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Reindeer winter forage

Long-term monitoring research

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Útdráttur: Náttúrustofa Austurlands hefur vaktað gróður og hreindýr á Norðausturlandi um nokkurt skeið. Í tengslum við þá vöktun voru settir upp vöktunarreitir árið 2018 í samvinnu við norsku Náttúrufræðistofnunina, Norsk institutt for naturforskning (NINA). Markmið vöktunarinnar er að kanna ástand vetrarhaga hreindýranna með það að leiðarljósi að tryggja sjálfbæra stjórnun hreindýrastofnsins.

Niðurstöður fyrstu mælinga árið 2018 leggja grunn að vöktuninni og gefa færi á samanburði við sambærilegar rannsóknir í Noregi.

Lykilorð: Hreindýr, vetrarbeit, fléttur, vöktun, Norðausturland

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Ásrún Elmarsdóttir

Náttúrustofa Austurlands

Reindeer winter forage
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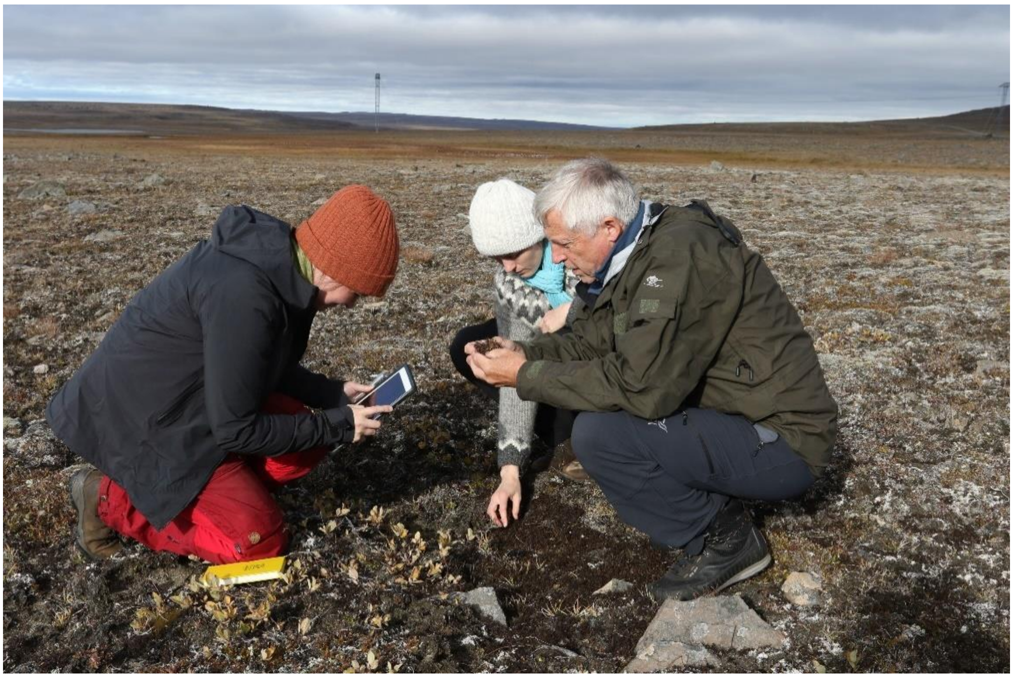

Guðrún Óskarsdóttir, Elín Guðmundsdóttir, Kristín Ágústsdóttir
& Hans Tømmervik

Carried out for Landsvirkjun

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Technical Report: Reindeer winter forage Long-term monitoring research		**Pages:** 21 **Appendices:** 1 **Photo on front page:** Lichen research in Fljótsdals-heiði. Photo: Skarphéðinn G. Þórisson

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Collaborators: Norsk institutt for naturforskning/ Norwegian Institute for Nature Research

Abstract:

Reindeer (*Rangifer tarandus*) are key species in the Arctic and are under threat of fragmentation and degradation of habitat. Access to winter forage, especially lichens, is considered one major factor determining growth of the species' populations. Thus, knowledge of the state of winter forage ranges is important to ensure adaptive management of reindeer populations. Long-term monitoring of winter foraging areas can provide augmented knowledge and has been carried out in Norway for decades. With this project, we aim to establish comparable methods between the Norwegian Institute for Nature Research (NINA) and the East Iceland Nature Research Centre (NA) for monitoring of reindeer winter forage.

In 2016, NA met up with NINA to study their monitoring of reindeer grazing areas in Hardangervidda in Norway. Each of NINA's monitoring sites included five plots, four were open for grazing but the fifth was covered with a mesh basked for comparison. In 2018, NINA's scientist Hans Tømmervik met up with NA to launch research on reindeer winter forage in Iceland with comparable methodology as carried out in Norway. Six transects with a total of 22 permanent monitoring sites were laid out in defined winter foraging areas in NE-Iceland.

Here we represent the results from the field study in Iceland. Lichen cover varied between transects, monitoring sites and plots and ranged from 8% to 22% on average at each transect. Most abundant lichen species throughout the study area were *Cetraria islandica* and *Cladonia arbuscula*.

The data from the field work in 2018 will be used as a baseline in the monitoring of reindeer winter forage rangelands in Iceland. Data gathering will be done with regular intervals and changes in lichen cover between years, transects and open/enclosed plots will be studied. This long-term monitoring research will provide information for sustainable management of reindeer stocks in both Iceland and Norway.

Keywords: Reindeer, winter forage, lichen, monitoring	**ISSN nr:** 2547-7439 (printed version) 2547-7447 (online version)
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Útdráttur

Hreindýr (*Rangifer tarandus*) eru lykiltegund í norðlægum vistkerfum og verða víða fyrir neikvæðum áhrifum vegna sundrunar og/eða eyðileggingu búsvæða. Framboð af fæðu yfir veturinn, sérstaklega fléttum, er talið vera einn af þeim þáttum sem segja til um stofnvöxt dýranna. Þekking á ástandi vetrarhaga þeirra er því mikilvæg til að geta tryggt sjálfbæra stjórnun hreindýrastofna. Langtímavöktun vetrarhaga getur veitt þá þekkingu og hefur slík vöktun verið í gangi í Noregi í áraraðir, undir stjórn norsku Náttúrufræðistofnunarinnar, Norsk institutt for naturforskning (NINA). Með þessu verkefni er komið upp sambærilegri vöktun hér á landi, undir stjórn Náttúrustofu Austurlands (NA).

Árið 2016 fór NA í heimsókn til NINA til að taka þátt í og fræðast um þeirra vöktun í Harðangri. Settir voru upp vöktunarreitir, sem samsettir voru úr fimm smáreitum, á sniðum sem fylgdu snjóléttum hryggjum þar sem þekja flétta var áberandi. Fjórir þeirra voru opnir fyrir beit en sá fimmti girtur af með vírgrind. Árið 2018 kom Hans Tømmervik frá NINA til Íslands og aðstoðaði NA við uppsetningu sambærilegra vöktunarreita. Sex snið með samtals 22 vöktunarreitum voru lögð út á Norðausturlandi.

Niðurstöður grunnrannsókna vöktunarinnar á Íslandi leiddu í ljós að þekja flétta var mismunandi milli sniða, vöktunarreita og smáreita og var á bilinu 8-22% á hverju sniði. Algengustu tegundir flétta á rannsóknarsvæðinu voru fjallagrös (*Cetraria islandica*) og hreindýrakrókar (*Cladonia arbuscula*).

Gögnin sem söfnuðust árið 2018 leggja grunninn að langtímavöktun á ástandi vetrarhaga hreindýra á Íslandi. Vöktunarreitirnir verða endurmældir reglulega og breytingar í þekju flétta milli ára, sniða og opinna/lokaðra smáreita verða kannaðar. Þessi vöktun verður mikilvæg viðbót við þekkingu á vistfræði hreindýra á Íslandi og mun nýtast til sjálfbærrar stjórnunar hreindýrastofnsins á Íslandi og jafnvel í Noregi.

Lykilorð: Hreindýr, vetrarbeit, fléttur, langtímavöktun

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Introduction

Reindeer (*Rangifer tarandus*) are key species in the Arctic and are under threat of fragmentation and degradation of habitat (Falldorf et al., 2014; Tømmervik et al., 2012). Access to winter forage, especially lichens, is considered one major factor determining growth of the species' populations (Heggberget et al., 2013). Thus, knowledge of the state of winter forage rangelands is important to ensure adaptive management of reindeer populations, both domestic and wild (Falldorf et al., 2014; Kjørstad et al., 2017). In Iceland, lichen-dominated heathlands are not as prominent as in the Norwegian reindeer winter rangelands (Ottóson et al., 2016; Tømmervik et al., 2014). Little is known about the importance of lichens as winter forage for Icelandic reindeer, but study by Kristbjörn Egilsson (1983) suggests that lichens are not as important for Icelandic reindeer as they seem to be for the Norwegian ones. A study on movements of Icelandic reindeer, using GPS collars, has showed that they adapt to their surroundings, grazing mainly in *Carex* moors and peatbogs where forage quality is poor, and in *Salix* heathlands where forage quality is richer (Þórisson, 2018).

Reindeer winter ranges have been changing considerably in the last decades, due to various human-related factors. Increased build-up of infrastructure, such as roads, inhibits the species which requires extensive seasonal movements to meet its nutritional needs (Kjørstad et al., 2017; Strand et al., 2006). In Hardangervidda, Norway, the population went through at least two overgrazing periods in the second half of the last century due to fragmented habitats but is now managed to protect vegetation and animal condition (Strand et al., 2006). With active management, aiming to protect and restore damaged winter rangelands, lichen biomass can increase rapidly, and winter grazing pastures recover (Tømmervik et al., 2012).

