

MOSSES OF THE SOUTH KAMCHATKA NATURE PARK (RUSSIAN FAR EAST)

МХИ ЮЖНО-КАМЧАТСКОГО ПРИРОДНОГО ПАРКА (РОССИЙСКИЙ ДАЛЬНИЙ ВОСТОК)

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Abstract

Moss flora of the South Kamchatka Nature Park is presented based on synthesis of the previously published data, revised collection of the Komarov Botanical Institute and rich recent collection by Bakalin and Klimova. The annotated list includes 222 species currently confirmed from the park, and it is supplemented by a list of erroneous and doubtful records. The flora includes such species rare for the Russia as *Anacamptodon kamchaticum*, *Andreaea nivalis*, *Brachydontium trichodes*, *Bryoxiphium norvegicum*, *Bryum salinum*, *Bucklandiella macounii*, *Climacium japonicum*, *Dicranum pacificum*, *Didymodon brachyphyllus*, *Dilutineuron corrugatum*, *Diobelonella palustris*, *Jochenia protuberans*, *Philonotis americana*, *Pohlia cardotii*, *Polytrichastrum sphaerothecium*, *Pseudoblindia falcata*, *Rhizomnium andrewsianum*, *R. nudum*, *Rhytidiadelphus pacificus*, *Schistidium tenuinerve*, *Sciurohypnum unicifolium*, *Sphagnum inexpectatum*. Several more widespread species occur here close their northern limits of distribution: *Atrichum flavisetum*, *Brachythecium buchananii*, *Claopodium pellucinerve*, *Myuroclada longiromea*, *Plagiomnium acutum*, while *Cinclidium subrotundum* occurs here near its southern limit. Especially interesting is the finding of *Philonotis* cf. *hastata*, which was probably brought with migratory birds from tropical or subtropical area.

Резюме

Представлен аннотированный список мхов Южно-Камчатского природного парка, в котором обобщены ранее опубликованные данные, результаты критической ревизии коллекций Ботанического института им. Комарова и результаты обработки коллекции, недавно собранной В.А. Бакалиным и К.Г. Климовой. Список включает 222 вида, нахождение которых в парке подтверждено; он также дополнен перечнем ошибочных и сомнительных указаний. Здесь были найдены многочисленные редкие в России виды: *Anacamptodon kamchaticum*, *Andreaea nivalis*, *Brachydontium trichodes*, *Bryoxiphium norvegicum*, *Bryum salinum*, *Bucklandiella macounii*, *Climacium japonicum*, *Dicranum pacificum*, *Didymodon brachyphyllus*, *Dilutineuron corrugatum*, *Diobelonella palustris*, *Jochenia protuberans*, *Philonotis americana*, *Pohlia cardotii*, *Polytrichastrum sphaerothecium*, *Pseudoblindia falcata*, *Rhizomnium andrewsianum*, *R. nudum*, *Rhytidiadelphus pacificus*, *Schistidium tenuinerve*, *Sciurohypnum unicifolium*, *Sphagnum inexpectatum*. Некоторые более широко распространенные виды находятся здесь у северной границы своего ареала: *Atrichum flavisetum*, *Brachythecium buchananii*, *Claopodium pellucinerve*, *Myuroclada longiromea*, *Plagiomnium acutum*; еще один вид, *Cinclidium subrotundum*, имеет здесь южную границу своего распространения. Особый интерес представляет находка *Philonotis* cf. *hastata*, возможно, занесенного перелетными птицами из тропических или субтропических регионов.

KEYWORDS: mosses; Kamchatka Peninsula; Northeast Asia; Pacific Ring of Fire; distribution patterns; nonvascular plants

INTRODUCTION

Kamchatka Peninsula is a vast territory, well known as an area with numerous volcanoes, geysers and spectacular mountains. Its bryophyte flora was summarized

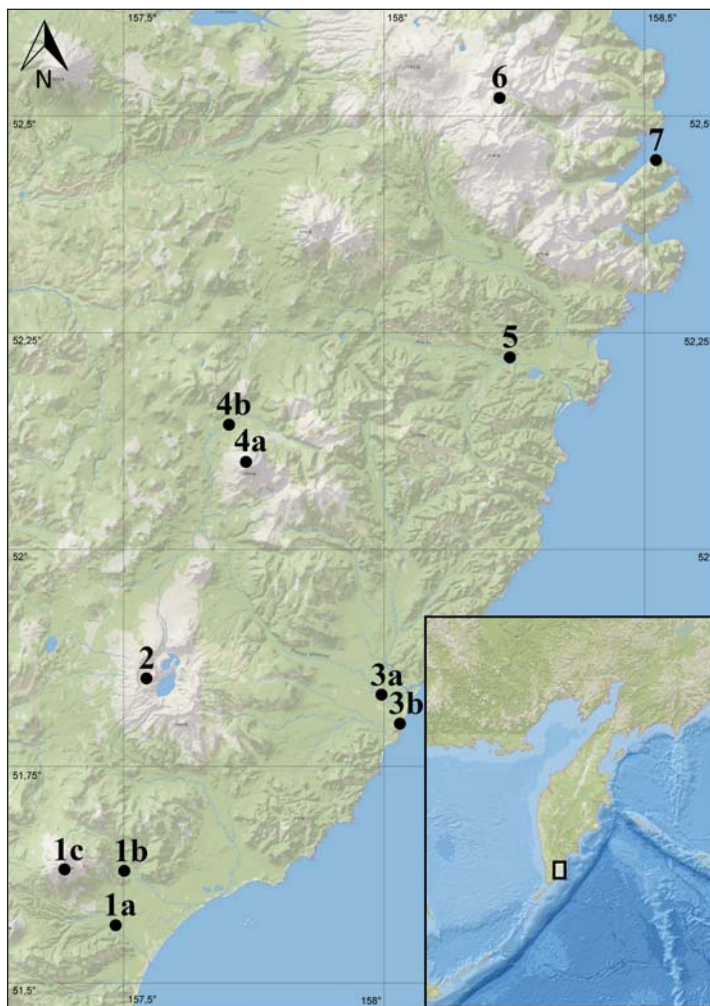
by Czernyadjeva (2012). Further studies added some more species, published recently in the check-list of the northern part of the Russian Far East (Afonina *et al.*, 2022). Definitely, additional exploration will continue

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- 1a. Il'inskaya River middle course, (51°30'N – 157°26'E), ~35–70 m a.s.l. Leg. V.A. Bakalin, 2021.
- 1b. Middle course of Zhyoltaya River valley (51°34'N – 157°27'E), ~110–220 m a.s.l. Leg. V.A. Bakalin, 2021.
- 1c. Eastern slope of Zheltovskaya Sopka Volcano (51°34'N – 157°20'E), ~1250–1900 m a.s.l. Leg. V.A. Bakalin, 2021.
2. Ksudach Mts. (Ksudach Volcano Caldera), (51°48'N – 157°30'E), ~600–900 m a.s.l. Leg. E. Hultén & R. Malaise, 1920–1922; V.A. Bakalin, 2021.
- 3a. Pravaya Khodutka River down course, (51°47'N – 157°57'E), ~15–25 m a.s.l. Leg. I.V. Czernyadjeva, 2002.
- 3b. Khodutka bay, (51°45'N – 158°00'E), 5 m a.s.l. Leg. I.V. Czernyadjeva, 2002.
- 4a. Vicinity of Khodutka Volcano (~52°04'N – 157°42'E) and Priyomysh Volcano (~52°06'N 157°39'E), ~1000–1800 m a.s.l. Leg. E. Hultén & R. Malaise, 1920–1922; V.A. Bakalin & K.G. Klimova, 2021.
- 4b. Vicinity Pravaya Khodutka River upper course (52°08'N – 157°39'E), ~250–350 m a.s.l., Leg. V.A. Bakalin & K.G. Klimova, 2021.
5. Asacha River lower course, (52°11'N – 158°12'), 15 m alt. Leg. V.A. Bakalin & K.G. Klimova, 2021.
6. Surroundings of Mutnovskaya Sopka Volcano (~52°30'N – 158°11'E), 900–1300 m a.s.l., Leg. O.A. Chernyagina & O. Kozalup, 2001; I.V. Czernyadjeva, 2002; V.A. Bakalin & K.G. Klimova, 2021.
7. Russian Bay (Akhomten) (~52°26'N – 158°30'E), ~10 m a.s.l. Leg. E. Hultén, R. Malaise, 1920–1922.

new records to the whole Kamchatka, as well to the areas that are at a special protection. By the latter reason, the present paper is aimed to get together the data on moss diversity of the South Kamchatka Nature Park, so to provide in future a solid ground for monitoring purposes.

