Species composition and richness along microtopographical gradient, Hardangervidda National Park, Southern Norway

Prakash Bhattarai

Thesis submitted in partial fulfilment of the requirements for the degree of

Master of Science in Biology

Biodiversity, Evolution and Ecology

Department of Biology
Faculty of Mathematics and Natural Sciences
University of Bergen, Norway
June 2017

Acknowledgements

I would like to thank my supervisors John-Arvid Grytnes, Kuber Prasad Bhatta and Ole Reidar Vetaas for their continuous assistance in realising this thesis, for their encouragement, support, guidance, valuable advice, comments, and ideas throughout the master thesis. Further, I would like to thank the Ecopotential Project H 2020 for financing my field work. Special thanks to Ole Reidar Vetaas for providing me with such an opportunity.

I would also like to thank the University of Bergen and the Ecological and Environmental Change Research Group (EECRG) for their financial support. I thank all members of the EECRG for making me feel welcome as a student among researchers.

I would like to thank my supervisors Ole Reidar Vetaas and Kuber Prasad Bhatta, researcher Tessa Bahiga Bargmann and my brave assistant Tone Martinessen for their continuous help, innovative ideas and building me up in the moments of desperation during my field work. Special thanks to Madan Krishna Suwal, Lila Nath Sharma, Til Prasad Pangali Sharma, Hari Adhikari, Dilli Prasad Paudel and Heather Key.

Finally, I thank my family and all my friends for encouraging me during my years of study.

Bergen, 1st June 2017

……………………………………

Prakash Bhattarai

Abstract

Snow, an effective insulator and a mediator of soil microclimate, determines the abundance and plant species richness patterns in the alpine life zone. The aims of this study are: first, to investigate the species composition of lichens and vascular plant species and relate it with microtopography at fine scale, second, to show the pattern of species richness of total plant species and other life forms with weighted average snow indicator values and third, to investigate whether microtopography causes any significant differences in species richness for total plant species and other life forms. All species (69) in 151 plots of 4 m^2 in 23 transects were used in the analysis. I performed detrended correspondence analysis to explore how microtopographical gradient was related to the variation in the species composition. Afterwards, the weighted average snow indicator value was calculated and used as snow cover gradient. A generalised linear model was used to reveal species richness patterns along the snow cover gradient. One-way ANOVA was performed on the 69 plots, distributed on the 23 transects to identify topographic variability in species richness. DCA analysis reveals that the first axis represents the complex gradient from snow free ridge to wet snowbed habitats and the second axis represents a gradient from acidic to calcareous sites. Species richness for total plant species, vascular plant species and herbaceous plant species increased with increase in WASI value, whilst species richness for lichen species declined substantially towards the maximum weighted average snow indicator value. In contrast, species richness for dwarf shrub species showed a unimodal relationship with hump shaped pattern against WASI. Lichen's species richness is greater in ridge and less in snowbeds, while all other life forms follow the opposite trend. Here, liquid water availability determines species richness in mountains, particularly in my study which is controlled by snow cover and prevalent wind direction. The short growing season limits species richness, although there is enough available water, which shows that time is an important vector that determines the species richness along the microtopographical gradient. Hence, this study illustrates that small-scale data reveals local variations, which are overlooked when using regional scale data, but provide important knowledge on how to optimise predictions for plant species composition and richness in space and time.

Keywords: Species richness water energy dynamics hypothesis WASI microtopography ordination

Table of contents

Introduction

Alpine area possess high floristic diversity in term of species richness (Körner, 2011) even within the short distances along local microtopographic gradients. Scandinavian mountains form small-scale mosaics of different plant assemblages, and species richness and composition varies strongly among these assemblages (Vonlanthen et al., 2006). Therefore, the primary interest among ecologists is to find the factors associated with this variation in species composition and species richness along gradients. There may be different patterns and drivers of species richness at different spatial scales. Species richness patterns at large spatial scales are the result of regional process while those at small spatial scales (local richness) are the result of either regional processes, i.e.by the regional availability of species (regional species pool) (Pärtel, 2002, Karlson et al., 2004, Ricklefs, 2004), or local processes like competition, predation, environmental variability, mutualism, resource productivity and resource diversity (Huston, 1999).

Many hypotheses have been proposed to explain the regional and local distribution of plant species (Fraser and Currie, 1996, Huston, 1999). Recently, the water-energy dynamics theory (O'Brien, 1993, O'Brien, 2006) has shown the potential to become a unifying theory for both regional as well as local scale species richness patterns (Vetaas, 2006). The interaction between energy and water is known to be an important driver of diversity patterns at a large spatial extent and crude grain size (O'Brien, 1993, O'Brien, 2006, Vetaas, 2006) for several taxonomic groups (Whittaker et al., 2007).

At high latitudes energy represents the limiting component of the interaction, whereas at lower latitudes water is the key limiting component (Hawkins et al., 2003). Nonetheless, water and energy related variables are the strongest predictor for plant species richness at higher latitudes (Hawkins et al., 2003). Mountain environments provide interesting study areas to explore the relationship between water variables, energy variables and species richness either along elevation gradients (Bhattarai and Vetaas, 2003, Bhattarai and Vetaas, 2006) or along microtopographical gradients (Vetaas, 2006).

Snow has long been recognized as a major factor that determines the abundance and plant species richness patterns in the alpine life zone (Braun-Blanquet, 1932, Gjærevoll, 1956, Bliss, 1963, Bliss, 1971, Evans and Fonda, 1990). In alpine areas, snow is an effective insulator and a mediator of soil microclimate. Depth and amount of snow cover influences the length of the growing season, protection against extreme cold, strong winds, drought, ice blast and solar radiation, and affects soil properties (Billings and Bliss, 1959, Körner, 2003, Hiller et al., 2005, Williams, 2015) Snow thus has control over all important environmental characteristics that determines the richness patterns of plant species in alpine areas.

Plant species in the treeless alpine area are distributed along a steep environmental gradient from snowbeds to wind-exposed ridges with little or no snow-cover during winter (Gjærevoll, 1956, Billings and Mooney, 1968). There are substantial differences in the energy and water from the xeric ridges in windy alpine landscapes to the moist snowbeds, a few metres apart. This causes a clear richness gradient for different plant functional groups. The endpoints of this gradient both represent extreme environments, and are characterised by the distribution of distinct plant assemblages along the snow cover gradient.

The ridge has lower winter temperatures, more mechanical stress by wind-blown ice crystals, insufficient water supply, no nutrient inflow with seeping soil water, but a longer growing season (Billings, 1973, Körner, 2003), whereas the snowbeds possess suitable temperature and nutrient inflow but exhibit the shorter length of growing season (Chen et al., 2008). The mid-point of the gradient may represent a more optimal environment, and therefore I would expect more species towards the centre and few species at the endpoints.

