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**Authors' contributions**

AS: designed and coordinated the study, determined the moss specimens, wrote the manuscript; RO: designed the study, determined the moss specimens, wrote the manuscript, contributed the distribution maps; NAK: determined the liverwort specimens, wrote the manuscript; WZ: collected the specimens, developed the tables, wrote the manuscript; KO: collected the specimens, developed the tables, contributed the study area map; WM: conceived and coordinated the study, collected the specimens, developed the tables, wrote the manuscript, contributed the study area map

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**Competing interests**

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## ORIGINAL RESEARCH PAPER

# A contribution to the knowledge of bryophytes in polar areas subjected to rapid deglaciation: a case study from southeastern Spitsbergen

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**Abstract**

The paper provides a list of 54 species of bryophytes (48 mosses and six liverworts) collected from Spitsbergen, the largest island of the Arctic Svalbard archipelago (Norwegian Arctic), in 2016. They were collected mainly from its southeastern coast (Sørkapp Land and Torell Land), which has been rapidly abandoned by glaciers in the last few decades and is heavily under-investigated bryologically. The most interesting and phytogeographically important findings are the mosses *Bryum salinum*, *Campylium longicuspis*, *Coscinodon cribrosus*, *Orthogrimmia sesitata*, *Pogonatum dentatum*, *Polytrichum juniperinum*, *Sanionia georgicouncinata*, *Schistidium frigidum*, and *S. pulchrum*, and the liverwort *Cephalozia bicuspidata*. For each species, a short taxonomic and phytogeographical comment is provided, and the distribution of 12 rare or otherwise phytogeographically interesting species in Svalbard is shown on maps.

**Keywords**

Arctic; distribution; liverworts; mosses; phytogeography; Svalbard

**Introduction**

While the areas of the western and northern parts of Spitsbergen, the largest island of the Arctic Svalbard archipelago (Norway), have been repeatedly used as a place of research on bryophytes, its southeastern coast is still very poorly studied bryologically. So far, no bryological data are available from Torell Land, and the only contribution regarding the bryophyte flora of Sørkapp Land was published by Kuc [1]. The study was based on a collection made by Professor K. Birkenmajer in 1962 during a geological survey of the northeastern part of the area. In total, five species of liverwort and 26 species of moss have hitherto been recorded from northeastern Sørkapp Land. The area covered by the present study has not been previously investigated botanically, apart from preliminary observations made in 2005 [2]. Studies of Svalbard bryophytes have a long history, dating back to the end of the seventeenth century [3]. The first chronological compilation of the moss flora was presented by Kuc [4] who recognized 265 species of moss from this

the article is properly cited.

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archipelago. In the most recent survey of bryophytes of Svalbard, Frisvoll and Elvebakk [3] recorded 85 species of liverwort and 288 species of moss in this area. Over the following 2 decades, studies on the bryoflora continued [5–24], providing much new distributional data for these plants in this Arctic archipelago. As the area of Svalbard is subjected to deglaciation in many places, new discoveries of species and changes in the frequency of species that are already known to exist there are to be expected.

The main objectives of the present study are: (i) complementing the knowledge on the diversity of the bryophyte flora of Spitsbergen; (ii) providing information on bryophytes occurring in areas that, until recently, were covered with ice.

## Material and methods

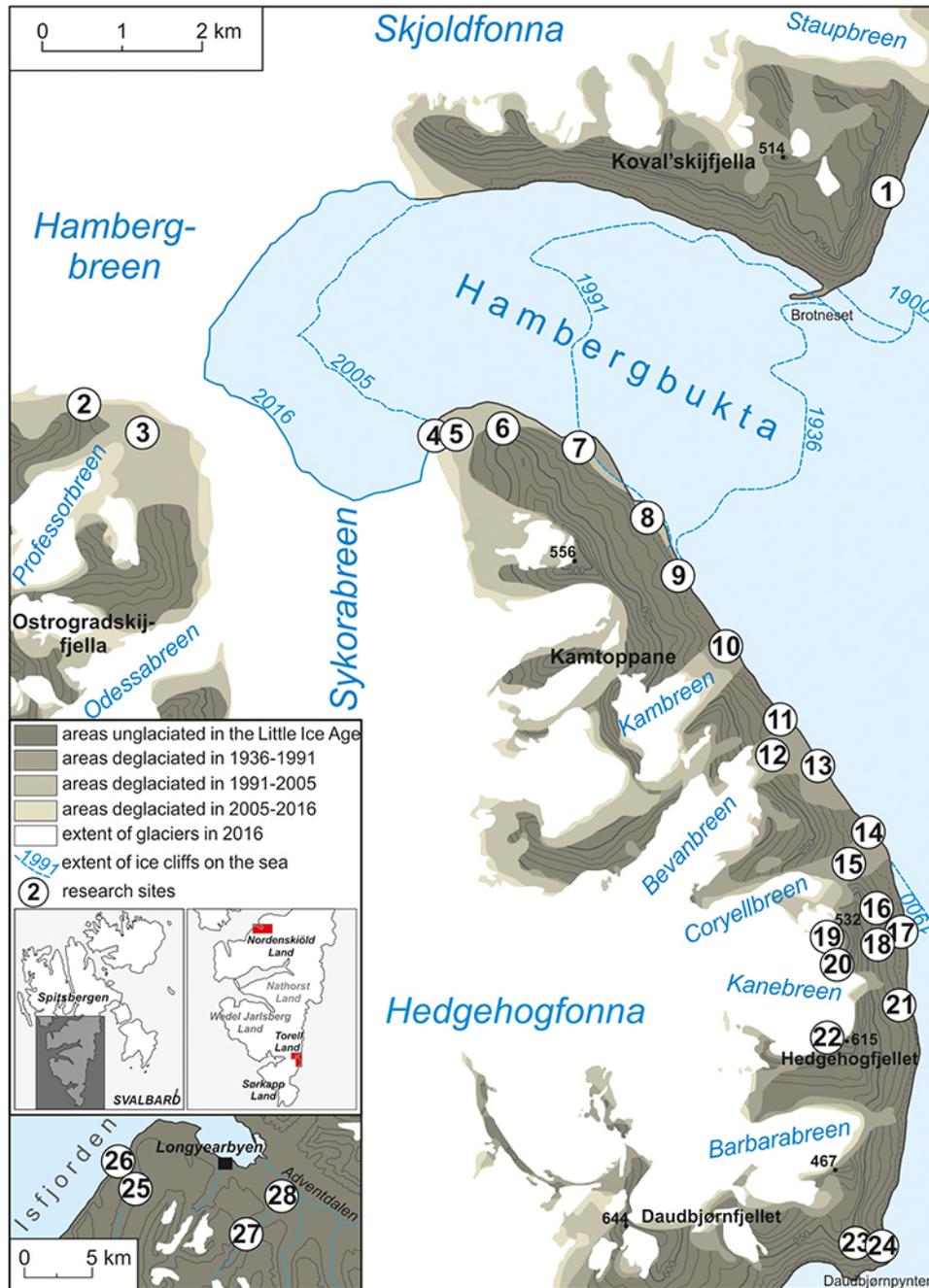
### Study area

Plant material was collected from research sites located in three separate areas in Spitsbergen. Most collections were made in Sørkapp Land and Torell Land on the southeastern coast of the island, which has undergone intensive deglaciation during the past century. The area of our exploration covers 156 km<sup>2</sup> and samples of bryophytes were taken from 24 sites located mainly near the coastline. The remaining four sites are located in the Endalen and Bjørndalen valleys, near Longyearbyen in Nordenskiöld Land in central-western Spitsbergen, an area that was only slightly glaciated during the Holocene (Fig. 1, Fig. 2, Tab. 1).

All collecting sites in the main three regions (Sørkapp Land, Torell Land, and Nordenskiöld Land) have the same tectonics and lithostratigraphy corresponding to the pre-Quaternary bedrock as well as consequential similar terrain relief of table mountains with extensive surface peneplanation. It is significant for plant development that soils in the majority of the investigated sites are derived from outcrops of the same pre-Quaternary sediments. The bedrock consists of overlapping layers of sandstones, mudstones, and siltstones which belong to the following four geological formations: the Upper-Cretaceous Carolinefjellet formation, which constitutes the foot and lower parts of mountain slopes, and three Tertiary formations, namely the Firkanten, Basilica, and Sarkofagen formations. Their chemical composition determines the occurrence of mainly acidic siliceous bedrocks with minor occurrence of carbonate rocks [25–30]. The rocks of these formations are not resistant, weathering easily into material with a full grain-size differentiation, ranging from clay to block fractions.

However, the study areas differ significantly in their climate features. The vicinity of Longyearbyen is one of the warmest areas on Spitsbergen due to its location on the inner part of Isfjorden, warmed by the West Spitsbergen Current, a warm and salty current that runs poleward just west of Spitsbergen [31]. Near sea level in Longyearbyen, during the period 1981–2010, the mean annual temperature was –5.2°C and the mean total annual precipitation was 191 mm [32], conditions which persist to the present. The southeastern Spitsbergen coast is much cooler under the influence of the cold East Spitsbergen Current flowing from the north [30]. Environmental features and rare seasonal meteorological observations provide evidence of this [33–35]. This climate differentiation occurred in Spitsbergen during all of the Holocene [32].