Climate change can have a range of different effects on lichens and other types of reindeer forage. Increased frequency of winter thaw and ground-icing events can kill lichens and may have extensive effects in boreal and Arctic lichen-dominated ecosystems (Bjerke, 2011). Warmer winters can also have negative effects on various vegetation that relies on snow cover through the cold season (Bjerke et al., 2017; Bokhorst et al., 2009). Climate-induced damage to vegetation grazed by reindeer can have negative effects on reindeer populations but so can climate-induced greening, where a warmer climate causes shrub with strong anti-browsing defences to expand at the cost of vegetation preferred by reindeer (Fauchald et al., 2017).

Long-term monitoring can shed a light on the effects of reindeer on winter forage areas and possibly vice versa and has been carried out in Norway for decades (Tømmervik et al., 2014). With this project, we aim to establish comparable methods between the Norwegian Institute for Nature Research (NINA) and the East Iceland Nature Research Centre (NA) for long-term monitoring of winter forage.

Methods

Monitoring in Hardangervidda, Norway

In August 2016, Icelandic scientists from NA met up with Norwegian scientists from NINA to study their methods of long-term monitoring of reindeer grazing areas in Norway. Some monitoring sites had already been established in winter forage areas around the country, but NA participated in establishing new sites in Hardangervidda. Sites were laid out along a transect, ca 500 m apart, and each transect generally consisted of five sites. When selecting a location for a new site, NINA researchers took the landscape into account and chose locations where reindeer are likely to be able to access the vegetation in the winter. For that reason, ridges where lichens were found which were thought to have less than 50 cm thick snow cover in winter were considered ideal.

Within each monitoring site, a group of five plots, 0.5 m x 0.5 m (0.25 m^2) in size, were established. Four of the plots were open for grazing by reindeer. The fifth plot was covered with a mesh basked to protect it from grazing for comparison (Fig. 1). The covered plot was located at a randomly chosen location within an ideal area like mentioned above. The other four plots were located 10 m east, south, west and north of the covered plot. All lichen species and the most abundant vascular plant species within each plot were recorded. The cover of each lichen species was estimated in percentage cover, and their height/thickness measured. Cover of large rocks or other substrates inhibiting potential vegetation cover was also estimated, along with unvegetated area where lichens could possibly grow. Lastly, obvious effects of grazing and tramping were recorded, and photographs were taken.

Elín Guðmundsdóttir, Guðrún Óskarsdóttir and Kristín Ágústsdóttir were in the NA field team. Erling J. Solberg, Olav Strand and Jon Mårdal were in the NINA field team and field work took place from 12th to 14th of August 2016.

Fig. 1. Mesh basket (left) fastened to the ground (right).

Monitoring in Northeast Iceland

In September 2018, Norwegian scientist Hans Tømmervik from NINA met up with Icelandic scientists from NA to launch research on reindeer winter forage in Iceland with comparable methodology as carried out in Norway. Six transects with a total of 22 permanent monitoring sites were laid out in NE-Iceland (Fig. 2) from the 3rd to the 7th of September. Plots open for grazing were marked with a wooden stake and both open and covered plots were 0.5 x 0.5 m^2 in size (Fig. 3).

Locations of monitoring sites were selected based on information on winter distribution of reindeer in NE-Iceland, both from GPS monitoring (Þórisson and Ágústsdóttir, 2014; unpublished data from NA) and from conventional random on-land sightings. Sites considered to experience winter grazing (Jökuldalsheiði and Fljótsdalsheiði) as well as sites in areas where reindeer have just recently expanded their distribution to and have not yet experienced much grazing (Þistilfjörður, Vopnafjörður and Bakkafjörður) were chosen (Fig. 2).

Four sites (nr. 1-4) were set up along the first transect (A) in Jökuldalsheiði (Fig. 2). Two sites (nr. 5-6) in one transect (B) and four (nr. 7-10) in another (C) were set up in Þistilfjörður. Four sites (nr. 11-14) were set up in Bakkafjörður (D) and another four (nr. 15-18) in Vopnafjörður (E) and the last four (nr. 19-22) were located in Fljótsdalsheiði (F) (Fig. 2). The last two sites, nr. 21 and 22, were laid out at a vegetation monitoring site that NA has been monitoring for over a decade. The site is 10 m x 10 m (100 m^2) and within it, ten plots (0.25 m^2) were laid out randomly in 2008 when vegetation monitoring started in the area (Guðmundsdóttir, 2009). The site was re-measured in 2016 (Óskarsdóttir et al., 2017) and in 2018, baskets were laid down over two of the ten plots and the other eight plots were kept open. Those two monitoring sites are therefore not structured like the other twenty sites in the study.

NDVI was measured directly at each plot with a Trimble Greenseeker Handheld Crop Sensor [GreenSeeker Handheld Crop Sensor. Available online: http://www.trimble.com/Agriculture/gs-handheld.aspx (accessed on 3rd of March 2016)], hereafter, Greenseeker. The Greenseeker is a portable, active sensor device that requires manual input for operation: a trigger is pulled which turns the sensor on, whereby light emitting diodes then beam near infrared (NIR: 780 +/- 10 nm) and red (670 +/- 10 nm) radiation onto the plant canopy or lichen cover, with the amount of light reflected back to the device—then measured via silicon diodes. Since the Greenseeker is an active sensor that both emits and measures light, it is not limited by constraints such as cloud cover, atmospheric pollution, shadows and humidity that accompany passive systems (Inman et al., 2007) such as passive NDVI sensors. We used the device for nadir sampling only at a height above ground level of 0.9 m and thus measurements covered a spot diameter of circa 0.38 m.

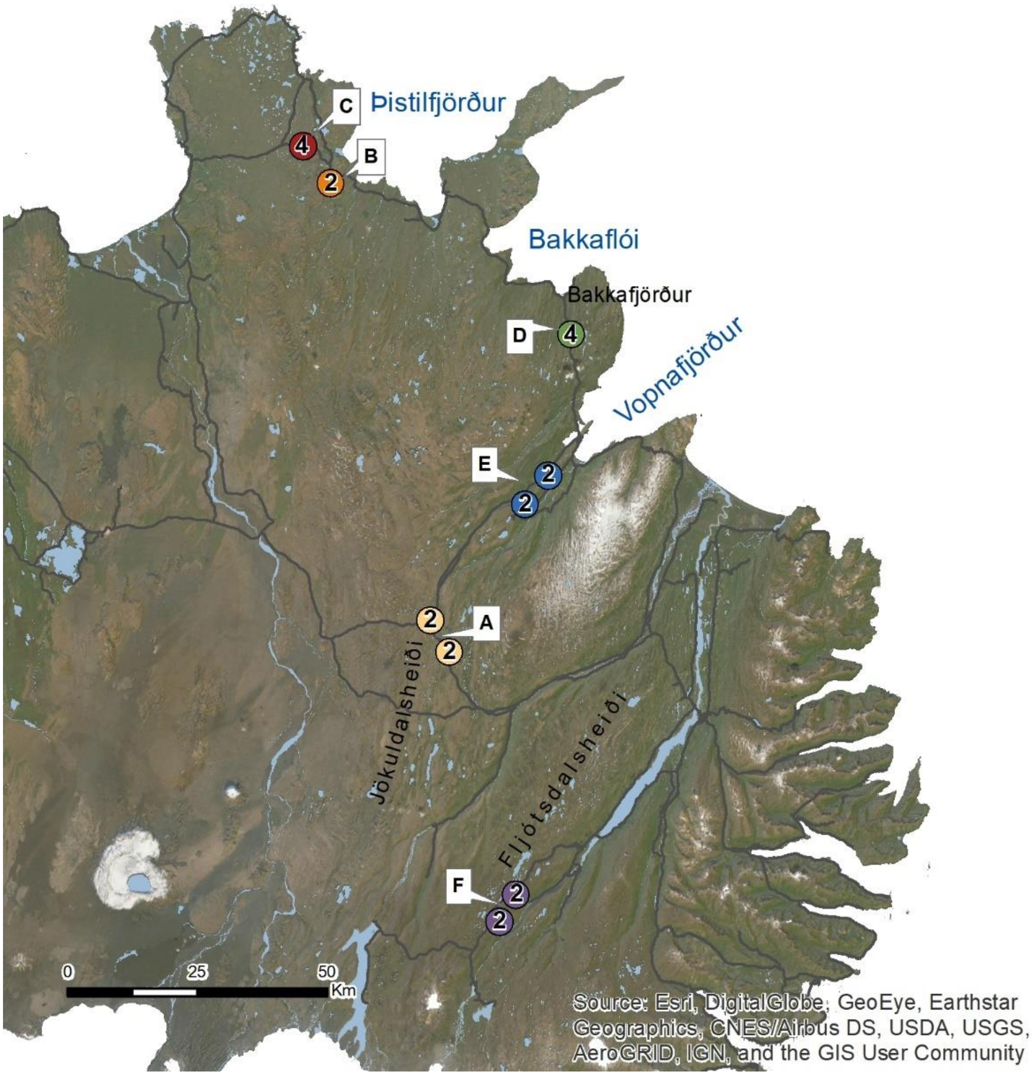

Fig. 2. Winter forage monitoring transects in NE-Iceland. The numbers within the circles indicate number of sites at each location.

