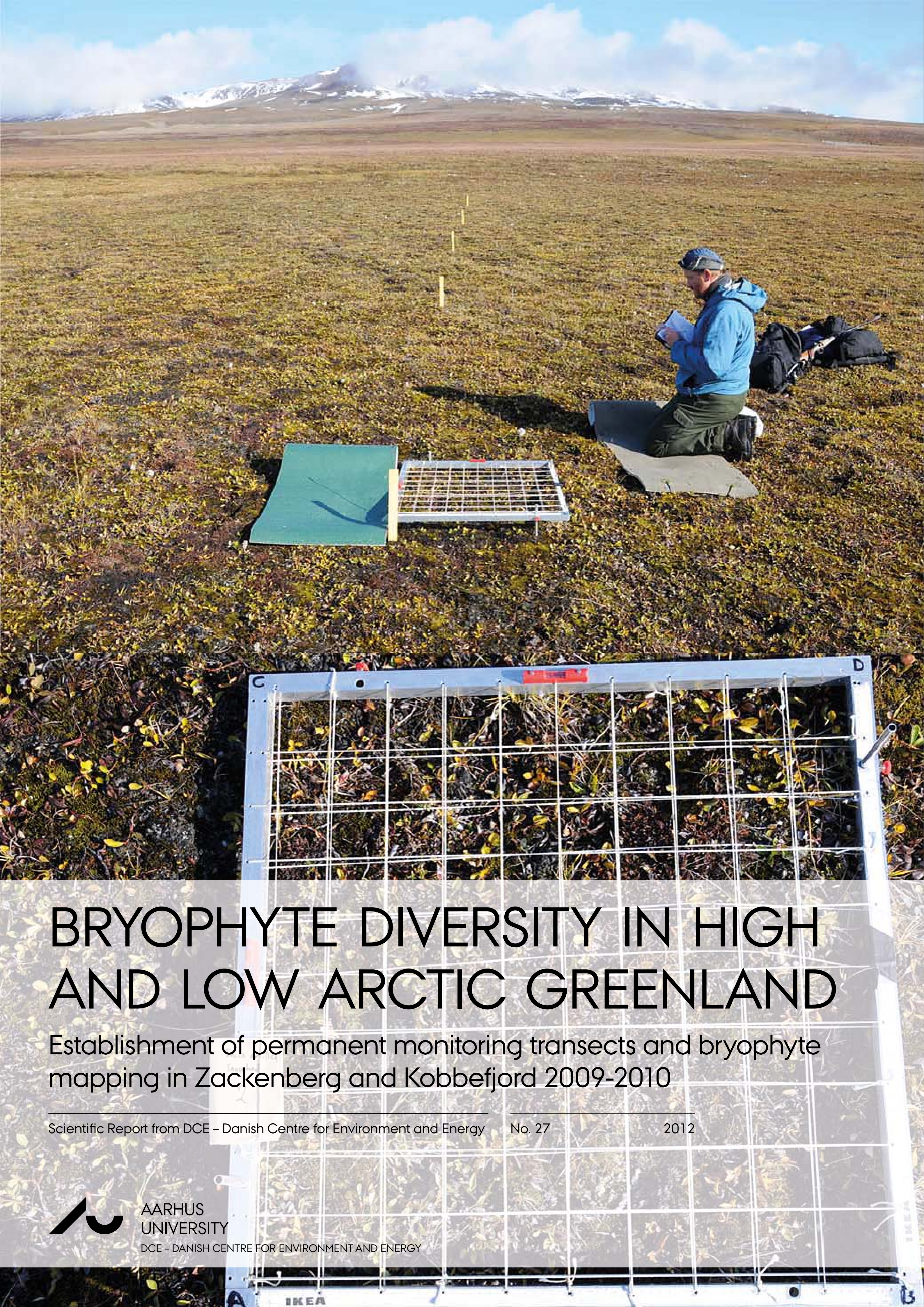

BRYOPHYTE DIVERSITY IN HIGH AND LOW ARCTIC GREENLAND

Establishment of permanent monitoring transects and bryophyte mapping in Zackenberg and Kobbefjord 2009-2010

Scientific Report from DCE – Danish Centre for Environment and Energy No. 27 2012

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Data sheet

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At both sites, bryophytes were one of the main components both in terms of species diversity and frequency in the vegetation. At Zackenberg, species diversity was higher for bryophytes than vascular plants in all transects, except for transects located in snow beds or in the high altitudinal fen. In terms of frequency bryophytes were the dominating functional group in most transects. In Kobbefjord, bryophytes exhibited higher species diversity than vascular plants in most vegetation types, but they were never the dominating group in terms of frequency.
The permanent monitoring infrastructure will allow for future reexaminations to assess the development in bryophyte species diversity in Greenland. All collected data are available through the database of Greenland Ecosystem Monitoring (www.g-e-m.dk).

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Preface

While the biodiversity of vascular plants is relatively well-known for the two monitoring sites within the Greenland Ecosystem Monitoring (Zackenberg and Kobbefjord), only little information is available on the diversity of the bryophytes there, and in Greenland in general. The aim of the present study was two-fold. Firstly, this study was initiated in order to provide a contemporary inventory of the bryophyte diversity at the two sites. Secondly, at both sites this study established a number of permanent transects for monitoring the changes in bryophyte diversity over the years. The present report thus both provides a status of the current bryophyte diversity at the two sites, but also provides a detailed description of the methodologies applied as well as descriptions of the general characteristics of the individual monitoring plots along the transects.

The present project was financially supported by the Danish Environmental Protection Agency, and Norwegian University of Science and Technology, Museum of Natural History and Archaeology in Trondheim, Norway.

The authors thank Aarhus University and Greenland Institute of Natural Resources for providing access to Zackenberg and Kobbefjord, respectively.

Summary

This report summarises the establishment of permanent bryophyte monitoring transects at high arctic Zackenberg and in low arctic Kobbefjord. Transects were established at Zackenberg in 2009 and in Kobbefjord in 2010. Along with the establishment of the permanent monitoring infrastructure, a detailed mapping of the bryophyte communities was conducted.

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The permanent monitoring infrastructure will allow for future re-examinations to assess the development in bryophyte species diversity in Greenland. All collected data are available through the database of Greenland Ecosystem Monitoring (www.g-e-m.dk).

Sammendrag

Denne rapport opsummerer etableringen af permanente transekter til monitering af mosser ved henholdsvis Zackenberg (højarktis) og Kobbefjord (lavarktis). Transekterne ved Zackenberg og Kobbefjord blev etableret i henholdsvis 2009 og 2010. I forbindelse med etableringen af transekterne blev der gennemført en detaljeret kortlægning af mos-samfundene på de to lokaliteter.

På begge lokaliteter var mosser en af de vigtigste vegetationskomponenter, både hvad angår artsdiversitet og hyppighed. Ved Zackenberg var artsdiversiteten af mosser højere end for karplanter i alle transekter, undtaget transekter i snelejer og højtliggende kær. I de fleste transekter var mosser desuden den dominerende gruppe mht. hyppighed. I Kobbefjord var artsdiversiteten af mosser også større end karplanternes i de fleste transekter, men mosser var aldrig den dominerende gruppe mht. hyppighed.

De permanente moniteringstransekter muliggør ved fremtidige gen-analyser en detaljeret vurdering af ændringerne i diversiteten af mosser i Grønland. Alle de indsamlede data er tilgængelige via databasen for Greenland Ecosystem Monitoring (www.g-e-m.dk).

1 Introduction

Bryophytes are an important plant group of arctic and tundra ecosystems both in relation to annual production of biomass and species diversity (Longton 1988). Based on data from different arctic communities in Alaska and Canada, annual net production of bryophytes is found to be highest in wet sedge moss meadow vegetation. Bryophytes also have a similar or higher annual net production compared to vascular plants (above ground biomass) in most of the wet meadow, grass heath and dwarf shrub heath vegetation studied (summarised by Longton 1988). The important role of bryophytes in relation to global carbon balance of peatlands and climatic warming was early recognised (Gorham 1991), but the effect of the expected changes in vegetation are predicted to be even stronger in the bryophyte dominated tundra areas (Gornall et al. 2007, Walker et al. 2006). Both peatland and tundra ecosystems are characterised by large areas of moist to wet soils with bryophytes as one of the dominating groups of plants. The poikilohydric nature of bryophytes makes them resistant to the repeated freezing and thawing in the Arctic. And a thick bryophyte layer ensures good insulation of the permafrost and also to some degree inhibits seed recruitment of vascular plants (Gornall et al. 2007, Soudzilovskaia et al. 2011). In bryophytes the lack of roots and conducting tissue for active uptake and transport of water and cuticles to hold water makes them dependent of a stable and humid microclimate for growth. Thus we find the most lush bryophyte vegetation in areas with stable water supply either by ground water, melting snow or by high frequency of precipitation. If the conditions become too dry for photosynthesis, the cells shut down the metabolism, and stay inactive until they are sufficiently moistened again.

There is a general trend that bryophyte diversity increases relative to vascular plant diversity with increasing latitude. It is estimated that the total arctic bryophyte flora consist of 600-700 species, compared with about 900 vascular plants (Longton 1988). For Svalbard 373 bryophytes and 173 vascular plants are known (Elvebakk and Prestrud 1996). In contrast the Scandinavian Peninsula has about twice as many vascular plant species as bryophyte species. The bryophyte flora of Greenland is relatively rich and consists of 613 species (Mogensen 1999). Norway which is of similar area as the ice free area of Greenland, but is mainly situated in the boreal zone, has 1071 bryophyte species (Hassel et al. 2010).

Most bryophytes found in the Arctic are also found in boreal and some even in temperate areas, but there are about 80 species that can be attributed to a circumpolar arctic element (Steere 1978). The lack of endemism among arctic bryophytes combined with a large number of circumpolar species, restricted to alpine areas if they occur outside the Arctic, may indicate that the arctic bryophytes in general have good capability of dispersal through production of spores, gemmae or gametophore fragments.

The vegetation in the Zackenberg valley in the high arctic zone (figure 1), is formerly mapped by Bay (1998) and the most important vegetation types for bryophytes by means of percentage cover are 1) grassland 98%, 2) fen 63 %, 3) *Vaccinium uliginosum* heath 31 %, 4) *Salix arctica* snow bed 14 % and 5) *Cassiope tetragona* heath 8%. A vegetation transect, "ZERO line", was established by Fredskild and Mogensen (1997). It starts by the shore in Young Sund and ends at Aucellabjerg 1040 m above sea level (Figure 2). In total 11 different vegetation types are described along the ZERO Line and the vegetation is described for 129 points along this transect. The vegetation in Kobbefjord, low arctic zone (figure 1), is not mapped in the whole valley, but is restricted to the "NERO line" transect (figure 2), established and described by Bay et al. (2008). The transect starts 166 m above sea level in a north-east facing slope, falls down to the valley bottom and rises to 400 m above sea level at a south-west facing slope. The NERO Line includes eight vegetation types, where the main vegetation types are 1) dwarf shrub heath with different subtypes according to the dominating shrub species, e.g. *Empetrum hermaphroditum*, *Vaccinium uliginosum*, 2) fen, 3) *Salix herbacea* snow bed, 4) *Salix glauca* copse and 5) herb slope. According to the Raunkjær analyses of the different vegetation types (Bay et al. 2008), bryophytes are very important in heath, snow bed and fen vegetation. The vegetation along the NERO Line is described in 91 points.

Figure 1. The classification of the Arctic into the high, low and sub-arctic regions based on the Circumpolar Arctic Vegetation Map (CAVM Team 2003). Also shown are the locations of Kobbefjord and Zackenberg.

The main aim of the current study was to establish permanent transects and plots for long term monitoring of bryophytes within the frames of the Zackenberg and Nuuk Ecological Research Operations. The main vegetation types in each area are to be represented and for one of the dominating vegetation types a transect covering an altitudinal gradient should be established.

2 Methods

Two sites in Greenland were selected for the establishment of the permanent monitoring infrastructure, low arctic Kobbefjord and high arctic Zackenberg (figure 2).

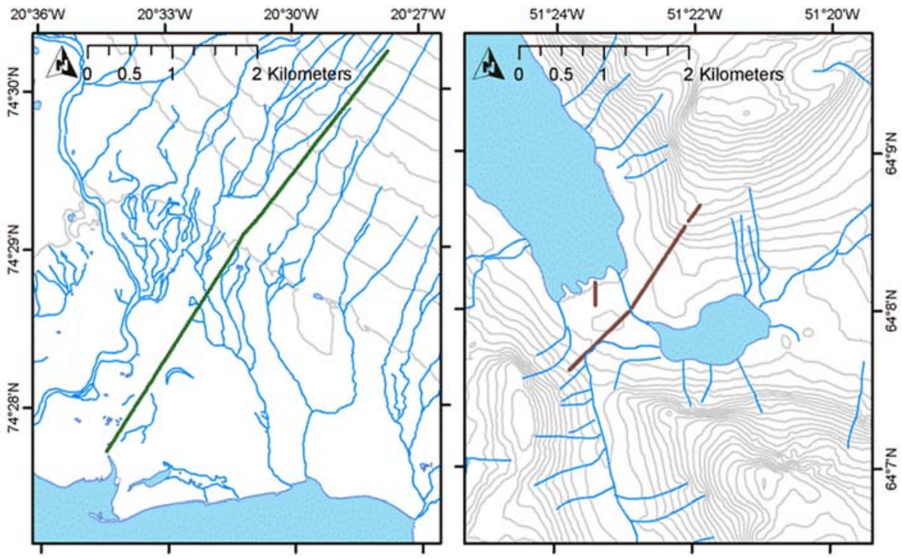


Figure 2. Location of the vegetation transects a) at Zackenberg (the ZERO Line) and b) in Kobbefjord (the NERO Line). The grey lines indicate the 50 meter equidistance.

The vegetation types described along the ZERO Line (Fredskild & Mogensen 1997) and the NERO Line (Bay et al. 2008) were used as background information to randomly choose plots for vegetation analysis (figure 2). Due to snow above 450 m a.s.l. during the field work in late August 2009 and to minimize the influence of salt spray from the sea only the mid part of the ZERO Line was available for analysis. This part of the ZERO Line starts by the end of the air strip at ZERO Line point 28 crossing the valley plain and elevates to point 101. The analysed plots for *Cassiope tetragona* heath, *Vaccinium uliginosum* heath and *Salix arctica* snow bed were randomly chosen among the ZERO Line points (28 to 101) representing these vegetation types as described by Fredskild & Mogensen (1997). In the same manner vegetation types described along the NERO Line (Bay et al. 2008) were used as background information to randomly choose plots for bryophyte analysis of fen, *Vaccinium uliginosum* heath and snow bed vegetation in Kobbefjord.

When we arrived at a randomly selected point, a transect was established 20 m north of and, if possible, parallel with the ZERO Line in Zackenberg, while 5 m northwest of, and, if possible, parallel to the NERO Line in Kobbefjord. If the target vegetation type changed into another type, the transect was adjusted so that all plots were placed in the vegetation type of interest. Details for deviating transects can be found in description of the specific transects.

In Zackenberg, fen vegetation was chosen for analysis along an altitudinal gradient from ZERO Line point 28 to 101. This was done by applying stratified sampling design, where we defined four altitudinal levels and randomly choose among fens at each level. However, it was only possible to choose among ZERO Line points at the lower level (40-135 m a.s.l.). For the three upper levels (136-230 m a.s.l., 231-325 m a.s.l. and 326-420 m a.s.l.) we had to search for fens at each level and then choose randomly among them. We had at least three different fen localities to choose among at each level.