The warmer climate resulted in relatively little glaciation and abundant Arctic tundra in the Longyearbyen vicinity. Even in the Little Ice Age, i.e., until the beginning of the twentieth century, the majority of the area was free of glacial ice. Nowadays, the glaciers occupy no more than 18% of the area [36,37]. On the eastern side, a much cooler climate has resulted in glaciation and very scant vegetation on the southeastern Spitsbergen coast. This area was mostly covered by glaciers in 1900, as shown on the map by Wassiliew [38]. Plants grew only in small oases there [39]. The transformation of the natural environment by the recession of glaciers has persisted in both areas since the beginning of the twentieth century due to global climate warming, but the changes have been much greater in the southeastern Spitsbergen coastal region than in the central west of the island. Glaciers covered 83% (129 km<sup>2</sup>) of all the areas of southeastern Spitsbergen in 1900, while in 1991 covered 63% (below 100 km<sup>2</sup>), and in 2016 only covered 47% (73 km<sup>2</sup>) of the area [38,40–43] (Tab. 2).

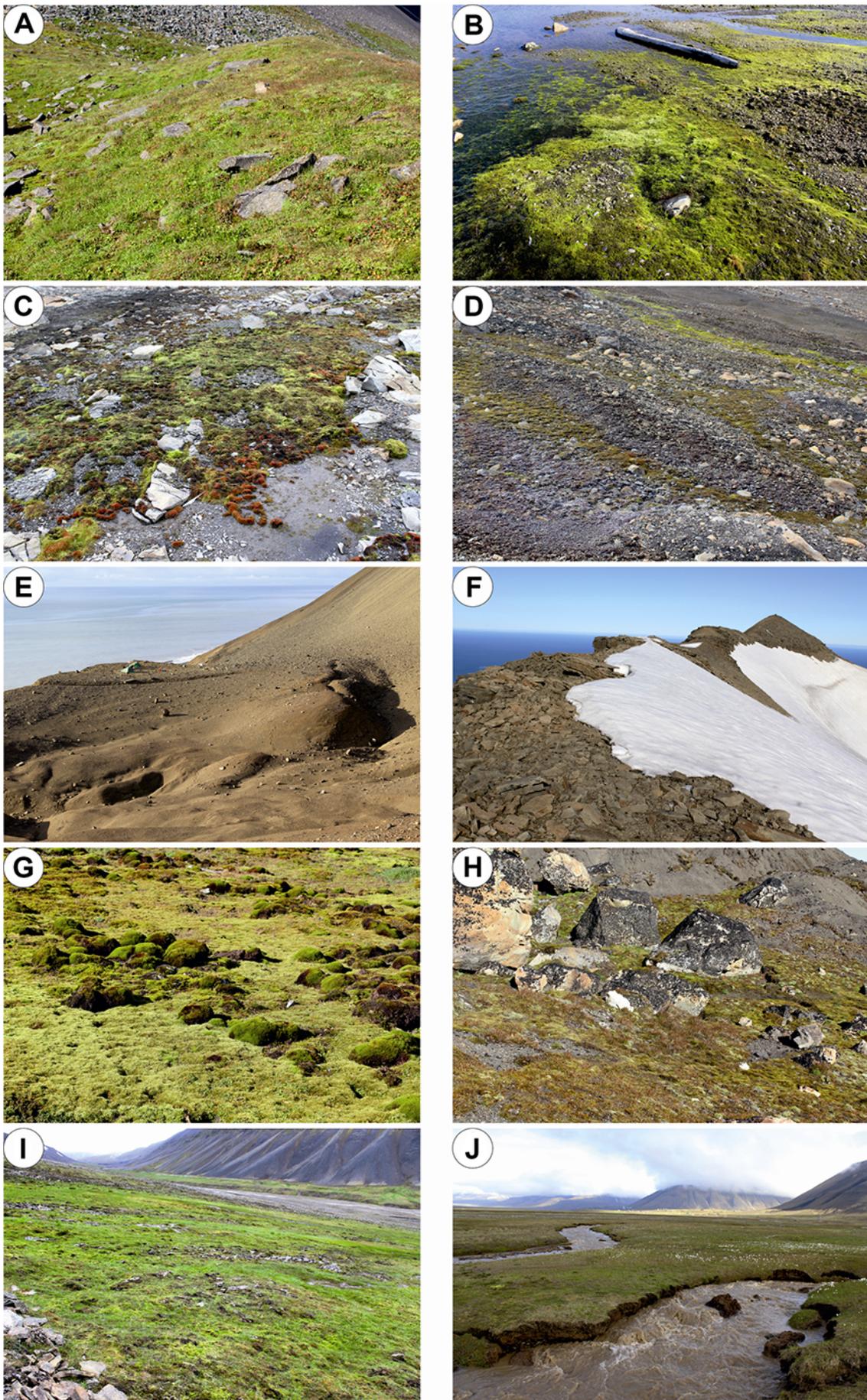


**Fig. 1** The map of the study area showing collection sites.

A completely new landscape (with new deposits and landforms as well as new water bodies, etc.) was formed in extensive areas abandoned by glaciers, and a vegetation cover has appeared due to rapid plant succession during the last few decades [2].

### Field surveys

Field surveys were conducted in July and August 2016. The material was collected from 28 research sites (Fig. 1, Fig. 2, Tab. 1) in three separate areas of Spitsbergen: on the northeastern Sørkapp Land (23 sites), on the southeastern Torell Land (one site), and near Longyearbyen (Nordenskiöld Land) in the Endalen and Bjørndalen valleys (four sites). A full set of 191 voucher specimens is preserved in the bryophyte herbarium of the W. Szafer Institute of Botany, Polish Academy of Sciences in Cracow (KRAM).



**Fig. 2** Overview of the selected research sites: (A) site No. 1; (B) site No. 11; (C) site No. 14; (D) site No. 15; (E) site No. 17; (F) site No. 22; (G) site No. 23; (H) site No. 24; (I) site No. 25; (J) site No. 28.

Tab. 1 Location of the research sites.

Site No.	Locality	$\lambda$	$\Phi$	Altitude (m a.s.l.)	Substrate	Habitats	Sampling date
1.	Coast at the foot of the Kovalskjiffella mountain ridge (Torell Land)	17°17'17.0"E	77°03'37.0"N	30	Soil	Moss-lichen tundra at the foot of multithousand bird colony	2016-07-25
2.	Northern slopes of the Ostrogradskjiffella mountain massive (Sørkapp Land)	16°53'09.7"E	77°02'13.3"N	128	Soil	Young rocky moraine	2016-08-12
3.	Valley in the front of the Professorbreen glacier (Sørkapp Land)	16°54'04.7"E	77°02'09.1"N	113	Soil	Young moraine	2016-08-12
4.	Peripheries of the Sykorabreen glacier – youngest (2005–2016) moraine (Sørkapp Land)	17°03'51.2"E	77°02'15.2"N	15	Mud	Young moraine with moss and single vascular plants	2016-08-01
5.	Peripheries of the Sykorabreen glacier – older (1991–2004) moraine (Sørkapp Land)	17°04'38.2"E	77°02'14.0"N	48	Soil	Young moraine, bird observation point	2016-08-01
6.	Old (1936–1990) moraine of the Hambergbreen glacier (Sørkapp Land)	17°04'01.9"E	77°02'6.1"N	62	Mud	Mud of the periodic moraine lake	2016-08-08
7.	Coastal plain on the Hambergbukta fjord (Sørkapp Land)	17°08'43.9"E	77°01'44.9"N	6	Soil	Top of the little moraine hill, bird observation point	2016-07-27
8.	Seashore at the foot of the Kamnova mountain (Sørkapp Land)	17°09'25.7"E	77°01'32.9"N	5	Soil	Muddy flat plain with vegetation patches	2016-07-27
9.	Eastern slopes of the Kamtoppane mountain (Sørkapp Land)	17°10'21.8"E	77°01'01.5"N	45	Soil	Lateral moraine from the end of the nineteenth century	2016-08-15
10.	Forefield of the Kambreen glacier (Sørkapp Land)	17°11'53.6"E	77°00'30.3"N	4	Soil	Dry, muddy flat with moss patches	2016-08-08
11.	Northern fore-field of the Bevanbreen glacier (Sørkapp Land)	17°13'22.3"E	77°00'03.8"N	4	Soil	Mossy little moraine hill, bird observation point	2016-07-27
12.	Fore-fields close to the front of the Bevanbreen glacier (Sørkapp Land)	17°12'51.7"E	76°59'56.8"N	71	Soil	Moraine with rocky blocks	2016-08-05
13.	Southern fore-field of the Bevanbreen glacier (Sørkapp Land)	17°13'57.2"E	76°59'52.0"N	2	Soil	Humid, muddy flat with moss patches	2016-07-27
14.	Foot of the Goeogtoppen mountain (Sørkapp Land)	17°15'35.8"E	76°59'19.0"N	2	Mud	Moss patch on the dry (former) lake's bottom	2016-07-27