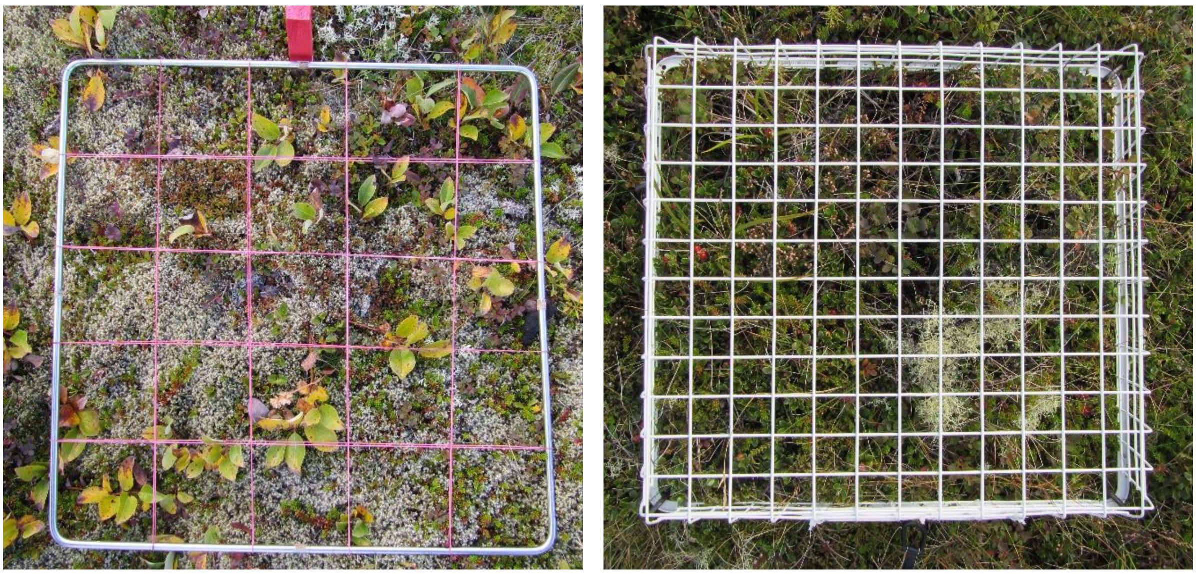

Fig. 3. Plots, open (left) and covered with a mesh basket (right).

Data analyses

For comparing lichen cover between transects, we used Analysis of Variance (ANOVA) with Tukey's post hoc test. To compare lichen cover between closed and open plots, we used unpaired *t*-test. For two monitoring sites, nr. 21 and 22 in Fljótsdalsheiði, Kruskal-Wallis Test was used to compare lichen cover from vegetation monitoring between the years 2008, 2016 and 2018. Kruskal-Wallis Test was also used to compare NDVI-values between transects. All data analyses were done in *R*, version 3.5.3 (R Core Team, 2019), in the *RStudio* interface (RStudio Team, 2018).

Results

Lichen cover

Lichen cover varied between transects (F=3.51, p<0.01; Fig. 4) and between monitoring sites (Fig. 5). On average, transect A had the greatest lichen cover (22%), which was significantly greater than the cover in transects B and F (p<0.05), which had the sparsest lichen cover (8%). Transect B consisted of only two sites while all others consisted of four sites (Fig. 5).

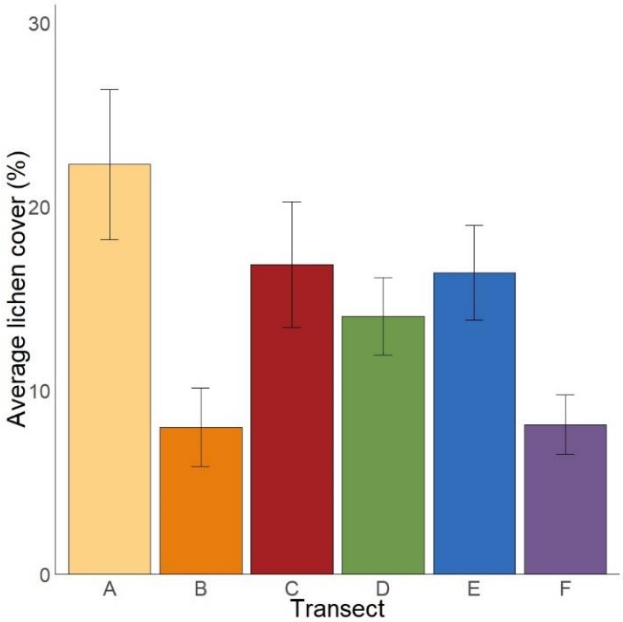

Fig. 4. Average cover of lichen in each transect (with standard error of the mean). Fill-colours represent location of transects in Fig. 2.

Lichen cover varied between plots as well (Fig. 5). At each monitoring site, one plot was closed for grazing while four plots were open for grazing. Maximum lichen cover (82%) was recorded in an open plot at monitoring site 1. Maximum lichen cover within enclosed plots was recorded at site 8, 54% (Fig. 5). Four plots had only 1% lichen coverage, two of them at site 6, transect B. Average lichen cover in all closed plots was 19%, but in open plots it was 14% (t=2.08, p=0.045).

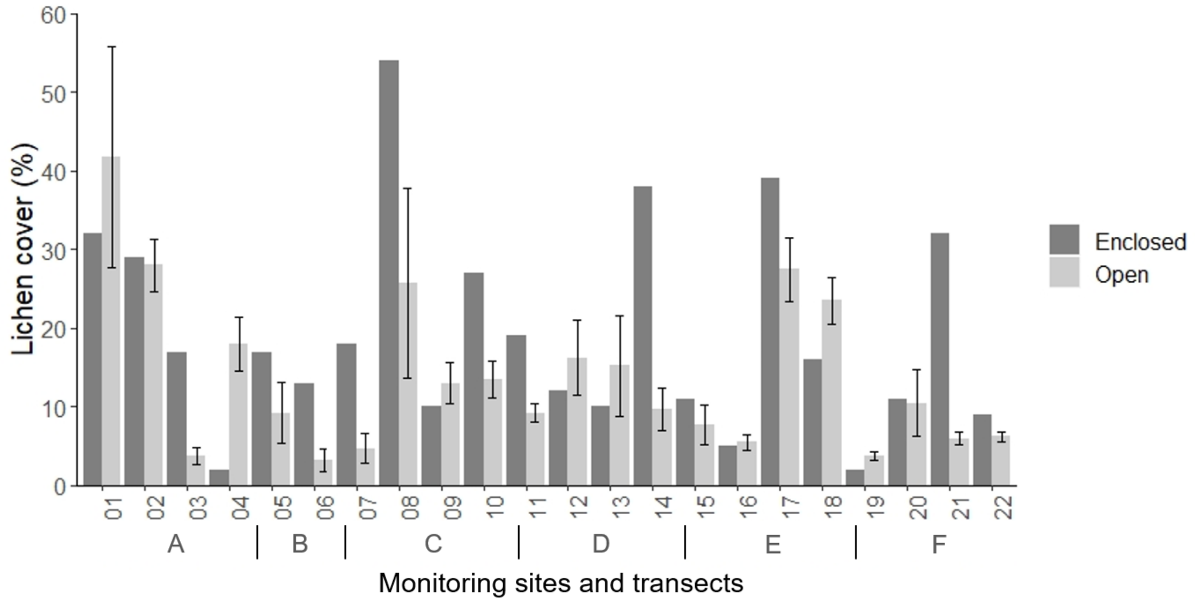

Fig. 5. Lichen cover inside and outside enclosures at all sites (with standard error of the mean for open plots).

Lichen cover at monitoring sites 21 and 22 in Fljótsdalsheiði decreased between years in some plots and increased in others (Fig. 6). The mean lichen cover in all plots was 13% in 2008, 16% in 2016 and 9% in 2018 and difference between years was not significant (*chi-squared*=5.53, *df*=2, *p*=0.06). Lichen cover was estimated according to adjusted Hult-Sernander cover scale (Sjörs, 1956) in 2008 and 2016 but not in 2018 so results may not be comparable between 2018 and earlier years. Most abundant species found in Fljótsdalsheiði were *Cladonia arbuscula*, *Cetraria islandica, Cetrariella delisei* and *Ochrolechia frigida* (Table 1).

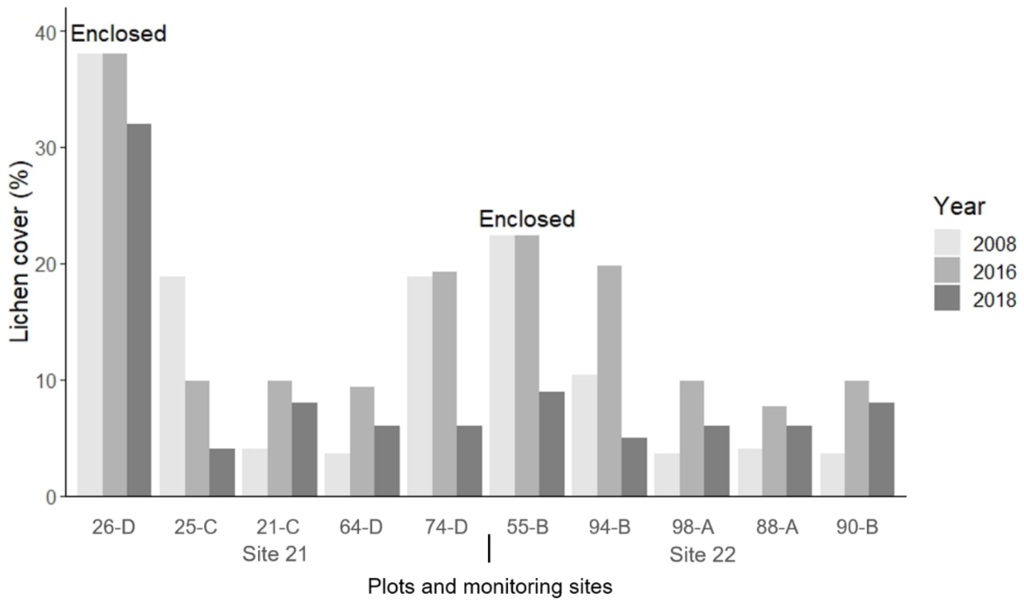

Fig. 6. Lichen cover in Fljótsdalsheiði in 2008, 2016 and 2018. Plot names are the same as in Óskarsdóttir et al. (2017) *and enclosed plots are marked.*

Lichen species

Number of lichen species found at each monitoring site varied from three to eleven (Table 1). Eleven species were found at site 12, but only three species were found at sites 1 and 3.