The water-energy dynamics (WED) hypothesis has been widely tested for patterns of plant species richness (O'Brien, 1993, O'Brien, 1998). The dynamics of species richness with respect to energy is determined by work done by liquid water over space and time (O'Brien, 2006). Mean annual precipitation is considered as a water variable and minimum monthly potential evapotranspiration is used as the energy variable (O'Brien, 2006, Vetaas, 2006). WED thus, determines the initial abiotic environmental conditions available for life to exist (O'Brien, 2006). The water-energy dynamics hypothesis predicts that species richness in dry regions is positively correlated with water availability, but negatively correlated with energy availability (Francis and Currie, 2003). Species richness in my study would expect to follow the WED hypothesis for all plant species and all other life forms along the microtopographical gradient. The availability of liquid water in my study increases linearly with increasing weighted average snow indicator values (i.e. from ridge to snowbeds), thus one may expect higher species richness towards snowbeds.

However, at the extremes of the gradient, i.e. exposed ridge, crustose lichens and sometimes mosses tend to occur (Gjærevoll, 1956, Billings and Mooney, 1968). Severe drought stress, temperature, and wind abrasion continuously trigger exposed ridges and hence, these ridges are beyond the limits of any vascular plants whereas occurance of crustose and sometimes fruticose lichens with an occasional occurrence of the plant species such as *Saxifraga oppositifolia* has been observed (Savile, 1961).

The plant species assembly provides us with an understanding of the abiotic environment as well as the biotic processes that shape the vegetation (Wisz et al., 2013). Therefore, change in vegetation along elevational and topographical gradients in mountains has long been a topic of investigation (Whittaker, 1967, Virtanen et al., 1997, Bruun et al., 2006). Many studies on small spatial scales claim that the habitat quality determines the plant species composition and richness where the environmental factors investigated were mostly climate, soil properties and light (Lee and La Roi, 1979, Vittoz et al., 2010). Moreover, grazing can have a different impact on species richness based on the nutrient availability of the habitat (Proulx and Mazumder, 1998). Nutrient rich soils with high grazing possess higher species richness than nutrient poor sites and nutrient poor soils with high grazing possess lower species richness than low grazing sites (Proulx and Mazumder, 1998). It has also been shown that calcium-rich substrates with a high pH have higher species richness than acid substrates (Michalet et al., 2002, Nagy et al., 2003, van der Welle et al., 2003).

Each species is adapted to physiography and a narrow range of certain environmental conditions, and reveal individualistic responses along the gradients (Whittaker, 1967). However, each species of an assembly may not be equally contributing to the dynamics over time and space. The dominant species is more important in driving biotic interactions (Whittaker, 1967), and therefore, knowing the environmental association of the dominant species helps to infer the abiotic environment of the whole assembly.

Plant species, thus, can be used as potential indicators of environmental conditions, and therefore, species indicator values can be used when there is a lack of multiple measurements of environmental variables, in absence of equipment and with no availability of old measurements (Diekmann, 1995, Diekmann, 2003). However, long established vegetation with a large number of species is required for greater precision to make any generalization of the environment (Thompson et al., 1993, Hill and Carey, 1997). Species indicator values for European plant species quantified by Ellenberg (Ellenberg, 1950, Ellenberg, 1974, Ellenberg, 1992) have been applied as a surrogate for environmental parameters throughout Europe (Koerner et al., 1997, Lawesson, 2000, Hill et al., 2000, Wamelink et al., 2002). Using (Ellenberg, 1950, Ellenberg, 1974, Ellenberg, 1992) indicator values has some limitations because the values are not systematically derived from the measurements, but are inferred from researcher's observations (Szymura et al., 2014). Species may shift in any direction across a geographical gradient (Kelly and Goulden, 2008), and in that case, using Ellenberg species indicator values might not give a reliable estimation of habitat characteristics (Økland, 1990, Diekmann, 2003). More precise estimation of the habitat quality based on species composition of a certain location demands species indicator values derived from the multiple actual measurements of the major environmental factors of that location. To overcome the drawbacks of the subjectively calculated Ellenberg's species indicator values, Odland and Munkerjord (2008) developed the more precise snow indicator (SI) values of 126 taxa from European alpine regions that provide the opportunity to explore the relationship between European alpine plant assemblages and snow cover gradient. The indicator value of all the species together within a plot can be used to calculate the weighted average snow indicator value of each sample plot (Diekmann, 2003, Odland and Munkejord, 2008).

The most common application of indicator values is the comparison of weighted averages between different plant community types (Diekmann, 2003). This technique has been used in vegetation ecology for a long time. Weighted average was used to analyse floristic data by means of ordination (Diekmann, 1994, Bucci and Borghetti, 1997, Ewald, 1999, Brunet and Tyler, 2000) and compile the size of the regional species pool of plant communities (Pärtel et al., 1996, Dupré, 2000). It was furthermore, used to characterise the ecology of species (Bossuyt and Hermy, 2001) and also to analyse floristic changes by comparing old and new vegetation samples in permanent or semi-permanent plots, (Diekmann et al., 1999, Bhatta and Vetaas, 2016). In Scandinavia, weighted average technique has been used to relate the distribution and composition of mountain plants along snow layer gradients (Odland and Munkejord, 2008).

The snow indicator values are thus, useful to deal with the multiple environmental parameters acting together in the environment. The weighted average of each sample plot is the easiest way to estimate the environmental variables which thereby can be used as a surrogate of complex environmental parameters acting together for the growth and development of the species (Diekmann, 2003). I therefore, used weighted average snow indicator values as a surrogate of environment parameters because weighted average snow indicator values represent the compilation of all the environmental parameters which is cost and time effective.

Until now, species richness along microtopographical gradients have rarely been studied although some studies (Virtanen et al., 1997, Bruun et al., 2006, Odland and Munkejord, 2008, Chen et al., 2008) investigate species richness along microtopographical gradient, but their study focuses mainly on either altitude (Virtanen et al., 1997, Bruun et al., 2006) or snow accumulation (Odland and Munkejord, 2008, Chen et al., 2008). The novelty of my research in this case is about the effect of microtopographical gradient in determining the species richness and species assembly through its effect on energy and water relationship. Moreover, I incorporate microtopographical gradient to describe the pattern of species richness at the fine scale within continuous mountain that is responsible for heterogenous plant assembly. In addition, I relate the effect of the weighted average snow indicator values for each plot with species richness.