Tab. 1 Continued

Site No.	Locality	$\lambda$	$\Phi$	Altitude (m a.s.l.)	Substrate	Habitats	Sampling date
15.	Fore-field of the Coryellbreen glacier close to its front (Sørkapp Land)	17°15'17.0"E	76°59'03.7"N	60	Soil/rock	Young moraine with moss and lichen patches	2016-07-30
16.	Eastern slopes of the Tvillingtoppen mountain (Sørkapp Land)	17°15'52.6"E	76°58'49.8"N	119	Rock	Wide slope flattening covered by debris and blocks	2016-08-19
17.	Foot of the Tvillingtoppen mountain (Sørkapp Land)	17°16'38.2"E	76°58'41.9"N	29	Soil/rock	Dry, old glacier moraine	2016-08-10
18.	Eastern slopes of the Tvillingtoppen mountain (Sørkapp Land)	17°15'47.1"E	76°58'37.2"N	217	Rock	Flat terrain with rocky blocks	2016-08-08
19.	Summit of the Tvillingtoppen mountain (Sørkapp Land)	17°14'57.5"E	76°58'35.0"N	531	Waste	Rock-waste slopes	2016-08-02
20.	South-western slopes of the Tvillingtoppen mountain (Sørkapp Land)	17°14'38.2"E	76°58'22.6"N	450	Rock	Rocky and rock-waste slopes	2016-08-02
21.	Slopes above the former Davislaguna Lake (Sørkapp Land)	17°16'07.7"E	76°58'7.5"N	68	Soil/rock	Rocky and rock-waste slopes	2016-08-07
22.	Summit of the Hedgehogfjellet mountain (Sørkapp Land)	17°14'58.9"E	76°57'52.0"N	600	Rock	Rock-debris on the top	2016-08-02
23.	"Alkekongedalen" above Daudbjørnpynnten headland (Sørkapp Land)	17°15'26.3"E	76°56'29.6"N	154	Soil	Moss-lichen tundra in big plant oasis	2016-07-28
24.	Uppermost part of the Daudbjørnpynnten headland (Sørkapp Land)	17°15'40.1"E	76°56'23.5"N	47	Soil	Small plant oasis at the foot of the little bird colony	2016-07-28
25.	Lower part of the Bjørndalen valley (Nordenskiöld Land)	15°20'45.1"E	78°12'58.4"N	53	Soil	Moss tundra on the valley's slope	2016-07-23
26.	Northern part of the Bjørndalen valley (Nordenskiöld Land)	15°20'29.7"E	78°13'08.2"N	49	Soil	Moss-lichen tundra	2016-07-23
27.	Endalen valley near the abandoned coal mine (Nordenskiöld Land)	15°43'38.8"E	78°10'46.0"N	130	Soil	Moss tundra on the valley's slope	2016-07-21
28.	Adventdalen valley (Nordenskiöld Land)	15°49'01.9"E	78°12'03.5"N	8	Soil	Grass tundra on the alluvial cone	2016-07-21

**Tab. 2** Changes in glaciation in the main research area in the period of 1900–2016.

Year	Glaciated area (156 km <sup>2</sup> = 100%)	
	km <sup>2</sup>	%
1900	129	83
1936	114	73
1991	99	63
2005	79	51
2016	73	47

For each species, all sites are listed by numbers that correspond to the map in Fig. 1. They are listed separately for each land including Nordenskiöld Land (N), Torell Land (T), and Sørkapp Land (S). These data are followed by evaluation of local frequency according to the scale: very rare (one–two records), rare (three–four), frequent (five–seven), and common (eight or more records), while the frequency and abundance of species in Spitsbergen is adopted from the treatment of Frisvoll and Elvebakk [3]. Finally, information on substrate and habitats, enumeration of accompanying species, a comment on the local distribution in Svalbard and, occasionally, some taxonomic notes are provided. The distribution of 12 rare or otherwise phytogeographically

interesting moss species in Svalbard is mapped (Fig. 3–Fig. 5). Literature data are marked with black circles dots, whereas new stations are marked with triangles.

## Results – list of species

The present paper provides information on 54 species of bryophytes from the south-eastern part of Spitsbergen. Of these, 10 species have been recorded from Torell Land, 35 species from Sørkapp Land, and 36 species from Nordenskiöld Land. All data from Torell Land and Sørkapp Land are new for the eastern parts of these areas. The most interesting findings are the mosses *Bryum salinum*, *Campylium longicuspis*, *Coscinodon cribrosus*, *Orthogrimmia sessitana*, *Polytrichum juniperinum*, *Sanionia georgicouninata*, *Schistidium frigidum*, and *S. pulchrum*, and the liverwort *Cephalozia bicuspidata*.

Species of liverworts and mosses are arranged alphabetically in the following compilation. For each species, all stations are listed by numbers which correspond to their locality on the map (Fig. 1). They are listed separately for each land including Nordenskiöld Land (N), Torell Land (T), and Sørkapp Land (S). These data are followed by an evaluation of the frequency and abundance, habitats, enumeration of accompanying species, and comments on local and global distributions. Occasionally, some taxonomic notes are provided.

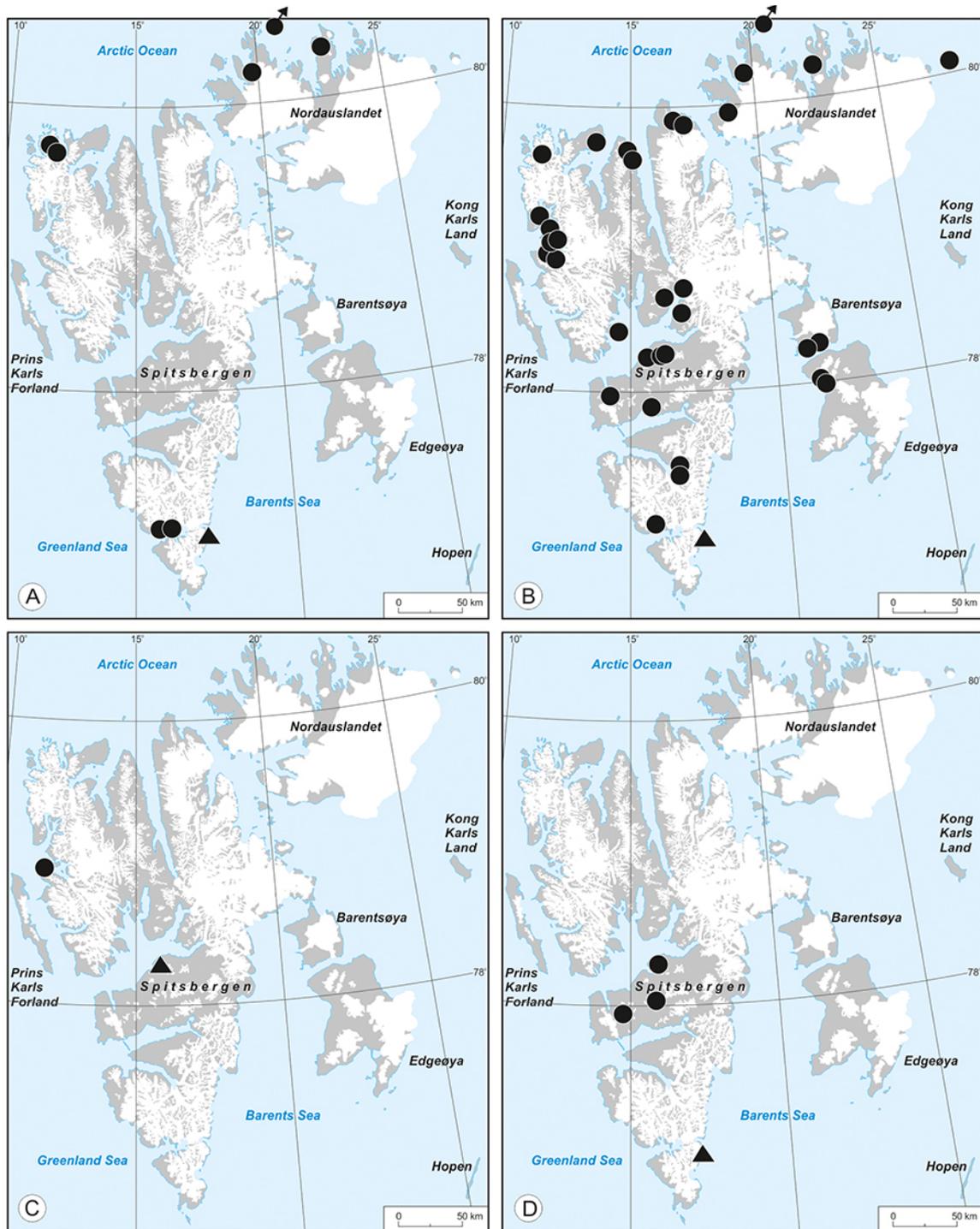
### Liverworts Marchantiophyta

1. *Blepharostoma trichophyllum* (L.) Dumort. subsp. *brevirete* (Bryhn & Kaal.) R. M. Schust. – stat.: N – 27