South Kamchatka Nature Park is situated in the south-east part of Kamchatka, in the most humid and volcanically active part of the peninsula, facing regular volcanic eruptions accompanied by catastrophic ashfalls. The environment features and the climate of the area are described in details by Bakalin *et al.* (2022). The most important climatic features are: 1) small annual temperature amplitude, 2) wet and cool summers, 3) mild winters with temperatures rarely falling below -10°C in the coldest months and 4) high snow cover, which reaches here the highest values in Pacific Asia (snow cover in average is more than 2 meters high, not taking into account redistribution). The mean annual temperature at the lower altitudes is slightly above zero, while in the mountains above ca. 500 m elev. it is below zero. The amount of precipitation gradually increases from foothills to mountain peaks from ca. 900 to 1100 mm per year.

The formation of the new relief elements and the destruction of the existing ones is intense. The vegetation cover is strongly affected by severe episodic destruction, thermal springs production, and abundant volcanic ash. At lower elevations, *Alnus fruticosa* thickets are widespread, while mountain tundra and pyroclastic “deserts” prevail in mountain areas (Fig. 2).

The park territory had been explored in 1920–1922 by Swedish Kamchatka expedition, namely by the botanist E. Hultén and entomologist R. Malaise. Their collections were identified and published by Melin (1924) and Möller (1927). Later Persson (1970) published additional data on collections of Malaise, who visited Kamchatka also in 1924–1926, however working in the area outside of the territory of the South Kamchatka Nature Park. In 2001 O.A. Chernyagina & O. Kozalup collected bryophytes in Mutnovsky Volcano area; in 2002 I.V. Czernyadjeva studied mosses in Mutnovsky volcano area and lower course of Pravaya Khodutka River. These collections were identified by Czernyadjeva and published by Czernyadjeva *et al.* (2005) and Czernyadjeva (2010, 2012).

New data were collected by Bakalin and Klimova during the field expedition to study the biodiversity of South



Fig. 1. Habitat diversity in the South Kamchatka Nature Park./ A: N-facing slope of Priyomysh Volcano covered mostly with *Alnus fruticosa* thickets with strips of creeping pyroclastics (view from loc. 4b). B: N-facing slope of Priyomysh Volcano, strip of creeping pyroclastics surrounded by *Alnus fruticosa* thickets, ca. 600 m a.s.l. (loc. 4a). C: caldera of Mutnovskaya Sopka Volcano, ca. 1500 m a.s.l. (loc. 6). D: N-facing slope of Mutnovskaya Sopka Volcano, moss-*Eriophorum-Juncus* community, ca. 1100 m a.s.l. (loc. 6). E: NW-facing slope of Khodutka Volcano, dwarf shrub-lichen tundra with rocky outcrops, 1085 m a.s.l. (loc. 4a). F: *Sphagnum compactum* dominating patch, 1654 m a.s.l. (loc. 4a). G: N-facing slope of Mutnovskaya Sopka Volcano, mats of *Bryum schleicheri* along sulphur-rich stream, 1182 m a.s.l. (loc. 6). H: *Betula ermanii* forest in Pravaya Khodutka River upper course, ca. 240 m a.s.l. (loc. 3b). I: Medvezhie hot springs, 784 m a.s.l. (loc. 6). J: ibid., *Polytrichum jensenii* mats, note +35.2 C° within the tuft.

Kamchatka Nature Park that was organized by the Park Directorate of 'Volcanoes of Kamchatka'. Five areas were visited on July 15 to August 15, 2021 (cf. Fig. 1). Main subject of their study has been focused on liverwort diversity, but a collection of mosses was gathered as well. Altogether 150 specimens were collected during this trip. Therefore, although collected materials are incomplete, considering the large size of the park, these additions contribute to the materials available and, being combined with previous data mostly gathered by Czernyadjeva, provide a rather comprehensive starting point for the further monitoring of the park territory.

SPECIES LIST

In the following list the species name is followed by the references to the previous reports; the species frequency (approximately: 1–3 records – rare; 4–6 – sporadic; >6 – common); localities according to map in Fig. 1; and habitat type. Species new for the area have no literature citation, and for them one of the Bakalin's collection numbers is given. Finally, S+ indicates the sporophyte presence in Bakalin collections. Specimens of V.A. Bakalin & K.G. Klimova are deposited in VGBI and MHA (numbers K-6-(1-16)-2021 to K-89(1-9)-2021). Some specimens of I.V. Czernyadjeva, numbers # 1-2002 to 106-2002, are cited; these specimens are in LE.

- Abietinella abietina* (Hedw.) M. Fleisch. – Rare, 4a, b; on soil near thermal pools; in dwarf shrub-low grass tundra, K-37-2-21.
- Amblystegium serpens* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Common; 3a, b; on fallen decaying trunks and soil in *Betula ermanii* forests of grass type and in floodplain willow stands; on river bank; on rocks with soil layer. S+.
- Amphidium lapponicum* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Rare; 2, 4b; in cliff crevice near waterfall; on rocks with soil layer.
- Anacamptodon kamchaticum* Czernyadjeva – Czernyadjeva, 2010, 2012. Sporadic; 1b, 4a; on trunks in *Betula ermanii* forests (dwarf shrub-herb, tall-forb and floodplain types). S+.
- Andreaea alpestris* (Thed.) Schimp. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on stone in dwarf shrub tundra. S+.
- A. nivalis* Hook. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6, 7; moist rocks on stream and river banks. S+.
- A. rupestris* Hedw. – Sporadic; 1c; on boulders and in crevices of rock outcrops; on boulders in dwarf shrub-low grass tundra, K-13-7-21.
- Anomobryum concinatum* (Spruce) Lindb. – Czernyadjeva, 2012. 3b; in rock crevice, with *Bryoerythrophyllum ferruginascens*, #20-2002.
- Aquilonium adscendens* (Lindb.) Hedenäs, Schlesak & D. Quandt – Czernyadjeva, 2010, 2012. Sporadic; 3b; on stones, rocks with a layer of soil, in rocks crevices; at base of trunk in *Betula ermanii* forest with *Calamagrostis*.
- A. plicatum* (Lindb.) Hedenäs, Schlesak & D. Quandt – Persson, 1970; Czernyadjeva, 2010, 2012. Sporadic; 3b, 7; at base of trunk in *Betula ermanii* forest with *Calamagrostis*, on soil dwarf shrub tundra; on stones with a layer of fine soil.
- Arctoa blyttii* (Bruch & Schimp.) Loeske – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on soil on swampy meadow.
- A. fulvella* (Dicks.) Bruch & Schimp. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 6; on soil in dwarf shrub, *Salix* and *Rhododendron* tundra; on fine soil between rocks and on stones with a layer of soil on slopes and screes; in rocks crevices; on streams banks; on hydrothermal field. S+.
- A. starkei* (F. Weber & D. Mohr) Loeske – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 2, 6, 7; on soil on slope; on stones with a layer of soil, rocks and river banks; on stones in dwarf shrub tundra; on wet boulders near stream. S+. With *Arctoa fulvella*, *Pseudoblastia falcata*, *Hymenoloma crispula*, *etc.*
- Atrichum cf. flavisetum* Mitt. – Rare; 5; on moist humus near thermal pool, K-57-2-21. S+.
- Aulacomnium palustre* (Hedw.) Schwägr. – Czernyadjeva, 2010, 2012. Common; 3a, b, 4b, 5; on stream banks; in sedge-*Sphagnum*, dwarf shrub-sedge and thermal mires.
- A. turgidum* (Wahlenb.) Schwägr. – Rare; 4a; in rock crevice, K-49-10-21
- Bartramia ithyphilla* Brid. – Czernyadjeva, 2010, 2012. Sporadic; 3b, c; on stones with a layer of soil and in crevices of rocks. S+.
- B. pomiformis* Hedw. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, with *Eurhynchiastrum pulchellum*, *Pohlia cruda*, #26-2002. S+.
- Brachydontium trichodes* (F. Weber) Milde – Czernyadjeva, 2011, 2012. Rare; 6; on bare clayish soil on steep slope, # 89-2002. S+.
- Brachythecium albicans* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Rare; 3a; in rock crevice, # 5-2002.
- B. buchananii* (Hook.) A. Jaeger – Czernyadjeva, 2010, 2012. Rare; 3a; in rock crevice, # 26-2002.
- B. hultenii* (E.B. Bartram) Min Lin & Y.F. Wang – Czernyadjeva, 2012. Sporadic; 3a, b; on soil in alder thickets with *Calamagrostis* and in willow stands; on seaside meadow; on river bank; on stones with a layer of fine soil.
- B. irinae* Ignatov – Czernyadjeva, 2012. Rare; 3b, c; on stones with a layer of fine soil; on soil in *Betula ermanii* forest with *Calamagrostis*; on soil on coastal meadow.
- B. mildeanum* (Schimp.) Schimp. ex Milde – Czernyadjeva, 2010, 2012. Sporadic; 3a; on soil on banks of rivers and streams; in dwarf shrub-sedge-*Sphagnum* mire.
- B. rivulare* Schimp. – Czernyadjeva, 2010, 2012. Sporadic; 1b, 3a; on banks of rivers and streams.
- Bryoerythrophyllum ferruginascens* (Stirt.) Giacom. – Czernyadjeva, 2010, 2012. Rare; 2, 3b; in rocks crevices, with *Anomobryum concinatum*.
- Bryoxiphium norvegicum* (Brid.) Mitt. – Rare; 4a; in rock crevice, K-46-3-21.
- Bryum alpinum* J. Huds. ex With. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on stream bank; on bare soil on thermal field.
- B. amblyodon* Müll. Hal. – Czernyadjeva, 2010, 2012. Sporadic; 3a, b; on bare soil near rocks; on river banks; in rocks crevices. S+.
- B. creberrimum* Taylor – Czernyadjeva, 2010, 2012. Rare; 3b; on bare soil on river bank. S+.
- B. elegans* Nees. ex Brid. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Rare; 4b, 6; on stones with a layer of fine soil; on soil in *Salix-Rhododendron* tundra.