In Kobbefjord, *Empetrum* heath vegetation was analysed along an altitudinal gradient on the south-west facing slope of the valley. Also here this was done by stratified sampling, where we defined three altitudinal levels and randomly choose among *Empetrum* heaths at each level. However, at the mid level there was only one *Empetrum* dominated heath, and thus this was analysed.

The vegetation analyses were carried out as described by Bay (1998). In each of the analysed vegetation types an analysis included five plots along a transect with a distance of about 5 m. Each plot was analysed by "pinpoint" analysis using a frame of 0.7 m × 0.7 m with 100 pins. Pin number one was in the northwest corner. The method follows the International tundra experiment (ITEX) concept (Walker 1996). For each pin, plant species and height were identified and recorded. Bryophytes were recorded to species level; when the species identity was uncertain, material of the species were searched for outside the plot and collected for determination at the laboratory. Lichens were recorded mainly to genus level, vascular plant species were identified as far as possible and classified as graminoids, club mosses, herbs and woody plants. In addition open ground (debris/soil/bare ground) was recorded. A free search within plots were undertaken to record additional bryophyte species, as the pinpoint method tends to miss rare species.

The plots were permanently marked to allow for future revisits to the exact same spot. The marking consist of aluminium pipes in the corners, i.e. in the holes after the frame feet. However, in Zackenberg aluminium pipes were only used in the south-western (corner A) and north-eastern corner. The south-eastern and north-western corners were marked by nails in the feet holes. Thus it should be possible to relocate the plots by GPS-position together with the use of a metal detector.

In Zackenberg the vegetation plots were analysed from August 19th to August 30th 2009 and in Kobbefjord from August 16th to August 24th 2010. At this time most vascular plants had finished flowering and started to set seeds/diaspores, and thus the plants started to get dead leaves. The frequency of vascular plants was therefore underestimated and we have probably also missed species flowering early in the season. But this fact also means that it was easier to see and identify the bryophytes at ground level.

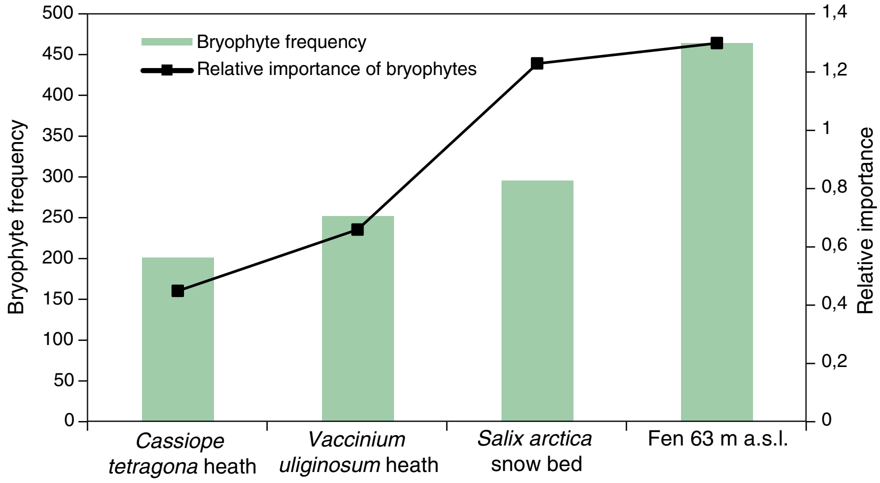
Nomenclature follows Hill et al. (2006) for mosses, Söderström et al. (2002) for liverworts, and Böcher et al. (1978) for vascular plants.

3 Results

3.1 Zackenberg

The frequency of bryophytes in the studied vegetation types showed an increase from the dry *Cassiope tetragona* heath to the moist *Vaccinium uliginosum* heath to the wet *Salix arctica* snow bed and fen (figure 3). Along the same moisture gradient the relative importance of bryophytes increased compared with the other functional plant groups (figure 4).

Figure 3. The frequency (sum of hits in 5 replicates) of bryophytes is increasing from dry to more wet vegetation types. Fen 63 m a.s.l. is included among the fens as it is approximately at the same elevation as the other vegetation types included. The relative importance of bryophytes in the different vegetation types is maximised in the snow bed vegetation. The relative importance of bryophytes is calculated as bryophyte frequency/vascular plants frequency.



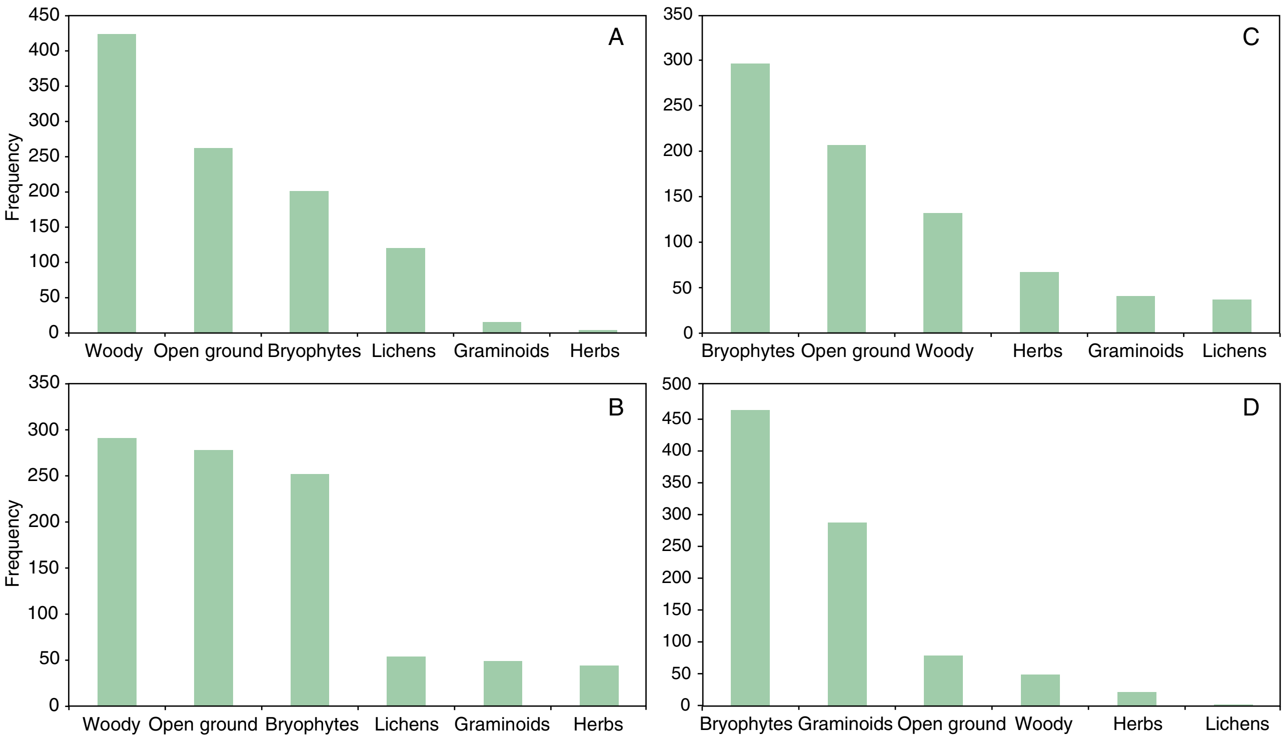


Figure 4. Frequency (sum of hits in 5 replicates) of species by functional groups in a) *Cassiope tetragona* heath, b) *Vaccinium uliginosum* heath, c) *Salix arctica* snow bed and d) fen 63 m a.s.l.

Species diversity was dominated by bryophytes in *Cassiope tetragona* heath, *Vaccinium uliginosum* heath and fen (63 m a.s.l.) vegetation, while vascular plants were the most species-rich plant group in the *Salix arctica* snow bed (table 1). Bryophyte species diversity thus seemed to be negatively related to the moisture gradient, while the relative importance of bryophytes increased along the same gradient. A closer look at the species composition showed that long-lived perennials were dominating in the wet vegetation, while pioneer and colonist species were almost absent (table 2). In the *Cassiope tetragona* heath and the *Vaccinium uliginosum* heath there were many pioneers and colonist species, and this may be explained by more open ground and possibly warmer microclimate compared to the wetter vegetation types.

Table 1. Plant diversity measured as number of species (cumulative over 5 replicates) in the analysed vegetation types.

Vegetation type	Bryophytes	Vascular plants
Cassiope tetragona heath	22	6
Vaccinium uliginosum heath	27	14
Salix arctica snow bed	11	14
Fen 63 m a.s.l.	21	12

Table 2. The five most frequent bryophytes in the analysed vegetation types. Frequencies are sums of hits in 5 replicates.

***Cassiope tetragona* heath**		***Vaccinium uliginosum* heath**		***Salix arctica* snow bed**		**Fen 63 m a.s.l.**	
Species	**Freq.**	**Species**	**Freq.**	**Species**	**Freq.**	**Species**	**Freq.**
Dicranum laevidens	43	*Dicranum sp.*	89	*Sanionia uncinata*	55	*Sanionia uncinata*	89
Sanionia uncinata	36	*Sanionia uncinata*	62	*Aulacomnium turgidum*	28	*Ptilidium ciliare*	62
Gymnomitrion corallioides	20	*Dicranum laevidens*	59	*Dicranum laevidens*	24	*Tomentypnum nitens*	59
Gymnomitrion concinnatum	16	*Racomitrium panschii*	36	*Polytrichum hyperboreum*	24	*Pseudocalliergon brevifolium*	36
Oncophorus wahlenbergii	13	*Polytrichum hyperboreum*	24	*Schistidium sp.*	19	*Onchophorus virens*	24

3.1.1 Description of the analysed vegetation plots

The original data for the pin point analysis are stored in the GEM database (www.g-e-m.dk). Photo documentation of the transects and the individual plots are presented in appendix 1 and 2.

***Cassiope tetragona* heath, ZERO Line point 51.**

Due to large variation in the vegetation, we had to move plot 1, 5 m east of point 51 along the ZERO Line. Five plots were established 20 m north of this point parallel to the ZERO Line. The vegetation is a *Cassiope* dominated heath with *Salix arctica* (table 3).

Tabel 3. *Cassiope tetragona* heath, plots established August 22nd 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	293	294	295	296	297
Position (hddd mm ss.s)	N74º28'48.3" W20º31'52.9"	N74º28'48.4" W20º31'52.6"	N74º28'48.6" W20º31'52.2"	N74º28'48.7"W20º31'51.9"	N74º28'48.8" W20º31'51.7"
Altitude m a.s.l.	41	42	42	42	42
Inclination (estimated)	0 %	1 %	2 %	1 %	0 %
Soil moisture	Moist	Dry	Dry	Dry	Dry
Ground texture	Rough, incomplete vegetation cover	Rather plain, small part with bare soil, some cracks > 5 cm	Crack 15 cm from NE-SW corner	Many cracks in soil, rough ground	Rising towards corners, some cracks
Additional bryophyte species	None	*Conostomum tetragonum, Polytrichum piliferum, Polytrichastrum alpinum, Aulacomnium turgidum*	*Pogonatum* cf. *dentatum, Racomitrium canescens, Polytrichastrum alpinum*, liverwort - crust with some possible add. species	*Polytrichastrum alpinum*	*Polytrichastrum alpinum, Tritomaria quinquedentata, Lophozia* sp., *Anastrophyllum minutum*

Vaccinium uliginosum heath, ZERO Line point 87.

Fredskild & Mogensen (1997) described this point as "A mixed, mossy heath with *Carex bigelowii*, *C. rupestris, Arctagrostis* and *Eriophorum triste*". In the upper part it gradually changed from a heath rich in *Vaccinium* to a *Salix-Cassiope* heath without *Vaccinium*." The first vegetation plots were placed 40 m east of point 87 along the ZERO Line to get continuous *Vaccinium* heath vegetation 20 m north of the ZERO Line (Vaccinium heath plot 1). The *Vaccinium* heath occurred as almost parallel stripes to the ZERO Line. The second plot was 5 m north (Vaccinium heath plot 2), to follow the stripe of *Vaccinium* heath plot three had to be moved 5 m south (toward the ZERO Line; Vaccinium heath plot 3). Plot four and five (Vaccinium heath plot 4 and 5) were placed at 5 m intervals from plot three (table 4).

Tabel 4. *Vaccinium uliginosum* heath, plots established August 20th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	277	278	282	283	284
Position (hddd mm ss.s)	N74º29'16.9" W20º30'36.4"	N74º29'17.1" W20º30'36.0"	N74º29'17.1" W20º30'35.1"	N74º29'17.3" W20º30'34.7"	N74º29'17.4" W20º30'34.4"
Altitude m a.s.l.	104	104	104	105	105
Inclination (estimated)	3 %	1-2 %	2-3 %	1 %	1 %
Soil moisture	Dry, earlier in season moist	Dry, earlier in season moist	Dry	Moist	Moist, slightly moister than plot 4
Ground texture	Some bare soil, soil with cracks up to 5 cm deep, but mostly smooth	Rather flat, plain surface, not many crevices and few depressions	Small depressions, bare mineral soil in small area	Plain surface with some cracks, none deep	Plain surface, very few cracks in soil
Additional bryophyte species	None	Liverworts (sampled outside plot)	*Ptilidium ciliare, Bartramia ithyphylla, Schistidium grandirete, Encalypta* cf. *alpina, Bryum* sp.	Additional *Conostomum tetragonum*	Additional *Encalypta rhaptocarpa, Bryum* sp, cf. *Pseudocalliergon, Ptilidium ciliare*

Salix arctica snow bed, ZERO Line point 88.
There was only a small strip with snow bed vegetation north of ZERO Line point 88. We therefore moved the transect to the south side of the ZERO Line. Plot 1 was established 20 m south of ZERO Line point 88 and the other four plots with 5 m interval eastwards parallel with the ZERO Line (table 5).

Table 5. *Salix arctica* snow bed, plots established August 24th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	324	325	326	327	328
Position (hddd mm ss.s)	N74º29'17.2" W20º30'29.5"	N74º29'17.4" W20º30'29.1"	N74º29'17.5" W20º30'28.7"	N74º29'17.6" W20º30'28.3"	N74º29'17.8" W20º30'27.8"
Altitude m a.s.l.	104	105	105	106	106
Inclination (estimated)	1-2 %	2 %	1 %	2 %	3-4 %
Soil moisture	Wet	Wet	Wet	Moist, but a bit drier than plot 1-3	Moist, as plot 4.
Ground texture	Even, only small unevenness in part of plot	Small humps, but rather even	Cracks, uneven 5-7 cm small depressions	Some depressions, 6-8 cm deep	Some soil solifluction along plot, small and few cracks
Additional bryophyte species	None	*Oncophorus wahlenbergii*	*Polytrichum piliferum*	*Schistidium grandirete, Polytrichum hyperboreum, Polytrichastrum alpinum*	*Tritomaria quinquedentata, Lophozia* sp.

Fen altitudinal gradient with four transects 63 m a.s.l. to 420 m a.s.l.
In the fen gradient the bryophytes constituted the major part of the vegetation at all altitudes (figure 5), but the frequency decreased with altitude (figure 6). Bryophytes were the more species rich group compared to vascular plants, except at the fen plots at highest altitude (table 6).