To fill this gap in understanding, I investigated three sites in Hardangervidda National Park which provided varying conditions for growth and development of plant species. Species frequency data and species abundance data were used in the analyses. Species frequency data was used for the ordination analysis to find the species composition with relation to microtopography and to investigate the difference of species richness within microtopographical gradient. Species abundance data was used to calculate weighted average snow indicator values. The main aims of this study are: first, to investigate the species composition of lichens and vascular plant species and relate it with microtopography at fine scale data; second, to show the pattern of species richness of total plant species, lichen, shrubs and graminoids with weighted average snow indicator values as a surrogate of environmental parameters and third, to investigate whether microtopography has any significant difference in species richness for total plant species, lichen species, shrubs and graminoids.

2. Materials and Methods

2.1 Study Area

2.1.1 Physiography

The Hardangervidda National Park comprises an area of about 3430 km^2, making it the largest alpine plateau in Europe. The area has an average altitude of 1100 to 1300 m above sea level (a.s.l.), however, most of the plateau is between 780 and 1300m above sea level (Rannow, 2013). Some peaks in the northern and south-western part of the plateau are above 1800m a.s.l. (Østbye et al., 1975). In general, the topography, is fairly flat, with height differences of 100–400 m (Falldorf et al., 2014). The map of the study area is given in Figure.1.

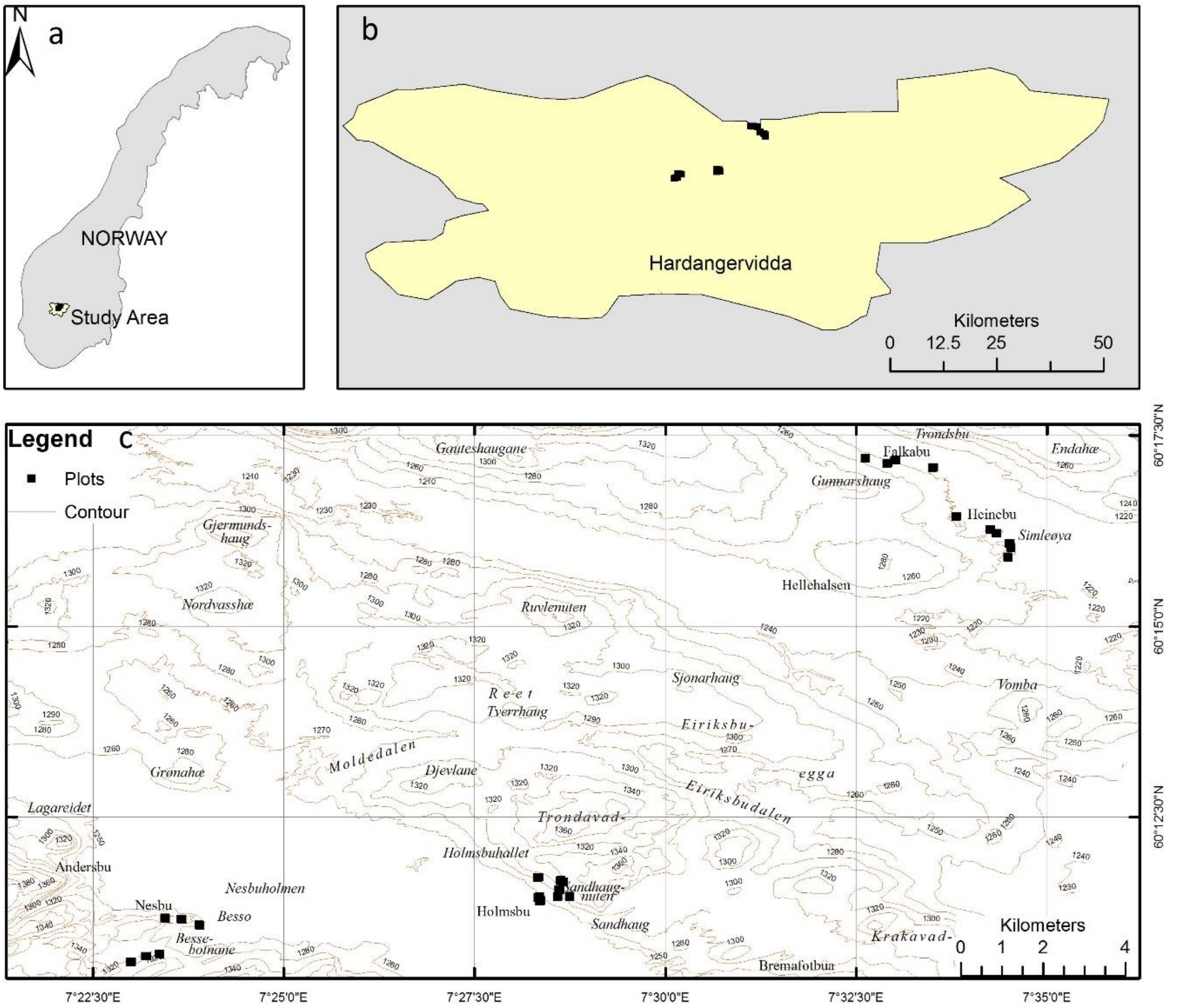


Figure. 1. Map of the study area showing a) Location of Hardangervidda in Norway b) Hardangervidda National Park c) Sampling sites (black squares) on topographic map.

Most of the Hardangervidda area is predominantely covered by an acidic and nutrient poor soil of precambrian rocks (Østbye et al., 1975). The area often possesses thin soil cover with considerable areas of bare rock. The present study was carried out both in nutrient rich sites as well as nutrient poor sites. Nutrient-rich sites consist of bedrocks such as phyllite, amphibolite, basalt, and schist (Naterstad, 1988), resulting in calcareous and nutrient rich soil, whereas nutrient poor sites consist of bedrock such as granite.

2.1.2 Climate

There is a variation in precipitation within the plateau; where the western and southern parts have an oceanic influence, with an annual precipitation of 1200-1800mm/yr, while the eastern and northern parts are more continental, with annual precipitation of 600-800mm/yr (Falldorf et al., 2014). The climate of the study site is oceanic-continental (Moen, 1999), consisting of a mean temperature in July and January of 7.8^0C and -10.3^0C respectively, with a mean annual precipitation of 990 mm (Reinhardt, 2013).