- B. intermedium* (Brid.) Blandow – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on thermal fields. S+.
- B. moravicum* Podp. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on thermal field.
- B. neodamense* Itzigs. – Czernyadjeva, 2010, 2012. Rare; 4b; on bare soil on river bank, # 25-2002.
- B. pallens* Sw. ex anon. – Czernyadjeva, 2010, 2012. Rare; 3b; on stream bank, # 12-2002. S+.
- B. pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 1b, 3a, 4b, 6; on stream bank; on thermal field; in dwarf shrub-sedge mire; on seaside forb meadow. S+.
- B. salinum* I. Hagen ex Limpr. – Czernyadjeva, 2010, 2012. Rare; 3a, b; on stones with a layer of fine soil; along sea-shore; on bare soil on river bank. S+.
- B. schleicheri* Schwägr. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 6; on banks of rivers and streams; on thermal fields; in alder thickets with *Calamagrostis*; with *Pohlia wahlenbergii*.
- B. turbinatum* (Hedw.) Turner – Czernyadjeva, 2012. Rare; 6; on river bank, with *Pohlia wahlenbergii*; # 97-2002.
- B. weigeli* Spreng. in Biehler. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6; on bare soil along cold and thermal streams; on thermal field.
- Bucklandiella macounii* (Kindb.) Bedn.-Ochyra & Ochyra subsp. *alpina* (E. Lawton) Bedn.-Ochyra & Ochyra – Rare; 2; on wet boulder near stream, K-27-9-21.
- B. microcarpa* (Hedw.) Bednarek-Ochyra & Ochyra – Rare; 4a; cliff in dwarf shrub-low grass tundra, K-45-4-21.
- B. sudetica* (Funck) Bednarek-Ochyra & Ochyra – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 1c, 6; on boulder in scoria field; on stones with a layer of soil on scree; on soil in dwarf shrub, dwarf shrub-low grass and sedge-willow tundra; on river banks.
- Calliergon cordifolium* (Hedw.) Kindb. – Möller, 1927; Czernyadjeva, 2010, 2012. Common; 1b, 2, 3a, b; on banks of rivers and streams; in dwarf shrub-sedge-*Sphagnum* and sedge mires; on wet soil in *Betula ermanii* forests of tall-forb and *Calamagrostis* types.
- C. giganteum* (Schimp.) Kindb. subsp. *sibiricum* Ignatova & Czernyadjeva – Rare; 3a; in hollow in sedge mire, #14-2002.
- C. richardsonii* (Mitt.) Kindb. – Rare; 3c, 5; in hollow in hummocky sedge mire, submerged in the small lake, # 9-2002.
- Calliergonella lindbergii* (Mitt.) Hedenäs – Möller, 1927; Rare; 2; no habitat data.
- Campylophyllopsis sommerfeltii* (Myrin) Ochyra – Rare; 3a; on fallen decaying trunk in floodplain willow stand with *Calamagrostis*; with *Sanionia uncinata*, # 22-2002. S+.
- Campylium protensum* (Brid.) Kindb. – Czernyadjeva, 2010, 2012. Rare; 3b; in dwarf shrub-sedge-*Sphagnum* and sedge mires; on forb seaside meadow.
- C. stellatum* (Hedw.) C.E.O. Jensen – Czernyadjeva, 2010, 2012. Sporadic; 1a, 1b, 4b; on pond bank; in wet hollows in swampy *Carex*-dwarf shrub communities; on wet soil in *Salix-Rhododendron* tundra.
- Ceratodon heterophyllus* Kindb. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; in *Salix-Rhododendron* tundra, # 93-2002.
- C. purpureus* (Hedw.) Brid. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 3a, b, 6, 7. On bare soil in various *Betula ermanii* forests, tundra, alder and *Pinus pumila* thickets; on stones with a layer of fine soil. S+.
- Cinclidium subrotundum* Lindb. – Czernyadjeva, 2010, 2012. Rare; 3b; in hollow of hummocky sedge mire, # 36-2002.
- Claopodium pellucinerve* (Mitt.) Besch. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, with *Eurhynchiastrum pulchellum*.
- Climacium dendroides* (Hedw.) F. Weber & D. Mohr – Möller, 1927; Czernyadjeva, 2010, 2012. Rare; 2, 3b; in hummocky dwarf shrub-sedge-*Sphagnum* mire; on stones with a layer of fine soil.
- C. japonicum* Lindb. – Rare; 1b; on bank of hot stream, K-6-10-21.
- Dichodontium pellucidum* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, #4-2002.
- Dicranella cerviculata* (Hedw.) Schimp. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Rare; 3b, 6; on bare soil on river bank and on thermal field. S+.
- D. crispa* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Rare; 3a, b; on bare soil on river banks. S+.
- D. subulata* (Hedw.) Schimp. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on bare clayish soil on steep slope; in wet willow tundra. S+.
- Dicranum cf. acutifolium* (Lindb. & Arnell) C.E.O. Jensen – Rare; 1c. Between stones on scoria field, K-11-5-21.
- D. bardunovii* Tubanova & Ignatova – Rare; 1b; on fallen decaying *Salix* trunk in *Salix schwerinii* forest, K-8-2-21.
- D. bonjeanii* De Not. – Czernyadjeva, 2010, 2012. Common; 1b, 3b; on pond bank; on soil in floodplain willow stands and *Pinus pumila* thickets with *Calamagrostis*; on forb sea-side meadows; on stones with a layer of fine soil.
- D. flexicaule* – Möller, 1927. Rare; 7; no habitat data.
- D. fragilifolium* Lindb. – Czernyadjeva, 2010, 2012. Rare; 3a, b; at base of tree trunks and on *Betula* trunks in *Betula ermanii* forests with *Calamagrostis* and forbs.
- D. fuscescens* Turner – Möller, 1927; Czernyadjeva, 2010, 2012. Common; 3a, b, 4a, 5, 7; at base of tree trunks and on decaying log in *Betula ermanii* forests with *Calamagrostis* and forbs; on soil in floodplain willow stands with forbs; in *Pinus pumila* thickets. S+.
- D. majus* Turner var. *majus* – Möller, 1927; Czernyadjeva, 2010, 2012. Sporadic; 3a, b, 4a, 7; at base of trunks and on decaying logs in *Betula ermanii* forests with *Calamagrostis* and forbs; on soil in floodplain willow stands with tall forbs. S+.
- D. majus* var. *orthophyllum* A. Braun ex Milde – Czernyadjeva, 2010, 2012. Rare; 3b; on hummocks in dwarf shrub-sedge-*Sphagnum* mire, # 28-2002.
- D. montanum* Hedw. – Czernyadjeva, 2010, 2012. Common; 3a, b; at base of tree trunks, on *Betula* trunks and decaying logs in *Betula ermanii* forests with *Calamagrostis*, shrubs and forbs.
- D. pacificum* Ignatova & Fedosov – Czernyadjeva, 2010, 2012. Rare; 1b, 3b; on *Betula* trunk bases in *Betula ermanii* forests; on alder bark in alder thickets with *Calamagrostis*.
- D. scoparium* Hedw. – Czernyadjeva, 2010, 2012. Rare; 3b; in seaside dwarf shrub tundra. S+.
- D. spadiceum* J.E. Zetterst. – Rare; 4a; in dwarf shrub-low grass tundra, K-39-5-21.
- Didymodon brachyphyllus* (Sullivan) R.H. Zander – Czernyadjeva, 2012. Rare; 3b; in rock crevice at sea shore, # 5-2002.
- Dilutineuron brevisetum* (Lindb.) Bednarek-Ochyra, Sawicki, Ochyra, Szczecińska & Plášek – Czernyadjeva, 2012. Sporadic; 6; on bare soil on steep slope; on stones on river and stream banks; on thermal field.