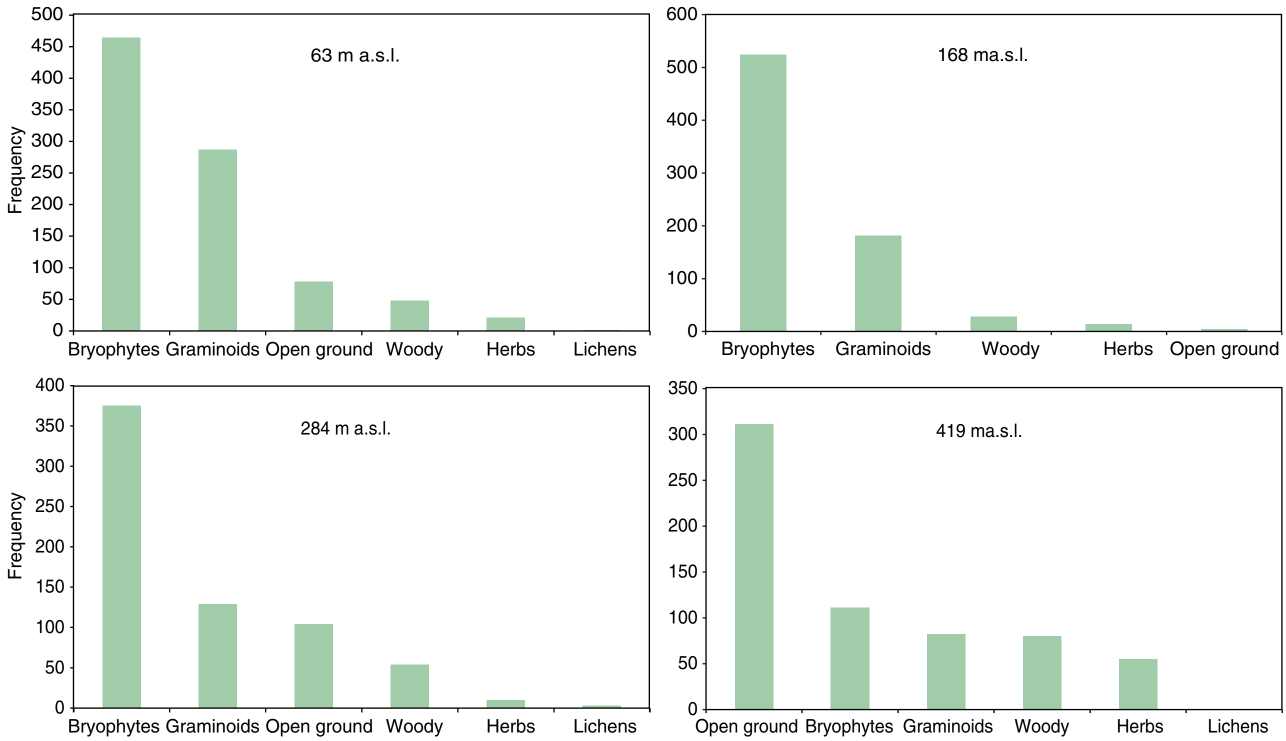


Figure 5. Frequency (sum of hits in 5 replicates) of species by functional groups in fens along an altitudinal gradient from 63 to 420 m a.s.l.

Figure 6. The bars show the frequency (sum of hits in 5 replicates) of bryophytes in *fen* vegetation with increasing altitude, while the line shows the relative importance of bryophytes at the different altitudes. The relative importance of bryophytes is calculated as bryophyte frequency/vascular plants frequency.

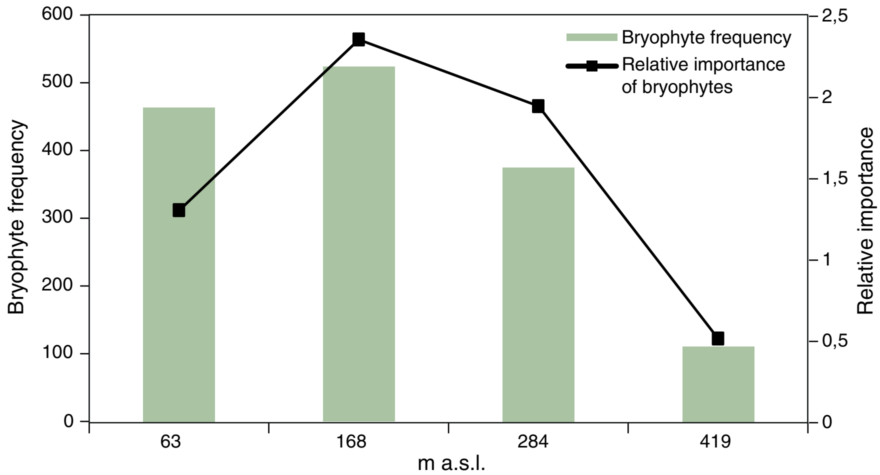


Table 6. Plant diversity measured as number of species (cumulative over 5 replicates) along the altitudinal fen gradient.

Fen altitude m a.s.l.	Bryophytes	Vascular plants
419	16	19
284	24	13
168	18	13
63	21	12

In terms of life history strategies we saw a dominance of long lived perennial species at the three lower fen transects. These species are characterised by investing most of their resources in vegetative growth and rarely reproduce sexually. The 419 m a.s.l. fen transect deviated from this picture by being dominated by colonist mosses, characterised by medium long life span and relatively high investments in reproduction (table 7).

Table 7. The five most frequent bryophytes in the analysed fen gradient. Frequencies are sums of hits in 5 replicates.

Fen 63 m a.s.l.		Fen 168 m a.s.l.		Fen 284 m a.s.l.		Fen 419 m a.s.l.	
Species	**Freq.**	**Species**	**Freq.**	**Species**	**Freq.**	**Species**	**Freq.**
Sanionia uncinata	116	*Sanionia uncinata*	106	*Campylium sp.*	84	*Bryum* sp.	23
Ptilidium ciliare	75	*Ptilidium ciliare*	75	*Tomentypnum nitens*	74	*Ditrichum flexicaule*	23
Tomentypnum nitens	34	*Campylium stellatum*	74	*Philonotis sp.*	56	*Sanionia uncinata*	23
Pseudocalliergon brevifolium	28	*Aulacomnium turgidum*	67	*Ditrichum flexicaule*	33	*Oncophorus wahlenbergii*	13
Onchophorus virens	27	*Polytrichum strictum*	48	*Sanionia uncinata*	32	*Scorpidium scorpioides*	8

3.1.2 Description of the analysed vegetation plots in the fen altitudinal gradient

Fen transect 1, ZERO Line 67 (63 m a.s.l.)

The fen vegetation by ZERO Line point 67 was in a restricted area. To place the transect at some distance away from the ZERO Line we had to move 30 m eastwards along the ZERO Line, then we were able to establish a transect with five plots at a distance of 10 m north of the ZERO Line (table 8).

Table 8. Fen transect 1, plots established August 27th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	377	373	374	375	376
Position (hddd mm ss.s)	N74º29'06.5" W20º31'07.8"	N74º29'06.7" W20º31'07.5"	N74º29'06.8" W20º31'07.0"	N74º29'06.9" W20º31'06.6"	N74º29'07.0" W20º31'06.1"
Altitude m a.s.l.	63	63	64	64	64
Inclination (estimated)	2 %	0-2 %	0-2 %, 1% average	0-5, 2% average	2 %
Soil moisture	Moist	Moist – wet	Wet	Wet, moist to standing water	Standing water – moist
Ground texture	Few small cracks, few cushions and depressions, otherwise even	One rock in plot, a larger depression, two levels in plot, otherwise even, no soil cracks	Open water in 40%, small hummocks and depressions, no cracks in soil, no stones	15 cm from top to bottom, large cushions and deep depressions, one bigger than the others, standing water	Some hummocks, smaller than previous plot, some open depressions
Additional bryophyte species	*Polytrichastrum alpinum*	*Aulacomnium turgidum, Dicranum* sp., *Bryum* sp.	*Bryum* sp.	None	*Oncophorus wahlenbergii, Oncophorus virens, Aulacomnium turgidum*

Fen transect 2, 168 m a.s.l.

Four fens were located at mid altitudinal level north of the ZERO Line and north of the closest river valley. One fen was randomly selected and a transect with five plots were established. The direction from plot 1 towards plot 5 was 69° (0-400° scale). The medium rich sloping fen with *Eriophorum triste, E. scheuchzeri, Poa arctica, Salix arctica, Carex bigelowii, Potentilla hyparctica, Carex capillaris, Juncus triglumis, Arctagrostis latifolia* and *Alopecurus alpinus* (*Juncus castaneus* was not observed) . A rock with another rock on top of it is situated 5 m southeast of plot 1 (table 9).

Tabel 9. Fen 2, plots established August 29th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	391	387	388	389	390
Position (hddd mm ss.s)	N74º29'39.2" W20º30'12.6"	N74º29'39.4" W20º30'12.4"	N74º29'39.5" W20º30'12.0"	N74º29'39.6" W20º30'11.6"	N74º29'39.7" W20º30'11.2"
Altitude m a.s.l.	168	168	168	169	169
Inclination (estimated)	3 %	3 %	2 %	2 %	3 %
Soil moisture	Moist	Moist	Moist	Moist	Moist
Ground texture	Even, but with one depression in upper part, no stones or soil cracks	Some depressions and a musk ox footprint, A ridge on one diagonal, otherwise even. No stones or cracks.	Very even, gently sloping	Even, plain, no hummocks or depressions or soil cracks	Two significant hummocks with minor depressions. Otherwise quite even.
Additional bryophyte species	*Scorpidium revolvens, Bryum pseudotriquetrum, Polytrichastrum alpinum, Ditrichum flexicaule*	*Ditrichum flexicaule*	*Tritomaria quinquedentata, Bryum pseudotriquetrum, Oncophorus wahlenbergii*	*Tritomaria quinquedentata, Scorpidium revolvens, Ptilidium ciliare*	*Tritomaria quinquedentata, Warnstorfia sarmentosa, Oncophorus wahlenbergii, Ditrichum flexicaule*

Fen transect 3, 284 m a.s.l.

Three fens were located at the upper altitudinal level north of the ZERO Line and north of the closest river valley. A fen was randomly selected and a transect with five plots were established. The direction from plot one towards plot five is 49° (0-400° scale). Rich sloping fen with *Juncus castaneus* as a character species, other vascular plants were *Pedicularis flammea, Saxifraga hirculus, Eriophorum triste, E. scheuchzeri, Salix arctica* and *Carex capillaris*. Rock with a white rock on top is located 4 m northwest of plot 1. Rock with grey rock on top of it 6 m east of plot 1 (table 10).

Table 10. Fen 3, plots established August 28th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	380	381	382	383	384
Position (hddd mm ss.s)	N74º29'56.2" W20º29'00.8"	N74º29'56.4" W20º29'00.6"	N74º29'56.6" W20º29'00.3"	N74º29'56.7" W20º29'00.1"	N74º29'56.9" W20º28'59.8"
Altitude m a.s.l.	284	285	285	285	286
Inclination (estimated)	3 %	3 %	2-3 %	3 %	3 %
Soil moisture	Moist	Moist	Moist	Moist	Moist
Ground texture	Even, no stones, no hummocks, no large cracks or depressions	Even surface, no stones, no bare soil or cracks, no hummocks	Even structure, no stones, hummocks or soil cracks	Some plots of bare soil, some small soil cracks, no stones, hummocks	Varied topography, small hummocks, some bare soil (20%), no stones or larger soil cracks
Additional bryophyte species	*Distichium inclinatum, Oncophorus wahlenbergii*	*Distichium capillaceum*	*Distichium inclinatum, Oncophorus wahlenbergii, Dichodontium pellucidum, Bryum sp.*	cf. *Tortula*	*Aulacomnium turgidum, Encalypta* cf. *procera, Scorpidium revolvens, Distichium capillaceum*

Fen transect 4, ZERO Line 101 (419 m a.s.l.)

The vegetation starts to break up at this altitude and it is difficult to find areas with homogenous vegetation due to frost and unstable soils (solifluction). Fredskild and Mogensen (1997) describes the vegetation as species rich, varying from *Dryas* and *Carex nardina* at dry soil to *Deschampsia brevifolia-Alopecurus-Juncus biglumis* on wet soils. The transect was placed 20 m north and 20 m east of the ZERO Line point 101, in wet fen with some seeping water. The transect consists of five plots with 5 m interval parallel to the ZERO Line (table 11).

Table 11. Fen 4, plots established August 25th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	338	339	340	341	342
Position (hddd mm ss.s)	N74º30'14.9" W20º27'45.9"	N74º30'15.0" W20º27'45.6"	N74º30'15.1" W20º27'45.3"	N74º30'15.3" W20º27'44.9"	N74º30'15.4" W20º27'44.5"
Altitude m a.s.l.	419	420	421	421	422
Inclination (estimated)	4%	3%	3%	2%	4-5%
Soil moisture	Moist	Moist-wet	Moist-wet	Moist-wet	Wet
Ground texture	One larger soil crack. Some hummocks in soil patterning the plot.	One large stone, one smaller, some bare soil, even sloping	Even, only some minor depressions	Some stones, mostly small and one a bit larger, bare soil, musk ox footprint, otherwise even	Two levels in plot, 75% wet and 25% drier part, even soil surface, no cracks, very few stones
Additional bryophyte species	*Tortella fragilis, Encalypta alpina, Campylium stellatum*	*Warnstorfia sarmentosa, Distichium* cf. *inclinatum, Encalypta* cf. *rhaptocarpa, Calliergon richardsonii*	*Tortella fragilis, Cirriphyllum cirrosum, Philonotis* cf. *fontana*	*Tortella fragilis, Ditrichum flexicaule, Syntrichia ruralis, Polytrichum hyperboreum, Encalypta alpina, Scorpidium scorpioides*	*Tortella fragilis, Polytrichum hyperboreum, Polytrichastrum alpinum, Cirriphyllum cirrosum*

3.2 Kobbefjord

The bryophytes show an expected increase in frequency from the very dense *Vaccinium uliginosum* heath dominated by woody plants and graminoids to the more open and moist *Salix herbacea* snow bed and poor fen vegetation. Surprisingly, we find the highest frequency of bryophytes in the moist *Empetrum* heath at 26 m a.s.l. (figure 7). The relative importance of bryophytes to vascular plants decrease from snow bed and poor fen vegetation to the *Vaccinium uliginosum* heath (table 12, figure 8).

