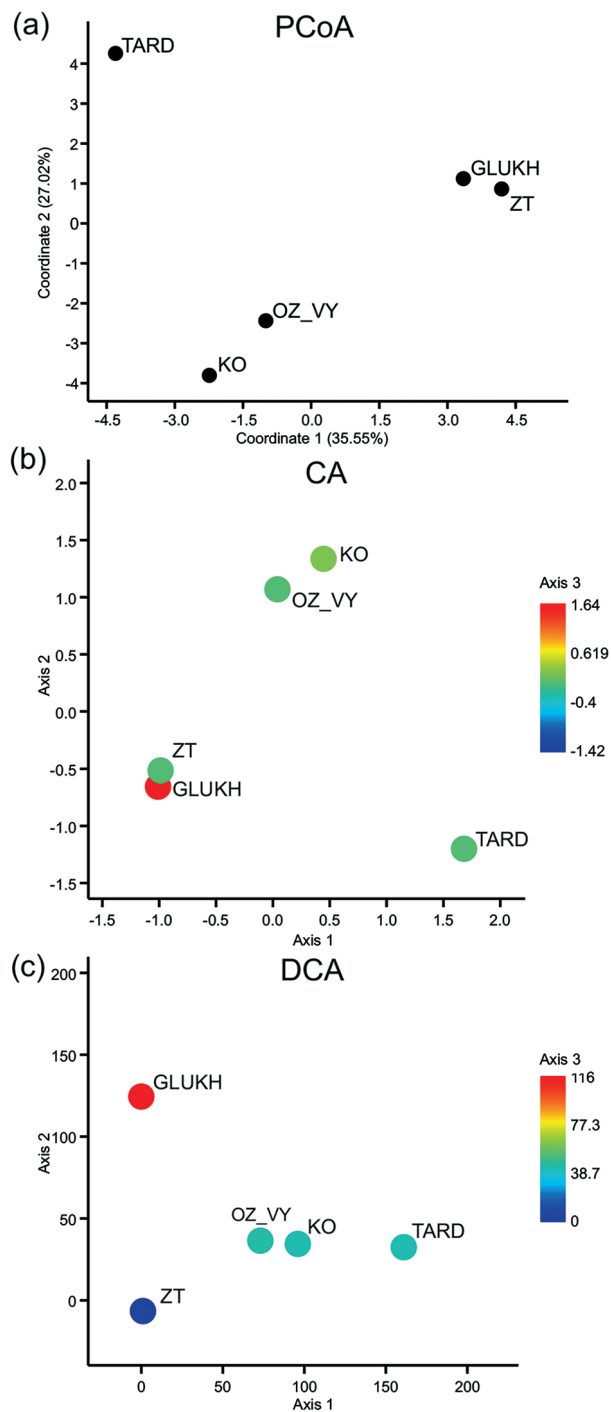


**Figure 2** Ordination scatterplots of floras based on PCoA (a), CA (b), and DCA (c). For the PCoA plot (a), the proportion of variance explained by each axis is indicated. The first two axes together explain >70% of the total variance, indicating a good representation of the true multi-dimensional distances between floras

**Table 4.** Dice similarity indices for the compared floras (abbreviations are given according Table 2). Color filling table cells ranging from red (the highest value) to blue (the lowest value).

|       | ZT     | GLUKH | OZ_VY | KO    | TARD |
|-------|--------|-------|-------|-------|------|
| ZT    | 1      |       |       |       |      |
| GLUKH | 0.7615 | 1     |       |       |      |
| OZ_VY | 0.676  | 0.670 | 1     |       |      |
| KO    | 0.675  | 0.661 | 0.740 | 1     |      |
| TARD  | 0.602  | 0.599 | 0.631 | 0.661 | 1    |