- D. corrugatum* (Bednarek-Ochyra) Bednarek-Ochyra, Sawicki, Ochyra, Szczecińska & Plášek. – Czernyadjeva, 2012. Rare; 6; on stone in dwarf shrub tundra, with *Bucklandiella sudetica* and *Niphotrichum canescens*, # 94-2002.
- D. fasciculare* (Hedw.) Bednarek-Ochyra, Sawicki, Ochyra, Szczecińska & Plášek – Czernyadjeva, 2010, 2012. Rare; 2, 3b; on dry cliffs in dwarf shrub-low grass tundra and on alpine heathland; on rocks.
- Diobelonella palustris* (Dicks.) Ochyra – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 1b, 2, 3b, 6, 7; on banks of cold and thermal streams; on bank of pond; on thermal fields; on moist clayish soil in snowbed.
- Distichium capillaceum* (Hedw.) Bruch & Schimp. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil. S+.
- D. inclinatum* (Hedw.) Bruch & Schimp. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, # 4-2002. S+.
- Ditrichum cylindricum* (Hedw.) Grout – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Rare; 3a, 6; on bare soil in *Betula ermanii* forest with forbs; on bare clayish soil. S+.
- D. heteromallum* (Hedw.) E. Britton – Czernyadjeva, 2010, 2012. Rare; 3b; on bare soil on river bank, # 25-2002. S+.
- D. pusillum* (Hedw.) Hampe – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Rare; 3b, 6; on bare soil on river bank and roadside. S+.
- Drepanocladus aduncus* (Hedw.) Warnst. – Czernyadjeva, 2010, 2012. Sporadic; 1b, 3b, 5; on moist soil along cold and hot streams; on river bank; in thermal mire.
- D. polygamus* (Schimp.) Hedenäs – Czernyadjeva, 2010, 2012. Rare; 3a, b; on seaside forb meadow; on stream bank; on bare soil in *Betula ermanii* forest. S+.
- D. sordidus* (Müll. Hal.) Hedenäs – 4b; in thermal pools near hot springs, on clayish soil on a bank of thermal pool, K-37-3-21.
- Encalypta raptocarpa* Schwägr. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, # 23-2002. S+.
- Eurhynchiastrum pulchellum* (Hedw.) Ignatov & Huttunen – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of soil and in rock crevices, with *Claopodium pellucinerve*, # 26-2002.
- Fissidens adianthoides* Hedw. – Czernyadjeva, 2010, 2012. Rare; 3b; on seaside forb meadow, # 3-2002.
- Grimmia alpestris* (F. Weber & D. Mohr) Schleich. ex Nees – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6; on stones along rivers and streams. S+.
- G. donniana* Sm. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, # 26-2002. S+.
- G. reflexidens* – Möller, 1927. Rare; 7; no habitat data.
- Helodium blandowii* (F. Weber & D. Mohr) Warnst. – Rare; 4b; on moist hummock in sedge-grass mire, K-34-5-21.
- Hygroamblystegium humile* (P. Beauv.) Vanderp., Goffinet & Hedenäs – Czernyadjeva, 2010, 2012. Rare; 3a; on decaying log in floodplain willow stand with *Calamagrostis*, # 22-2002.
- H. varium* (Hedw.) Mönk. – Rare; 3b; in crevices of rocks at seaside, # 5-2002.
- Hygrohypnella ochracea* (Turner ex Wilson) Ignatov & Ignatova – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 1b, 6; on stream and river banks.
- Hylocomiadelphus triquetrus* (Hedw.) Ochyra & Stebel – Czernyadjeva, 2010, 2012. Rare; 1b, 3b; on scoria in *Betula ermanii* forest; on stones with a layer of fine soil.
- Hylocomium splendens* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Common; 3a, b, 4a; on moist cliff; on stones with a layer of fine soil; on soil in *Betula ermanii* forest.
- Hymenoloma crispulum* (Hedw.) Ochyra – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3b, 4a, 6; on boulder in dwarf shrub-low grass tundra; on rock surfaces and on stones with a layer of fine soil; with *Arctoa fulvella* and *A. starkei*.
- Hypnum cupressiforme* Hedw. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil.
- Jochenia protuberans* (Brid.) Jan Kučera & Ignatov – Rare; 3a, b; at base of tree trunk in *Betula ermanii* forest of dwarf shrub & forb type; on decaying log in *Pinus pumila* thickets with *Calamagrostis*; 31-2002.
- Leptobryum pyriforme* (Hedw.) Wilson. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on bare clayish soil on steep slope; on thermal field.
- Leptodyctium riparium* (Hedw.) Warnst. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 1a, 6; in wet hollow on meadow with shrubby *Salix*; in stream.
- Lescuraea incurvata* (Hedw.) E. Lawton – Rare; 1b; on moist boulder on stream bank, K-9-9-21.
- Lewinskya sordida* (Sull. & Lesq.) F. Lara, Garilleti & Goffinet – Czernyadjeva, 2010, 2012. Sporadic; 3a; on *Betula* trunk in *Betula ermanii* forests with *Calamagrostis* and forbs; on tree trunk in floodplain willow stand with *Calamagrostis*. S+.
- Meesia triquetra* (Jolycl.) Ångstr. – Czernyadjeva, 2010, 2012. Rare; 3b; in hollow in hummocky sedge mire, # 36-2002.
- Mielichhoferia elongata* (Hoppe & Hornsch.) Nees & Hornsch. – Rare; 6; in cliff crevice, K-79-4-21.
- Mnium laevinerve* Cardot – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, # 26-2002.
- M. lycopodioides* Schwägr. – Czernyadjeva, 2010, 2012. Rare; 3a, b; on stones with a layer of fine soil; at base of trunk in floodplain willow stand with *Calamagrostis*.
- Myurella julacea* (Schwägr.) Schimp. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, with *Myurella sibirica*.
- M. sibirica* (Müll. Hal.) Reimers – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, with *Myurella julacea*, # 23-2002.
- Myuroclada longiromea* (Müll. Hal.) M.Li, Y.-F. Wang, Ignatov & Huttunen – Czernyadjeva, 2010, 2012. Rare; 3b, 5; on stones with a layer of fine soil; in thermal mire, # 4-2002.
- Niphotrichum canescens* (Hedw.) Bednarek-Ochyra & Ochyra – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 1b, 2, 4a, 6; on soil in alpine heathland, dwarf shrub, dwarf shrub-low grass and shrub tundra; pyroclastic deposits in *Betula ermanii* forest.
- N. ericoides* (Brid.) Bednarek-Ochyra et Ochyra – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on bare clayish soil on steep slope, # 89-2002.
- N. muticum* (Kindb.) Bednarek-Ochyra & Ochyra – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on fine soil between rocks on slope to river, # 96-2002.
- Oligotrichum hercynicum* (Hedw.) Lam. & DC. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 6; on bare soil on steep slope and roadside; on stream banks; in nival dwarf shrub tundra; in alder thickets. S+.
- O. parallelum* (Mitt.) Kindb. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3b, 6, 7; on bare soil on steep slope and roadside; on river and stream banks.