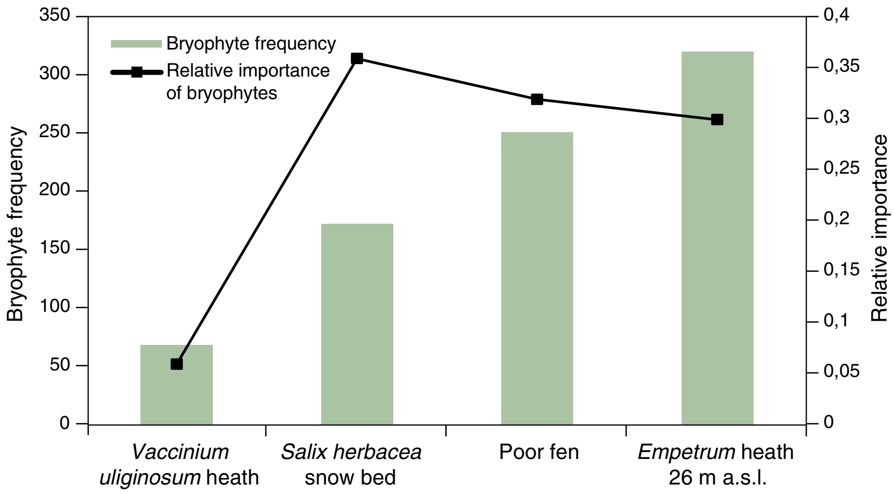


Figure 7. The frequency (sum of hits in 5 replicates) of bryophytes is increasing from dry to more wet vegetation types, while the relative importance of bryophytes in the different vegetation types is at maximum in the snow bed vegetation. The relative importance of bryophytes is calculated as bryophyte frequency/vascular plants frequency. *Empetrum* heath 26 m a.s.l. is included among the *Empetrum* heaths as it is approximately at the same elevation as the other vegetation types included.

Table 12. Plant diversity measured as number of species (cumulative over 5 replicates) in the analysed vegetation types.

Vegetation type	Bryophytes	Vascular plants
Empetrum heath 26 m a.s.l.	11	8
Poor fen	17	9
Salix herbacea snow bed	15	14
Vaccinium uliginosum heath	9	13

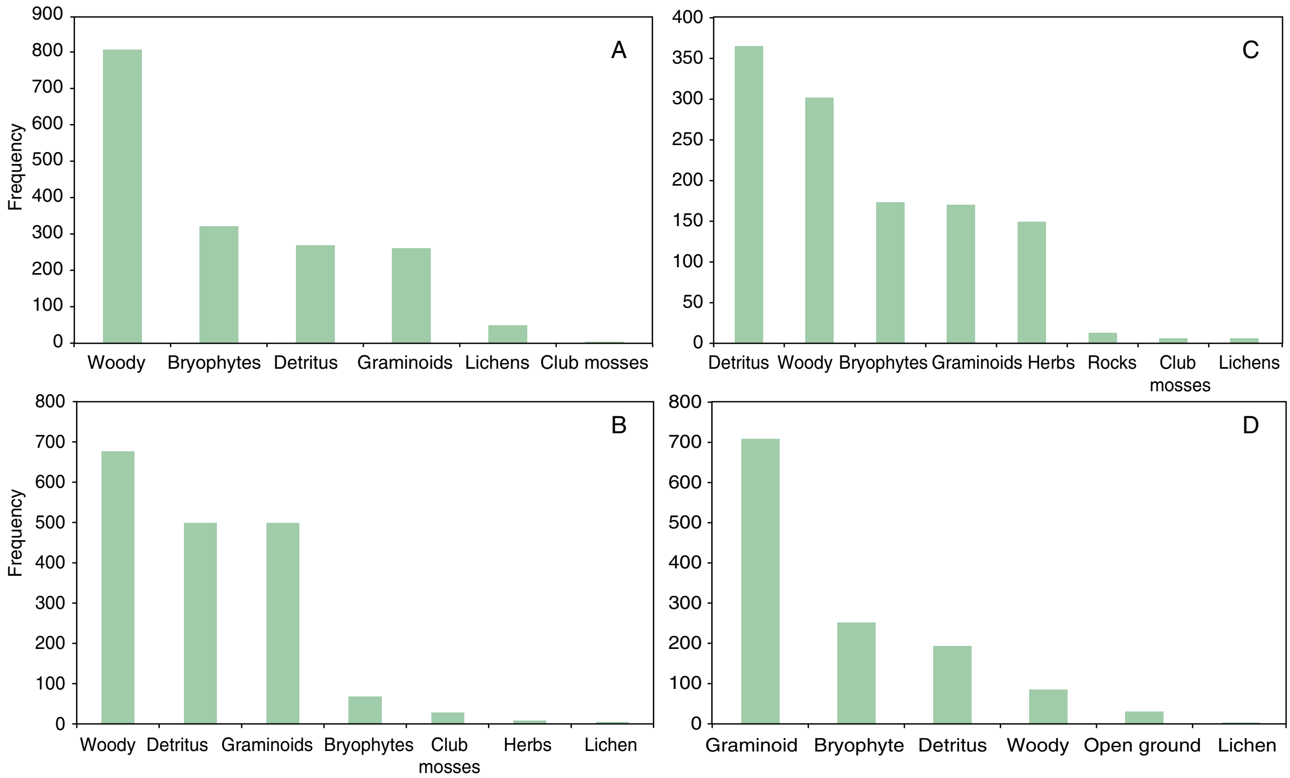


Figure 8. Frequency (sum of hits in 5 replicates) of species by functional groups in a) *Empetrum* heath 26 m a.s.l., b) *Vaccinium uliginosum* heath, c) *Salix herbacea* snow bed and d) poor fen.

Plant species diversity in poor fen vegetation was dominated by bryophytes. In other vegetation types, the diversity of bryophytes was about the same as vascular plants (table 12). Bryophyte species diversity tends to increase with increased soil moisture, while the opposite is the case for vascular plants. If we take a closer look at the species list we see that long lived perennials (small spores) and long lived shuttle (large spores) are dominating all studied vegetation types (table 13).

Table 13. The five most frequent bryophytes in the analysed vegetation types. Frequencies are sums of hits in 5 replicates.

Poor fen		***Vaccinium uliginosum* heath**		***Salix herbacea* snow bed**	
Species	**Freq.**	**Species**	**Freq.**	**Species**	**Freq.**
Sphagnum lindbergii	106	*Dicranum fuscescens*	21	*Polytrichastrum alpinum*	62
Sphagnum compactum	34	*Dicranum flexicaule*	13	*Brachythecium sp.*	57
Loeskypnum badium	33	*Sanionia uncinata*	13	*Barbilophozia hatchery*	9
Gymnocolea inflata	24	*Barbilophozia hatcheri*	5	*Dicranum cf. flexicaule*	8
Warnstorfia fluitans	11	*Polytrichastrum alpinum*	4	*Polytrichum juniperinum*	7

3.2.1 Description of the analysed vegetation plots

Poor fen vegetation, NERO Line point 50-51

Plot 1 was established 11 m north of the NERO Line point 50 and three m east of the NERO Line. The following plots were placed with five m intervals towards NERO Line point 51, parallel to the NERO Line (table 14).

Table 14. Poor fen vegetation, plots established August 23rd and 24th 2010.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	936	937	938	939	940
Position (hddd mm ss.s)	N64º08'05.8" W51º22'45.5"	N64º08'05.9" W51º22'45.3"	N64º08'06.0" W551º22'45.1"	N64º08'06.2" W51º22'44.9"	N64º08'06.3" W51º22'44.8"
Altitude m a.s.l.	22	22	22	21	21
Inclination (estimated)	4º	12º	4º	0º	8º
Soil moisture	Wet	Wet	Wet	Wet	Very wet, open water in 25% of the plot
Ground texture	Some bare peat patches resulting from erosion. No rocks or big soil cracks	Even plot with three large cushions of *Scirpus caespitosus*. One rock is visible in plot.	Even plot is one the edge of a small brook/seepage. No visible rocks or soil cracks.	Even plot. No visible rocks or soil cracks.	Even plot. No visible rocks or soil cracks.
Additional bryophyte species	None	*Polytrichastrum alpinum, Gymnocolea inflata, Oncophorus wahlenbergii*	Pioneer bryophytes in bottom layer were hard to see due to high water level this day.	*Sphagnum balticum*	None

Salix herbacea snow bed vegetation, NERO Line point 5-6

The transect was placed east of the NERO Line and starts five m east of NERO Line point five. The transect follows the snow bed and the distance to the NERO Line gradually increases. Plot 5 is 13 m east of the NERO Line point seven. Description of the plot is given in table 15.

Table 15. *Salix herbacea* snow bed, plots established August 17th 2010.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	867	868	869	870	871
Position (hddd mm ss.s)	N64º07'39.2" W51º23'41.8"	N64º07'39.3" W51º23'41.5"	N64º07'39.2" W51º23'41.1"	N64º07'39.2" W51º23'40.7"	N64º07'39.3" W51º23'40.5"
Altitude m a.s.l.	135	133	131	130	128
Inclination (estimated)	16º	27º	15º	16º	20º
Soil moisture	Moist	Moist	Moist	Moist	Moist
Ground texture	Big rock in lower part of plot, mostly outside plot. No soil cracks.	Ca. 10 % of plot is made up by one big rock. Almost no bare soil. No soil cracks.	Even texture throughout plot.	Some small rocks, dense vegetation. Even texture throughout plot.	Even texture. Few rocks. Even and dense vegetation.
Additional bryophyte species	None	*Timmia austriaca*	*Lophozia* sp., *Polytrichum juniperinum, Polytrichum piliferum*	*Racomitrium elongatum, Sanionia uncinata, Polytrichum piliferum*	*Racomitrium elongatum*

Vaccinium uliginosum heath, NERO Line point 69-70

Originally, *Vaccinium uliginosum* heath is classified between the NERO Line points 70-71, but this was a too small area to place the plots. However, there was an area with well-developed *Vaccinium* heath below point 70, and we decided to use this. The transect was placed five m northwest of the NERO Line and parallel to this. Plot 1 is at the lowest altitude. There is a big rock just south east of plot 2. For description of the plots see table 16.

Table 16. *Vaccinium uliginosum* heath, plots established August18th 2010.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	878	879	880	881	882
Position (hddd mm ss.s)	N64º08'23.8" W51º22'19.9"	N64º08'23.9" W51º22'19.6"	N64º08'24.0" W51º22'19.4"	N64º08'24.1" W51º22'19.3"	N64º08'24.3" W51º22'19.1"
Altitude m a.s.l.	91	92	93	95	96
Inclination (estimated)	2º	16º	12º	4º	23º
Soil moisture	Dry-moist	Moist-dry	Moist	Moist	Moist
Ground texture	Flat plot with one stone inside plot, stone with vegetation on top, 20 cm higher than rest of the plot. No soil cracks.	Even plot with small depressions with *Sphagnum* spp.	Dense vegetation in even/flat plot. No particular textures to mention.	Uneven plot texture, dense cover of vegetation, seepage through plot.	Dense vegetation, even plot without hummocks or other particular features.
Additional bryophyte species	None	*Dicranum* cf. *fuscescens*	*Barbilophozia hatcheri*	*Barbilophozia lycopodioides, Sanionia uncinata, Brachythecium* sp. *Polytrichastrum alpinum*	*Brachythecium* cf. *reflexum*

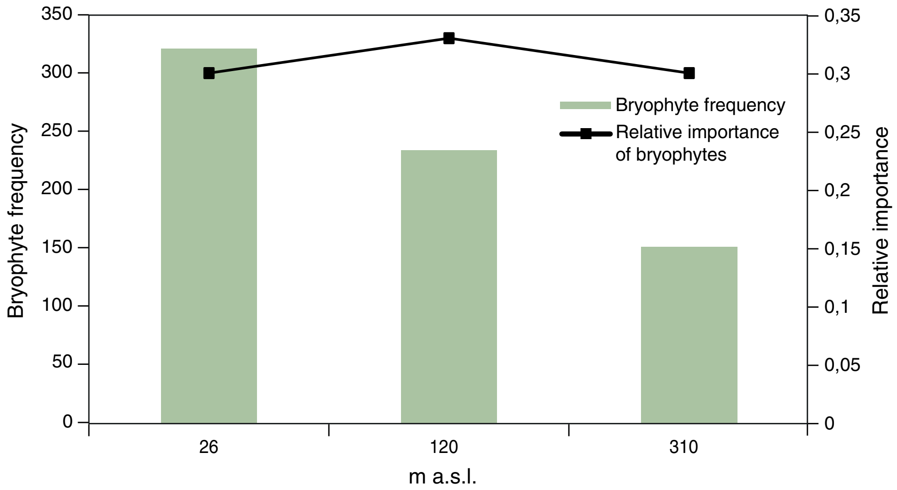
Empetrum heath altitudinal gradient with three transects from 26 m to 310 m a.s.l.

Across the *Empetrum* heath altitudinal gradient, the bryophytes constituted about 0.3 (measured as bryophyte frequency/vascular plant frequency) of the vegetation at all altitudes, but the absolute frequency decreased with altitude (figure 9), indicating that the vegetation became more open at higher altitudes. In terms of plant species diversity, bryophytes were the more species rich group at the lowest altitude, while vascular plants and bryophytes were similar at the two highest altitudes (table 17). Woody plants, mainly *Empetrum,* constituted the major part of the vegetation at all altitudes with bryophytes as the second most frequent functional group (figure 10).

Table 17. Plant species diversity (cumulative over 5 replicates) along the altitudinal *Empetrum* heath gradient.

Empetrum heath transects (m a.s.l.)	Bryophyte species	Vascular plant species
310	6	6
120	6	6
26	11	8

Figure 9. The bars shows the frequency (sum of hits in 5 replicates) of bryophytes in *Empetrum* heath vegetation with increasing altitude, while the line show the relative importance of bryophytes at the different altitudes. The relative importance of bryophytes is calculated as bryophyte frequency/vascular plants frequency.



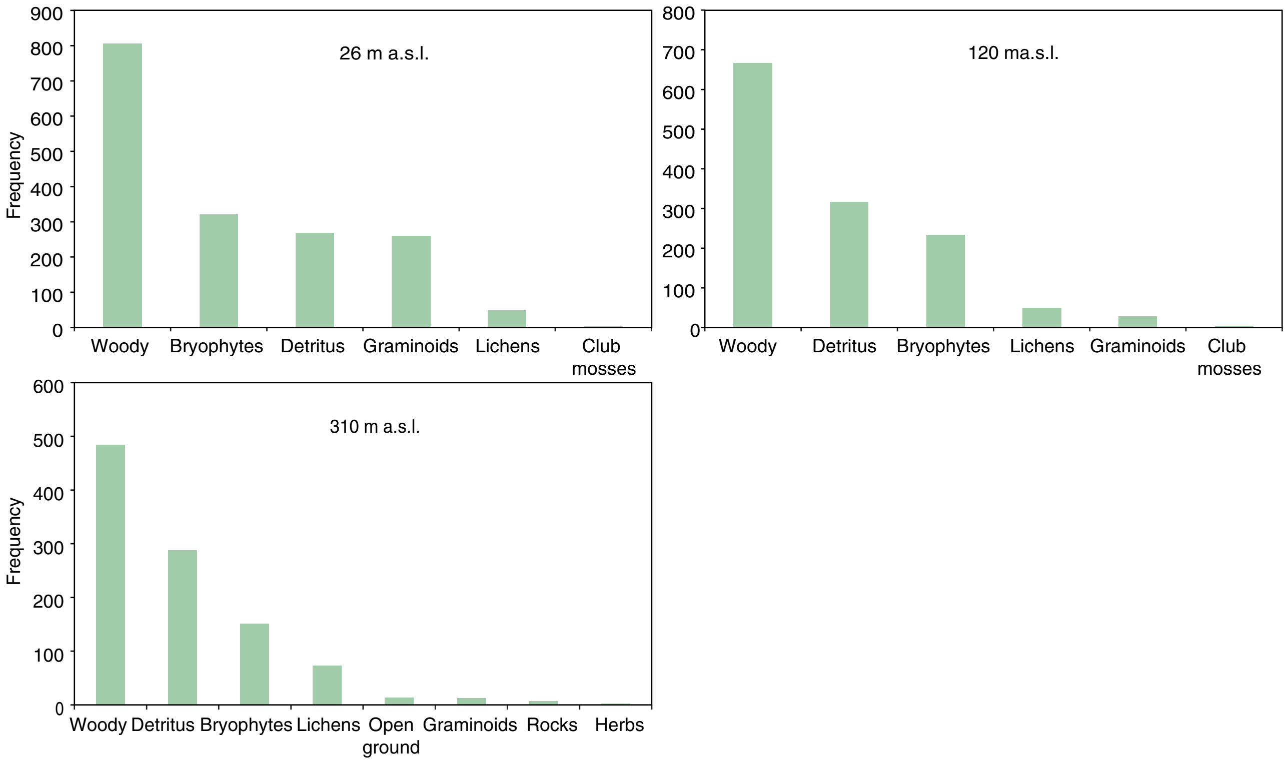


Figure 10. Frequency (sum of hits in 5 replicates) of species by functional groups in *Empetrum* heath along an altitudinal gradient from 26 to 310 m a.s.l.