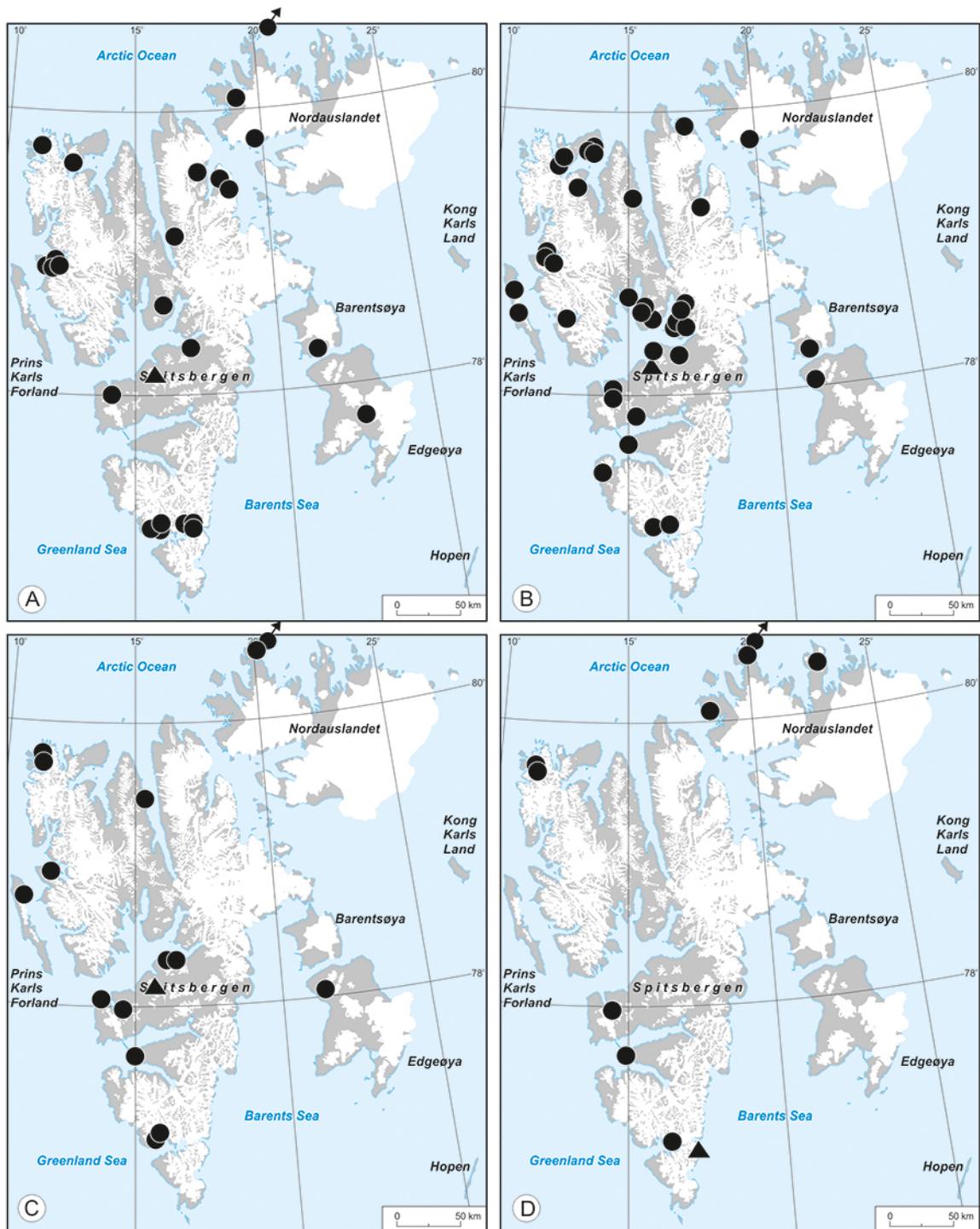
Sparse, found forming a small tuft with *Lophozia ventricosa*, *Sphenolobus minutus* var. *grandis*, and *Trilophozia quinqueidentata* var. *turgida*. It is one of the most widespread liverworts in Svalbard but is presented here as an Arctic subspecies only [44,45]. The subspecies *trichophyllum* has been reported from some sites in western Spitsbergen [46–49], but the relevant voucher specimens need re-assessment.

2. *Cephalozia bicuspidata* (L.) Dumort. – stat.: N – 27

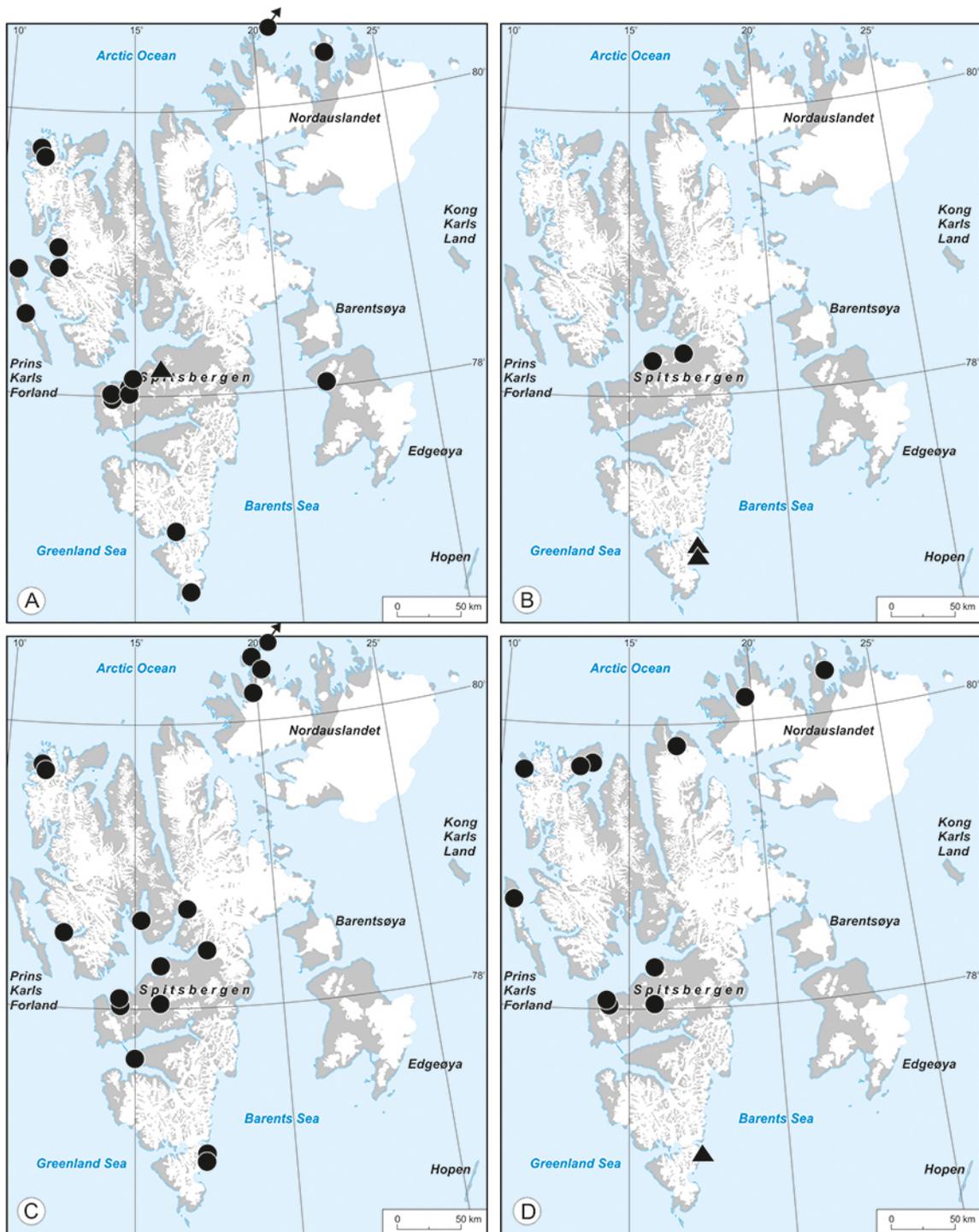
Very rare, found in a large pure tuft. The midleaf cells of the plants are 25–30 µm wide and 30–37(–50) µm long and the dorsal stem cells are 37–45 µm wide, fitting well in *Cephalozia bicuspidata*. They differ from the closely related *C. ambigua* C. Mass., which is often considered a subspecies or variety of *C. bicuspidata*, in its larger cells, stem, and leaf cells. In *C. ambigua*, midleaf cells are ca. (18–)20–24 × (22–)28–35 µm [50]. According to Frisvoll and Elvebakk [3], *C. bicuspidata* is rare in Svalbard, specifically stressing that “the presence on Svalbard of *C. bicuspidata* is perhaps not yet absolutely certain because of the identification problems”. These two species, *C. bicuspidata* and *C. ambigua*, appear to be widespread in the appropriate sites of Svalbard.



**Fig. 3** Geographical distribution of *Andreaea blyttii* (A), *Bryum cryophilum* (B), *Campylium longicuspis* (C), and *Coscinodon cribrosus* (D) in the Svalbard archipelago. Literature data are marked with black circles, while new records are marked with black triangles. Occurrence on Chermisideøya and/or Parryøya north of Nordauslandet beyond the map is indicated by the arrow.



**Fig. 4** Geographical distribution of *Hygrohypnella polaris* (A), *Hypnum bambergeri* (B), *H. callichroum* (C), and *Kiaeria blyttii* (D) in the Svalbard archipelago. Literature data are marked with black circles, while new records are marked with black triangles. Occurrence on Chermisøya and/or Parryøya north of Nordauslandet beyond the map is indicated by the arrow.



**Fig. 5** Geographical distribution of *Kiaeria glacialis* (A), *Orthogrimmia sessitana* (B), *Pohlia wahlenbergii* (C), and *Sanionia georgicouninata* (D) in the Svalbard archipelago. Literature data are marked with black circles, while new records are marked with black triangles. Occurrence on ChermSIDEØYA and/or ParryØYA north of Nordauslandet beyond the map is indicated by the arrow.

### 3. *Lophozia ventricosa* (Dicks.) Dumort. s. l. – stat.: N – 27

The scanty material, collected only from a single site and with disintegrated oil bodies, precludes a more accurate determination of the material. Most leaf lobes end in (1–)2–4 superposed cells, the perichaetial leaves have single teeth and the perianth mouth is armed with multicellular (up to five superposed cells) teeth. These features were reported as diagnostic for *Lophozia subapiculata* R. M. Schust. & Damsh., but the studied specimen differs in the darker vinaceous pigmentation of the stem and leaf base, as well as having more deeply bilobed leaves (up to 0.3–0.4) and clearly colenchymatous leaf cells with distinctly convex lateral wall trigones that contradict the description of *L. subapiculata* [51]. Plants of similar appearance have been collected by N. Konstantinova (unpublished data) in Collesbukta and on the left bank of Bogebecken in Spitsbergen. The latter plants were referred to *L. silvicoloides* N. Kitag. [8] based on the long teeth of the perianth and biconcentric oil bodies. *Lophozia ventricosa* has been reported from Svalbard [3] but *Lophozia* s. str. needs to be revised in this Arctic archipelago following an updated taxonomy of this group.