- Orthothecium strictum* Lorentz – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, # 4-2002.
- Paraleucobryum longifolium* (Hedw.) Loeske – Czernyadjeva, 2010, 2012. Rare; 3b; in rock crevice, # 26-2002. S+.
- Philonotis americana* Dism. – Rare; 5; in wet hollow near hot springs, K-57-19-21.
- P. cf. hastata* (Duby) Wijk & Margad. – Rare; 2; Ksudach Volcano Caldera, Klyuchevoye Lake area, the area with many solfatara at ridgeline surrounded by fine soil and cliffs. Open moist cliff crevice filled with fine soil in the steam. K-23-6-21. The species identity is discussed below.
- P. fontana* (Hedw.) Brid. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 1b, 4b, 5, 6, 7; on soil along cold and hot streams; on river banks; on soil on thermal fields; in nival community.
- P. tomentella* Molendo – Rare; 5; wet hollow around hot springs, K-57-12-21.
- P. yezoana* Besch & Cardot ex Cardot. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on soil and stones with a layer of soil in stream; near thermal springs; with *P. fontana* and *Pohlia wahlenbergii*.
- Plagiomnium acutum* (Lindb.) T.J. Kop. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones with a layer of fine soil, # 26-2002.
- P. cuspidatum* (Hedw.) T. J. Kop. – Czernyadjeva, 2010, 2012. Rare; 3b; at base of trunk in *Betula ermanii* forest with *Calamagrostis*, # 27-2002.
- P. ellipticum* (Brid.) T.J. Kop. – Czernyadjeva, 2010, 2012. Sporadic; 3a, b; on soil in *Betula ermanii* forests with *Calamagrostis* and on seaside forb meadow; on stream bank.
- P. medium* (Bruch & Schimp.) T.J. Kop. – Czernyadjeva, 2010, 2012. Sporadic; 1b, 3a, b; on stream banks; on fine soil between stones; in floodplain willow stands with *Calamagrostis*.
- Plagiothecium cavifolium* (Brid.) Z. Iwats. – Czernyadjeva, 2010, 2012. Sporadic; 3a, b; at base of trunk in floodplain willow stands with *Calamagrostis*; on river banks; on stones with a layer of fine soil. S+.
- P. denticulatum* (Hedw.) Schimp. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 1b, 3a, b, 6, 7; at bases of tree trunks, on decaying logs and on soil in *Betula ermanii* forests and alder thickets; on bare soil on river and stream banks. S+.
- P. latebricola* Bruch & Schimp. – Czernyadjeva, 2010, 2012. Rare; 3a; on decaying log in floodplain willow stand with *Calamagrostis*, # 22-2002. S+.
- P. rossicum* Ignatov & Ignatova – Rare; 1b; on base of *Betula* trunk in *Betula ermanii* forest, K-6-4-21.
- P. svalbardense* Frisvoll – Rare; 3a; on decaying log and soil in *Pinus pumila* thickets of grass type, # 31-2002.
- Platyhypnum duriusculum* (De Not.) Ochyra – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on rocks in streams. S+.
- P. molle* (Hedw.) Loeske – Rare; 1b; on rocks in rivers and streams.
- Pleurozium schreberi* (Brid.) Mitt. – Czernyadjeva, 2010, 2012. Sporadic; 3a, b; at bases of tree trunks and on soil in *Betula ermanii* forests; on stones with a layer of fine soil.
- Pogonatum dentatum* (Brid.) Brid. – Czernyadjeva, 2010, 2012. Rare; 3b, 6; on bare soil along roadside and on river bank; on white pumice.
- P. urnigerum* (Hedw.) P. Beauv – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 1b, 1c, 3a, b, 6; on bare soil on steep slopes; on soil between rocks and on stones with a layer of fine soil; on fallen decaying *Salix* trunk on stream bank; on thermal field.
- Pohlia andalusica* (Hoehnel) Broth. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on soil in dwarf shrub and *Salix* tundra.
- P. annotina* (Hedw.) Lindb. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 3a, b, 6; on bare soil on steep slopes and on roadsides, on river and stream banks; on thermal fields.
- P. cardotii* (Renauld) Broth. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6; on bare soil on stream banks; on fine soil between rocks of screes; with *Pohlia annotina*, *Polytrichastrum sexangulare*.
- P. cruda* (Hedw.) Lindb. – Möller, 1927; Czernyadjeva, 2010, 2012. Common; 3a, b, 7; on bare soil on steep slopes and on river banks; on seaside meadow; at base of trunk in *Betula ermanii* forest; in crevices and on stones with a layer of fine soil. S+.
- P. drummondii* (Müll. Hal.) A.L. Andrews – Möller, 1927; Persson, 1970; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3b, 6, 7; in rock crevices; on bare soil in wet *Salix* tundra.
- P. filum* (Schimp.) Mårtensson – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 2, 6; on bare soil on stream and river banks; on steep slopes; on bare soil in *Salix* tundra; on swampy meadow; in cliff crevice in alpine heathland.
- P. ludwigii* (Spreng. ex Schwägr.) Broth. – Rare; 6; on wet boulders near streams, K-74-10-21.
- P. nutans* (Hedw.) Lindb. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 3a, b, 6, 7; on stream and river banks; on steep slopes; at base of trunks in *Betula ermanii* forests; on soil in *Salix* tundra; on thermal fields. S+.
- P. prolifera* (Kindb.) Lindb. ex Broth. – Persson, 1970; Czernyadjeva, 2010, 2012. Common; 3a, b, 7; on bare soil on steep slopes; on river banks; at base of trunks in *Betula ermanii* forests and floodplain willow stands with *Calamagrostis*; in rocks crevices. S+.
- P. wahlenbergii* (F. Weber & D. Mohr) A.L. Andrews – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 1b, 3a, b, 6; on stream and river banks; in *Salix* tundra; on seaside forb meadows; on thermal fields; in nival forb community.
- Polytrichastrum alpinum* (Hedw.) G.L. Sm. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 3a, b, 6, 7; on bare soil on roadsides and river banks; at base of trunks and on soil in *Betula ermanii* forests; in alder thickets; on stones with a layer of fine soil. S+.
- P. septentrionale* (Brid.) E.I. Ivanova, N.E. Bell & Ignatov – Rare; 4a; in cliff crevice on scoria field, K-43-6-21.
- P. sexangulare* (Floerke ex Brid.) G.L.Sm. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6; on stream banks; in dwarf shrub tundra; on screes. S+.
- P. sphaerothecium* (Besch.) J.-P. Frahm – Rare; 2; in cliff crevice on alpine heathland, K-31-19-21.
- Polytrichum commune* Hedw. – Möller, 1927. Sporadic; 5, 6, 7; no habitat data.
- P. longisetum* Sw. ex Brid. – Czernyadjeva, 2010, 2012. Rare; 3b; on bare soil on river bank, with *Polytrichastrum alpinum*, # 25-2002.
- P. jensenii* I. Hagen – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6; on clayish soil in thermal field.
- P. juniperinum* Hedw. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. rare; 4a, 6; in wet *Salix* tundra.
- P. piliferum* Hedw. – Möller, 1927; Czernyadjeva *et al.*, 2005;