Table 1. Lichen species found at each monitoring site.

Sites	*Alectoria sp.*	*Alectoria nigricans*	*Alectoria ochroleuca*	*Cetraria sp.*	*Cetraria islandica*	*Cetrariella delisei*	*Cladonia sp.*	*Cladonia arbuscula*	*Cladonia glacialis*	*Cladonia gracilis*	*Cladonia rangiferina*	*Cladonia uncialis*	*Flavocetraria nivalis*	*Ochrolechia frigida*	*Peltigera sp.*	*Sphaerophorus globusus*	*Stereocaulon sp.*	*Thamnolia vermicularis*	*Other lichen*
1					x			x									x		
2					x		x	x									x		x
3					x		x								x				
4	x			x	x		x	x						x	x		x	x	
5					x			x						x			x	x	
6					x		x	x						x			x	x	
7			x		x			x					x	x			x	x	
8					x			x		x	x	x		x	x		x		
9					x			x				x					x	x	
10					x			x		x	x			x			x		
11					x			x			x				x		x	x	
12			x		x			x		x	x	x		x	x	x	x	x	
13		x	x		x			x							x		x	x	
14					x			x		x	x	x	x		x		x	x	
15			x		x								x	x	x			x	
16	x		x		x				x	x			x		x		x	x	
17		x	x		x			x					x	x			x	x	
18		x	x		x			x		x			x	x			x	x	
19					x			x		x			x	x			x	x	
20					x	x		x						x				x	
21					x	x		x						x	x				
22					x	x		x						x					

Most abundant lichen species groups throughout the study area were *Cetraria/-ella* (combined in one group) and *Cladonia* (Fig. 7). *Ochrolechia, Alectoria* and *Flavocetraria* were noticeable at a few of the monitoring sites. *Peltigera, Stereocaulon* and *Thamnolia* occurred at most sites but their cover was generally sparse (Fig. 7).

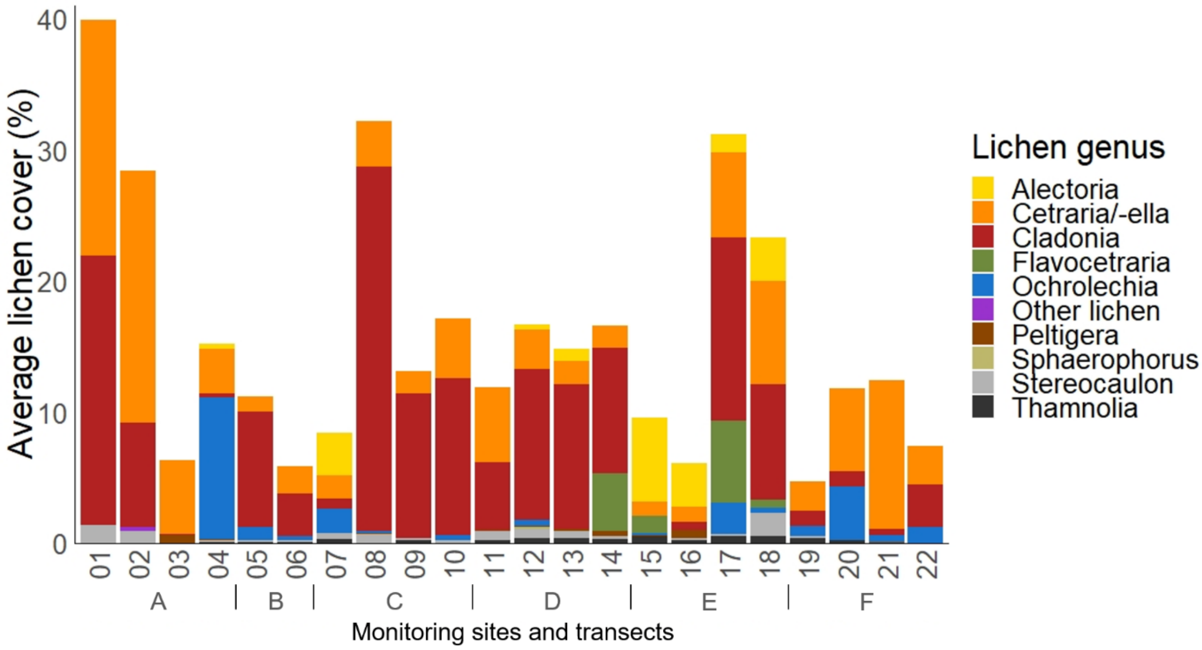

Fig. 7. Species group cover at each monitoring site.

Of the lichen species groups that are not procumbent, *Alectoria* grew tallest (or thickest) and reached 11 cm at site 12 (Fig. 8). *Cetraria-/ella*, *Cladonia* and *Flavocetraria* lichens were ≤ 7 cm thick.

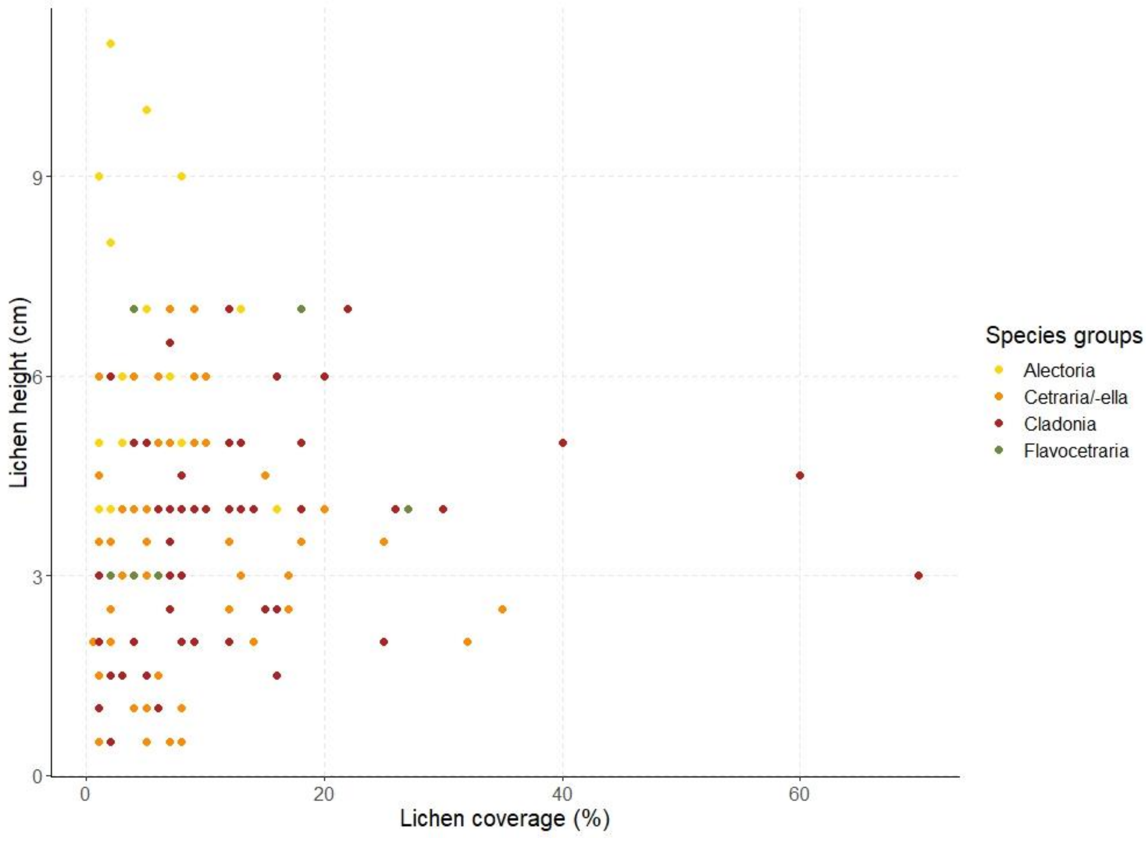

Fig. 8. Height of a few lichen species groups vs. their cover. Point-colours are the same as bar-colours in Fig. 7.

Greenseeker NDVI

On average, transect F had the lowest average NDVI-values (0.37; Fig. 9; *chi squared*=37.11, *df*=5, *p*<0.001), which were significantly lower than values in transects C, D and E (p<0.01). Transect E had the highest average NDVI-values (0.57), significantly higher than in transect A (p=0.01), as well as in transect F.