In terms of life history strategies we saw a dominance of long lived perennial moss species at all altitudes. These species are characterised by investing most of their resources in vegetative growth and rarely reproduce sexually. t the highest altitude some colonist mosses characterised by medium long life span and relatively high investments in reproduction were also among the more frequent species (table 18).

Table 18. The five most frequent bryophytes in the analysed *Empetrum* heath gradient. Frequencies are sums of hits in 5 replicates.

26 m a.s.l.		120 m a.s.l.		310 m a.s.l.	
Species	**Freq.**	**Species**	**Freq.**	**Species**	**Freq.**
Pleurozium schreberi	128	*Pleurozium schreberi*	102	*Ptilidium ciliare*	77
Dicranum cf. *flexicaule*	76	*Dicranum* cf. *flexicaule*	72	*Dicranum* cf. *flexicaule*	63
Sphagnum russowii	62	*Ptilidium ciliare*	43	*Cephaloziella* sp.	8
Ptilidium ciliare	19	*Hylocomium splendens*	13	*Pohlia nutans*	1
Polytrichum strictum	14	*Sanionia uncinata*	3	*Sphagnum compactum*	1

3.2.2 Description of the analysed vegetation plots in the *Empetrum* heath altitudinal gradient

Empetrum heath transect 1, NERO Line 52 (26 m a.s.l.)

The transect starts 10 m north of the NERO Line point 52, and three m east of the NERO Line. The plots were placed at five m intervals parallel to the NERO Line, except for plot 5 which was only four m away from plot four due to upcoming fen vegetation (table 19).

Table 19. *Empetrum* heath transect 1, plots established August 22th 2010.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	918	919	920	921	922
Position (hddd mm ss.s)	N64º08'07.7" W51º22'42.6"	N64º08'07.8" W51º22'42.4"	N64º08'08.0" W51º22'42.2"	N64º08'08.1" W51º22'42.0"	N64º08'08.2" W51º22'41.8"
Altitude m a.s.l.	26	26	26	26	26
Inclination (estimated)	4º	8º	8º	8º	4º
Soil moisture	Moist	Moist	Moist	Moist	Moist
Ground texture	No rocks, soil cracks or no disturbance patches.	Even plot in even slope. No rocks, soil cracks or no disturbance patches.	Flat, even plot in even slope. No visible rocks, soil cracks or disturbance patches.	Even plot, mostly flat. No visible rocks, soil cracks or disturbance patches.	Even plot. Almost no depressions. No soil cracks.
Additional bryophyte species	None	*Barbilophozia lycopodioides, Ptilidium ciliare*	*Lophozia ventricosa* s.l., *Ptilidium ciliare*	*Lophozia ventricosa* s.l., *Ptilidium ciliare, Barbilophozia lycopodioides, Mylia anomala, Calypogeia* sp.	*Lophozia ventricosa* s.l., *Dicranum flexicaule*

Empetrum heath transect 2, NERO Line 74 (120 m a.s.l.).

Empetrum heath occupies rather small areas by the NERO Line point 74. To get this altitudinal level represented (about 100 m a.s.l.), we chose to use the available areas of *Empetrum* heath. The consequence of this was that the transect had to be divided in two, with three plots southwest of the NERO Line point 74. This transect was only five m long so the plots were rather close to each other. The two other plots were placed northeast of the NERO Line point 73. Plot 4 is 11.5 m northeast of the NERO Line point 73 (table 20).

Table 20. *Empetrum* heath 2, plots established August 21th 2009.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	912	913	914	915	916
Position (hddd mm ss.s)	N64º08'26.1" W51º22'17.0"	N64º08'26.2" W51º22'16.9"	N64º08'26.2" W51º22'16.8"	N64º08'25.7" W51º22'16.0"	N64º08'25.6" W51º22'15.9"
Altitude m a.s.l.	106	116	121	122	121
Inclination (estimated)	20º	20º	16º	16º	12º
Soil moisture	Dry	Dry	Dry	Dry	Dry
Ground texture	Some soil cracks. No bare soil or rocks. Even slope in plot.	Even slope in plot. No soil cracks or rocks.	Even plot without soil cracks or rocks.	Uneven plot. Disturbed part in upper slope. No rocks or soil cracks.	Even, flat plot. No rocks or bare soil. No soil cracks or disturbance patches.
Additional bryophyte species	None	None	*Pleurozium schreberi*	*Barbilophozia lycopodioides, Ptilidium ciliare*	None

Empetrum heath transect 3, NERO Line 76-77 (310 m a.s.l.)

Due to high wind exposure and open soil by the NERO Line point 76, we started the transect by the NERO Line point 77. The first plot is placed 20 m south of and five m northwest of the NERO Line point 77. The transect has plots with five m interval and is parallel to the NERO Line (table 21).

Table 21. *Empetrum* heath 3, plots established August 19th 2010.

Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
GPS way point	898	894	895	896	897
Position (hddd mm ss.s)	N64º08'33.2" W51º22'06.6"	N64º08'33.3" W51º22'06.4"	N64º08'33.5" W51º22'06.1"	N64º08'33.6" W51º22'05.8"	N64º08'33.7" W51º22'05.6"
Altitude m a.s.l.	308	309	311	314	313
Inclination (estimated)	23º	16º	16º	16º	16º
Soil moisture	Dry	Dry	Dry	Dry	Very dry
Ground texture	Some small soil cracks in plot. Some small rocks and some obvious frost and wind disturbance.	Even plot with some few, small soil cracks. No hummocks.	Some rocks in lower part of slope in plot (SW corner). Some bare soil in small patches of plot.	Even and flat plot. No rocks or soil cracks. One small depression in plot.	Bare soil in some parts of plot. Some small rocks.
Additional bryophyte species	*Ptilidium ciliare, Bartramia ithyphylla, Anastrophyllum minutum*	None	None	None	None

4 Concluding remarks

In both the high arctic and the low arctic sites, the bryophytes were one of the main components both in terms of species diversity and frequency in the vegetation. In the high arctic Zackenberg area species diversity was higher for bryophytes than vascular plants in all the studied vegetation types except for the transects in snow bed and high altitudinal fen (419 m a.s.l.). In terms of frequency, bryophytes were the dominating functional group in all transects except the *Cassiope* and *Vaccinium* heath where woody plants not surprisingly were dominating. In the low arctic Kobbefjord area, the bryophytes have higher species diversity than vascular plants in most of the studied vegetation types, but they were never the dominating group in terms of frequency. In Kobbefjord woody plants were the functional group with highest frequency in all studied vegetation types, except poor fen vegetation where graminoids were the dominating group. However, bryophytes were the second most frequent functional group in all vegetation types, except the *Vaccinium* heath where they were third (after woody plants and graminoids).

The altitudinal transect of fen vegetation in Zackenberg did not show the expected decline in species diversity with altitude, but we saw a shift in dominant species from competitive perennials at the three lower altitudes to opportunistic colonist species at the highest altitude. This may be due to a disturbance effect as the frequency of open ground was about three times higher at the highest altitude compared with the lower fens. The difference in disturbance also seemed to be the explanation for why we found the highest bryophyte frequency in the fen 168 m a.s.l. where the frequency of open ground was very low. The kind of disturbance seemed to be mainly trampling/grazing effect of the muskox at the three lowest altitudes while disturbance by frost and water movement were the important factors at the highest altitude.

In the *Empetrum* heath in Kobbefjord we found a weak, though expected decline in species diversity of bryophytes and vascular plants with altitude. But there was no obvious shift in species composition in relation to life history strategies (as in Zackenberg). However, the frequency of bryophytes and vascular plants consistently decreased with altitude, resulting in a relative constant component of bryophytes in the vegetation across altitudes. The main disturbance factor along this gradient seem to be a more rough and harsh (wind and temperature) environment with increasing altitude.

Vaccinium heath was studied in both areas. Clear differences were observed between low arctic *Vaccinium* heath dominated by woody plants and graminoids as compared with the more bryophyte dominated high arctic *Vaccinium* heath. This was probably the same effect as observed along the *Empetrum* heath altitudinal gradient with more dense vegetation at the lower altitudes. However the effect seemed to be much stronger from low arctic to the high arctic than along the c. 300 m long altitudinal gradient.

The other type of vegetation studied in both areas was the snow bed community. Also here we saw as a general trend that woody plants were more dominating functional group at the low arctic site in Kobbefjord. Also saw that the frequency of bryophytes was much lower in Kobbefjord than in Zackenberg snow beds. Thus it seems that the low arctic snow beds were more stabilised by vascular plants, which was also indicated by much lower frequency of open ground.

Expectations for future response of the bryophytes to climatic warming are that vascular plant vegetation will increase in height and be followed by increased shadowing and litter deposition, which will further decrease both bryophyte cover and species diversity. We expect to see the largest effects of warming in communities were the water stress will increase most, i.e. communities with stable moisture today that in the future may periodically dry with increased temperature and altered snow accumulation patterns. Increased humidity by more frequent or higher precipitation could level out this effect, while a shift to more continental climate with less precipitation would strengthen the effect of increased temperature.

Interacting effects with herbivores like lemmings, disturbance from geese and trampling and grazing by muskoxen can change the dynamics of the bryophyte carpets.

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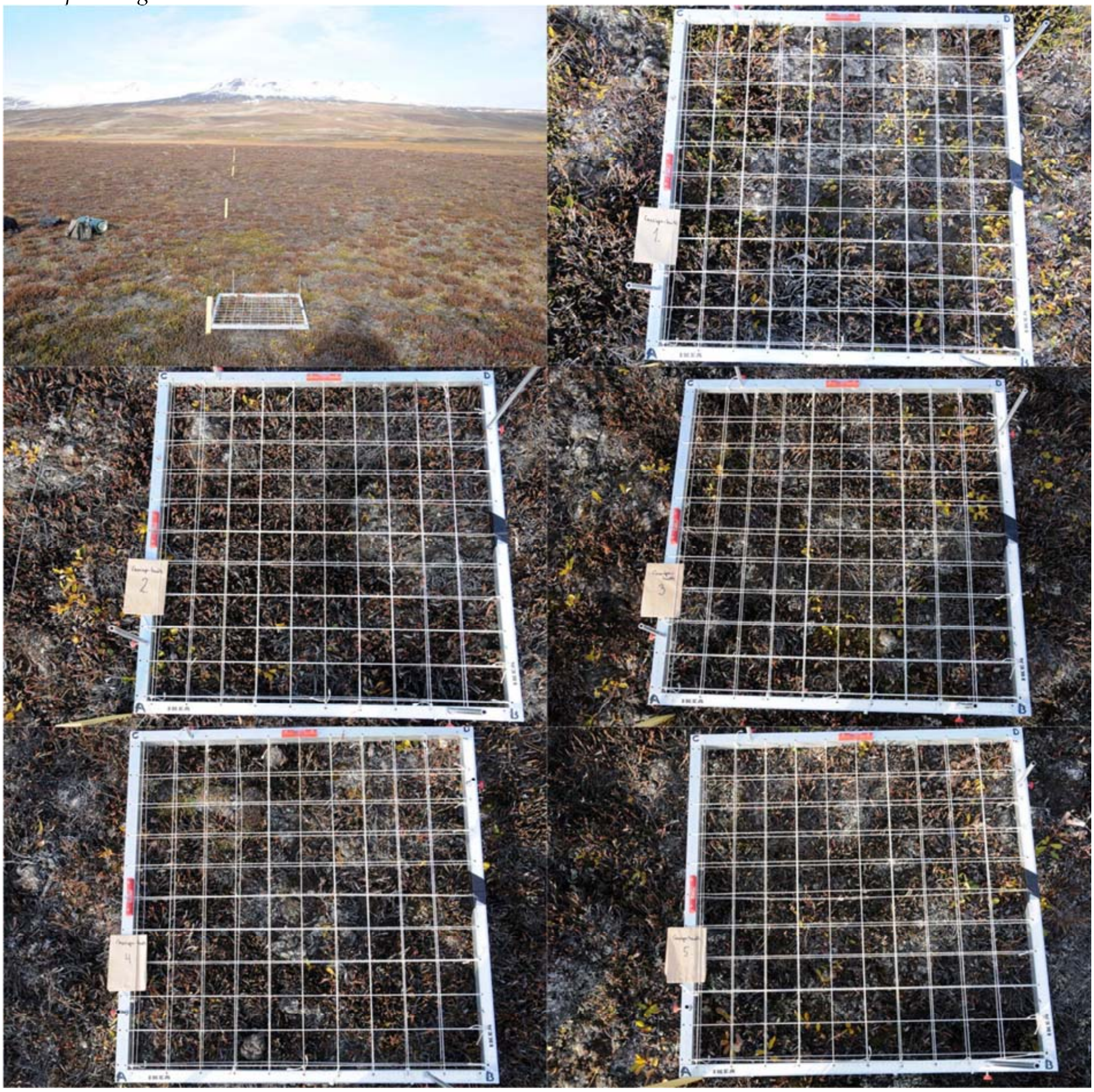
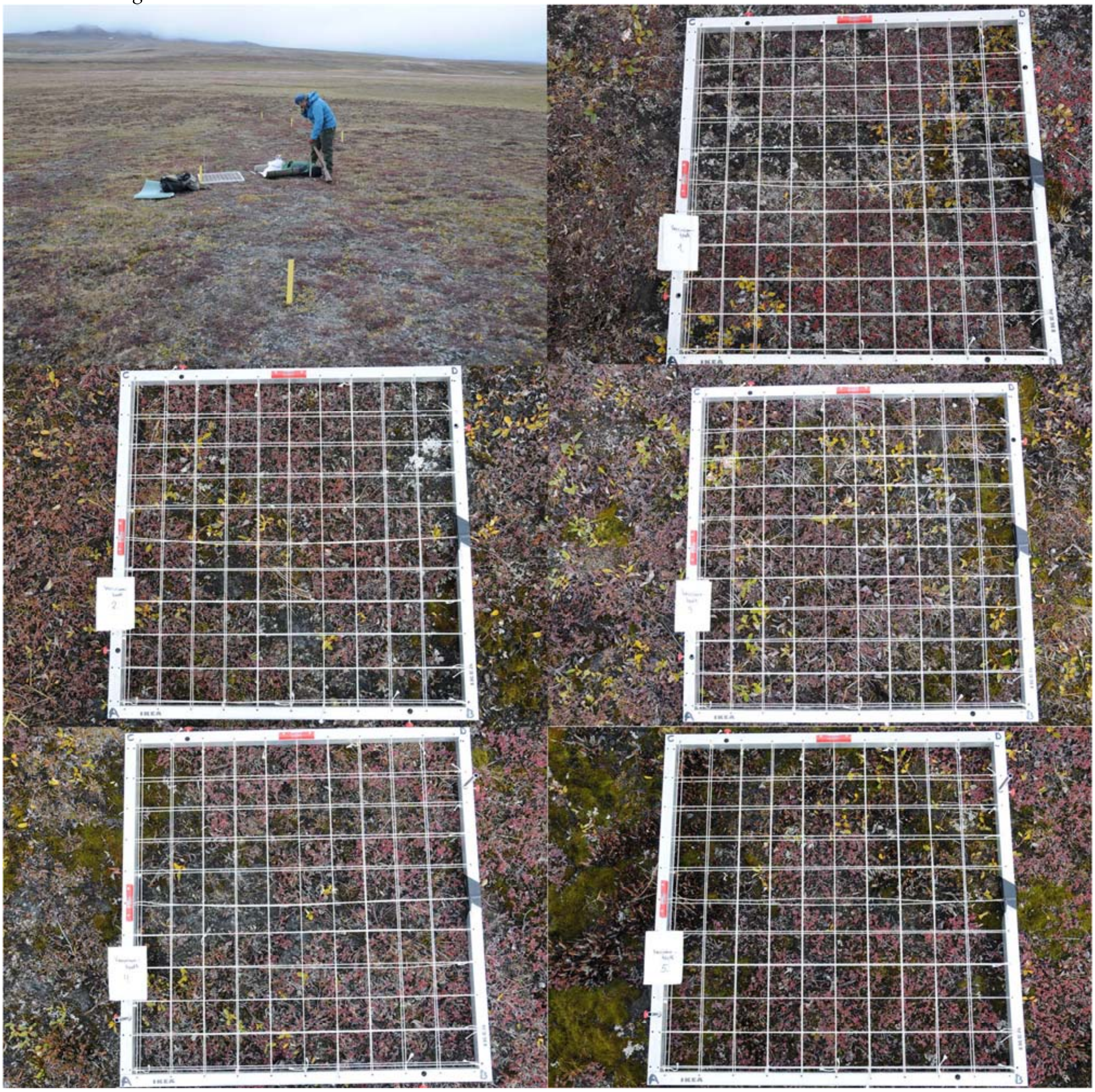
Appendix 1 Photos of the analysed transects and plots at Zackenberg