The Mt. Ko is traditionally treated as part of the middle Sikhote-Alin, as we have mentioned above. Our results suggest nuances to this placement rather than clearly confirming or refuting it. The analysis of floristic element proportions (Table 3) shows that Mt. Ko flora occupies an intermediate position between the OZ\_VY and TARD floras – the middle and the northern parts of the Sikhote-Alin. At the same time, the floras located further south (GLUKH and ZT) show different patterns of floristic element distribution by latitudinal type (Table 3). The Dice similarity index and multivariate methods (PCoA, CA) confirm this: Mt. Ko is near to OZ\_VY (maintaining its intermediate position) and roughly equally distant from GLUKH and TARD (Table 4, Figs 6a,b). Slightly higher similarity to ZT flora does not change the overall picture. The DCA results also well illustrate the identified patterns, highlighting the connections of the Mt. Ko flora with OZ\_VY and TARD through the “northern” part of the species spectrum and the intermediate position of Mt. Ko itself within this group of floras (Fig. 2c, Table 3). In any case, the liverwort flora of Mt. Ko objectively has much more northern features than other local floras of the middle Sikhote-Alin (Klimova & Bakalin 2025), and even more so than any flora from the southern part of this mountain region (Klimova et al. 2024).

Due to its intermediate position, Mt. Ko flora cannot be considered closest to the Tardoki-Yani flora, despite strong physical-geographical similarities: similar elevation range (500–600 to 2090 m a.s.l.), similar vegetation and habitats (Bakalin 2015), similar glacial history (Varfolomeeva 1957, Gotvansky & Makhinov 1983), and nearly identical climate (bioclimatic indices for the Tardoki-Yani Range are provided in Table S2). At the same time, Tardoki-Yani Range has been described as the largest southern refugium for arctic-montane flora in East Asia (Bakalin 2015). To determine whether Mt. Ko can be regarded as a refugium of the arctic-montane flora as well, we compare the floras of these two mountain areas in more detail.

Table 3 shows that the overall proportions of distribution types are very similar across two floras, including the three leading groups of floristic elements and area types, despite differences in total species numbers. Nevertheless, the number of boreal-temperate taxa (Table 3) differs notably: KO flora has nearly twice as many as TARD flora, likely due to its more southern position. Of the boreal-temperate species in TARD flora, 50% are shared with KO, while for KO flora, shared species make up less than one third. After a closer look we found no clear link between the occurrence of boreal-temperate species in the communities studied and the frequency of collector visits to particular vegetation types on Mt. Ko and the Tardoki-Yani Range.

The most striking difference is in arctic-montane species: Mt. Tardoki-Yani has significantly more (both in percentages and absolute numbers), which justifies its status as a refugium of the arctic-montane flora. A comparison of the arctic-montane species lists from both areas may provide further information: Table 5 lists all arctic-montane species from Mt. Ko and Tardoki-Yani Range; 15 are shared by both mountains, about half of the species in each area. Among these, five taxa were not recorded in the Sikhote-Alin south

of Mt. Ko: *Lejeunea alaskana*, *Nardia insecta*, *Gymnomitrium commutatum*, *G. concinnatum*, *G. corallioides*. *Lejeunea alaskana* was previously known from Tardoki-Yani Range (48°N) as one of its southernmost localities worldwide (Bakalin 2015). Our study now extends its range south to Mt. Ko (47°N). The nearest other localities are the Badzhal Range (50°N), 400 km northwest (Bakalin & Klimova 2023), and Mt. Balagan on Sakhalin (50°N), over 600 km northeast (Bakalin et al. 2019). Previous records of *Gymnomitrium commutatum* from Primorsky Territory (as *Marsupella commutata*, Gambaryan 1992, 2001) and GBIF records (Cris & Melechin 2019, Melchin et al. 2021) refer to *G. parvitetum* – a taxon reinstated to species rank by Mamontov et al. (2018). Both taxa occur in Japan and Korea (Mamontov et al. 2018). The other arctic-montane species shared by the two mountains also occur in the Sikhote-Alin south of 47°N (Klimova & Bakalin 2025, Klimova et al. 2024).

For three species – *Blepharostoma brevirete*, *Plagiochila arctica*, and *Radula prolifera* – Tardoki-Yani Range is still the southernmost known locality worldwide. We did not find them on Mt. Ko or Mt. Sputnik. Several times in the field, based on similar habitats and associated species, we thought we had collected *Radula prolifera* on Mt. Ko. But laboratory identification assigned all specimens to *Radula obtusiloba*, probably the North American subspecies with many small-leaved branches (ssp. *polyclada*).

*Lophozia savicziae* was also considered to have its northernmost locality on Tardoki-Yani Range until recently. However, according to Konstantinova & Vilnet (2025), it is an allopolyploid species definitely known only from Murmansk Region. The identity of our Tardoki-Yani specimens assigned to *Lophozia savicziae* remains unclear and requires molecular genetic confirmation.