2.1.3 Vegetation and animals

The vegetation of the Hardangervidda was divided into ten different categories (Lye, 1975). However, it can be broadly divided into five different communities. The **subalpine Birch forest**, dominated by *Betula pubescens* ssp. *tortuosa, Juniperus communis, Vaccinium myrtillus, Deschampsia jlexuosa, Maianthemum bifolia, Melampyrum pratense, Solidago virgaurea, Trientalis europaea*, is found in the eastern and western side of the National Park. The **lichen heaths** on Hardangervidda occur in localities with very sparse snow cover. The dominated plant species are *Empetrum hermaphroditum, Vaccinium vitis-idaea* and the lichens *Alectoria ochroleuca, Cetaria nivalis, Cladonia mitis, C. rangiferina* and *Ochroleucia frigida*. **Heaths and Meadows** in poor soil is a rather heterogeneous group of communities. The plant species dominating in this habitat are *Vaccinium myrtillus, Deschampsia flexuosa, Festuca ovina, Carex bigelowii, Juncus trifidus, Hieracium alpinum* in poor soil whereas, *Anthoxanthum odoratum* and *Alchemilla alpine* on slightly better soils. However, nutrient rich meadows are charecterised by species like *Geranium silvaticum, Alchemilla glomerulans, Deschampsia caespitosa*, *Salix glauca* and *S. lapponum.* Species such as *Carex nigra, Comarum palustre, Leontodon autumnalis, Polygonum viviparum,* and *Ranunculus acris* are commonly found in nutrient rich **Mires,** whereas species such as *Eriophorum angustifolium,* more rarely *Carex rostrata* or *Eriophorum scheuehzeri* are dominant in nutrient poor soil**.** The

Snowbed Communities are dominated by *Salix herbacea* and bryophytes such as *Dicranum starkei*, *Gymnomitrium concinnatum* and *Marsupella varians*.

Reindeer (*Rangifer tarandus tarandus* L.) and small rodent species such as lemming (*Lemmus lemmus*) and root vole (*Microtus oeconomus*) are the important hervivores in Hardangervidda (Reinhardt, 2013). The study area also consists the threatened birds species like *Melanitta fusca* and *Gallinago media*, and also some other common birds species such as *Gavia arctica*, *Aquila chrysaetos* and *Calidris temminckii (*BirdLife International, 2017*)*.

2.1.4 Land Use

The Hardangervidda plateau is charecterised by several anthropogenic disturbances such as infrastructure development, hydropower production, tourism, and browsing and grazing of domestic animals (DIRNAT, 2003). The reindeer population in Hardangervidda is the keystone species in ecosystem functioning, and it is actively controlled by hunting (Bjerketvedt et al., 2014). Hence, hunting is the predominant driving force for the size of the reindeer population, which again influences the lichen heaths. The effects of other driving forces on vegetation like recreational activities and infrastructure development are more indirect.

2.2 Study Sites

Three sites were investigated in this study. A summary of the study sites is given in Table 1.

Table1. Sites details of the study area.

Name of the Site	**Number of Transects**	**Number of Plots**	**Coordinates (in degree)**	**Altitudinal range (m asl)**
Trondsbu	9	58	60.2650N-60.2866N 7.548389E-7.5755E	1213 m - 1234 m
Sandhaug	8	52	60.1899N-60.1951N 7.47208E-7.47916E	1255 m – 1312 m
Besso	6	41	60.1766N-60.1863N 7.39836E-7.38311E	1261 m – 1314 m

2.2.1 Trondsbu

Trondsbu is the northern most site in our study situated in the Northern boarder of the Hardangervidda National Park. The study site consists of many small esker of about 10 m – 15 m of altitude. The study site is composed of basal conglomerates and metasandstones, overlain by quartz schist which results in a nutrient poor soil. The ridge of the small hills consist of the lichens heaths dominated by *Cetaria nivalis*, *Alectoria ochroleuca* and *Alectoria nigricans*. The snowbed consists *Salix herbacea, Carex canacens* and *Luzula frigida* and mosses. The intermediate area between ridge and snowbed consist of shrub species such as *Empetrum hermaphroditum, Vaccinium vitis-idaea, Vaccinium myrtilus,* lichens species such as *Cladonia rengiferina*, *Cladonia arbuscula* and sedges such as *Carex biglowii*.

2.2.2 Sandhaug and Besso

Sandhaug and Besso are located in the cetral part of the Hardangervidda National Park. The study sites consist of many small mountain peaks ca. 300m above the plateau. The vegetation of the mountain is homogenous and many ridges and snowbeds are present on each mountain. The transects vary in length from 28m length to 32m length, and the average altitudinal gradient is of 12 m asl. The study site consists of conglomerate which is overlain by quartz schist plus the presence of phyllite in the mountains make the soil nutrient rich. Big bolders of granite are often present in Sandhaug whereas they are rarely present in Besso. The dominant vegetation on the ridges consist of lichen species such as *Cetaria nivalis, Alectoria ochroleuca*, *Alectoria nigricans* and vascular plants such as *Empetrum hermaphroditum* and *Vaccinium vitis-idaea.* The snowbeds consist of sedges and grasses such as *Luzula frigida*, *Carex biglowii*, *Festuca ovina*, *Nardus stricta* and herbaceous species such as *Bistorta vivipara*, *Ranunculus archis* and *Rumex acetosa*. Shrub species like *Salix herbacea* and *Betula nana* often predominate snowbeds. The intermediate zone consists of both lichen species such as *Cladonia rengifierina*, *Cladonia arbuscula* and *Cetaria islandica* and shrub species such as *Empetrum hermaphroditum, Vaccinium vitis-idaea* and *Juniperous communis*.

2.3 Methodology

2.3.1 Sampling methods

The field sampling was accomplished from 3rd June to 22nd June 2016. The field site was choosen according to the topography of the area. The area was visited by a team of scientists and many potential hill sites were marked using a GPS receiver (Garmin eTrex Euro, Garmin Ltd., Olathe, Kansas, USA) in order to establish the transect. The average transect length was

24m from snowbed to ridge at Trondsbu. All together nine hills which were at least 100m apart from the previous sampling hill were choosen for sampling in Trondsbu. There were altogether 9 transects, and the length of the transects in Tronsdbu vary from 24m to 32m in length.

The sites, Sandhaug and Besso consist of chains of hills which are about 900m to 1000m in average length (metre tape) from ridge to the base of the mountain, possess many snowbeds and ridges within each hills. Each ridge and snowbed gradient within the hills was considered as a site. The slope and the indicator species were considered to lay a transect. A slope of 0^0-5^0 with species like *Alectoria ochroleuca, Alectoria nigricans* and *Cetaria nivalis* was defined as a ridge and the base of that ridge with a slope of 0^0-5^0 with indicator species like *Salix herbacea,* grasses species such as *Luzula frigida*, *Festuca ovina* and herbaceous species such as *Bistorta vivipara, Ranunculus archis, Rumex asotosa, Alchimella alpine* was defined as the snowbed. The length of transects vary between 20m to 32m in length. Each transect is 100m apart from the previous transect. In Sandhaug, there were eight transect and the length of transect vary from 20m to 32m where as in Besso there were six transect and the length of the transect vary from 24m to 28m.