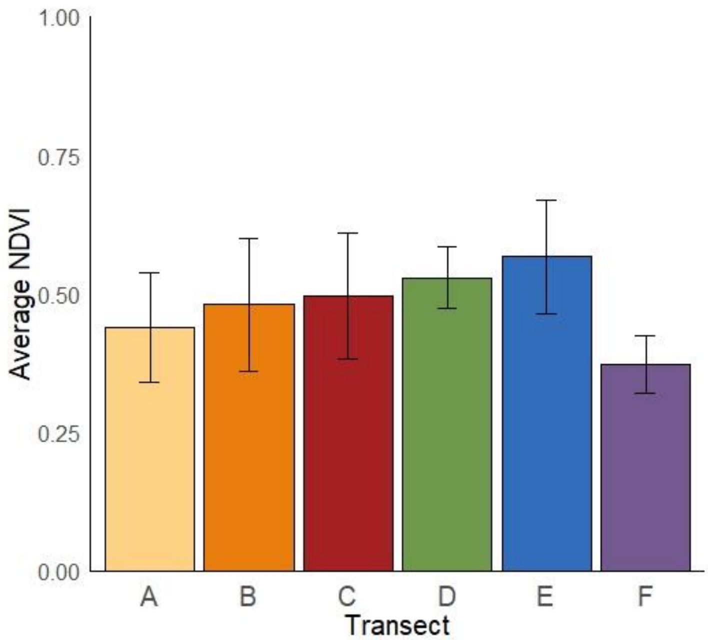

Fig. 9. Average NDVI in each transect (with standard deviation of the mean). Fill-colours represent location of transects in Fig. 2.

When studying the NDVI results visually with regards to lichen cover (Fig. 10), the lichen-dominated plots seemed to have rather low NDVI-values (Fig. 11) compared to plots with less lichen. Where lichen cover was sparse, the NDVI-values ranged from <0.3 to >0.7, the lowest values coming from plots where overall vegetation cover was sparse and the highest values from plots with great vascular plant cover (Fig. 12). The moss-dominated plots (*Racomitrium* sp.) seemed to have much higher NDVI-values in wet conditions than in dry conditions (Fig. 13).

When studying the NDVI results visually with regards to lichen colour, no obvious pattern was detected, other than plots with neither ≥10% cover of white nor brown lichens naturally had lower lichen cover (Fig. 10). However, plots with high cover of unvegetated surface generally seemed to have lower NDVI-values than plots with more vegetative cover (Fig. 10). Plots with low NDVI-values despite low cover of unvegetated surface generally had a high cover of dry moss, biological soil crust or vegetation that had begun the process of autumn leaf senescence (Fig. 14).

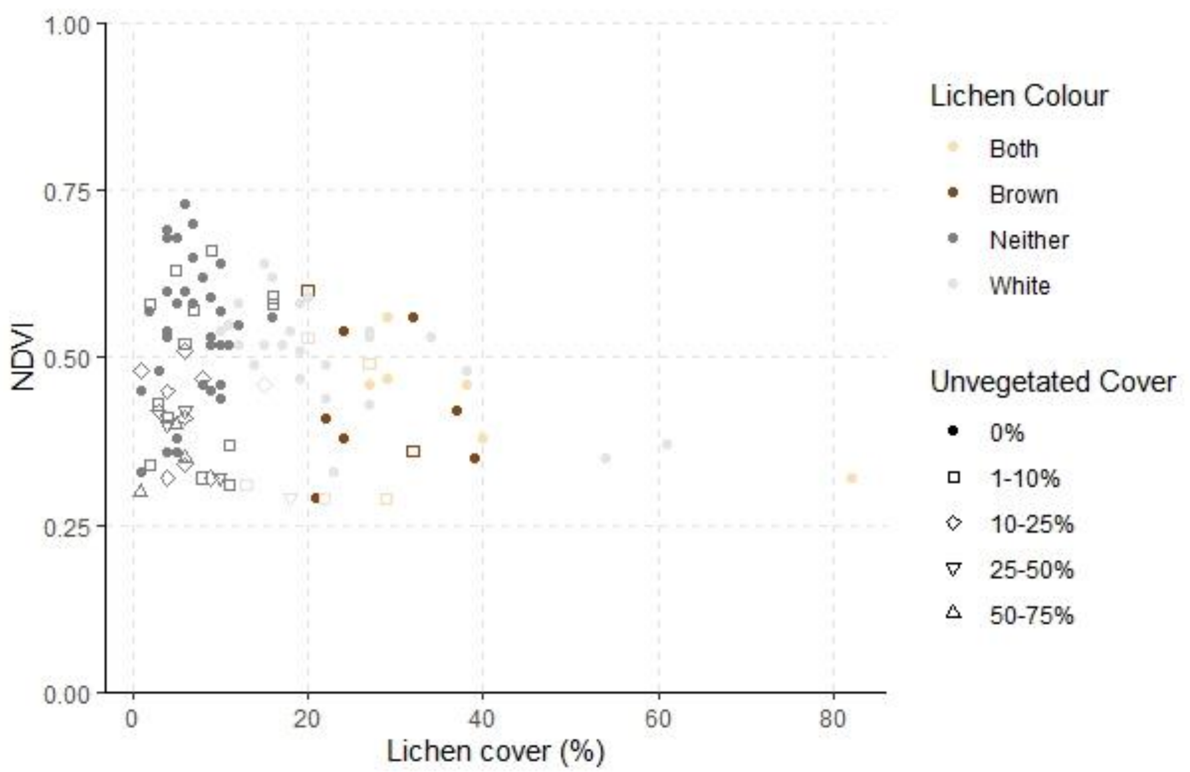

Fig. 10. NDVI vs. lichen cover. Colours represent the colours of lichens with ≥10% cover and shapes represent the cover of unvegetated surface.

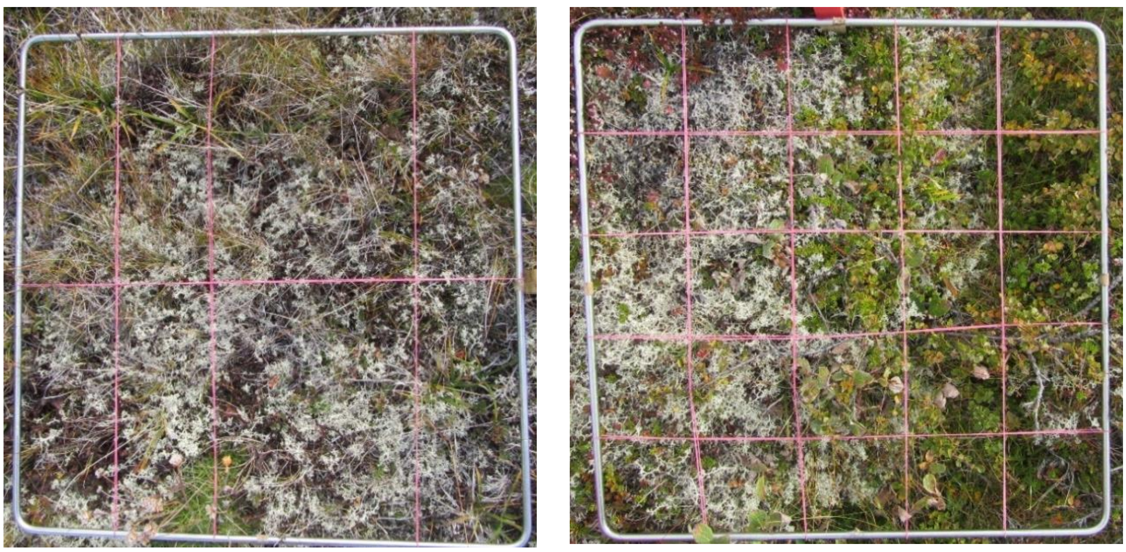

Fig. 11. Plots with great lichen cover. The plot on the left had 82% lichen cover (NDVI-value: 0.32) and the plot on the right had 61% lichen cover (NDVI-value: 0.37).

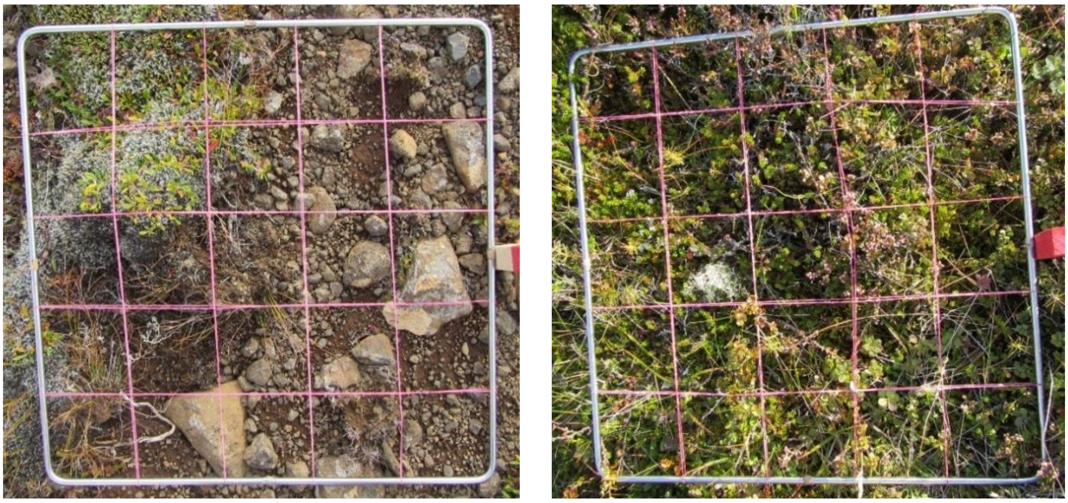

Fig. 12. Plots with sparse lichen cover. In the plot on the left, overall vegetation cover was sparse (NDVI-value: 0.30) but the plot on the right had great vascular plant cover (NDVI-value: 0.73).