We also did not find a number of other phytogeographically interesting taxa known from Tardoki-Yani Range: *Cryptocolea imbricata*, *Gymnomitrium alpinum*, *Marsupella boeckii*, *Scapania spitsbergensis*, *Pleurocladula albescens*, and *Sauteria alpina*.

There are at least three possible explanations for the absence of several arctic-montane species known from Tardoki-Yani Range in our collections from Mt. Ko. First – the flora was not fully studied. Many habitats remain unsurveyed; future expeditions could potentially increase the number of species, including phytogeographic rarities. Second – Mt. Ko is 200 km south of Tardoki-Yani Range. Glaciations and periglacial areas also occurred here (Gotvansky & Makhinov 1983), so the aforementioned arctic-montane species could have reached Mt. Ko but were later “washed out” from the flora due to population isolation from source areas – the same effect seen in island floras: loss of taxa without connectivity or recolonization sources (MacArthur & Wilson 1967, Riebesell 1982). Third – unsuitable habitats on Mt. Ko and Mt. Sputnik. For instance, too few cliffs and rock outcrops with the required slope exposure (northern/northeastern), the necessary rock composition (water extract pH), and the appropriate moisture conditions.

Conversely, several arctic-montane taxa found on Mt. Ko are absent from Tardoki-Yani Range and are new to the Sikhote-Alin. One example is the arctic-montane circumpolar *Marsupella sprucei*. In the Russian Far East, this species

**Table 5.** Arctic-montane taxa occurring on Mt. Ko (KO) and the Tardoki-Yani Range (TARD).

| Species name                                        | KO | TARD |
|-----------------------------------------------------|----|------|
| <b>Species shared by both mountains</b>             |    |      |
| <i>Anthelia juratzkana</i>                          | +  | +    |
| <i>Diplophyllum albicans</i>                        | +  | +    |
| <i>Frullania subarctica</i>                         | +  | +    |
| <i>Gymnomitrium commutatum</i>                      | +  | +    |
| <i>Gymnomitrium concinnatum</i>                     | +  | +    |
| <i>Gymnomitrium corallioides</i>                    | +  | +    |
| <i>Jungermannia pumila</i>                          | +  | +    |
| <i>Lejeunea alaskana</i>                            | +  | +    |
| <i>Nardia insecta</i>                               | +  | +    |
| <i>Preissia quadrata</i>                            | +  | +    |
| <i>Pseudolophozia sudetica</i>                      | +  | +    |
| <i>Scapania crassiretis</i>                         | +  | +    |
| <i>Scapania microdonta</i>                          | +  | +    |
| <i>Scapania sphaerifera</i>                         | +  | +    |
| <i>Tetralophozia setiformis</i>                     | +  | +    |
| <b>Species occurring only on Mt. Ko</b>             |    |      |
| <i>Cephalozia arctica</i>                           | +  | -    |
| <i>Cephalozia varians</i>                           | +  | -    |
| <i>Herbertus arcticus</i>                           | +  | -    |
| <i>Lophozia murmanica</i>                           | +  | -    |
| <i>Mannia gracilis</i>                              | +  | -    |
| <i>Marsupella sprucei</i>                           | +  | -    |
| <i>Neoorthocaulis binsteadii</i>                    | +  | -    |
| <i>Pseudolophozia debilisformis</i>                 | +  | -    |
| <i>Scapania rufidula</i>                            | +  | -    |
| <i>Scapania tundrae</i>                             | +  | -    |
| <b>Species occurring only on Tardoki-Yani Range</b> |    |      |
| <i>Blepharostoma brevirete</i>                      | -  | +    |
| <i>Cryptocolea imbricata</i>                        | -  | +    |
| <i>Gymnomitrium alpinum</i>                         | -  | +    |
| <i>Jungermannia exsertifolia</i>                    | -  | +    |
| <i>Lophozia “savicziae”</i>                         | -  | +    |
| <i>Marsupella boeckii</i>                           | -  | +    |
| <i>Peltolepis quadrata</i>                          | -  | +    |
| <i>Plagiochila arctica</i>                          | -  | +    |
| <i>Pleurocladula albescens</i>                      | -  | +    |
| <i>Protochilopsis grandiretis</i>                   | -  | +    |
| <i>Radula prolifera</i>                             | -  | +    |
| <i>Sauteria alpina</i>                              | -  | +    |
| <i>Scapania gymnostomophila</i>                     | -  | +    |
| <i>Scapania spitsbergensis</i>                      | -  | +    |
| <i>Solenostoma confertissimum</i>                   | -  | +    |