All the transects were measured with zero at the ridge and the measuring tape running towards the base. The length of the transects were determined by the distance between the ridge and the snowbed. A systematic sampling method was used to fix the position of the plots within the transects. The first plots of $4m^2$ were located on the ridge and the next plots 2m down hill until the snowbed (see Figure 2). The $4m^2$ plot was further divided into four $1m^2$ subplots for my convenience to record the species present in each sub plot. The two ends of each transect were marked by iron nails in order to replicate the study in successive years. A detailled schematic representation of the sampling method is given in Figure 2.

All the vascular plants and the macro lichens within each $1m^2$ subplot were recorded. Presence/ absence data was used to reveal species frequency of each plot. Longitude, latitude and altitude of each $4m^2$ plot were recorded using a GPS receiver (Garmin eTrex Euro, Garmin Ltd., Olathe, Kansas, USA). Moss cover, bare land, herb cover, lichen cover and grass cover in each plot were estimated but were not used in this study.

2.3.2 Specimens collection and identification

Prior to the detailed sampling of the transects, the study area was observed by the team of plant ecologists and all the plants in the study sites (both vascular plants and macro lichen) were collected, identified, dried and a small herbaria was made (small herbarium specimens booklet) for further identification of plant species in detailed sampling. This small herbaria was used extensively while recording species from the sampling plots. The new speciemens observed in the plot were collected, tagged, identified, dried and added to the small herbarium specimens booklet. A magnifying glass (Ruper Viking 15x / 8x duel folding lens, Japan) was used for species determination. Lid and Lid (2005) was used for identification and nomenclature of the vascular plant species while Øvstedal et al. (2009) was used for identification and nomenclature of lichen species. Most of the species were identified to species level whereas some species were identified to genus level. All of these species were used in statistical analysis.

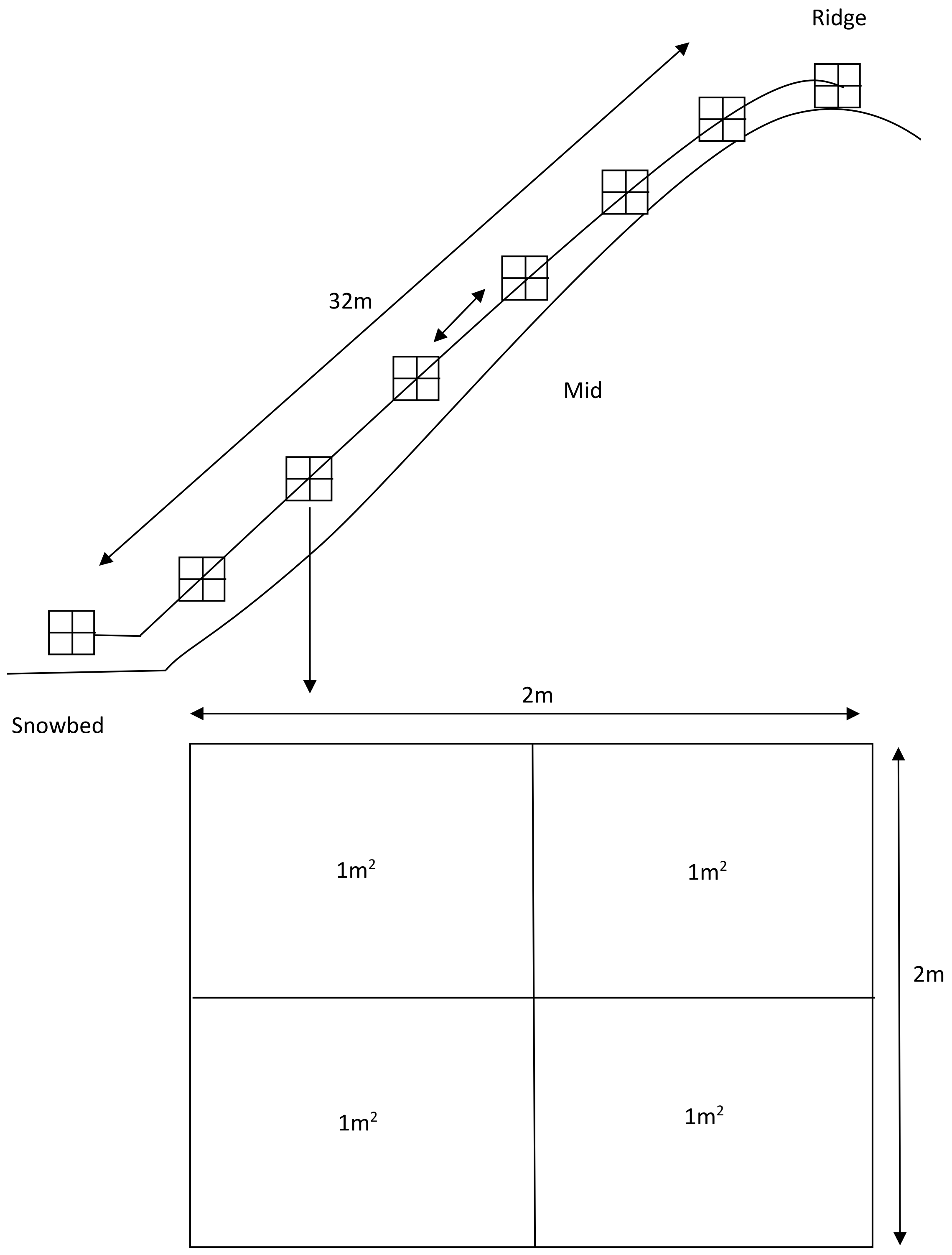


Figure 2. Schematic representation of sampling method and sampling plot. The representative transect length shown above is 32m, the transect lengths vary between 20m to 32m and the number of plots in each transect vary from 5 to 8.

2.3.3 Statistical analysis

Detrended correspondence analysis (DCA) was performed to describe the variation in species composition along the ridge-snowbed gradient and to explore how microtopography relates to this variation. One way anova was used to reveal the difference in species richness with microtopography and the Tukey HSD test to show the difference in species richness within zonation. Regression analysis was performed to see the relationship between species richness and snow cover gradient (WASI) in the study area. All the analyses were carried out in R version 3.3.1 (R Core Team, 2016).