### 4. *Scapania obcordata* (Berggr.) S. W. Arnell – stat.: S – 19

Only several shoots, without gemmae, but having weakly keeled and relatively large trigones, which are more or less typical for this species, were found mixed with other bryophytes. This species was originally described from material collected in Svalbard [52] and is widely distributed but scattered in the high Arctic. Additionally, it is known from the bipolar stations in the northern maritime Antarctic and on subantarctic South Georgia [53–55]. The species is widespread in Svalbard [3,10] (also unpublished data).

### 5. *Sphenobolus minutus* (Schreb. ex D. Crantz) Berggr. var. *grandis* (Gottsche ex Lindb.) R. M. Schust. – stat.: N – 27

A single specimen was found in a tuft with *Blepharostoma trichophyllum* subsp. *brevirete* and *Trilophozia quinquedentata* var. *turgida*. The cup-shaped leaves with marginal cells 18–20 µm wide are characteristic of this species, one of the most frequent and widespread liverworts species in Svalbard [3].

### 6. *Trilophozia quinquedentata* (Huds.) Bakalin var. *turgida* (Lindb.) Konstant. – stat.: N – 27

Found growing sparingly in a tuft together with *Blepharostoma trichophyllum* subsp. *brevirete* and *Sphenobolus minutus* var. *grandis*. This variety is characterized by its median leaf marginal cells 18–20(–22) µm, large bulging trigones, and cuspidate leaf lobes [8,9]. *Trilophozia quinquedentata* is one of the most widespread and very variable species in Svalbard, being represented by several varieties.

## Mosses Bryophyta

### 1. *Amblystegium serpens* (Hedw.) Schimp. – stat.: S – 8

A very rare species growing sparsely on soil. The species is widely distributed but scattered throughout the archipelago [3] but it is recorded for the first time from Sørkapp Land.

### 2. *Andreaea blyttii* Schimp. – stat.: S – 22

Occurs infrequently on dry rock-debris in the foreground of a glacier, from where it was collected growing in association with *Hymenoloma crispulum* and *Schistidium pulchrum*. The species is rare and widely scattered in Hornsund [56] in the southern and also in several stations in northwestern parts of Spitsbergen and on Nordaustlandet [3,4,17], but it is recorded for the first time on the eastern coast of Spitsbergen (Fig. 3A). The species occurs on noncalcareous boulders, especially on sheltered overhung surfaces,

sometimes even on gentle rock outcrops or on fine earth between stones and boulders. Found as pure cushions or, rarely, mixed with *Kiaeria glacialis*.

3. *Aulacomnium turgidum* (Wahlenb.) Schwägr. – stat.: N – 25, 26, 27, 28; S – 23, 24

A frequent species on moraines, rocky slopes, and mossy tundra on flat terrain, usually occurring abundantly in large pure stands or in turves mixed with other mosses, including *Dicranum elongatum*, *D. laevidens*, *D. spadiceum*, *Hylocomium splendens*, *Niphotrichum canescens* var. *latifolium*, *Racomitrium lanuginosum*, *Sanionia uncinata*, and *Tomentypnum nitens*. It is one of the most common species of moss in the Svalbard archipelago [3,4,17], which was previously reported also from Sørkapp Land [1].

4. *Bartramia ithyphylla* Brid. – stat.: N – 26

A very rare species which occurs on soil on young moraine debris in tufts dominated by *Hypnum bambergeri*, *Niphotrichum canescens* subsp. *latifolium*, *Oncophorus virens*, *Pohlia cruda*, *Racomitrium lanuginosum*, and *Timmia bavarica*. It is otherwise a fairly frequent moss species occurring throughout most of Spitsbergen in a wide range of habitats, especially on stony ground and in rock fissures [3].

5. *Brachythecium turgidum* (Hartm.) Kindb. – stat.: T – 1

A very rare species found growing sparsely in a tuft of mosses in mossy tundra, associated with *Bryum pseudotriquetrum*, *B. pallescens*, *Niphotrichum canescens* subsp. *latifolium*, *Pohlia nutans*, *Polytrichastrum alpinum*, *Racomitrium lanuginosum*, *Sanionia uncinata*, *Syntrichia ruralis*, and *Tomentypnum nitens*. A common species, widespread throughout the Svalbard archipelago [3,4].

6. *Bryum cryophilum* Mårt. – stat.: S – 5

A very rare species growing sparsely in the moss-lichen tundra associated with *Bryum pseudotriquetrum*, *B. salinum*, and *Sanionia uncinata*. This handsome species is widespread and common throughout Spitsbergen [3,4] but it has not hitherto been recorded from Sørkapp Land (Fig. 3B).

7. *Bryum pallescens* Schwägr. – stat.: N – 25; T – 1; S – 4, 6, 13, 14, 15

A frequent and locally abundant species growing on soil in the moss-lichen tundra and on young moraines, together with *Dicranum elongatum*, *D. spadiceum*, *Distichium capillaceum*, *Niphotrichum canescens* subsp. *latifolium*, *Pogonatum urnigerum*, *Pohlia nutans*, and *Sanionia uncinata*. It is widespread and frequent throughout Spitsbergen [3] but it has not hitherto been recorded from Sørkapp Land.

8. *Bryum pseudotriquetrum* (Hedw.) P. Gaertn. B. Mey. & Scherb. – stat.: T – 1; S – 4, 5, 12

A rare species but growing usually in abundance in the moss-lichen tundra, usually together with *Pohlia wahlenbergii*, *Sanionia uncinata*, and *Tomentypnum nitens*. It is apparently one of the most common species of the genus *Bryum* Hedw. in Spitsbergen [3], but it has not hitherto been recorded from Sørkapp Land.

9. *Bryum salinum* I. Hagen ex Limpr. – stat.: S – 5

A very rare species growing on soil in the moss-lichen tundra below a large bird colony, found in association with *Bryum pseudotriquetrum*, *B. cryophilum*, and *Sanionia uncinata*. The plants are in a fine fruiting condition. Hitherto, the species has been collected only once from Kongsfjorden [44], although *Bryum spitsbergense* Arnell from Storfjorden on the east side of Spitsbergen [57] is possibly conspecific with *B. salinum* [3]. The species was recently reported from Edgeøya [21].

10. *Calliergon richardsonii* (Mitt.) Kindb. – stat.: N – 28

Some shoots of this distinct species were found in a patch of *Aulacomnium turgidum* collected on a steep rocky slope. *Calliergon richardsonii* occurs commonly in suitable habitats throughout the Svalbard archipelago, but it has sometimes been confused with other species of the genus, including *C. giganteum* (Schimp.) Kindb. and *C. cordifolium* (Hedw.) Kindb. [3].

11. *Campylium longicuspis* (Lindb. & Arnell) Hedenäs – stat.: N – 25

Scant material of this species was extracted from a patch of *Aulacomnium turgidum* collected on an old moraine where it grew in association with *Polytrichum strictum*, *Sanionia uncinata*, *Sphagnum squarrosum*, and *Tomentypnum nitens*. This Arctic species is exceedingly rare and, so far, it has been collected only once on Spitsbergen in the northwest of the island [3] (Fig. 3C).

12. *Ceratodon purpureus* (Hedw.) Brid. – stat.: S – 3, 7, 11, 21

A rare, but possibly under-collected, species in the study area. It is an epigeal moss growing on soil on moraines and on stony ground together with *Pogonatum capillare*, *P. urnigerum*, *Pohlia nutans*, *P. wahlenbergii*, *Polytrichum juniperinum*, and *Syntrichia ruralis*. The species is scattered or locally common throughout the whole archipelago [3] and it has previously been recorded from Sørkapp Land [1].

13. *Coscinodon cribrosus* (Hedw.) Spruce – stat.: S – 21

A very rare species found growing sparsely on stony ground in association with *Orthogrimmia sessitana*. So far, *Coscinodon cribrosus* has been recorded only at three sites on Spitsbergen, namely from Adeventendalen in the Hornsund region and from Kolfjellet and Hillestadfjellet in Van Mijenfjorden [3,14] (Fig. 3D).

14. *Dicranum elongatum* Schwägr. – stat.: N – 25, 26; S – 24

A rare species, but occurring in abundance at all sites, grows in very compact tufts with a red-brown tomentum of rhizoids. Found on moraines in association with *Dicranum spadiceum*, *Hylocomium splendens*, *Niphotrichum canescens* subsp. *latifolium*, *Racomitrium lanuginosum*, and *Sanionia uncinata*. It is a frequent species in the Svalbard archipelago [3], but hitherto has not been recorded from Sørkapp Land.

15. *Dicranum laevidens* R. S. Williams – stat.: N – 27; S – 24

A very rare but fairly abundant species, occurring on moraines in association with *Hypnum callichroum*, *Aulacomnium turgidum*, *Hylocomium splendens*, *Kiaeria glacialis*, *Polytrichum strictum*, and *Sanionia uncinata*. Its distribution in the Svalbard archipelago is not accurately known because the species has not been distinguished from *D. angustum* Lindb. Apparently, it is the most common species of the *D. angustum* complex, widespread over most of Spitsbergen and recorded also from Bjørnøya [3] and, recently, from Edgeøya [21].

16. *Dicranum spadiceum* J.E.Zetterst. – stat.: N – 25, 26

A very rare but abundant species, thriving on stony ground on moraines together with *Dicranum elongatum*, *Hylocomium splendens*, *Polytrichum strictum*, *Racomitrium lanuginosum*, and *Sanionia uncinata*. It is widely distributed throughout Spitsbergen [3] and, recently, also recorded from Edgeøya [21].