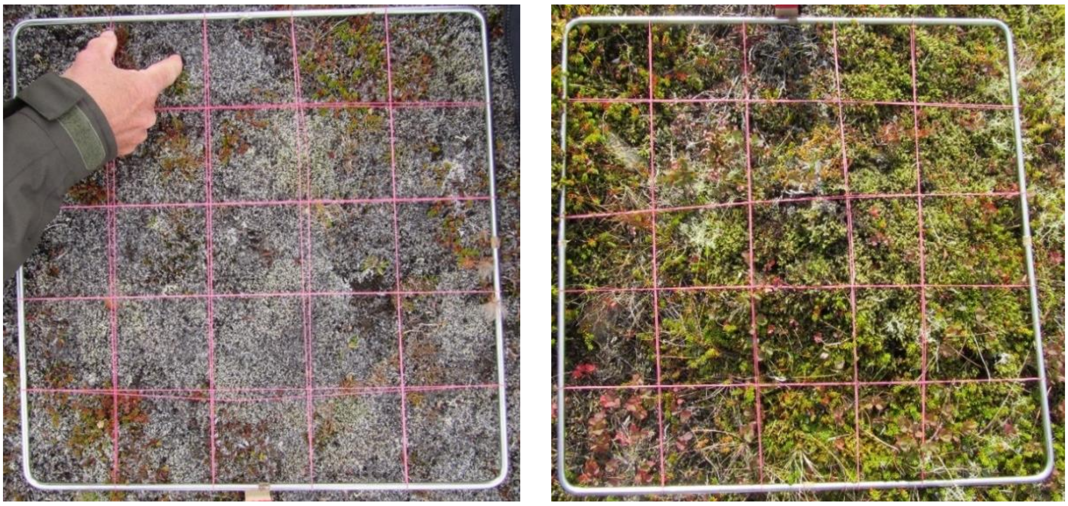

Fig. 13. Moss-dominated plots. In the plot on the left, the Racomitrium *moss is dry (NDVI-value: 0.34) but in the plot on the right, it was much wetter (NDVI-value: 0.63).*

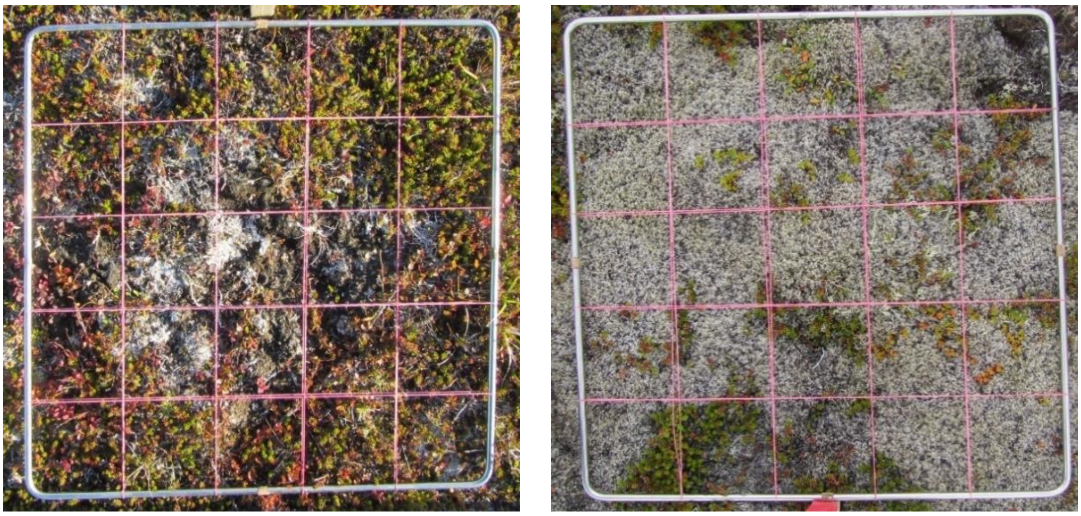

Fig. 14. Plots with low NDVI-values despite low cover of unvegetated surface. In the plot on the left, biological soil crust and autumn leaf senescence are visible (NDVI-value: 0.33) while the plot on the right is dominated by dry Racomitrium *moss (NDVI-value: 0.33).*

Discussions

The data collected in 2018 will be used as a base in the monitoring of reindeer winter forage rangelands in Iceland. Transects A and F are located in areas that reindeer have utilized for a long time while grazing pressure at transects D and E has recently increased (since 2000) and transects B and C are at the edge of their current distribution (Þórisson and Þórarinsdóttir, 2019). With the enclosed plots, our aim is to study the effect of grazing on lichens and with time, identify the state and transition of these important reindeer winter ranges.

In Norway, lichens often dominate reindeer diets in winter and productivity has been shown to be higher in lichen-rich than lichen-poor ranges (Heggberget et al., 2013). To conserve wild reindeer, as Norway has committed to do, it is therefore important to effectively monitor and manage the population status and lichen resources (Kjørstad et al., 2017). Where lichens are abundant, they may constitute more than 80% of reindeer stomach content during winter, but in lichen-poor rangelands the proportion is around 25% (Heggberget et al., 2013). Recording dominant lichen species is also an important part of monitoring reindeer winter ranges as previous studies (Solberg, 1970; Svihus & Holand, 2000) have shown that lichens of the genus *Cetraria* have a higher nutrient content compared to *Cladonia* and *Stereocaulon* species (as cited in Storeheier et al., 2002b, p. 253).

In Iceland, lichen-dominated heathlands are less prominent than they are in the reindeer winter rangelands in Norway (Ottóson et al., 2016; Tømmervik et al., 2014). A research done in Iceland in 1980-1982 showed that in the more lichen-rich research areas (Jökuldalsheiði, transect A), lichens constituted on average around half of the reindeer's stomach contents from autumn until spring and in the more lichen-poor areas (Fljótsdalsheiði, transect F), lichens made up around 20% of the stomach content in spring and autumn and only 3% in winter (Egilsson, 1983). Vegetation commonly found in reindeer stomachs all year round in Iceland were sedges, grasses and shrubs (Egilsson, 1983), in similar proportions as in the stomachs of reindeer in lichen-poor Fennoscandian ranges (Heggberget et al., 2013). Egilsson's research (1983) on the stomach content of Icelandic reindeer is one of very few researches on the matter published in Iceland. Adding more research in that field would be very beneficial for this research. Research in Norway has also focused on the importance of vascular plants like grasses and sedges in the winter diet for reindeer. The conclusion so far is that grasses can add significantly to the diet during the winter since certain graminoids can preserve 50% of their nutrients like proteins in midwinter (Storeheier et al., 2002a). This is also an interest topic to study in Iceland.

During the field work in Norway and Iceland, we witnessed the difference described above in average lichen cover and height between the countries. Using comparable monitoring methods in both countries might help us anticipate how reindeer populations can adapt to changes in lichen cover. Therefore, we are very interested to continue our informative and enjoyable cooperation. At the monitoring sites in Iceland, data will be gathered every five years and changes in lichen cover between years, transects and open/enclosed plots will be studied. This long-term monitoring research will add beneficial knowledge to foregoing studies on reindeer populations and will provide successive tools for adaptive and successful management of reindeer stocks in both Iceland and Norway.

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Appendix 1

Data from the field work (list of vascular plant species and NDVI records are not shown).

Transect A, monitoring site 1

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	7	3
1	*Cetraria islandica*	25	3.5
2	*Cladonia arbuscula*	25	2
2	*Cetraria islandica*	15	4,5
3	*Cladonia arbuscula*	70	3
3	*Cetraria islandica*	12	3.5
4	*Cetraria islandica*	20	4
4	*Sterocaulon* sp	4	1
5	*Cetraria islandica*	18	4
5	*Sterocaulon* sp	3	1
5	*Cladonia arbuscula*	x	

Transect A, monitoring site 2

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	12	2
1	*Cetraria islandica*	17	3
2	*Sterocaulon* sp	4	1
2	*Cladonia arbuscula*	2	2
2	*Cetraria islandica*	18	3.5
3	*Cetraria islandica*	35	2.5
3	*Cladonia* sp	2	
3	Other lichen	x	
4	*Cladonia arbuscula*	8	2
4	*Cetraria islandica*	14	2
4	*Sterocaulon* sp	x	
5	*Cetraria islandica*	12	2.5
5	*Cladonia arbuscula*	16	1.5
5	Other lichen	1	
5	Unvegetated	2	

Transect A, monitoring site 3

Plot	Species	Coverage (%)	Height (cm)
1	*Cetraria islandica*	17	2.5
2	*Cetraria islandica*	5	3
3	*Cladonia* sp	x	
4	*Cetraria islandica*	3	1.5
4	*Peltigera* sp	3	na
4	Litter / Unvegetated	1	
5	*Cetraria islandica*	3	na

Transect A, monitoring site 4

Plot	Species	Coverage (%)	Height (cm)
1	*Cetraria islandica*	2	na
1	Unvegetated	2	
2	*Cetraria islandica*	1	na
2	Biological soil crust	18	
2	*Ochrolechia frigida*	22	
3	Biological soil crust	10	
3	*Ochrolechia frigida*	18	
3	*Cetraria* sp	4	na
3	*Cladonia arbuscula*	x	
4	*Alectoria* sp	2	na
4	*Cladonia* sp	1	na
4	*Peltigera* sp	x	
4	Biological soil crust	4	
4	*Cetraria* sp	5	na
5	*Thamnolia vermicularis*	x	
5	*Ochrolechia frigida*	14	
5	*Cetraria* sp	5	na
5	Biological soil crust	2	
5	*Sterocaulon* sp	x	