2.3.3.1 Detrended correspondence analysis (DCA)

DCA analysis was used to explore the species composition in the study area because it provides an order of species and plots reflecting the main underlying environmental variable, which can be easily interpreted in terms of ecological turnover (Hill and Gauch, 1980, Gauch, 1982). DCA is a commonly used method in ordination analysis because it reduces the arch effect and improves multidimensional-rescaling (Hill and Gauch, 1980, Gauch, 1982). DCA produces both species scores as well as sample scores (Hill and Gauch, 1980), species scores indicate the relative position of taxa in the reduced space. DCA axes represent the relative position of the species (species distribution) with respect to the underlying environmental gradient (Correa-Metrio et al., 2014). Snowcover and microtopography were used to explain the composition of species in this study. The ridge microtopography was defined as the plots placed in the top of the mountain, which had the slope range of 0^0 to 5^0. The mid microtopography started next to the ridge and extended to the base of the mountain (snowbeds) which had a slope of 6^0 to 30^0 and the snowbed microtopography was in the base of the mountain which had a slope angle of 0^0 to 5^0.

2.3.3.2 Weighted average snow indicator values and relative distance

The weighted average snow indicator values for each plot running along the snow gradient was calculated using the snow indicator value for each species calculated by Odland and Munkejord (2008) because most of the species in this study are present in their species list. The weighted average snow indicator value for each plot was based on the frequency of the species present in all the subplots and calculated by using the following equation (absent species and species lacking indicator value are ignored) (Diekmann, 2003) :

$$\text{WASI} = \sum_{i=1}^{n}(r_{ij} * x_i) / \sum_{i=1}^{n} r_{ij}$$

where WASI is weighted average snow indicator values for the actual plot, r_{ij} is the response of species i in sample plot j, and x_i the indicator value of species i.

The position of each of the plots in the transect was measured using a measuring tape. The length of the transect was not uniform so the relative distance of each plot from the ridge was calculated for consistency in the position of the plots.

2.3.3.3 Regression Analysis

Regression analysis was performed to explore the relationship between the species richness and weighted average snow indicator values (WASI) and also between species richness and relative distance. Species richness was treated as the response variable and WASI and relative distance as the predictor variable. A Generalised Linear model (GLM) (McCullagh and Nelder, 1989, Dobson and Barnett, 2008) was used to elucidate the species richness pattern with respect to WASI and relative distance. Both the WASI and relative distance were used as a surrogate of snow cover gradient and regression of species richness along relative distance was only used as a supportive analysis for WASI. The response variable was continuous therefore a log linear model with a Poisson error distribution was used for the analysis. To handle over-dispersion of the deviance, a quasi-poisson error distribution with F test statistics was used (Crawley, 2012). The significance of each model was tested with a null model and each other upto the third order polynomials. The more complex model was accepted as the final model if the P value was significant. Finally, the fitted model was used to plot the trend in species richness in relation to WASI as well as relative distance.

2.3.3.4 Analysis of Variance (ANOVA)

One-way ANOVA was performed on the 69 plots distributed on the 23 transects to identify topographic variability in species richness. A plot from ridge (top of the hill), a plot from mid (middle part of the hill) and a plot from the snowbed (base of the hill) from each transect were taken into consideration to test the variability in species richness with respect to microtopography. The F ratio and the P values were taken into consideration to determine the significant effect of the microtopography on species richness in the data set.

When a significant effect of microtopography on species richness was found in one-way ANOVA, the post-hoc Tukey's Honestly Significant Difference test (Tukey, 1953) was applied to see the significant differences among multiple means. The t value and the P values were considered to determine the significant variability on species richness within microtopography (i.e. ridge microtopography, mid microtopography and snowbed microtopography).

3. Results

3.1 Species Composition

All together 69 species were recorded from 151 plots (4 m^2) of which 52 species were vascular plants and 17 species were lichen (see Appendix 1 for species list and the abbreviation used in ordination). All 69 species from the 151 plots were used in the DCA, which described the species composition of the vegetation in relation to microtopography of the area. Eigenvalues for the first three axes of the DCA for sites declined rapidly (0.347, 0.081, 0.073) indicating that the first axis explained most of the variation whereas Axis II and Axis III explained much less (see Table 2). The species turnover expressed in SD-units are 3.1 and 1.8 for the two first axes respectively. The overall interpretation is that the first axis represents a complex gradient from snow free ridge to wet snowbed habitats. The second axis represents a gradient from acidic (low axis II) to calcareous sites, but this was only found in the moist parts of axis I.

The microtopography of the plots had a significant relation with species assemble in space ($R^2 = 0.5021$, $p = < 0.05$). Both the ridge plots and snowbed plots were characterised by high loadings on the first axis but in opposite directions (Axis I = -0.754 and Axis II = - 0.079 for ridge plots and Axis I = 0.925 and Axis II = -0.116 for snowbed plots; Figure 3) clearly demonstrating the gradient in species compositional turnover with respect to microtopography.

Plant species associated with ridge (e.g. *Alectoria ochroleuca, Alectoria nigricans, Sphaerophorus globosus* and V*accinium vitis-idaea*) were ordinated in the negative part of the DCA axis I which dominates the oligotrophic area with very sparse snow cover, whereas snowbed species (e.g. *Anthoxanthum odoratum, Bistorta vivipara, Festuca spicata, Pyrola alpine* and *Rumex acetosa*) were ordinated over the positive side of the same axis. These species are found in the slightly better soil in comparison to the oligotrophic plant species (e.g. *Alchemilla alpine, Alchemilla vulgaris, Luzula frigida, Festuca spicata*) which are ordinated on the DCA axis 1 (Figure. 4). Species that grow in nutrient rich soil (e.g. *Salix reticulate, Salix lapponica, Saussurea alpinum, Gentiana purpurea* and *Ranunculus acris*) had a high positive score on the DCA axis 2. Species like *Arctostaphylos alpinus* and *A. uva-ursi* and *Astragalus norvegicus* shared similar kinds of environmental parametres and obtained negative DCA 1 and negative DCA 2 scores.