17. *Distichium capillaceum* (Hedw.) Bruch & Schimp. – stat.: N – 25

A very rare species collected from an old moraine in association with *Bartramia ithyphylla*, *Hypnum bambergi*, *Niphotrichum canescens* subsp. *latifolium*, *Oncophorus*

*virens*, *Pohlia cruda*, and *Racomitrium lanuginosum*. A common species throughout the Svalbard archipelago [3], has previously been recorded from Sørkapp Land [1].

18. *Drepanocladus aduncus* (Hedw.) Warnst. – stat.: S – 8, 18

A very rare species, found growing abundantly on soil (with *Pohlia wahlenbergii*) on a moraine and on rocks. It is a very variable taxon and Żarnowiec [58] recognized two distinct species in this complex, *D. aduncus* s. str. and *D. polycarpus* (Voit) Warnst., which differ primarily from each other in the leaf areolation. The former species was not recorded from Spitsbergen by Żarnowiec [58], but apparently only some selected specimens have been studied from this Arctic island. Hence, the large material of this genus from Spitsbergen needs a careful taxonomic assessment to resolve the problem of the status of the local plants.

19. *Drepanocladus polycarpus* (Voit) Warnst. – stat.: S – 3, 21

Only two quite abundant collections of this species are available from the study area, both originating from the mossy tundra. This species is apparently widespread in the Svalbard archipelago and all collections examined by Żarnowiec [58], in his monographic studies of this complex, were referred to this species, which is primarily characterized by relatively short laminal cells, to 50 µm. This species was recently reported from the Grønfjord area [13].

20. *Hylocomium splendens* (Hedw.) Schimp. – stat.: N – 25, 26, 27

A rare species in dry or humid sites on soil and stony ground on moraines, growing usually in abundance in moss stands, mainly with *Aulacomnium turgidum*, *Dicranum elongatum*, *D. laevidens*, *D. spadicum*, *Niphotrichum canescens* subsp. *latifolium*, and *Sanionia uncinata* as associates. It is one of the most common species of moss in the Svalbard archipelago, forming various habitat modifications [3,4].

21. *Hygrohypnella polaris* (Lindb.) Ignatov & Ignatova – stat.: N – 27

A very rare species collected only once on a young moraine where it occurred as a small monospecific patch. The species is widespread in the north of the archipelago on Spitsbergen and Nordauslandet and in the southern part of Spitsbergen it is common in the Hornsund area [56]. The species was recorded on Barentsøya [2] and recently in Austre-Grønfjordbreen glacier (Grønfjorden) [20], Tordalen [24], Bertilbreen glacier surface in the environs of Pyramiden (Billefjorden) [23] and Edgeøya [21] (Fig. 4A).

22. *Hymenoloma crispulum* (Hedw.) Ochyra – stat.: N – 26; S – 9, 18, 22

A fairly rare moss but locally growing in abundance on soil, rocky ground, and rock-debris in dry and humid sites on moraines, snow beds, and often on newly deglaciated ground. In the study area, it was found in association with *Andreaea blyttii*, *Niphotrichum canescens* subsp. *latifolium*, and *Schistidium pulchrum*. *Hymenoloma crispula* usually produces sporophytes in great profusion. It is a frequent species throughout the archipelago [3,4] but it has not hitherto been recorded from Sørkapp Land.

23. *Hypnum bambergeri* Schimp. – stat.: N – 26

A few shoots of this very rare species were found as an admixture in a tuft of several species of moss, including *Bartramia ithyphylla*, *Distichium capillaceum*, *Niphotrichum canescens* subsp. *latifolium*, *Pohlia cruda*, *Racomitrium lanuginosum*, and *Timmia bavarica* collected on a young moraine. Generally, it is a frequent and widely distributed species in the Svalbard archipelago, although it does not seem to have been collected in the central and southern parts of the eastern coast of Spitsbergen [3,4] (Fig. 4B).

24. *Hypnum callichroum* Brid. – stat.: N – 27

A very rare species, found as a small admixture in a tuft of *Aulacomnium turgidum* along with *Dicranum laevidens*, *Hylocomium splendens*, *Kiaeria glacialis*, *Polytrichum strictum*, and *Sanionia uncinata*. It is a relatively rare species on Spitsbergen, widely distributed but scattered in the western part of the island and so far it has not been recorded from the island's eastern coast [3,4]. It was recently reported from Linnévatnet lake in Nordenskiöld Land [15] and Edgeøya [21] (Fig. 4C).

25. *Kiaeria blyttii* (Bruch & Schimp.) Broth. – stat.: S – 19

One large pure tuft was found on a moraine with rocky blocks. The species is widely distributed but scattered on Spitsbergen and Nordauslandet. According to Kuc [4], all known records of the species are from western Spitsbergen and from the eastern coast the species has not previously been recorded (Fig. 4D).

26. *Kiaeria glacialis* (Berggr.) I. Hagen. – stat.: N – 27

The species was collected only once but growing in abundance on a young rocky moraine in a large tuft of *Aulacomnium turgidum* in association with *Dicranum laevidens*, *Hylocomium splendens*, *Hypnum callichroum*, *Polytrichum strictum*, and *Sanionia uncinata*. The species is widely distributed on Spitsbergen, especially in its western part, but from the eastern coast it has not been hitherto recorded [4]. Recently, it was recorded from Prins Oscars Land (Nordauslandet) [17] and Edgeøya [21] (Fig. 5A).

27. *Leptobryum pyriforme* (Hedw.) Wilson – stat.: S – 4

An infrequent species growing on bare soil on moraines, usually with *Bryum pallescens*, *Pohlia wahlenbergii*, and *Pogonatum urnigerum*. It is widely distributed and locally common, though scattered throughout the island, often on disturbed, anthropogenic habitats and bird perches [3] but it has not hitherto been recorded from Sørkapp Land.

28. *Niphotrichum canescens* (Hedw.) Bednarek-Ochyra & Ochyra subsp. *latifolium* (C. E. O. Jensen) Bednarek-Ochyra & Ochyra – stat.: N – 25, 26, 27; T – 1; S – 19, 24

The traditionally conceived *Niphotrichum canescens* proved to be a collective species and a thorough taxonomic study of this complex [59] [as *Racomitrium canescens* (Hedw.) Brid.)] revealed that it actually consists of eight species, three of which are known to occur in Svalbard [60]. Of these, *N. canescens* is the most widespread species of this group in this arctic archipelago and it is here represented exclusively by subsp. *latifolium* which is a northern variant of this species. In contrast, the type subspecies is a temperate taxon occurring primarily in the southern part of the Holarctic [59]. The taxonomic status of these two subspecies needs careful study because morphological differences in the shape of leaves and hair-points, which are considered to be the most important diagnostic characters, do not seem to be always evident and sharp. As a result, some plants cannot be easily assigned to subspecies. Putting aside the taxonomic problems associated with the infraspecific classification, *N. canescens* is a rather frequent species in the study area, growing usually in abundance in various communities of the mossy tundra and on ground on moraines, usually in association with such species as *Pogonatum urnigerum*, *Pohlia nutans*, *Polytrichastrum alpinum*, *Polytrichum piliferum*, *Racomitrium lanuginosum*, *Sanionia uncinata*, and *Syntrichia ruralis*. This distinct and unmistakable taxon is common and widespread over the whole Svalbard archipelago [60], including Sørkapp Land [1].

29. *Oncophorus virens* (Hedw.) Brid. – stat.: N – 25, 26

A very rare species growing sparsely on soil on moraines as an admixture in tufts of such species as *Bartramia ithyphylla*, *Distichium capillaceum*, *Hypnum bambergeri*, *Niphotrichum canescens* subsp. *latifolium*, *Pohlia cruda*, and *Racomitrium lanuginosum*. It is a ubiquitous species widespread and usually common throughout Spitsbergen [3] which has already been recorded from Sørkapp Land [1].

30. *Orthogrimmia sessitana* (De Not.) Ochyra & Żarnowiec – stat.: S – 21, 24

A very rare rupestral species found growing quite abundantly and with sporophytes on a stony slope and on an old moraine together with *Coscinodon cribrosus* and *Schistidium papillosum*. Hitherto, only two localities of this species have been known from Spitsbergen, from Bjørndalen and Longyearbyen [3] (Fig. 5B).

31. *Pogonatum dentatum* (Brid.) Brid. – stat.: S – 20, 21

A very rare and scarce species in the study area growing on bare soil on moraines with *Pohlia nutans*, *Ceratodon purpureus*, *Pogonatum urnigerum*, *Polytrichum juniperinum*, and *Sanionia uncinata*. It was reported for the first time in Spitsbergen from Hornsund [56] and later collected at some widely scattered sites in western Spitsbergen [3], including the Grønford area [13] and Nordaustlandet, Prince Oscar Land [17], and herein it is recorded for the first time from the eastern part of the island.

32. *Pogonatum urnigerum* (Hedw.) P. Beauv. – stat.: N – 27; S – 4, 7, 11, 12, 15, 17, 19, 21, 24

A common and locally abundant species growing in a wide range of habitats, predominantly on soil on moraines, rocky ground, scree slopes, and in the bryophyte and lichen tundra. Its most frequent associates are *Bryum pallescens*, *Ceratodon purpureus*, *Niphotrichum canescens* subsp. *canescens* and subsp. *latifolium*, *Pohlia nutans*, and *Sanionia uncinata*. It is widespread throughout Spitsbergen, especially in its western part, but very seldom collected in the eastern coast [1,3,4].

33. *Pohlia cruda* (Hedw.) Lindb. – stat.: N – 25, 26, 27

A rare species growing sparsely on soil as an admixture in patches of bryophytes along with *Bartramia ithyphylla*, *Distichium capillaceum*, *Hypnum bambergi*, *Niphotrichum canescens* subsp. *latifolium*, *Polytrichum piliferum*, *Racomitrium lanuginosum*, and *Timmia bavarica*. It is widespread throughout the whole Svalbard archipelago [3,4].