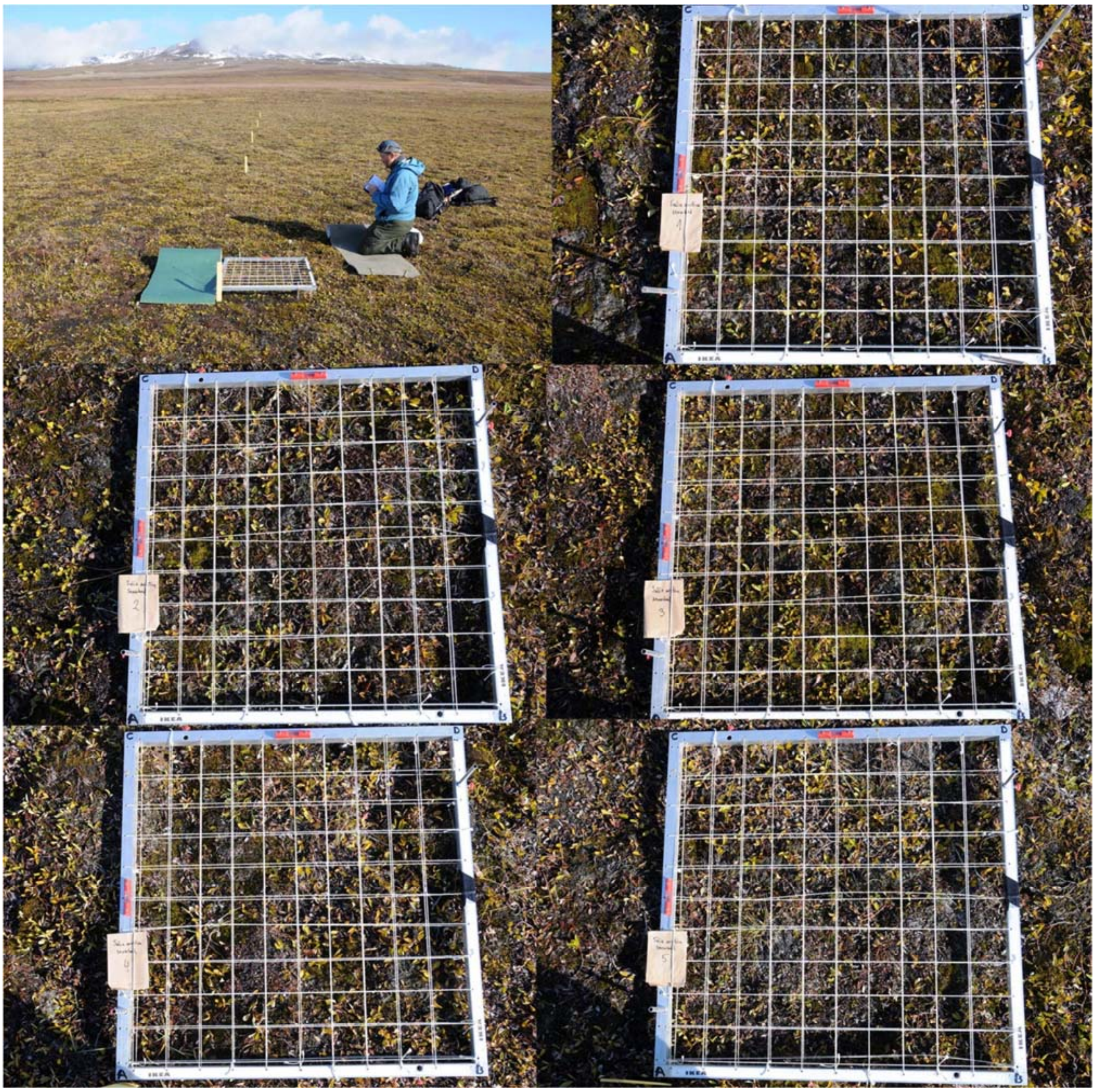
Cassiope tetragona heath



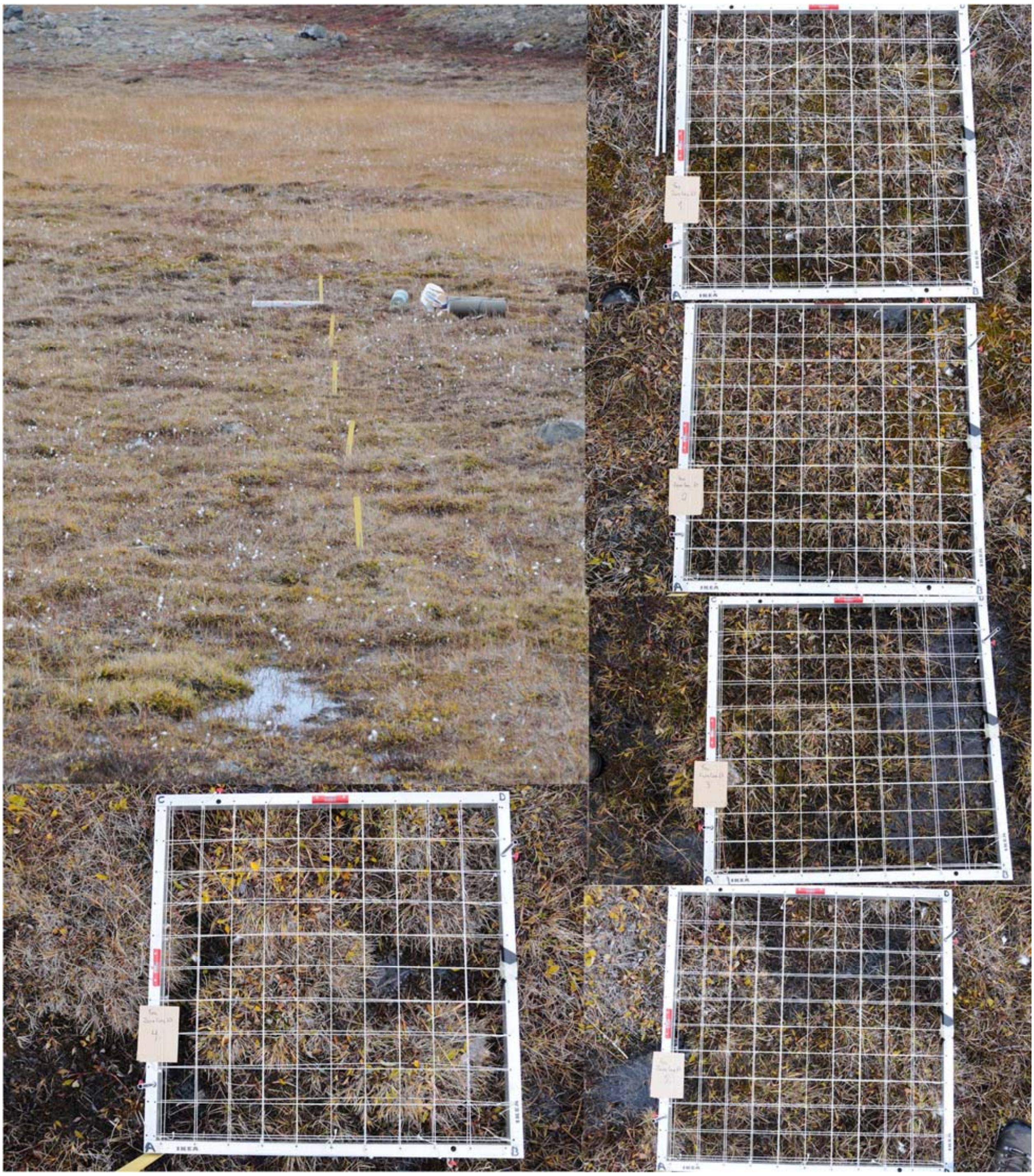
Vaccinium uliginosum heath



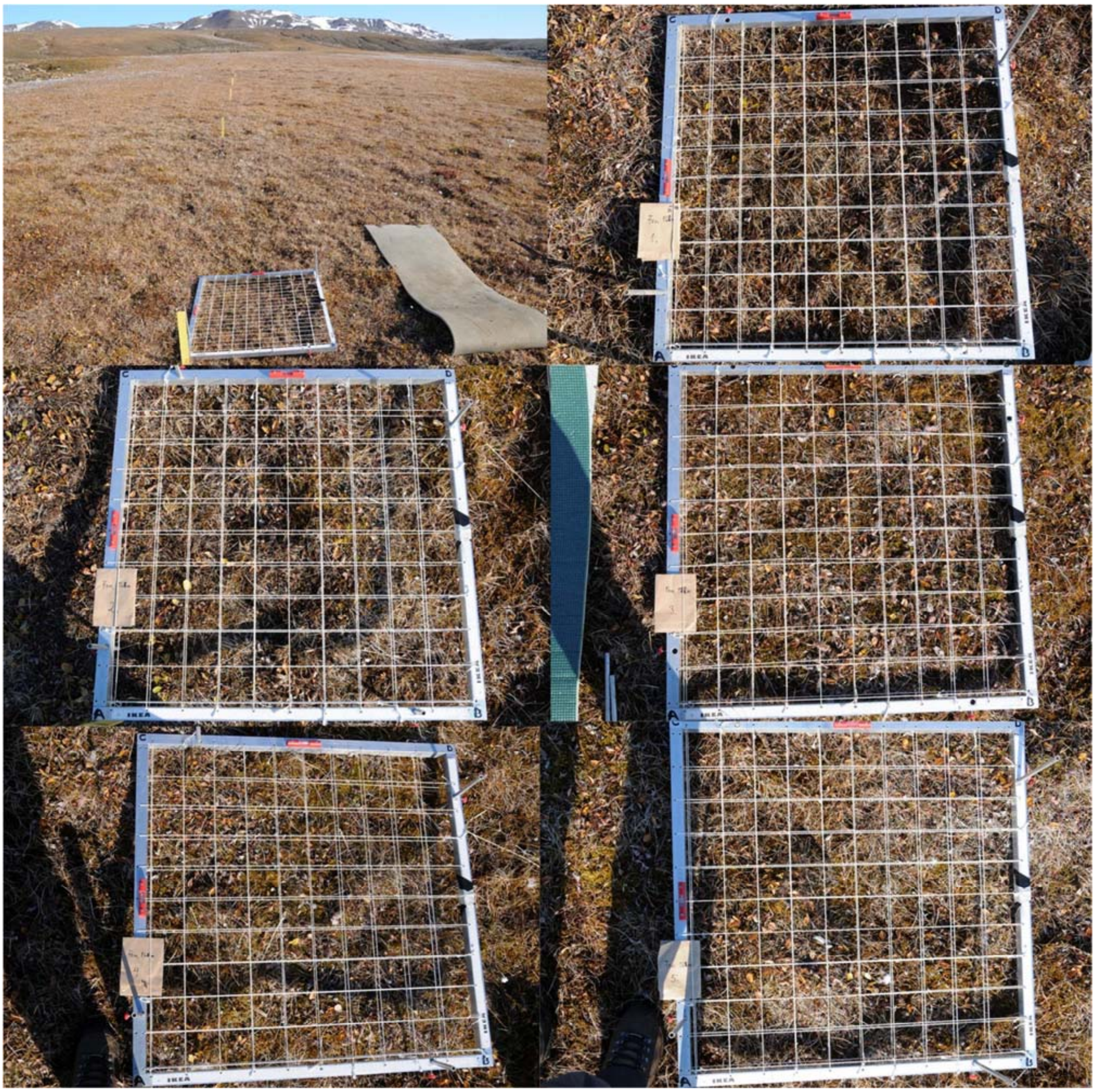
Salix arctica snow bed