Transect B, monitoring site 5

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	16	2.5
1	*Cetraria islandica*	1	2
1	*Thamnolia vermicularis*	x	
2	*Cladonia arbuscula*	2	2
2	*Cetraria islandica*	x	
3	Unvegetated	4	
3	*Cladonia arbuscula*	15	2.5
3	*Ochrolechia frigida*	5	
3	*Cetraria islandica*	x	2
4	*Cetraria islandica*	2	3
4	*Cladonia arbuscula*	7	3.5
4	Unvegetated	1	
5	*Cladonia arbuscula*	4	2
5	*Cetraria islandica*	2	2.5
5	Unvegetated	16	
5	*Stereocaulon* sp	x	

Transect B, monitoring site 6

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	10	4
1	Unvegetated	2	
1	*Cetraria islandica*	3	3
2	Dead moss	50	
2	*Cladonia arbuscula*	2	3
2	*Thamnolia vermicularis*	x	1
2	*Ochrolechia frigida*	1	
2	*Cetraria islandica*	1	1
3	*Cladonia arbuscula*	1	1
3	*Cetraria islandica*	x	
3	Unvegetated	55	
3	*Cladonia* sp	x	
4	*Cetraria islandica*	5	3.5
4	*Cladonia arbuscula*	2	na
4	*Stereocaulon* sp	x	
4	Unvegetated	4	
5	*Cladonia arbuscula*	1	na
5	*Cetraria islandica*	x	
5	*Ochrolechia frigida*	x	
5	Unvegetated	18	
5	*Cetraria ericetorum*	x	

Transect C, monitoring site 7

Plot	Species	Coverage (%)	Height (cm)
1	*Alectoria ochroleuca*	16	4
1	*Cetraria ericetorum*	x	
1	*Ochrolechia frigida*	2	
1	Unvegetated	38	
2	*Cetraria ericetorum*	x	
2	*Cladonia arbuscula*	1	1.5
2	*Thamnolia vermicularis*	x	
3	*Thamnolia vermicularis*	x	
3	*Cladonia arbuscula*	x	
3	Unvegetated	30	
3	*Ochrolechia frigida*	5	
3	*Cetraria ericetorum*	4	na
3	*Cetraria islandica*	1	na
3	*Sterocaulon* sp	x	
4	Unvegetated	47	
4	*Cladonia arbuscula*	2	1.5
4	*Cetraria islandica*	x	
4	*Sterocaulon* sp	2	
5	*Cetraria nivalis*	x	
5	*Cladonia arbuscula*	x	
5	*Cetraria ericetorum*	1	na
5	Unvegetated	12	
5	*Cetraria islandica*	1	2
5	*Thamnolia vermicularis*	x	
5	*Ochrolechia frigida*	2	

Transect C, monitoring site 8

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia uncialis*	7	6.5
1	*Cladonia rangiferina*	4	5
1	*Cladonia arbuscula*	40	5
1	*Sterocaulon* sp	1	
1	*Cetraria islandica*	2	3
1	*Cladonia gracilis*	x	
2	*Cladonia arbuscula*	60	4.5
2	*Cetraria islandica*	1	3.5
2	*Cladonia gracilis*	x	
3	Unvegetated	2	
3	*Cetraria islandica*	13	3
3	*Cladonia arbuscula*	7	2.5
3	*Ochrolechia frigida*	x	
4	*Cladonia arbuscula*	12	2
4	*Sterocaulon* sp	2	
4	*Cladonia rangiferina*	x	
4	*Peltigera* sp	x	
4	*Cetraria islandica*	1	3
5	*Cladonia rangiferina*	7	3
5	*Sterocaulon* sp	x	
5	*Cladonia arbuscula*	x	
5	*Cetraria islandica*	x	

Transect C, monitoring site 9

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	10	5
1	*Cetraria islandica*	x	
1	*Cladonia uncialis*	x	
1	*Thamnolia vermicularis*	x	
1	*Sterocaulon* sp	x	
2	*Cladonia arbuscula*	16	6
2	*Cetraria islandica*	4	4
2	*Cladonia uncialis*	x	
2	*Sterocaulon* sp	x	
3	*Cladonia arbuscula*	8	4.5
3	*Cetraria islandica*	1	3.5
3	*Thamnolia vermicularis*	x	
4	*Cladonia arbuscula*	13	5
4	*Cetraria islandica*	1	4.5
5	*Cladonia arbuscula*	7	5
5	*Cetraria islandica*	2	4

Transect C, monitoring site 10

Plot	Species	Coverage (%)	Height (cm)
1	*Cetraria islandica*	9	6
1	*Cladonia arbuscula*	18	5
1	*Ochrolechia frigida*	x	
2	*Cladonia arbuscula*	7	4
2	*Cetraria islandica*	2	3.5
2	*Ochrolechia frigida*	x	
3	*Cladonia arbuscula*	18	4
3	*Cladonia rangiferina*	x	
3	*Cladonia gracilis*	x	
3	*Cetraria islandica*	1	4
4	*Cladonia arbuscula*	9	2
4	*Cetraria islandica*	1	3
4	*Sterocaulon* sp	x	
4	*Ochrolechia frigida*	x	
4	*Cetraria ericetorum*	x	
4	Biological soil crust	x	
5	*Cetraria islandica*	9	4
5	*Cladonia arbuscula*	7	4
5	*Sterocaulon* sp	x	
5	Unvegetated	3	
5	*Ochrolechia frigida*	x	

Transect D, monitoring site 11

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	9	5
1	*Cetraria islandica*	9	7
1	*Thamnolia vermicularis*	x	
1	*Sterocaulon* sp	1	
1	*Cladonia rangiferina*	x	
2	*Cladonia arbuscula*	6	5
2	*Cetraria islandica*	4	6
2	*Thamnolia vermicularis*	x	
2	*Sterocaulon* sp	x	
2	*Peltigera* sp	x	
3	*Cladonia arbuscula*	6	5
3	*Cetraria islandica*	4	6
3	*Cetraria ericetorum*	x	
4	*Cladonia arbuscula*	1	4
4	*Cetraria ericetorum*	1	1.5
4	*Cladonia rangiferina*	x	
4	*Sterocaulon* sp	2	
4	*Cetraria islandica*	7	7
5	*Cladonia arbuscula*	3	5
5	*Cetraria islandica*	3	5

Transect D, monitoring site 12

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	6	5
1	*Cetraria islandica*	6	6
1	*Peltigera* sp	x	
1	*Thamnolia vermicularis*	x	
1	*Cladonia rangiferina*	x	
1	*Cladonia uncialis*	x	
2	*Cladonia arbuscula*	1	4
2	*Cetraria islandica*	1	6
2	*Thamnolia vermicularis*	x	
2	*Ochrolechia frigida*	2	
2	*Cladonia gracilis*	x	
2	*Sphaerophorus globusus*	x	
3	*Cladonia arbuscula*	12	7
3	*Cladonia rangiferina*	1	4
3	*Thamnolia vermicularis*	x	
3	*Cetraria islandica*	2	6
3	*Sterocaulon* sp	x	
4	*Cladonia arbuscula*	22	7
4	*Cetraria islandica*	3	6
4	*Alectoria ochroleuca*	2	11
4	*Thamnolia vermicularis*	x	
4	*Cladonia gracilis*	x	
5	*Cladonia arbuscula*	12	4
5	*Cetraria islandica*	3	5
5	*Sterocaulon* sp	3	5
5	*Cladonia gracilis*	1	na
5	*Cladonia rangiferina*	x	
5	*Ochrolechia frigida*	x	

Transect D, monitoring site 13

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	6	4
1	*Thamnolia vermicularis*	x	
1	*Cetraria islandica*	3	5
1	*Alectoria nigricans*	1	4
2	*Cladonia arbuscula*	1	4
2	*Cetraria islandica*	1	5
2	*Alectoria ochroleuca*	3	6
2	*Sterocaulon* sp	x	
2	*Thamnolia vermicularis*	x	
2	*Alectoria nigricans*	x	
3	*Cladonia arbuscula*	30	4
3	*Cetraria islandica*	3	4
3	*Peltigera* sp	1	na
4	*Cladonia arbuscula*	10	4
4	*Cetraria islandica*	1	4
4	*Sterocaulon* sp	1	
4	*Thamnolia vermicularis*	x	
5	*Cladonia arbuscula*	8	4
5	*Sterocaulon* sp	1	
5	*Thamnolia vermicularis*	x	
5	*Cetraria islandica*	1	4

Transect D, monitoring site 14

Plot	Species	Coverage (%)	Height (cm)
1	*Flavocetraria nivalis*	18	7
1	*Cladonia arbuscula*	20	6
1	*Stereocaulon* sp	x	
1	*Thamnolia vermicularis*	x	
1	*Cetraria islandica*	x	
2	*Cladonia arbuscula*	2	4
2	*Cladonia uncialis*	x	
2	*Cladonia rangiferina*	x	
2	*Stereocaulon* sp	x	
2	*Thamnolia vermicularis*	x	
2	*Peltigera* sp	2	na
2	*Cetraria islandica*	x	
3	*Cladonia arbuscula*	12	5
3	*Cetraria islandica*	x	
3	*Cladonia gracilis*	x	
4	*Cladonia arbuscula*	5	5
4	*Cetraria islandica*	7	7
4	*Cladonia rangiferina*	4	6
5	*Flavocetraria nivalis*	4	7
5	*Cladonia arbuscula*	3	5
5	*Thamnolia vermicularis*	x	
5	*Cladonia gracilis*	x	