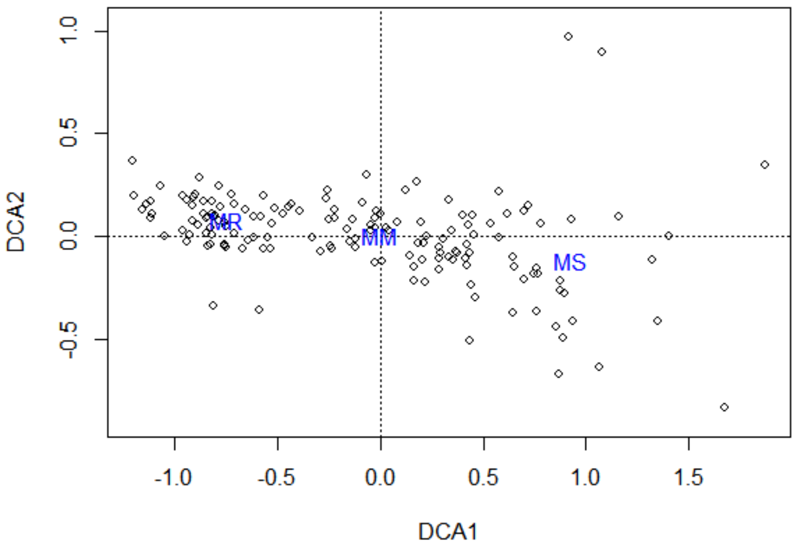


Figure 3. DCA showing the distribution of sampling plots in relation to DCA Axis I and Axis II where MR is ridge microtopography, MM is mid microtopography and MS is snowbed microtopography. The sampling plots in the negative DCA I score represent the Ridge plots and the positive DCA I scores represent the snowbed plots.

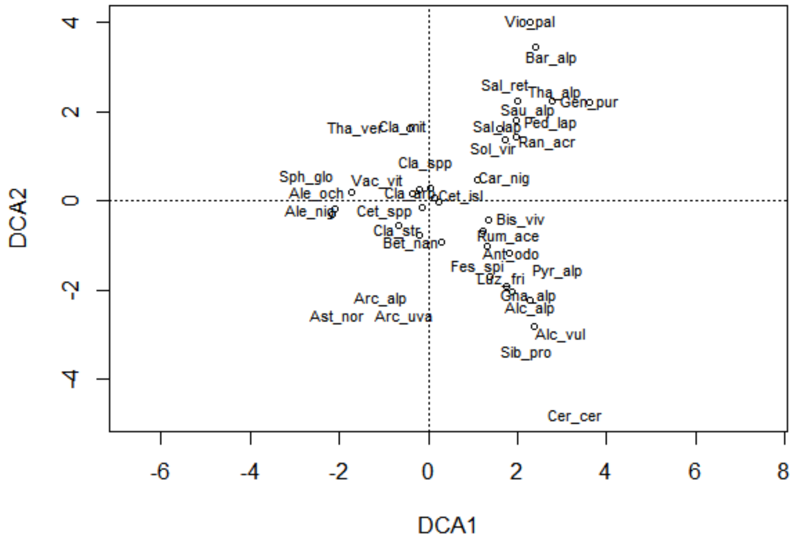


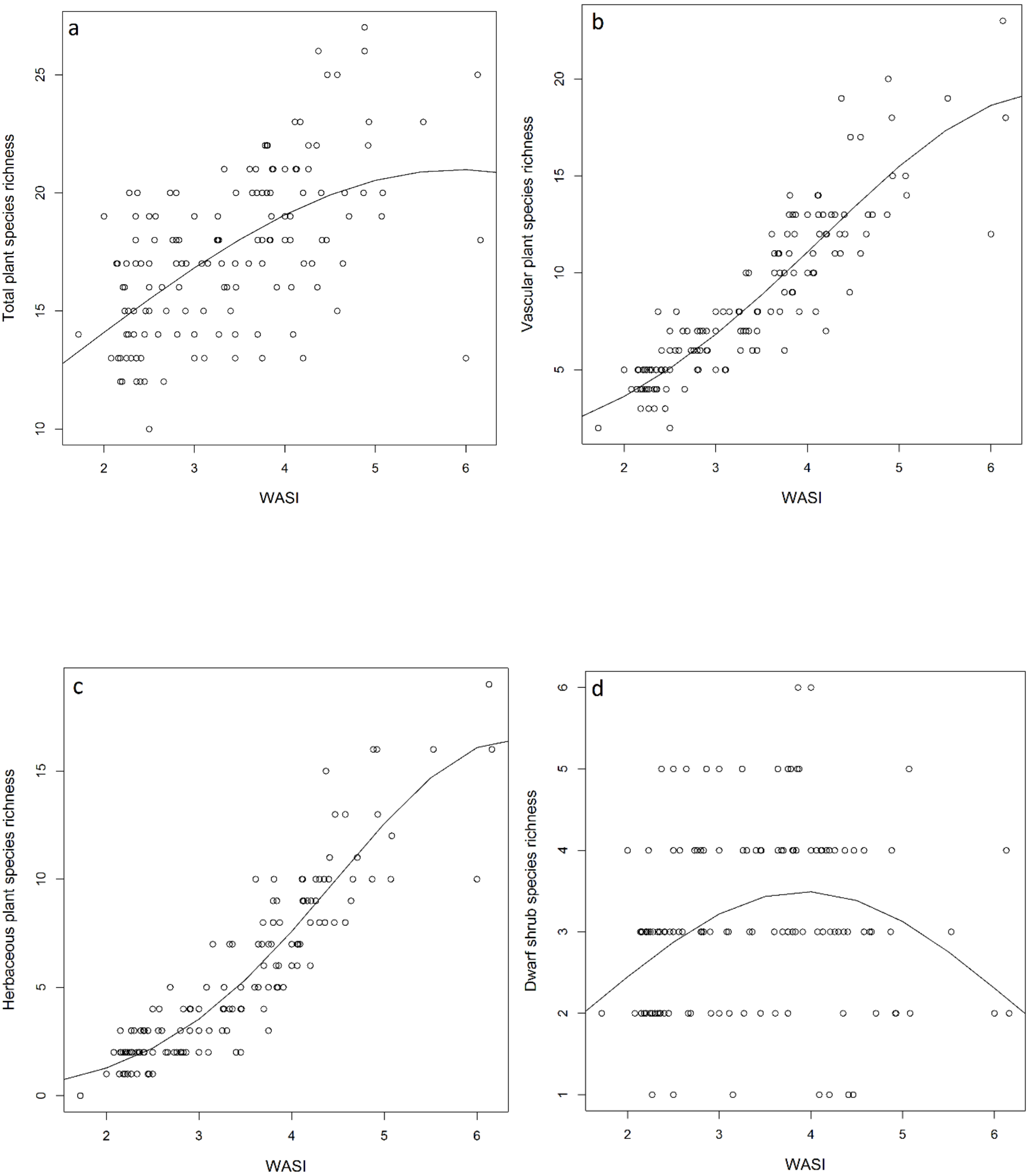
Figure 4. DCA plot showing the distribution of the species with respect to DCA Axes I and DCA Axes II, the species clustered in DCA I and DCA II axis are associated with each other and share common environmental parametres.