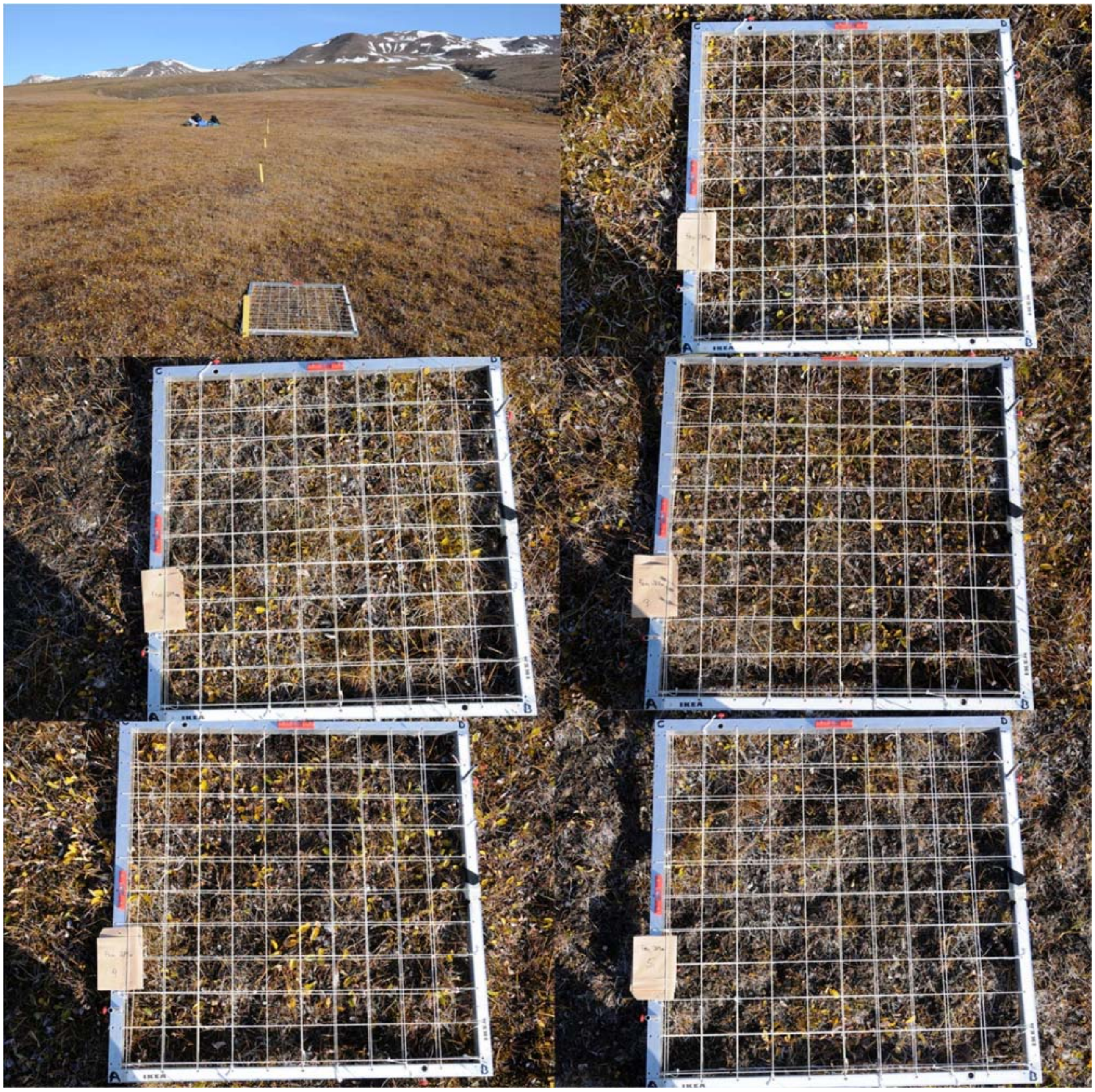
Fen 63 m a.s.l.



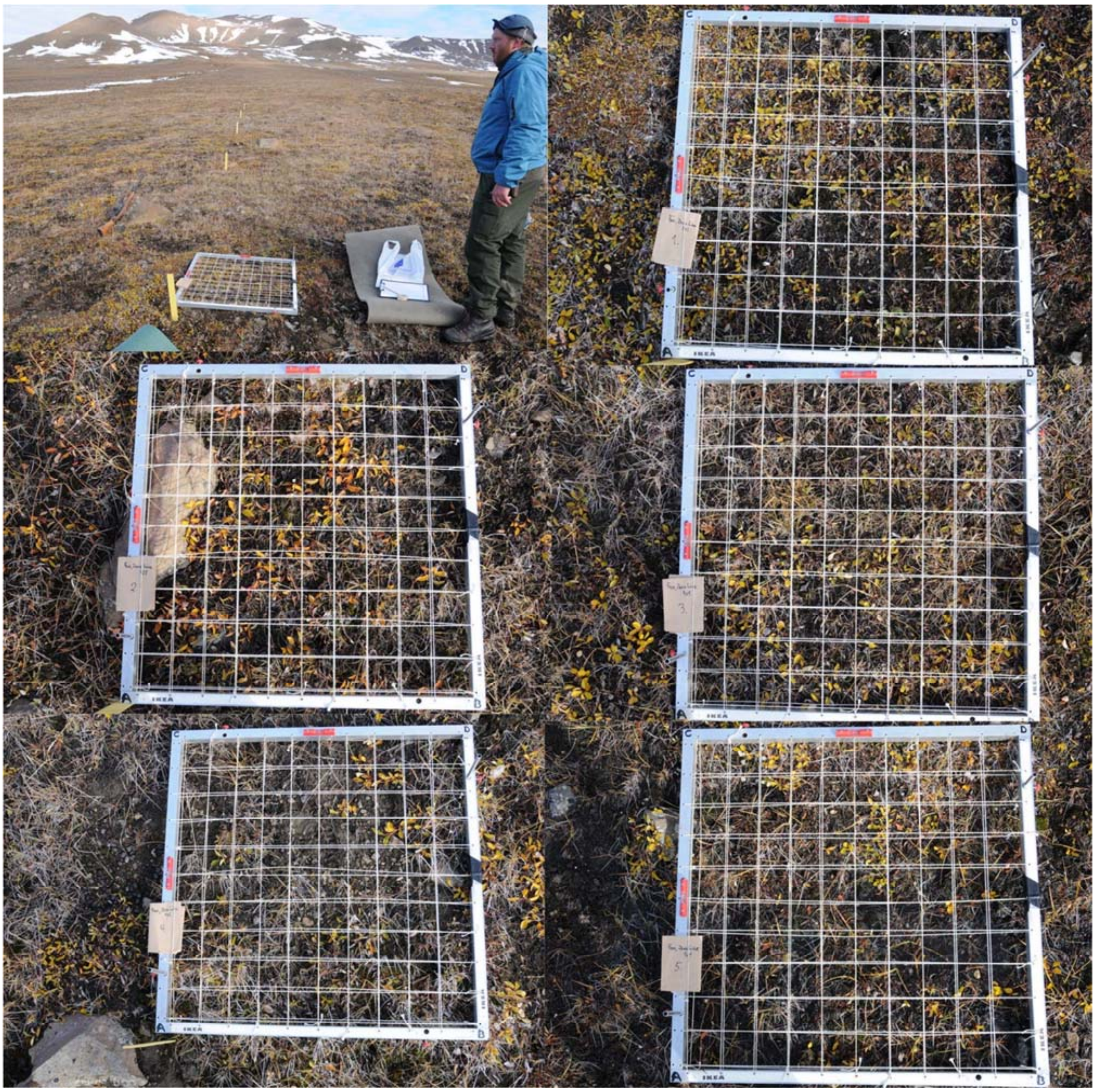
Fen 168 m a.s.l.



Fen 284 m a.s.l.

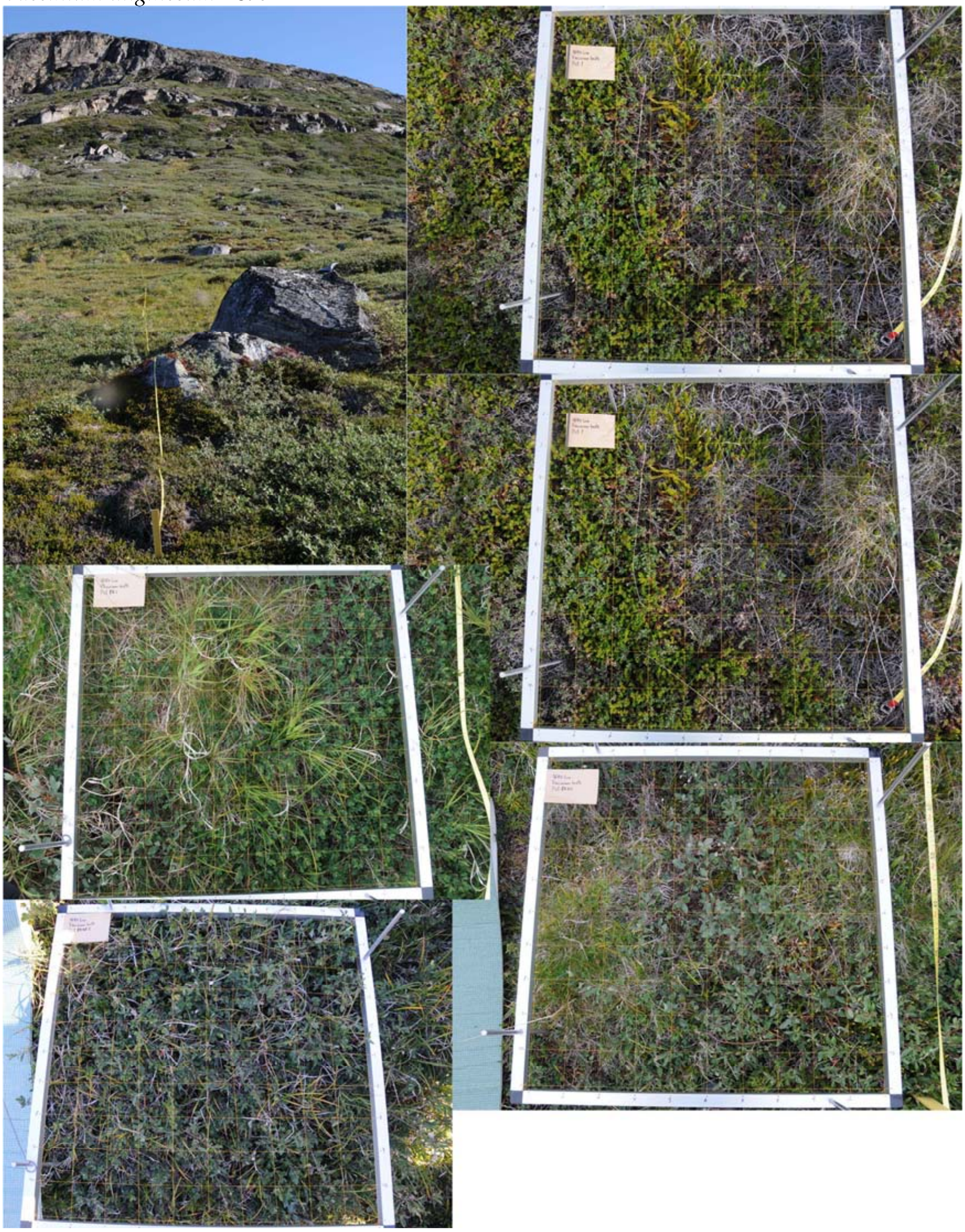


Fen 419 m a.s.l.