34. *Pohlia nutans* (Hedw.) Lindb. – stat.: T – 1; S – 12, 17, 20, 21, 24

A frequent and fairly abundant species growing on soil in the mossy and lichen tundra, on scree slopes and old moraines in dry and humid sites, often accompanied by *Bryum pseudotriquetrum*, *B. pallescens*, *Niphotrichum canescens* subsp. *latifolium*, *Pogonatum capillare*, *P. dentatum*, *Polytrichastrum alpinum*, *Racomitrium lanuginosum*, and *Sanionia uncinata*. It is very common throughout Spitsbergen [3,4] but herein it is recorded for the first time from Sørkapp Land.

35. *Pohlia wahlenbergii* (F. Weber & D. Mohr) A. L. Andrews – stat.: N – 27, 28; S – 2, 3, 4, 6, 8, 10, 12, 13, 14, 16, 20, 21, 22

A common and abundant species. Its juvenile plants have commonly been collected from humid bare soil on moraines, together with *Bryum pseudotriquetrum* and *Ceratodon purpureus*, as a primary colonizer of newly exposed ground. The species is considered to be very rare in Spitsbergen [3] but it has already been recorded from Sørkapp Land [1]. Recently, it was reported from the Grønford area [13], Van Mijenfjord area [14], Pyramiden and Mimerbukta near Pyramiden [24], and Prince Oscar Land on Nordaustlandet [17]. According to some authors, for example Kuc [4], this species may be more frequent than suggested by its published records and its occurrence in great quantity in the study area seems to confirm this assumption (Fig. 5C).

36. *Polytrichastrum alpinum* (Hedw.) G. L. Sm. – stat.: T – 1; S – 14, 18, 22, 24

A fairly frequent species usually growing in abundance in various types of tundra, on stony ground and rock-debris, usually in association with *Bryum pallescens*, *Niphotrichum canescens* subsp. *latifolium*, *Pohlia nutans*, *Racomitrium lanuginosum*, and *Sanionia*

*uncinata*. It is a very common and very variable moss, occurring throughout the whole archipelago [3,4], although it has not hitherto been recorded from Sørkapp Land.

37. *Polytrichum juniperinum* Hedw. – stat.: S – 21

A very rare species collected on a rocky slope where it was growing sparsely on small patches of soil between boulders in association with *Ceratodon purpureus*, *Pogonatum urnigerum*, and *Pohlia nutans*. Although the species was reported many times from Spitsbergen, its true distribution and frequency are unknown because it has often been confused with other species of the genus, especially *P. strictum*. It has recently been recorded from the Grønford area [13], Prins Oscars Land (Nordaustlandet) [17], Edgeøya and Barentsøya [21] and between Pyramiden and Odinfjellet [24].

38. *Polytrichum piliferum* Hedw. – stat.: N – 27.

A very rare species found growing sparsely on soil on a young moraine together with *Niphotrichum canescens* subsp. *latifolium*, *Pogonatum urnigerum*, and *Racomitrium lanuginosum*. It is widely distributed and rather frequent on the northern and western coasts of Spitsbergen but until now it had not been recorded on the eastern coast [4].

39. *Polytrichum strictum* Brid. – stat.: N – 25, 27; S – 24

An infrequent species growing on muddy soil and on rocky ground on moraines, usually in abundance together with *Aulacomnium turgidum*, *Campylium longicuspis*, *Sanionia uncinata*, *Sphagnum squarrosum*, and *Tomentypnum nitens*. It is widespread throughout Spitsbergen [3,4], including Sørkapp Land [1].

40. *Racomitrium lanuginosum* (Hedw.) Brid. – stat.: N – 26, 27; T – 1; S – 12, 24

A frequent and locally abundant species usually forming extensive dense carpets on relatively dry, stable moraines and in the mossy tundra on flat areas. Its most frequent associates are, among other things, *Bryum pallescens*, *Hylocomium splendens*, *Niphotrichum canescens* subsp. *latifolium*, *Pogonatum urnigerum*, *Pohlia nutans*, *Polytrichastrum alpinum*, and *Sanionia uncinata*. It is one of the most common bryophytes in the Svalbard archipelago [60], including Sørkapp Land [1].

41. *Sanionia georgicouncinata* (Müll. Hal.) Ochyra & Hedenäs – stat.: S – 22

A fairly large pure patch of this species was located at one site on dry soil at the glacier foreland. This species had been recorded for the first time from Spitsbergen as *Sanionia nivalis* Hedenäs [61] and later some additional collections of this species were reported from various sites on this island [3,13,14,16]. However, it has been shown that this northern species is conspecific with *S. georgicouncinata*, an austral species known from subantarctic South Georgia and the northern maritime Antarctic [62–64]. The present material is entirely sterile and the sporophyte characters separating this species from *S. uncinata* (Hedw.) Loeske, namely the reduced and irregularly perforated endostome and acute to short-acuminate inner perichaetial leaves with strongly denticulate or dentate distal margins, cannot be checked. However, the structure of the alar and supra-alar cells which form a large, oval basal marginal group immediately separate the two species. *Sanionia georgicouncinata* is apparently rare species in Svalbard (Fig. 5D).

42. *Sanionia uncinata* (Hedw.) Loeske – stat.: N – 25, 26, 27, 28; T – 1; S – 2, 5, 7, 14, 19, 20, 24

A common species, growing usually in abundance in a wide range of dry and wet habitats in the mossy and lichen tundra, on moraines, rocks, scree and stony ground, forming either pure stands or growing with a long array of associates, including *Aulacomnium turgidum*, *Bryum pallescens*, *Dicranum elongatum*, *D. spadiceum*, *Hylocomium splendens*, *Niphotrichum canescens* subsp. *latifolium*, *Pogonatum urnigerum*, *Pohlia nutans*,

*Polytrichastrum alpinum*, and *Racomitrium lanuginosum*. It is a ubiquitous species, widespread throughout the whole Svalbard archipelago [3], including Sørkapp Land [1].

#### 43. *Schistidium frigidum* H. H. Blom – stat.: S – 17

The genus *Schistidium* Bruch & Schimp. is well represented in the polar regions of both hemispheres. For example, it is the largest moss genus in the Antarctic [64–72]. In the Svalbard archipelago, only six species of *Schistidium* have been recorded [4]. However, as a result of the taxonomic revision of the *S. apocarpum* (Hedw.) Bruch & Schimp. complex [73], this number markedly increased and currently no fewer than 16 species of *Schistidium* are known from this arctic archipelago [3,14,74]. The genus is still poorly known in Svalbard in terms of frequency and cover, but this poor knowledge is also reflected in many other parts of the globe.

*Schistidium frigidum* has long remained neglected and only recently it was described as new to science [73], yet it is a widely distributed, panholarctic species with an arctic-alpine distribution. It appears to be one of the most common species of the genus on Spitsbergen, at least judging from the number of specimens cited in the protologue [73]. In the study area, the species was once found in fairly large quantity from dry soil on old moraine.

#### 44. *Schistidium papillosum* Culm. – stat.: S – 24

A small tuft of this species was collected in an arctic oasis below a small bird colony, growing together with *Orthogrimmia sessitana*. The species appears to be common in Svalbard and most collections reported from this archipelago and referred to as *Grimmia gracilis* Schwägr or *Schistidium strictum* (Turner) Mårt. actually belong to this species [3].

#### 45. *Schistidium pulchrum* H. H. Blom – stat.: S – 22

A small tuft of this species was found on dry rock-debris on the fore-field of a glacier, growing together with *Hymenoloma crispulum* and *Andreaea blyttii*. The species was only recently described as new to science and it appears to be very rare on Spitsbergen, known only from Ny-Ålesund and Kollerfjorden [73] and also recorded from Bjørnøya [3]. The global geographical distribution of *Schistidium pulchrum* is still poorly known, yet it appears to be a panboreal Holarctic species penetrating into the Arctic and to the mountains in the southern parts of the Holarctic [73].

#### 46. *Sphagnum squarrosum* Crome – stat.: N – 25

A very rare species, found at a single station but growing abundantly in the wet mossy tundra in association with *Aulacomnium turgidum*, *Campylium longicuspis*, *Polytrichum strictum*, *Sanionia uncinata*, and *Tomentypnum nitens*. It is the most frequent peat moss species in Svalbard [75], common in central Spitsbergen and rare and occasional on the northern and western coast. Some solitary records of *Sphagnum squarrosum* are also known from Nordaustlandet, Kongsøya, and Edgeøya in the Svalbard archipelago.

#### 47. *Sphagnum teres* (Hedw.) Ångstr. – stat.: N – 27

A very rare species discovered at one locality in the wet mossy tundra growing in association with *Sphagnum warnstorffii*. The species is infrequent in Spitsbergen and previously known only from the central part of the island [75]. Apart from Spitsbergen, it has only recently been recorded from Edgeøya in the Svalbard archipelago [21].

#### 48. *Sphagnum warnstorffii* Russow – stat.: N – 27

A very rare species collected only at one station in the wet mossy tundra growing in association with *Sphagnum teres*. *Sphagnum warnstorffii* is the only red-pigmented taxon among the peat mosses in Svalbard but the local plants represent a distinct arctic morph

which differs in the overall appearance from the typical boreal and nemoral morphs. Yet, they are characterized by having typical small and ringed pores on the distal part of the convex leaf surface which are typical of *S. warnstorffii*. The species is rather rare in Spitsbergen, known only from the central part of the island and only once it was collected on its northwestern coast [75].