Transect E, monitoring site 15

Plot	Species	Coverage (%)	Height (cm)
1	*Alectoria ochroleuca*	5	7
1	*Flavocetraria nivalis*	6	3
1	*Cetraria islandica*	x	
1	*Thamnolia vermicularis*	x	
2	*Alectoria ochroleuca*	4	6
2	*Thamnolia vermicularis*	x	
2	(Species name missing)	x	
2	*Cetraria ericetorum*	1	3
2	*Ochrolechia frigida*	x	
2	Unvegetated	5	
3	*Alectoria ochroleuca*	3	6
3	*Cetraria islandica*	1	4
3	*Cetraria ericetorum*	na	na
3	*Thamnolia vermicularis*	x	
4	*Alectoria ochroleuca*	13	7
4	*Cetraria islandica*	x	
4	*Cetraria ericetorum*	2	2
4	*Thamnolia vermicularis*	x	
4	Unvegetated	10	
4	*Peltigera* sp	x	
4	*Ochrolechia frigida*	x	
5	*Alectoria ochroleuca*	7	6
5	*Flavocetraria nivalis*	x	
5	*Cetraria islandica*	x	
5	*Thamnolia vermicularis*	x	

Transect E, monitoring site 16

Plot	Species	Coverage (%)	Height (cm)
1	*Alectoria ochroleuca*	5	10
1	*Alectoria* sp	x	
1	*Cladonia gracilis*	x	
2	*Alectoria ochroleuca*	8	9
2	*Cetraria islandica*	x	
3	*Cetraria islandica*	1	na
3	*Alectoria ochroleuca*	1	9
3	*Sterocaulon* sp	1	4
3	*Peltigera* sp	3	na
3	*Cladonia gracilis*	x	
3	*Thamnolia vermicularis*	x	
4	*Cetraria nivalis*	4	6
4	*Cetraria islandica*	x	
5	*Alectoria ochroleuca*	2	8
5	*Thamnolia vermicularis*	x	
5	*Cladonia glacialis*	2	6

Transect E, monitoring site 17

Plot	Species	Coverage (%)	Height (cm)
1	*Flavocetraria nivalis*	27	4
1	*Cetraria islandica*	3	4
1	*Cladonia arbuscula*	9	4
1	*Alectoria ochroleuca*	x	
1	*Alectoria nigricans*	x	
1	*Cetraria ericetorum*	x	
1	*Thamnolia vermicularis*	x	
1	*Stereocaulon* sp	x	
1	*Ochrolechia frigida*	x	
2	*Cetraria islandica*	9	5
2	*Cladonia arbuscula*	26	4
2	*Ochrolechia frigida*	3	
2	*Thamnolia vermicularis*	x	
3	*Cladonia arbuscula*	14	4
3	*Cetraria islandica*	7	5
3	*Ochrolechia frigida*	4	
3	*Cetraria ericetorum*	1	2
3	*Alectoria nigricans*	1	5
3	*Thamnolia vermicularis*	x	
4	*Ochrolechia frigida*	x	
4	*Cladonia arbuscula*	8	3
4	*Alectoria ochroleuca*	4	3
4	*Cetraria islandica*	5	4
4	*Alectoria nigricans*	1	3
4	*Stereocaulon* sp	x	
4	*Cetraria ericetorum*	x	
4	*Thamnolia vermicularis*	x	
5	*Cladonia arbuscula*	13	4
5	*Flavocetraria nivalis*	4	3
5	*Cetraria islandica*	6	5
5	*Ochrolechia frigida*	4	
5	*Thamnolia vermicularis*	x	
5	*Cetraria ericetorum*	x	
5	Unvegetated	6	
5	Biological soil crust	x	

Transect E, monitoring site 18

Plot	Species	Coverage (%)	Height (cm)
1	*Alectoria ochroleuca*	8	5
1	*Ochrolechia frigida*	2	
1	*Cetraria islandica*	4	4
1	*Stereocaulon* sp	1	
1	*Cladonia arbuscula*	1	3
1	*Thamnolia vermicularis*	x	
1	*Flavocetraria nivalis*	x	
1	*Cetraria ericetorum*	x	
2	*Cetraria islandica*	8	4
2	*Cladonia arbuscula*	8	4
2	Unvegetated	1	
2	*Thamnolia vermicularis*	x	
2	*Alectoria nigricans*	x	
3	*Cladonia arbuscula*	8	4
3	*Cetraria islandica*	4	4
3	*Flavocetraria nivalis*	x	
3	*Alectoria ochroleuca*	3	5
3	*Stereocaulon* sp	4	
3	*Cetraria ericetorum*	2	2
3	*Alectoria nigricans*	1	4
3	*Thamnolia vermicularis*	x	
4	*Flavocetraria nivalis*	2	3
4	*Cladonia arbuscula*	14	4
4	*Cetraria islandica*	10	6
4	*Alectoria nigricans*	1	4
4	*Stereocaulon* sp	2	
4	*Thamnolia vermicularis*	x	
4	*Cetraria ericetorum*	x	
4	*Cladonia gracilis*	x	
5	*Cladonia arbuscula*	12	4
5	*Alectoria ochroleuca*	2	4
5	*Cetraria islandica*	10	5
5	*Alectoria nigricans*	1	4
5	*Stereocaulon* sp	2	
5	*Thamnolia vermicularis*	x	
5	*Cetraria ericetorum*	x	
5	*Cladonia gracilis*	x	

Transect F, monitoring site 19

Plot	Species	Coverage (%)	Height (cm)
1	*Thamnolia vermicularis*	x	
1	*Cetraria nivalis*	2	0.5
1	*Cladonia arbuscula*	x	
1	Unvegetated	1	
1	*Cetraria islandica*	x	
2	*Cetraria nivalis*	1	1
2	*Cladonia arbuscula*	1	1.5
2	Unvegetated	11	
2	*Thamnolia vermicularis*	x	
2	*Cladonia gracilis*	x	
2	*Cetraria islandica*	x	
2	*Ochrolechia frigida*	1	
2	*Cetraria ericetorum*	1	1
3	*Cladonia arbuscula*	x	
3	*Cetraria islandica*	1	1.5
3	*Cetraria ericetorum*	na	
3	*Ochrolechia frigida*	2	
3	Unvegetated	2	
3	*Thamnolia vermicularis*	x	
3	*Stereocaulon* sp	x	
4	*Cetraria nivalis*	1	0.5
4	*Cladonia arbuscula*	x	
4	*Cetraria islandica*	1	1
4	*Thamnolia vermicularis*	x	
4	*Cetraria ericetorum*	1	0.5
4	Unvegetated	11	
4	*Ochrolechia frigida*	x	
5	*Cladonia arbuscula*	3	1.5
5	*Cetraria islandica*	1	1
5	*Cetraria ericetorum*	1	0.5
5	*Ochrolechia frigida*	x	
5	Biological soil crust	1	

Transect F, monitoring site 20

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	3	1.5
1	*Cetraria islandica*	5	1
1	*Ochrolechia frigida*	3	
1	Unvegetated	7	
1	*Cetraria ericetorum*	x	
2	*Cladonia arbuscula*	x	
2	*Cetraria islandica*	6	1.5
2	*Cetraria ericetorum*	x	
2	*Ochrolechia frigida*	3	
2	Unvegetated	11	
2	*Thamnolia vermicularis*	x	
3	*Ochrolechia frigida*	x	
3	*Cladonia arbuscula*	x	
3	*Cetraria islandica*	1	0.5
3	*Thamnolia vermicularis*	x	
3	*Cetraria ericetorum*	1	0.5
3	Unvegetated	1	
4	*Ochrolechia frigida*	12	
4	*Cladonia arbuscula*	1	1
4	*Cetrariella delisei*	8	0.5
4	Unvegetated	7	
4	*Cetraria islandica*	1	0.5
5	*Ochrolechia frigida*	2	
5	*Cladonia arbuscula*	1	2
5	*Cetrariella delisei*	7	0.5
5	*Cetraria islandica*	x	
5	Unvegetated	3	
5	*Cetraria ericetorum*	1	0.5

Transect F, monitoring site 21

Plot	Species	Coverage (%)	Height (cm)
1	*Cetrariella delisei*	32	2
1	*Cladonia arbuscula*	x	
1	*Ochrolechia frigida*	x	
1	Unvegetated	2	
1	*Cetraria islandica*	x	
2	*Cetrariella delisei*	4	1
2	*Cladonia arbuscula*	x	
2	*Cetraria islandica*	x	
2	Unvegetated	5	
2	*Ochrolechia frigida*	na	
3	Unvegetated	20	
3	*Cetrariella delisei*	8	1
3	*Cladonia arbuscula*	x	
3	*Ochrolechia frigida*	x	
3	*Cetraria islandica*	x	
4	*Cetrariella delisei*	6	1.5
4	*Cladonia arbuscula*	x	
4	*Ochrolechia frigida*	x	
4	Unvegetated	30	
5	*Ochrolechia frigida*	1	
5	*Cladonia arbuscula*	x	
5	*Peltigera* sp	x	
5	Unvegetated	65	
5	*Cetrariella delisei*	5	na

Transect F, monitoring site 22

Plot	Species	Coverage (%)	Height (cm)
1	*Cladonia arbuscula*	3	1.5
1	*Cetrariella delisei*	6	1
1	*Cetraria islandica*	x	
2	Unvegetated	50	
2	*Cetrariella delisei*	5	0.5
2	*Cladonia arbuscula*	x	
2	*Ochrolechia frigida*	x	
3	*Cladonia arbuscula*	6	1
3	Unvegetated	14	
3	*Ochrolechia frigida*	x	
3	*Cetrariella delisei*	x	
4	*Cladonia arbuscula*	2	0.5
4	*Ochrolechia frigida*	3	
4	Unvegetated	13	
4	*Cetrariella delisei*	1	na
4	*Cetraria islandica*	x	
5	*Ochrolechia frigida*	2	
5	Unvegetated	6	
5	*Cladonia arbuscula*	5	1.5
5	*Cetrariella delisei*	1	na

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