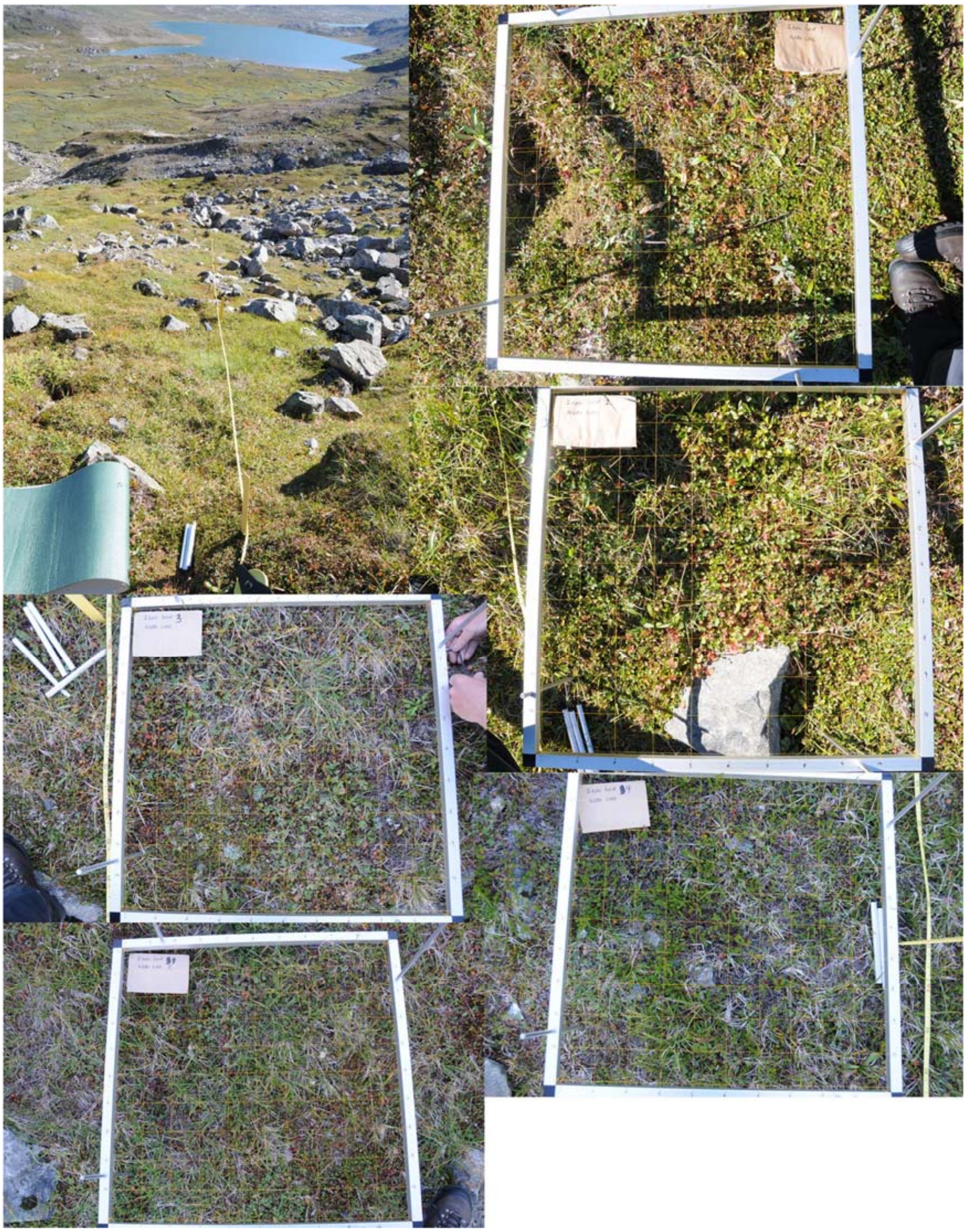


Appendix 2 Photos of the analysed transects and plots at Kobbefjord

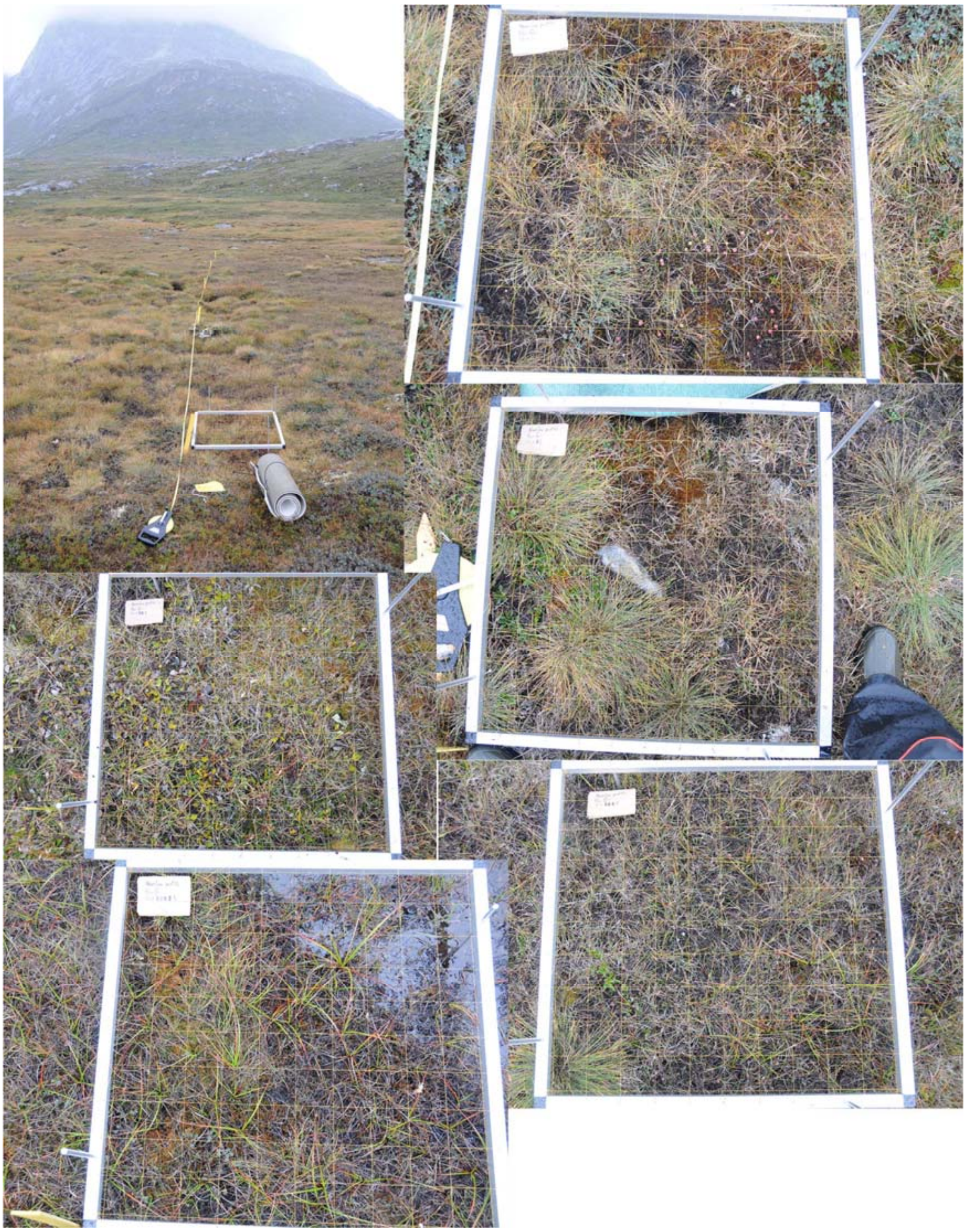
Vaccinium uliginosum heath



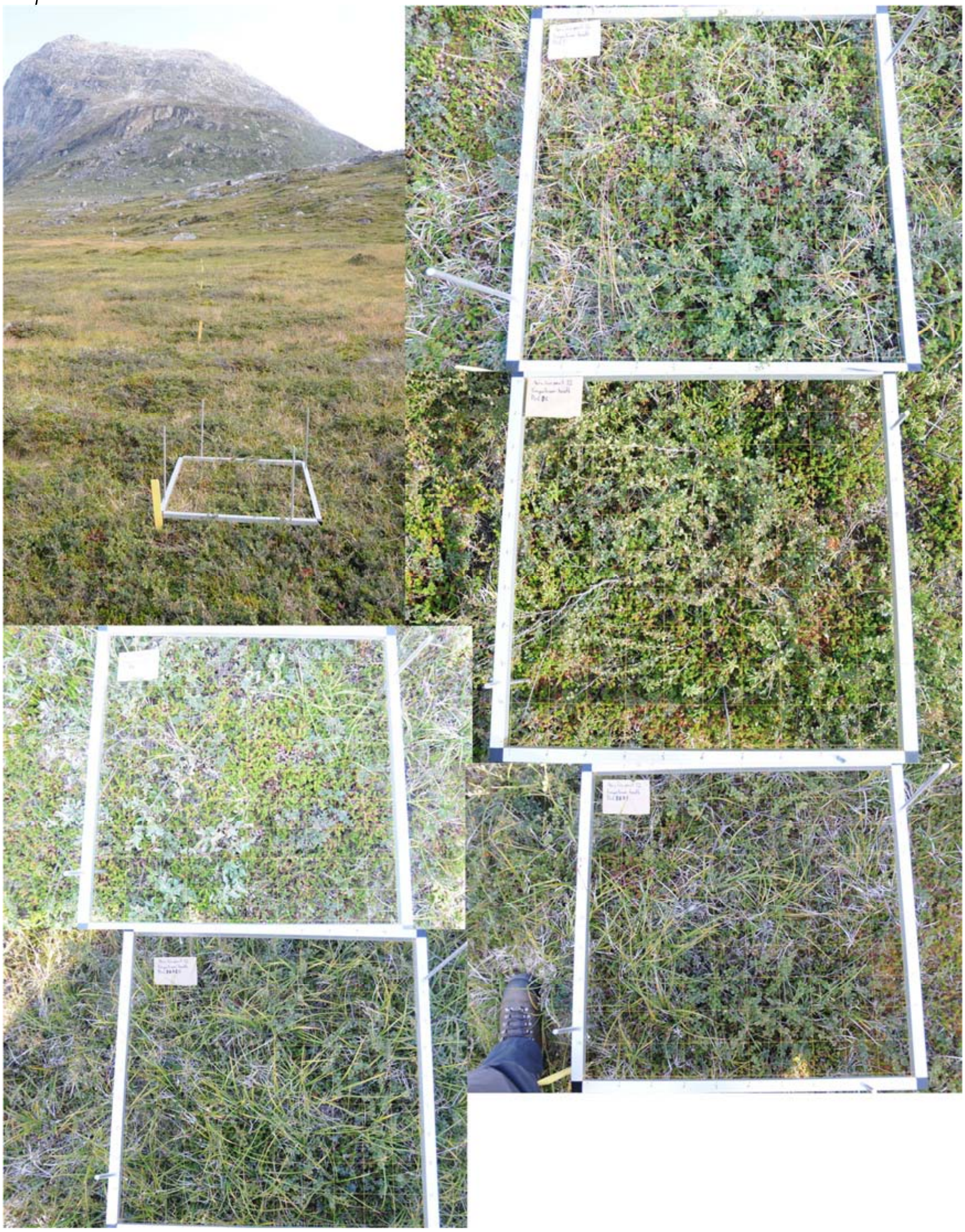
Salix herbacea snow bed



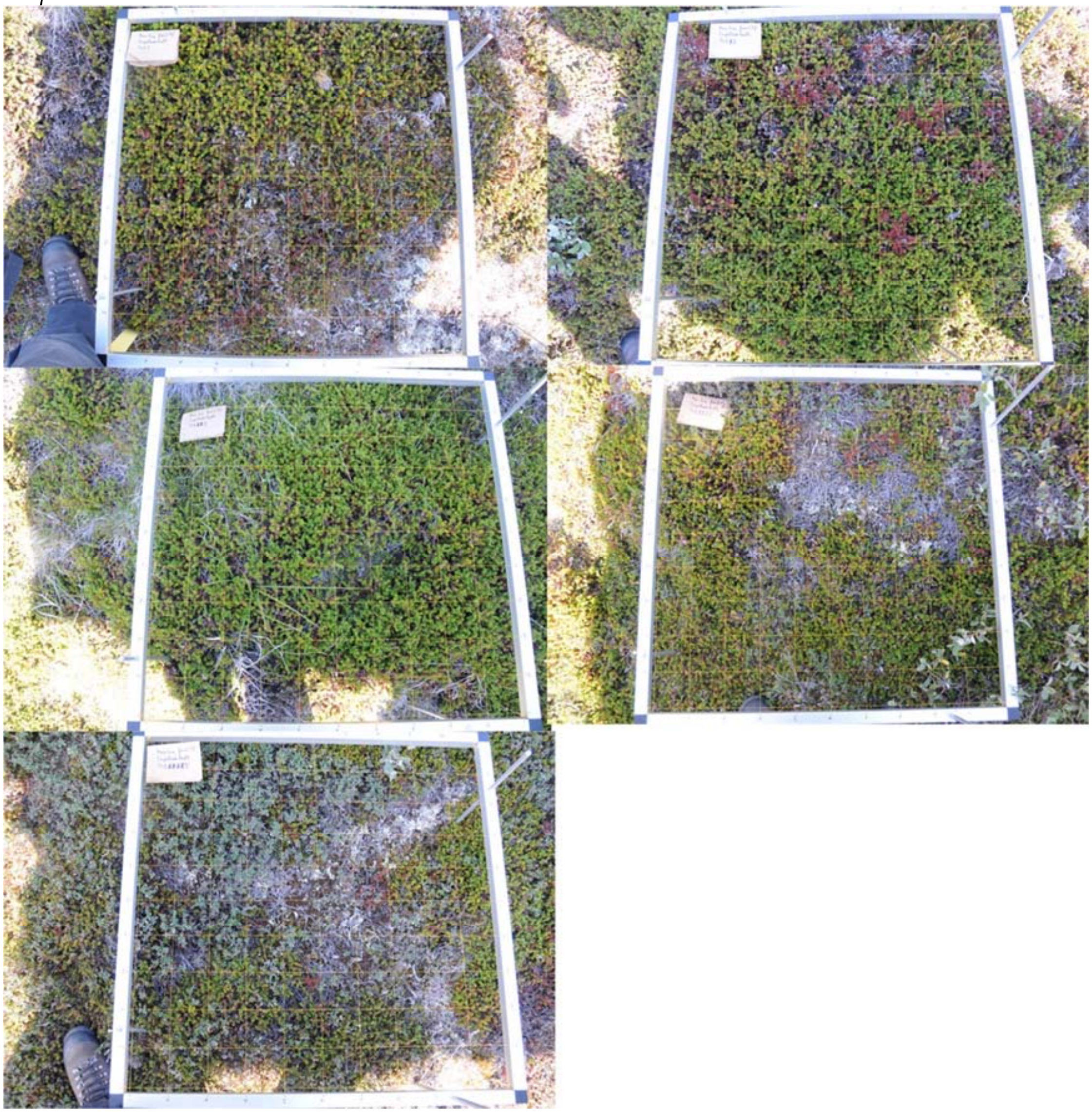
Poor fen



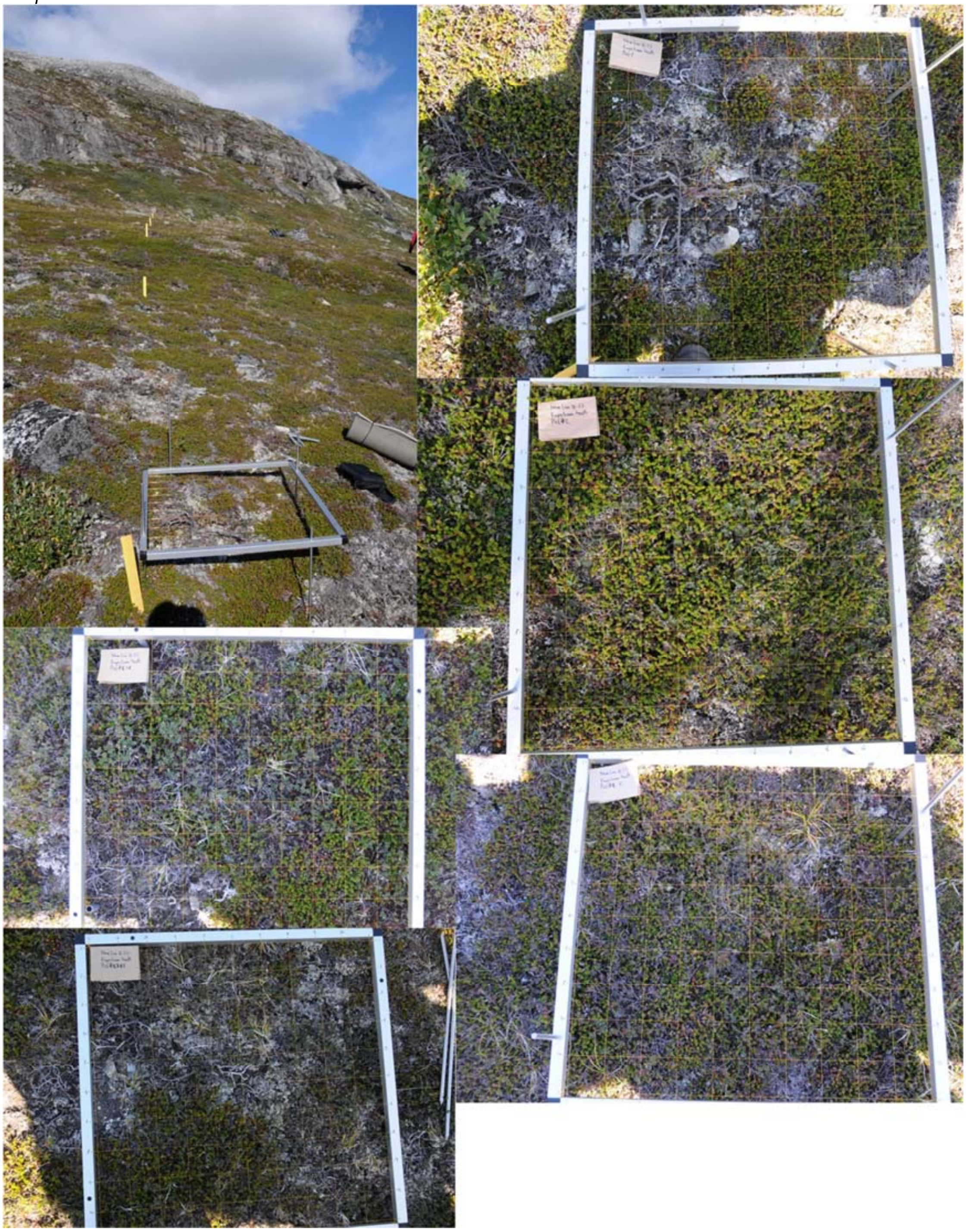
Empetrum heath 26 m a.s.l.



Empetrum heath 120 m a.s.l.



Empetrum heath 310 m a.s.l.



BRYOPHYTE DIVERSITY IN HIGH AND LOW ARCTIC GREENLAND

Establishment of permanent monitoring transects and bryophyte mapping in Zackenberg and Kobbefjord 2009-2010

This report summarises the establishment of permanent bryophyte monitoring transects at high arctic Zackenberg and in low arctic Kobbefjord. Transects were established at Zackenberg in 2009 and in Kobbefjord in 2010. Along with the establishment of the permanent monitoring infrastructure, a detailed mapping of the bryophyte communities was conducted.

At both sites, bryophytes were one of the main components both in terms of species diversity and frequency in the vegetation. At Zackenberg, species diversity was higher for bryophytes than vascular plants in all transects, except for transects located in snow beds or in the high altitudinal fen. In terms of frequency bryophytes were the dominating functional group in most transects. In Kobbefjord, bryophytes exhibited higher species diversity than vascular plants in most vegetation types, but they were never the dominating group in terms of frequency.

The permanent monitoring infrastructure will allow for future re-examinations to assess the development in bryophyte species diversity in Greenland. All collected data are available through the database of Greenland Ecosystem Monitoring (www.g-e-m.dk).

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