- Czernyadjeva, 2010, 2012. Common; 3a, b, 4a, 6, 7; on bare soil on stream banks and steep slopes; on soil in dwarf shrub, dwarf shrub-low grass and *Salix* tundra; on swampy meadow; on fine soil between stones and on stones with a layer of fine soil.
- P. strictum* Brid. – Czernyadjeva, 2010, 2012. Rare; 3b; on hummocks in dwarf shrub-sedge-*Sphagnum* mire.
- Pseudoblindia falcata* (Hedw.) Fedosov, M. Stech & Ignatov – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Common; 6; on stones and soil on streams banks; on fine soil between stones on steep slopes and screes; in *Salix* tundra; on thermal field; with *Arctoa fulvella* and *A. starkei*.
- Pseudobryum cinclidioides* (Huebener) T.J. Kop. – Czernyadjeva, 2010, 2012. Sporadic; 3a, b; on river banks; in *Betula ermanii* forest with *Calamagrostis*; on dwarf shrub-sedge-*Sphagnum* mire.
- Pseudoleskeella nervosa* (Brid.) Nyholm – Czernyadjeva, 2010, 2012. Rare; 3b; on rocks near seaside.
- P. rupestris* (Berggr.) Hedenäs & L. Söderstr. – Rare; 1b; moist boulder along stream with *Schistidium* sp. K-9-10-21.
- Pterigynandrum filiforme* Hedw. – Czernyadjeva, 2010, 2012. Rare; 3b; on rock; on trunk in *Betula ermanii* forest with *Calamagrostis*.
- Ptilium crista-castrensis* (Hedw.) De Not. – Möller, 1927. Rare; 7; no habitat data.
- Pylaisia polyantha* (Hedw.) Schimp. – Czernyadjeva, 2010, 2012. Rare; 3b; on trunks in alder thickets with *Calamagrostis*. S+.
- Racomitrium lanuginosum* (Hedw.) Brid. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 2, 3b, 6; on stones with a layer of fine soil; in dwarf shrub tundra; in cliff crevice in alpine heathland.
- Rhizomnium andrewsianum* (Steere) T.J. Kop. – Rare; 4b; on stream bank, K-34-14-21.
- R. gracile* T.J. Kop. – Czernyadjeva, 2010, 2012. Rare; 3b; in sedge mire, # 10-2002.
- R. magnifolium* (Horik.) T.J. Kop. – Czernyadjeva, 2010, 2012. Rare; 3b; on stream bank; in sedge mire; at base of trunk in *Betula ermanii* forest with *Calamagrostis*.
- R. nudum* (E. Britton & R.S. Williams) T.J. Kop. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on slope, #101-2002.
- R. pseudopunctatum* (Bruch & Schimp.) T.J. Kop. – Czernyadjeva, 2010, 2012. Rare; 1a, 3b; in wet hollow in swampy *Carex*-dwarf shrub community; in dwarf shrub-sedge-*Sphagnum* mire.
- Rhodobryum roseum* (Hedw.) Limpr. – Czernyadjeva, 2010, 2012. Rare; 3b; on fine soil between rocks.
- Rhytidadelphus japonicus* (Reimes) T.J. Kop. – Rare; 3b; on stones with a layer of fine soil on seaside, # 4-2002.
- R. pacificus* Ignatov, Ignatova & Fedosov – Rare; 4b; on clayish soil in thermal pool near hot springs, K-37-1-21.
- R. squarrosus* (Hedw.) Warnst. – Möller, 1927; Czernyadjeva, 2010, 2012. Rare; 2, 3b; on stones with a layer of fine soil in grass and dwarf shrub community.
- Rhytidium rugosum* (Hedw.) Kindb. – Czernyadjeva, 2010, 2012. Rare; 2, 3b, 4a; on hummocks in hummocky tundra; in cliff crevice in dwarf shrub-low grass tundra; on stones with a layer of fine soil.
- Sanionia uncinata* (Hedw.) Loeske – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 1b, 3a, b, 4a, 6, 7, 1b, 4a; at base of trunk, on decaying log and soil in various *Betula ermanii* forests; in alder thickets; in low dwarf shrub-moss, grass-dwarf shrub, and *Salix* tundra.
- Sarmentypnum exannulatum* (Schimp.) Hedenäs – Czernyadjeva, 2010, 2012. Common; 3a, b, 4b; on stream bank; in wet hollows in sedge-*Sphagnum* and hummocky dwarf shrub-sedge-*Sphagnum* mires; in sedge swamp.
- S. sarmentosum* (Wahlenb.) Tuom. & T.J. Kop. – Möller, 1927; Czernyadjeva, 2010, 2012. Rare; 3b, 7; in wet hollow in hummocky sedge mire.
- Schistidium maritimum* (Sm. ex R. Scott) Bruch & Schimp. – Czernyadjeva, 2010, 2012. Rare; 3b; on stones and in crevices of seaside cliffs.
- S. papillosum* Culm. – Czernyadjeva, 2010, 2012. Rare; 3b; on rocks. S+.
- S. rivulare* (Brid.) Podp. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 1b, 6; on moist stones near streams and rivers. S+.
- S. tenuinerve* Ignatova & H.H. Blom – Czernyadjeva, 2012. Rare; 3b; on rock, # 2-2002. S+.
- Sciuro-hypnum plumosum* (Hedw.) Ignatov & Huttunen – Czernyadjeva, 2010, 2012. Rare; 2, 3b; on rock, in moist cliff crevice near waterfall.
- S. reflexum* (Starke) Ignatov & Huttunen – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Common; 3a, b, 6, 7; at bases of trunks, on decaying logs, rarely on soil in *Betula ermanii* forests, in floodplain willow stands, in *Pinus pumila* and alder thickets; on stones with a layer of fine soil. S+.
- S. starkei* (Brid.) Ignatov & Huttunen – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Rare; 3a, b; on decaying logs and soil in *Pinus pumila* thickets; on soil in alder thickets with *Rhododendron*. S+.
- S. unicifolium* (Broth. & Paris) Ochyra & Zarnowiec – Czernyadjeva, 2010, 2012. Rare; 2, 3c; on dry cliffs on stream bank; on rock.
- Scorpidium revolvens* (Sw. ex anon.) Rubers – Czernyadjeva, 2010, 2012. Sporadic; 1b, 3b; in wet hollows in hummocky sedge and dwarf shrub-sedge mires; in sedge-moss swamps; on banks of ponds.
- S. scorpioides* (Hedw.) Limpr. – Czernyadjeva, 2010, 2012. Sporadic; 3b, 5; in wet hollows of *Sphagnum*-sedge mesotrophic and dwarf shrub-sedge-*Sphagnum* mires; in sedge-moss swamps; on lake shore.
- Sphagnum angustifolium* (C.E.O. Jensen ex Russow) C.E.O. Jensen – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3a, b, 6; in dwarf shrub-sedge-*Sphagnum* and sedge-*Sphagnum* mires; on thermal fields.
- S. annulatum* H. Lindb. ex Warnst. – Czernyadjeva, 2010, 2012. Rare; 3b; in sedge-moss mire, # 29-2002.
- S. cf. capillifolium* (Ehrh.) Hedw. – Rare; 5; on hummock in *Sphagnum*-sedge mesotrophic mire, K-55-7-21.
- S. centrale* C.E.O. Jensen – Czernyadjeva, 2010, 2012. Rare; 3b; in dwarf shrub-sedge-*Sphagnum* mire, # 28-2002.
- S. compactum* Lam. & DC. – Czernyadjeva, 2010, 2012. Sporadic; 2, 3a, 4a, 6; in dwarf shrub-sedge-*Sphagnum* and hummocky sedge mires; on wet soil in low dwarf shrub-moss, hummocky and sedge-moss tundra; in moist cliff crevice on alpine heathland.
- S. divinum* Flatberg & Hassel – Czernyadjeva, 2012. Sporadic; 3a, b, 5; on hummocks in dwarf shrub-sedge-*Sphagnum* mires; in wet hollow near small pool in complex swampy massif.
- S. fallax* (H. Klinggr.) H. Klinggr. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Rare; 3a, 6; in dwarf shrub-sedge-*Sphagnum* and sedge-*Sphagnum* mires; on thermal field.

- S. fimbriatum* Wilson – Rare; 5, 6; in thermal mires and thermal streams; K-57-11-21.
- S. fuscum* (Schimp.) H. Klinggr. – Czernyadjeva, 2010, 2012. Rare; 3a, 5; on hummocks of dwarf shrub-sedge-*Sphagnum* mires; in *Sphagnum*-hummock in complex swampy massif.
- S. girgensohnii* Russow – Melin, 1924; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3a, b, 4a, 5, 6; on hummocks in dwarf shrub-sedge-*Sphagnum* mires; on thermal field; on moist cliff.
- S. inexpectatum* Flatberg – Czernyadjeva, 2010, 2012. Rare; 3a, b; on hummocks in dwarf shrub-sedge-*Sphagnum* mires.
- S. majus* (Russow) C.E.O. Jensen – Czernyadjeva, 2010, 2012. Rare; 3b; on stream bank, # 12-2002.
- S. mirum* Flatberg & Thingsgaard – Rare; 1b, 4b, 5; on bank of pond; in hollow and on hummocks in *Sphagnum*-sedge mesotrophic mires; K-34-4-21.
- S. cf. orientale* L.I. Savicz – Rare; 5; on hummock in mire; K-54-1-21.
- S. papillosum* Lindb. – Czernyadjeva, 2010, 2012. Sporadic; 3a, 5; on hummocks in hummocky dwarf shrub-sedge-*Sphagnum* mire; on soil in sedge mire; on hummocks in complex swampy massif.
- S. platyphyllum* (Lindb. ex Braithw.) Warnst. – Czernyadjeva, 2010, 2012. Sporadic; 3b; in sedge and sedge-moss swamps; in wet hollows in dwarf shrub-sedge-*Sphagnum* mires.
- S. riparium* Ångstr. – Melin, 1924; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on thermal field, # 87-2002.
- S. rubellum* Wilson – Czernyadjeva, 2010, 2012. Rare; 3a; in dwarf shrub-sedge-*Sphagnum* mire, # 20-2002.
- S. russowii* Warnst. – Melin, 1924; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3a, b, 4b, 6, 7; in dwarf shrub-sedge-*Sphagnum* mires; on moist hummock in sedge-grass mire; on thermal fields.
- S. squarrosum* Crome – Melin, 1924; Czernyadjeva, 2012. Sporadic; 1a, b, 4b, 5, 7; on bank of pond; in swampy *Carex*-dwarf shrub community; in sedge-grass and *Sphagnum*-sedge mesotrophic mires.
- S. subsecundum* Nees – Melin, 1924; Czernyadjeva, 2010, 2012. Rare; 3a, 7; in hollow in dwarf shrub-sedge-*Sphagnum* mire.
- S. teres* (Schimp.) Ångstr. – Melin, 1924; Czernyadjeva, 2012. Rare; 5, 7; in wet hollow in complex swampy massif.
- S. warnstorffii* Russow – Czernyadjeva, 2010, 2012. Sporadic; 3a, b; 5; in dwarf shrub-sedge-*Sphagnum* and sedge-*Sphagnum* mires; in sedge swamp; in wet hollows in complex swampy massif.
- Straminergon stramineum* (Dicks. ex Brid.) Hedenäs – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2010, 2012. Sporadic; 3b, 5, 6, 7; in sedge-*Sphagnum* mire; in wet hollows in complex swampy massif; in thermal mire and thermal field; on wet soil on slope.
- Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr – Czernyadjeva, 2010, 2012. Sporadic; 1c, 3b, 4a; on stones with a layer of fine soil; on scoria field; in cliff crevice in dwarf shrub-low grass tundra.
- Tetraplodon mnioides* (Hedw.) Bruch & Schimp. – Rare; 4a; in dwarf shrub-low grass tundra, K-39-4-21.
- T. urceolatus* (Hedw.) Bruch & Schimp. – Rare; 4a; in dwarf shrub-low grass tundra, K-39-3-21.
- Tomentypnum nitens* (Hedw.) Loeske – Czernyadjeva, 2010, 2012. Rare; 3b; in dwarf shrub-sedge-*Sphagnum* mires.
- Tortula leucostoma* (R. Br.) Hook. & Grev. – Czernyadjeva, 2010, 2012. Rare; 3b; on bare soil on steep slope to sea coast, # 15-2002. S+.
- T. mucronifolia* Schwägr. – Czernyadjeva, 2010, 2012. Rare; 3b; in rocks crevices, # 5-2002. S+.
- T. edentula* Ignatova & Ignatov:– Rare; 6; on cliff between white pumice deposits, K-72-1-21. S+.
- Trachycystis flagellaris* (Sull. & Lesq.) Lindb. – Czernyadjeva, 2010, 2012. Rare; 3a; at base of trunk in *Betula ermanii* forest with *Calamagrostis*, # 27-2002.
- Ulota intermedia* Schimp. – Rare; 3a; on trunk in *Betula ermanii* forest with forbs, # 33-2002. S+.
- U. drummondii* (Hook. & Grev.) Brid. – Czernyadjeva, 2010, 2012. Common; 1b, 3a, b; on tree trunks in *Betula ermanii* forests, alder thickets, floodplain willow and *Salix schwerinii* stands. S+.
- Warnstorfia fluitans* (Hedw.) Loeske. – Möller, 1927; Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Rare; 6; on thermal bank; on thermal field.
- W. pseudostraminea* (Müll. Hal.) Tuom. & T.J. Kop. – Czernyadjeva *et al.*, 2005; Czernyadjeva, 2012. Sporadic; 6; on soil and stones on banks of cold and hydrothermal streams; on thermal fields; in forb nival community.