49. *Straminergon stramineum* (Brid.) Hedenäs – stat.: S – 2, 23

Fairly occasional in the study area but growing abundantly in patches with *Aulacomnium turgidum*. It is one of the most common moss species in Spitsbergen occurring in various communities in the mossy tundra [3] but it has not hitherto been recorded from Sørkapp Land.

50. *Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr – stat.: T – 1; S – 7

An infrequently recorded species in the mossy tundra and on soil on the moraines, growing in turves of other mosses including *Ceratodon purpureus*, *Niphotrichum canescens* subsp. *latifolium*, *Pohlia nutans*, *Polytrichastrum alpinum*, and *Racomitrium lanuginosum*. It is common throughout the Svalbard archipelago in a wide range of habitats [3], including Sørkapp Land [1].

51. *Timmia bavarica* Hessel. – stat.: N – 26

Very rare in the study area, occurring as an admixture in a tuft of *Bartramia ithyphylla*, *Hypnum bambergeri*, *Niphotrichum canescens* subsp. *latifolium*, *Oncophorus virens*, *Pohlia cruda*, and *Racomitrium lanuginosum*. It is widely distributed throughout Spitsbergen but generally sparse [3].

52. *Tomentypnum nitens* (Hedw.) Loeske – stat.: N – 25, 27; T – 1

A rare but locally abundant species in wet sites in mossy tundra on moraines, often growing together with *Aulacomnium turgidum*, *Bryum pseudotriquetrum*, *Polytrichum strictum*, *Sanionia uncinata*, and *Warnstorffia sarmentosa*. It is one of the most common and dominant species in its habitats in Spitsbergen; widespread throughout the island [3,4].

53. *Warnstorffia sarmentosa* (Wahlenb.) Hedenäs – stat.: N – 27; S – 2, 13

A rare species, although locally growing in abundance, forming pure stands in wet sites in mossy tundra on moraines and on dripping stones, sometimes associated with *Tomentypnum nitens* and *Warnstorffia tundrae*. It is widely distributed throughout the whole island [3,4], but it has not hitherto been recorded from Sørkapp Land.

54. *Warnstorffia tundrae* (Arnell) Loeske – stat.: N – 27

Collected once in a wet site in the mossy tundra growing together with *Warnstorffia sarmentosa*. The species is very rare in Spitsbergen, known only from Hornsund [56], Kongsfjorden [44], but according to Frisvoll and Elvebakk [3] it is frequent in western and northern Spitsbergen.

## Discussion

Apart from Franz Josef Land, the Svalbard archipelago is the only European territory situated in the high Arctic. Like elsewhere in polar regions of both hemispheres, the vegetation cover is dominated by cryptogams, of which bryophytes represent significant constituents of the flora. During almost two and a half centuries of intensive exploration of this land and taxonomic investigations, 563 species of bryophytes have been recorded from Svalbard, and they have been critically evaluated in the annotated

catalog of Frisvoll and Elvebakk [3]. These authors showed that no fewer than 190 species have been erroneously reported from Svalbard and should be excluded from the bryoflora of this archipelago. Most records of these excluded species proved to be based upon misidentifications, and only a much smaller number of species appeared to be conspecific with species previously collected and described in other regions. It is worth noting that a similarly large number of excluded moss taxa have been detected in the Antarctic [64]. In the 175 years from 1833 to 2008, no less than 303 moss taxa have been recorded from this largely ice-covered continent, but critical evaluations of the voucher collections resulted in the exclusion of 190 moss taxa from the bryoflora of Antarctica.

Since the publication of the catalog of Svalbard bryophytes [3], field studies have resulted in a number of new discoveries of bryophytes from Spitsbergen and its adjacent islands, e.g., [8,9,11,12,15,17,18,21,76]. The identification of Svalbard's bryophytes is always very hard. The habitus is quite different in Svalbard compared to Europe. As a result, erroneous new records for the archipelago have appeared, including *Odontochisma sphagni* (Dicks.) Dumort. [77], *Barbilophozia floerkei* (F. Weber & D. Mohr) Loeske [78], and *Cephaloziella rubella* (Nees) Warnst. [79]. A revision of the voucher specimens of the first two species by one of us (NAK) revealed that they actually refer to *Jungermannia polaris* Lindb. and *Neo-orthocaulis hyperboreus* (R. M. Schust.) L. Söderstr., De Roo & Hedde.

Spitsbergen, the largest island of the Svalbard archipelago, is markedly diverse climatically and, accordingly, various parts of the island differ in the extent of ice-free areas. As a result, the island is still unevenly explored bryologically and botanically. Its central and western parts have a much warmer climate and consequently much larger expanses of terrain that are not glaciated and have a well-developed vegetation cover. In contrast, the eastern and southeastern coasts of Spitsbergen have a much more severe climate, resulting in extensive glaciations of large expanses of terrain and small ice-free outcrops available for colonization by plants and lichens. These exposures are often inaccessible, and many such sites have not so far been botanically explored, including the eastern parts of Sørkapp Land and Torell Land. However, the effects of global warming and climate change are predicted to be most pronounced at high latitudes. In the case of bryophytes, these impacts will mainly concern their biology and physiology [80].

Significant climate change has been confirmed in the Arctic at the end of the twentieth century. This vast region has had a rapid increase in mean temperatures over the past few decades, twice the rate of the rest of the world. Continuing climate change in the Arctic will result in forest expansions into tundra biomes, and the tundra vegetation will greatly change, shifting in its extent, distribution, and species composition [81].

The expected changes are becoming more and more visible, and they are confirmed by the results of the present floristic studies. The recent deglaciation has exposed vast expanses of land that are being colonized by various groups of organisms, including bryophytes. As a result, a number of moss species have been recorded for the first time on the eastern coast of Spitsbergen, including *Andreaea blyttii*, *Bryum salinum*, *Coscinodon cribrosus*, *Orthogrimmia sessitana*, *Pogonatum dentatum*, *Polytrichum juniperinum*, *Sanionia georgicouncinata*, *Scapania obcordata*, *Schistidium frigidum*, and *S. pulchrum*. Most of these are rare in Svalbard, and changes in local distribution of such species associated with deglaciation are an interesting ecological problem that requires further study and long-term monitoring.

A very interesting case is presented by *Pohlia wahlenbergii*, a species that is otherwise rare and scattered in Spitsbergen [3] (Fig. 5C). In Sørkapp Land, it occurs very abundantly as a primary colonizer of young moraines. A similar phenomenon was recently observed in this species on King George Island, South Shetland Islands, Antarctica. Four decades ago, this species was very rare on this island [62], whereas now it has been observed in masses on young moraines in Ezcurra Inlet (M. Wierzgoń, personal communication).

Floristic data can be used to undertake an attempt to assess the development of the bryophyte flora in areas where rapid retreat of glaciers has occurred. Unfortunately, it is difficult to determine the rate of colonization of rocks and soils by bryophytes or to describe phases of such succession in terms of species composition of recently deglaciated substrata. These questions can only be resolved on the basis of long-term observations and analyses of vegetation on permanent research plots. An additional complication

can arise due to the possibility of some species surviving in situ on small unglaciated specks of ground. It was recently proved that at least some bryophyte species could have survived for a long time under ice cover and continued their growth after ice melting. For example, in the Canadian Arctic Archipelago, rapid glacier retreats exposed plant communities originated from the Little Ice Age (1,550–1,850 Kya) and, as a result, some bryophytes developed green stem apices or lateral innovations, suggesting their potential regrowth [82]. Moreover, we do not know anything about propagule banks buried in soil, which certainly affect the species composition of the flora, or the role of wind and/or birds as vehicles in long-distance dispersal of diaspores. For example, the mass occurrence of the moss *Pohlia wahlenbergii* in some recently deglaciated areas may represent good evidence regarding the successful development of bryophyte colonies from buried or superficial spores or vegetative propagules deposited in soil banks.

In this context, field observations (made by WZ, KO, and WM) in eastern Sørkapp Land lead to the following conclusions:

- The present vegetation cover was significantly more extensive in 2016 than in 2005, including areas covered by ice or slush in 2005. This means that bryophyte colonies developed almost immediately in deglaciated areas.
- The areas where glaciers recently retreated are situated at a distance of about 30–40 km from western Sørkapp Land, which is covered by close luxuriant vegetation.
- The study area was mostly covered by glaciers during the Little Ice Age, except from the Daudbjørnpynten headland and its vicinity (a short valley above it), which were not glaciated and did not undergo intensive slope processes either during the Little Ice Age or afterwards [83]; some slopes outside the glaciers and the vicinity of Daudbjørnpynten underwent intensive geomorphic processes.

According to these observations, the development of the vegetation cover was generally impossible in eastern Sørkapp Land during the Little Ice Age (except for the vicinity of Daudbjørnpynten) and the current state of the vegetation has been a result of plant colonization since the beginning of the twentieth century. The nearest sources of propagules appear to be the area of Daudbjørnpynten and western Sørkapp Land, although they could be transported by wind or birds from more distant areas.

Regarding rare species of moss, it is worth noting the second discovery of *Campylium longicuspis* in Svalbard (Fig. 3C), the third of *Orthogrimmia sessitana*, and the fourth one of *Coscinodon cribrosus* (Fig. 3D) in the archipelago.

Apart from rare species, the core of the moss flora in Sørkapp Land consists of some moss species which are ubiquitous on Spitsbergen and in Svalbard, including *Bryum pallescens*, *Ceratodon purpureus*, *Hymenoloma crispulum*, *Pogonatum urnigerum*, *Pohlia nutans*, *Polytrichastrum alpinum*, *Racomitrium lanuginosum*, and *Sanionia uncinata*. So far, some 26 species of moss have been recorded from the northeastern part of Sørkapp Land [1] and in the present account, 25 species have been added to the moss flora of this area.

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