occurs in Magadan Territory (Bakalin et al. 2023) and across most insular areas (Commander Islands – Medny Island, Kamchatka, Sakhalin – Bakalin 2010, Bakalin 2012). On the mainland, however, it was previously known only from the western coast of the Sea of Okhotsk near Ayan Settlement at 56°N (Bakalin et al. 2021b). After a long gap, it was found on Mt. Ko (47°N).

The arctic-montane circumpolar *Neoorthocaulis binsteadii* is not rare in the Russian Far East north of 50° N. It is widespread in Chukotka, Kamchatka, Magadan Region, and in the insular part of the Far East it is known from Bering Island, Paramushir, and northern Sakhalin. In the mainland Russian Far East, the closest known localities to Mt. Sputnik are the Badzhal Range (400 km northwest) and the Yam-Alin Range (700 km northwest) (Cherdantseva et al. 1997). In Russia, its abundance varies from rare to common by region, occurring across arctic latitudes, northern European Russia, Siberia, and Yakutia (Konstantinova et al. 2009, Potemkin & Sofronova 2009). South of 50°N in East Asia, it is rare, and our find at 47°N is currently the southernmost known.

The arctic-montane circumpolar *Scapania tundrae* (which we verified using molecular genetic methods, unpublished) ranges from unique to rare across Russia (cf. Potemkin &

Sofronova 2009). It occurs throughout the Arctic – from European Russia to Chukotka, as well as northwestern European Russia, the Northern and Subpolar Urals, and southern Siberia (Konstantinova et al. 2009, Potemkin & Sofronova 2009). The species is relatively rare globally; localities south of 61°N are very rare. It is known from Spitsbergen, northern Europe, West and East Greenland, northwestern Canada, and Alaska (Schuster 1974, Damsholt 2002, 2013). In the Russian Far East, only a few localities are known: Chukotka, Kamchatka, Magadan Region (Bakalin 2010, Bakalin et al. 2023). One of the southernmost (49°N) is Kharmikotan Island (Koroteeva 2012). Thus, Mt. Sputnik (47°N) is currently the southernmost known locality of this species worldwide.

*Biantheridium undulifolium*, an arctic-boreal circumpolar species, is new to the Sikhote-Alin. It is listed in the latest edition of the Red Data Book of the Russian Federation as VU (Geltman 2024). The IUCN Red List global status of the species is VU (Vulnerable), in Europe – EN (Endangered) (The IUCN Red List, 2025). In Russia, the main localities are concentrated in the Asian part of the country in two bands: north of 60° N and south of 55° N (Geltman 2024), with 5-degree gap between them. Exceptions include several localities in the Polar and Southern Urals (Konstantinova et al. 2009, Konstantinova & Lapshina 2014, 2017, Baisheva et al. 2015). In the Russian Far East, the species is known from several localities: Wrangel Island and Chukotka (Afonina 2000), Magadan Region (Bakalin et al. 2023), northern Kamchatka Territory (Schljakov 1975, 1979), and northern Sakhalin (Bakalin 2012). Globally, *Biantheridium undulifolium* occurs in Western, Eastern, and Northern Europe, where it is rare; in North America it is known from Baffin Island and from NW, W, and S Greenland (Damsholt 2002, 2013, Paton 1999). In Asia, records exist from China (Heilongjiang, Liaoning, Jilin, Anhui, Tibet, Yunnan, Jiangxi, Zhejiang, Fujian) (Gao & Chang 1981, Chou 1985, Gao & Cao 2000, Gao 2003) and North Korea (Gao & Chang 1983a, 1983b, Kim & Hwang 1991). However, the identity of so-named plants from China and Korean Peninsula needs additional verification using molecular-genetic methods. According to Damsholt (2002:196), the species may be a Pleistocene relict.