EXCLUDED TAXA

- Anomobryum julaceum* (Schrad. ex P. Gaertn., B. May & Scherb.) Schimp. – Czernyadjeva, 2010. Reidentified to *A. concinnatum*.
- Sciuro-hypnum oedipodium* (Mitt.) Ignatov et Huttunen – Czernyadjeva *et al.*, 2005. Reidentified to *S. curtum*.
- Calliergon giganteum* (Schimp.) Kindb. – Möller H. 1927, Czernyadjeva, 2010, 2012. Reidentified to *C. giganteum* subsp. *sibiricum*.
- Calliergon megalophyllum* Mikut. – Czernyadjeva, 2010, 2012. Reidentified to *C. richardsonii*.
- Campylidium hispidulum* (Brid.) Ochyra – Czernyadjeva, 2010, 2012. Reidentified to *Campylophyllopsis sommerfeltii*.
- Ditrichum lineare* (Sw.) Lindb. – Czernyadjeva *et al.*, 2005; Reidentified to *D. pusillum*.
- Philonotis caespitosa* Jur. – Czernyadjeva, 2010. Reidentified to *P. fontana*.
- Plagiothecium laetum* Schimp. – Czernyadjeva, 2010; 2012. Reidentified to *Plagiothecium svalbardense*.
- Plagiothecium nemorale* (Mitt.) A. Jaeger – Möller, 1927, Persson, 1970. The species is absent in the flora of the northern Far East (Ignatov & Ignatova, 2020).
- Pohlia tundrae* A.J. Shaw – Czernyadjeva, 2010, 2012. Reidentified to *P. prolifera*.
- Rhytidiadelphus japonicus* (Reimes) T.J. Kop. var. *kamchaticus* Czernyadjeva et Ignatov – Czernyadjeva *et al.*, 2010. Reidentified to *Rhytidiadelphus japonicus*.
- Schistidium flaccidum* (De Not.) Ochyra. – Czernyadjeva, 2010. Reidentified to *Schistidium tenuinerve*.
- Schistidium maritimum* subsp. *piliferum* (I. Hagen) B. Bremer – Czernyadjeva, 2010, 2012. Reidentified to *S. maritimum*.
- Sphagnum magellanicum* Brid. – Czernyadjeva, 2010, 2012. Reidentified to *S. divinum*.
- Stereodon pallescens* (Hedw.) Mitt. – Czernyadjeva, 2010; 2012. Reidentified to *Jochenia protuberans*.
- Ulota crispa* (Hedw.) Brid. – Czernyadjeva, 2010; 2012. Reidentified to *U. intermedia*.

DISCUSSION

Moss flora of the South Kamchatka Nature Park currently includes 223 species, 30 being added from the recent collections. This list is unlikely complete, as an intentional work for the complete inventory of moss diver-

sity in this area has not been conducted. However, a sufficient number of rare species indicates that the core of the moss flora is revealed.

Among the rare moss species some are the widespread in the southern part of the Russian Far East but rare in Kamchatka because of its cooler climate. Among them are *Atrichum* cf. *flavisetum*, *Brachythecium buchananii*, *Claopodium pellucinerve*, *Climacium japonicum*, *Dicranum pacificum*, *Jochenia protuberans*, *Myuroclada longiramea*, *Plagiomnium acutum*, *Trachycystis flagellaris*. Most of them are confined in Kamchatka to southern and also warmer western coast. Being protected from the humid winds from the Pacific Ocean, the West of Kamchatka is the richest in terms of southern species. The South Kamchatka Nature Park is otherwise exposed to the ocean, and is relatively poor in species of this group. One species, *Tortula edentula*, described recently from South Kuril Islands (Ignatova & Ignatov, 2009) and later found in Commander Islands (Fedosov *et al.*, 2012), is new to Kamchatka. *Atrichum* cf. *flavisetum*, is likely new to Kamchatka, too, though a plant of this group found by V.E. Fedosov in Kronotsky State Reserve and reported as *A. undulatum* (Hedw.) P. Beauv. may be the same as ours (Sofronova *et al.*, 2016). That collection of Fedosov was sterile, precluding any exact identification, while the specimen collected by Bakalin & Klimova has erect capsules, synoicous inflorescences, leaves with rather high ventral lamellae, thus it is mostly consistent with *A. flavisetum*, but with many sporophyte being single, and only few were two per perichaetia (which contradicts *Atrichum flavisetum* s. str.). Considering a very difficult taxonomy of *Atrichum undulatum*-group in East Asia (Noguchi & Osada, 1961), where plants possess to several ploidy levels the exact placement is difficult. However plastid region rps4, which has few substitutions, allowing separation *Atrichum undulatum* from, in Kamchatkan plant is identical with *A. flavisetum* (Genbank accession number OQ053976). Another species, *Philonotis* cf. *hastata*, having mainly subtropical and tropical distribution, was never reported in Russia; its identity is commented in a separate chapter below.

The species with mainly northern distribution include *Andreaea nivalis*, *Brachydontium trichodes*, *Bryoxiphium norvegicum*, *Cinclidium subrotundum*, *Pseudoblindia falcata*, and *Rhizomnium andrewsianum*; they occur in the southern Kamchatka rather close near their southern limit (omitting from consideration very high mountains in low latitudes). Some of them are even not rare, e.g. *Andreaea nivalis*, despite this chionophilous species would hardly be expected at the latitude of London at the sea level: in UK it occurs only above 600 m in northern Scotland (Blockeel *et al.*, 2014).

Another phylogeographically interesting group of mosses is one composed by hyperoceanic species: all these species avoid the occurrence in inland continental environments. The group includes *Anacamptodon kamchaticum*, *Bucklandiella macounii*, *Diobelonella palustris*,

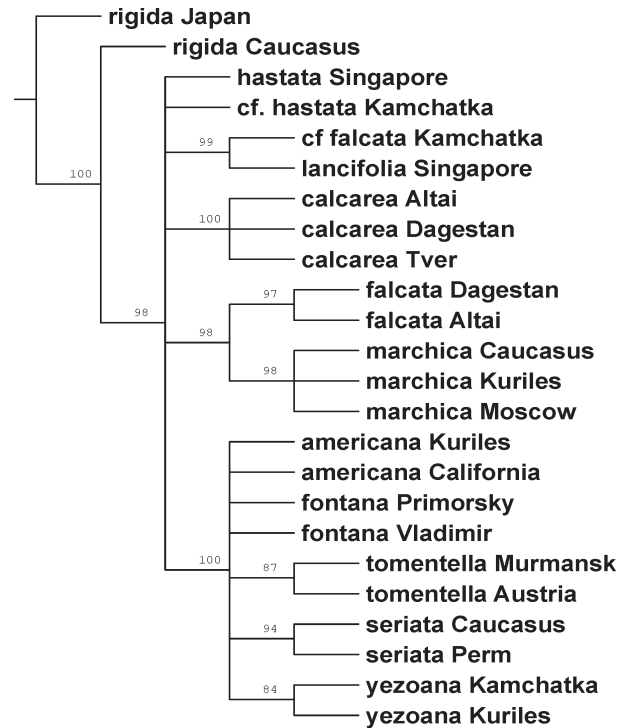


Fig. 3. Jackknife tree found in MP analysis of nuclear ITS1-2 sequences of *Philonotis*. Support values >50%, calculated by 1000 iterations in Nona, are indicated below branches. Ksudach plant is named cf. *hastata* Kamchatka.

The ITS sequence of Ksudach plant (Genbank accession number OQ023515) was added to the dataset under in Koponen *et al.* (2012) analysis of *Philonotis* (reduced for numerous accessions of *P. fontana* and *P. tomentella*), and aligned using Bioedit (Hall, 1999). Phylogenetic tree is built in performed in Nona (Goloboff, 1994) in the Winclada shell (Nixon, 1999), with bootstrap calculations for 1000 replications (N searches 100, starting trees per rep 100, max trees 100, do max).

Plastid *trnL*-F analysis results in unresolved tree, Ksudach plant (Genbank accession number OQ053975) obviously belong to group of plants with papillae in distal cell end, without further resolution.

Jochenia protuberans, *Philonotis americana*, *Pohlia cardotii*, *Rhizomnium nudum*, *Sciuro-hypnum unicifolium*. These species are not so much restricted by their latitudinal limits, but do not grow further inland, probably lacking an ability to tolerate long desiccation.

Within the park itself the particular attention has to be addressed to the lower course of Pravaya Khodutka River where the diversity of habitats is high; this territory houses relatively rare mire species (*Tomentypnum nitens*, *Sphagnum inexpectatum*, *Pseudobryum cinclidioides*) and epiphytic mosses (*Ulota* spp., *Pseudoleskeella*, *Pterigynandrum*, *Pylaisia*), that were not recorded in other areas where *Pinus pumila* thickets prevail. The diversity of saxicolous species is also outstanding in lower course of Pravaya Khodutka River; it includes both rare species (e.g. *Schistidium tenuinerve*) and not so rare in Kamchatka, but in the park recorded only here (*Schistidium maritimum*, *S. papillosum*).

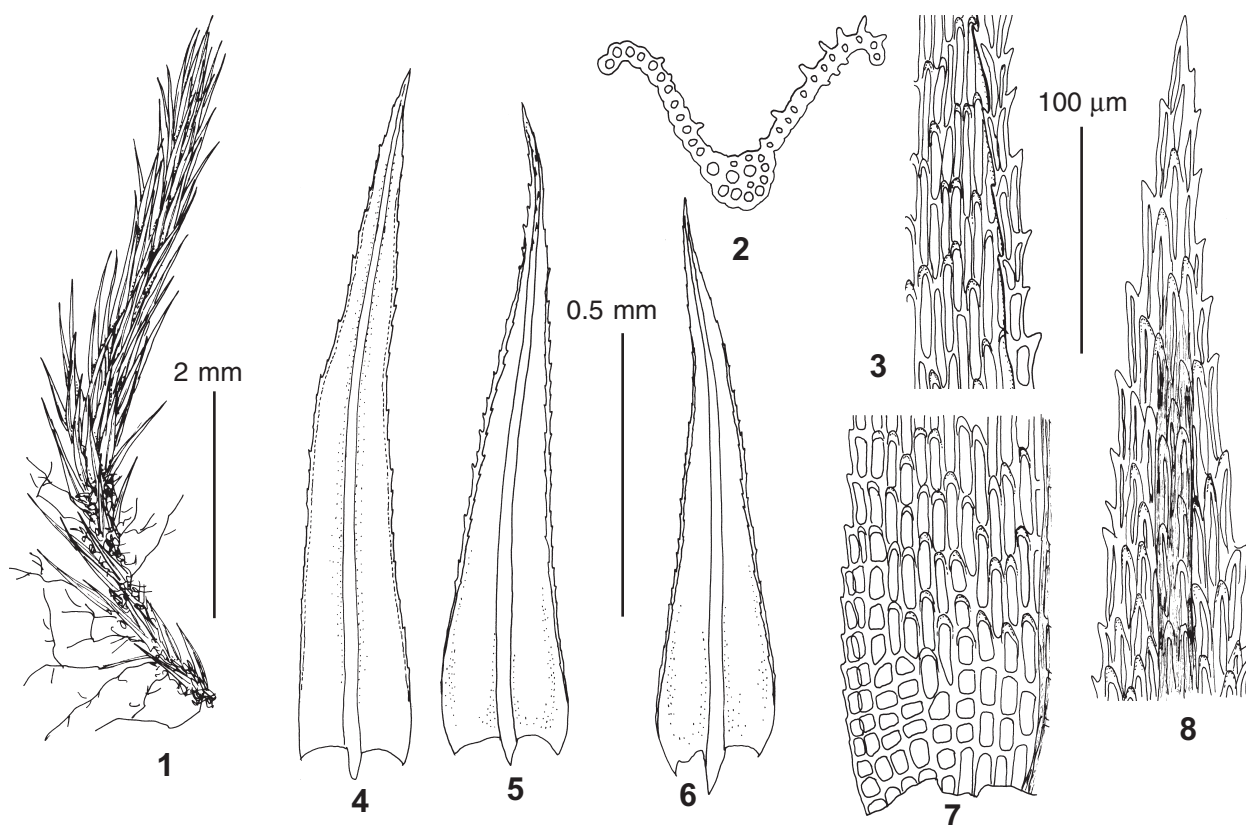


Fig. 4. *Philonotis* cf. *hastata* (sect. *Philonotula*) (from: Bakalin K-23-6-21, MHA): 1 – habit, dry; 2 – leaf transverse section; 3 – mid-leaf laminal cells; 4–6 – leaves; 7 – basal laminal cells; 8 – upper laminal cells. Scale bars: 2 mm for 1; 0.5 mm for 4–6; 100 µm for 2–3, 7–8.

Another very important place is Mutnovskaya Sopka Volcano, the area where such very rare species as *Brachydontium trichodes* and *Pohlia cardotii* occur.

And finally, Ksudach Volcano Caldera, Klyuchevoe Lake area should be at special attention, as thermal fields provide a habitat for thermophilous species, which are still not fully understood and either represent a highly disjunctive populations of tropical species or endemic species of Kamchatka. Especially *Philonotis* cf. *hastata* is one of special concern.

ON THE *PHILONOTIS* cf. *HASTATA* IDENTITY

A *Philonotis* species collected at Ksudach Volcano Caldera has leaf cells with distal papilla. This character is rare in Russian species of the genus; most of them have proximal papillae in leaf cells, while the distal ones are characteristic for tropical and otherwise southern species. The molecular barcoding data indicate the maximal similarity of the Ksudach *Philonotis* to *P. hastata* specimen from Singapore. The similarity is not very high, although among others, both Singaporian and Ksudach specimens have a subidentical 36 bp insertion in ITS2 that differs these two specimens from any other species represented in this analysis. Morphological similarity of the Ksudach *Philonotis* and *P. hastata* are also quite moderate: the latter has broader leaves, whereas Ksudach plants have narrow leaves, being superficially most similar to *P. rigida* (Fig. 2).

Despite the numerous attempts to revise South-East Asian *Philonotis* species, their taxonomy remains insufficiently known, which does not allow us at the moment decide, if the Ksudach *Philonotis* is one of much more southern species of the genus, brought to Kamchatka with migratory birds, or it is an undescribed relic species. The former explanation is consistent with another unexpected finding in this place of a largely southern *Scapania parvixta* Steph., at more than 1000 km north of the nearest locality in South Kurils and Japan (Bakalin *et al.*, 2022).

Examples of southern mosses found in the thermal fields of Kamchatka are known for one *Philonotis* (named cf. *falcata* in Fig. 2), discussed in details by Koponen *et al.* (2012) and for *Campylopus umbellatus*, found in Kamchatka isolated from the nearest place in Central Japan for more than 1000 km (Ignatova & Samkova, 2006).

ACKNOWLEDGMENTS

We thank Oxana I. Kuznetsova for sequencing several samples for this study. The study of I.V. Czernyadjeva was carried out in within the framework of the institutional research project (Herbarium collections of BIN RAS (history, conservation, investigation and replenishment) of the Komarov Botanical Institute of the Russian Academy of Sciences), № 122011900032-7. The work of E.A. Ignatova and M.S. Ignatov was supported by RSF project № 18-14-00121. V.A. Bakalin and K.G. Klimo-

va are sincerely grateful to the directorate of the Volcanoes of Kamchatka consortium in the face of Lyubov Yu. Timofeeva and Nikolai N. Pozdnyakov for their generous support of the field research in the South Kamchatka Nature Park in 2021. The work of Bakalin and Klimova was partially supported by the Russian Foundation for Basic Research (grant no. 20-04-00278) and is within the frame of the institutional research project “Cryptogamic Biota of Pacific Asia” (no. 122040800088-5).

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Received 15 September 2022 Accepted 6 December 2022