Another species deserves special mention – *Calypogeia kamchatica*. Based on currently available data, we classify this recently described taxon (Bakalin et al. 2022) as arctic-boreal Amphi-Pacific. Most known localities are in the insular Russian Far East (Kamchatka, Iturup Isl., Kunashir Isl., 44–53°N), where it grows in wet, often thermal habitats (Bakalin et al. 2022). The only known occurrence of the species in mainland Asia to date is the Dzhugdzhur Range (western coast of the Sea of Okhotsk, 56° N) (Bakalin et al. 2022). Thus, the find of *Calypogeia kamchatica* on Mt. Ko is the second for mainland Asia and the first for the Sikhote-Alin. The identity of southern locations of this species need additional confirmation.

An analysis of floristic relationships using the Dice similarity index and various multivariate methods (PCoA, CA, DCA) revealed that the flora of Mt. Ko and its surrounding areas is closely related to both the floras of the

middle Sikhote-Alin and the northernmost highest peak in the Tardoki-Yani Range (Table 4). This indicates that Mt. Ko occupies an intermediate position between those. Additionally, it is part of a cluster that includes the northernmost floras studied, specifically the Mt. Vysokaya–Ozyornoe Plateau, the Mt. Ko– Mt. Sputnik massif, and the Tardoki-Yani Range.

Although the floras are distributed along a latitudinal gradient, their pairwise Dice similarities show an uneven density in the species composition space: two clusters of high similarity – (ZT, GLUKH) and (KO, OZ\_VY) – separated by a less dense region. PCoA and CA, by preserving local distances, transform these clusters into discrete groups. In contrast, DCA, through detrending and rescaling, reduces the influence of local clustering and reveals a continuous gradient, along which the floras become ordered primarily by latitude (from southern ZT to northern TARD), despite the anomalously high similarity between ZT and GLUKH.

Our review shows that Mt. Ko has historically possessed – and still possesses – the physiogeographic conditions to maintain arctic-montane species. Nevertheless, we found only eight arctic-montane taxa not recorded south of this area in the Sikhote-Alin. Of these, only three (*Marsipella sprucei*, *Neoorthocaulis binsteadii*, and *Scapania tundrae*) are absent from Tardoki-Yani Range, which is regarded as the largest refugium of the arctic-alpine flora in the Russian Far East (Bakalin 2015). Although the flora of Mt. Ko initially appeared to be more closely related to that of Tardoki-Yani Range, both qualitative and quantitative analyses suggest that it occupies an intermediate position between Tardoki-Yani (nearly 2° further north) and the Ozyornoe Plateau–Mt. Vysokaya floras (1° further south), with Mt. Ko showing stronger affinities to the latter.

## CONCLUSIONS

The currently known liverwort diversity of the Mt. Ko and its surroundings comprises 123 species, which exceeds the average number of species recorded for the studied local floras of the Middle and Northern Sikhote-Alin.

Based on floristic element and area type spectra, the flora may be classified as montane arctic-boreal circumpolar–East Asian. Compared to other Sikhote-Alin floras (Klimova et al. 2024, Klimova & Bakalin 2025), it has a higher proportion of arctic-montane taxa (not less than 20 % of the total species) and includes several arctic-montane species new to the Sikhote-Alin (*Marsipella sprucei*, *Neoorthocaulis binsteadii*, *Scapania tundrae*). Some species have their southernmost localities here – either in mainland Asia (*Gymnomitrium concinatum*, *G. corallioides*, *Marsipella sprucei*, *Nardia insecta*, *Neoorthocaulis binsteadii*) or worldwide (*Lejeunea alaskana*, *Scapania tundrae*). *Gymnomitrium commutatum* has not been found south of this area in the Sikhote-Alin, although it occurs further south in mainland Pacific Asia, e.g., in Korea (Bakalin et al. 2021a) and Mt. Changbai in China (Söderström 2000).

The results thus both support and challenge the idea of Mt. Ko as a southern refugium of the arctic-montane flora. On one hand, several diagnostic arctic-montane taxa are missing from the massif, and the total number of arc-

tic-montane species is lower than on Tardoki-Yani Range. On the other hand, we found several arctic-montane species that are absent even from Tardoki-Yani. It is important to note that the species lists of both floras are incomplete. However, we assume that the newly discovered taxa are unlikely to change the overall floristic pattern. Further surveys of the liverwort flora in the Ko–Sputnik–Ostraya massif, including yet unexplored areas (especially on lower elevations), could help clarify this matter.

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