Table2. Detrended correspondence analysis results for all plant species.

DCA	DCA 1	DCA 2	DCA 3
Eigen values	0.3479	0.0815	0.07395
Decorana values	0.3660	0.1228	0.09053
Axis lengths	3.0772	1.8010	1.53629

3.2 Species richness and Weighted average snow indicator values (WASI)

Regression analysis (GLM) revealed a curvilinear relationship in species richness for total plant species and all other life forms except for dwarf shrub species when regressed against the weighted average snow indicator values (Figure 5.; Table 3). The same pattern was evident when the weighted average snow indicator value was substituted by the relative distance from the top (Appendix 3). Species richness for total plant species (F=5.526, p= <0.05), vascular plant species (F=34.36, p=<0.01), herbaceous plant species (F=55.622, p=<0.01) and lichen species (F=35.927, p=<0.01) have a curvilinear relationship with WASI, although they had a significant second order term (Figure. 5, Table 3). Species richness for total plant species, vascular plant species and herbaceous plant species increased with an increase in the WASI values, indicating that these life forms possess mostly snow loving species whereas, species richness for lichen species declined substantially towards the higher weighted average snow indicator values. In contrast, species richness for dwarf shrub species showed a unimodal relationship with a hump shaped pattern against the weighted average snow indicator values (Figure. 5; Table 3). Here, the number of shrub species declined substantially towards the two extremes of the snow cover gradient while more species were found to be accumulated at the middle, forming a hump shaped pattern.


a
Total plant species richness
10
15
20
25
2
3
4
5
6
WASI
b
Vascular plant species richness
5
10
15
20
2
3
4
5
6
WASI
c
Herbaceous plant species richness
0
5
10
15
2
3
4
5
6
WASI
d
Dwarf shrub species richness
1
2
3
4
5
6
2
3
4
5
6
WASI

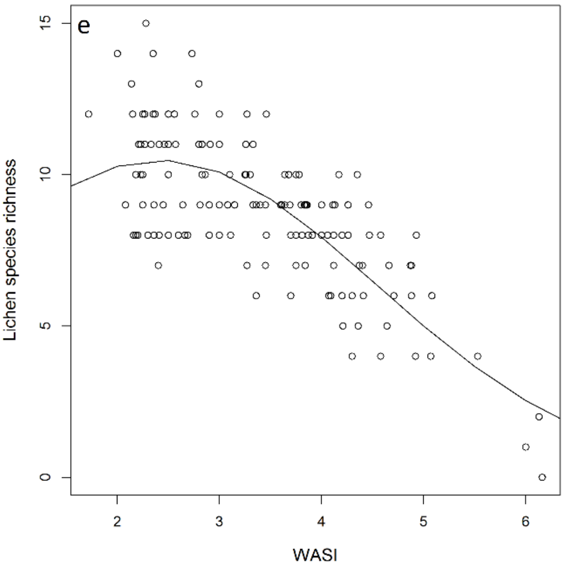


Figure 5. Species richness of: a) total plant species, b) vascular plant species c) herbaceous plant species, d) dwarf shrub species and e) lichen species with weighted average snow indicator values. The line was fitted by generalized linear model.

Table. 3. Summary of generalized linear model used to describe the relationship between species richness and weighted average snow indicator values (WASI). Regression statistics for species richness: (Species richness is a response variable and WASI is a Predictor).

Response variable	Model	Polynomial order	Res DF	Res deviance	DF	Deviance	F value	Pr(>F)
	Null	0	150	99.934	0			
Total plant species	GLM	1	149	65.927	1	34.006	80.432	0.001
	GLM	2	148	63.641	2	2.286	5.526	0.05
	Null	0	150	306.103	0			
Vascular plant species	GLM	1	149	64.192	1	241.92	64.192	0.001
	GLM	2	148	52.465	2	11.726	34.36	0.001
	Null	0	150	425.21	0			
Herb species	GLM	1	149	87.19	1	338.01	614.13	0.001
	GLM	2	148	63.944	2	23.248	55.622	0.001
	Null	0	150	58.243	0			
Dwarf shrub	GLM	1	149	56.650	1	1.593	4.5014	0.05
	GLM	2	148	51.903	2	4.747	14.634	0.001
	Null	0	150	122.973	0			
Lichen species	GLM	1	149	64.507	1	58.465	155.31	0.001
	GLM	2	148	52.695	2	11.812	35.927	0.001

3.3 Species Richness and Microtopography

Species richness of all plant species, vascular plant species, herbaceous plant species and lichen species differed significantly along the microtopographical gradient (Figure 6; Table 4). The comparison of different life forms with microtopography showed different trends in species richness. The species richness of total plant species was highest in the snowbed (19.6 ± 3.7), declined by 10% from snowbed to middle of the microtopographical gradient (17.6 ± 2.9) and further declined by 23% from snowbed to ridge (15 ± 2). Similarly, total plant species richness declined by 14.77% from middle of the microtopographical gradient to snowbed. Vascular plant species richness was least in ridge (5.5 ± 2.3) and increasedby 40% from ridge to middle of the microtopoographical gradient (7.7 ± 2.8), which further increased by 152% from ridge to snowbed (13.9 ± 3.8). Similarly, vascular plant species richness increases by 80% from middle of the microtopographical gradient to snowbed.

Herbaceous plant species follow a similar trend as that seen in vascular plant species. Herbaceous plant species richness was least on the ridge (2.6 ± 2.1) and increased by 73% from ridge to the middle of the microtopographical gradient (4.5 ± 2.4), which further increased exponentially by 323% from ridge to snowbed (11 ± 3.6). Similarly, herbaceous plant species richness increased by 144% from middle of the microtopographical gradient to snowbed. In contrast, dwarf shrubs followed a different trend in species richness in comparison to other life forms. Species richness of dwarf shrubs remained almost constant with microtopographical change (see Table 4), representing 2.9 ± 1 species on ridge, 3.2 ± 1 species on middle of the microtopographical gradient and 2.9 ± 1 species on snowbed respectively. Lichen species remained almost constant between ridge (9.5 ± 1.7) and the middle of the microtopographical gradient (9.4 ± 2.7) but decreased by 39% and 38% from ridge to snowbed (5.6 ± 2.3) and the middle of the microtopographical gradient to snowbed respectively.

The TUKEY HSD test showed that the species richness of total plant species, vascular plant species and herbaceous plant species differed significantly among ridge and middle of the microtoopographical gradient, ridge and snowbed, and middle of the microtopographical gradient and snowbed (see Table 5). In contrast, lichen species richness differed significantly from ridge to snowbed and mid to snowbed but remain constant from ridge to mid (see Table 5).

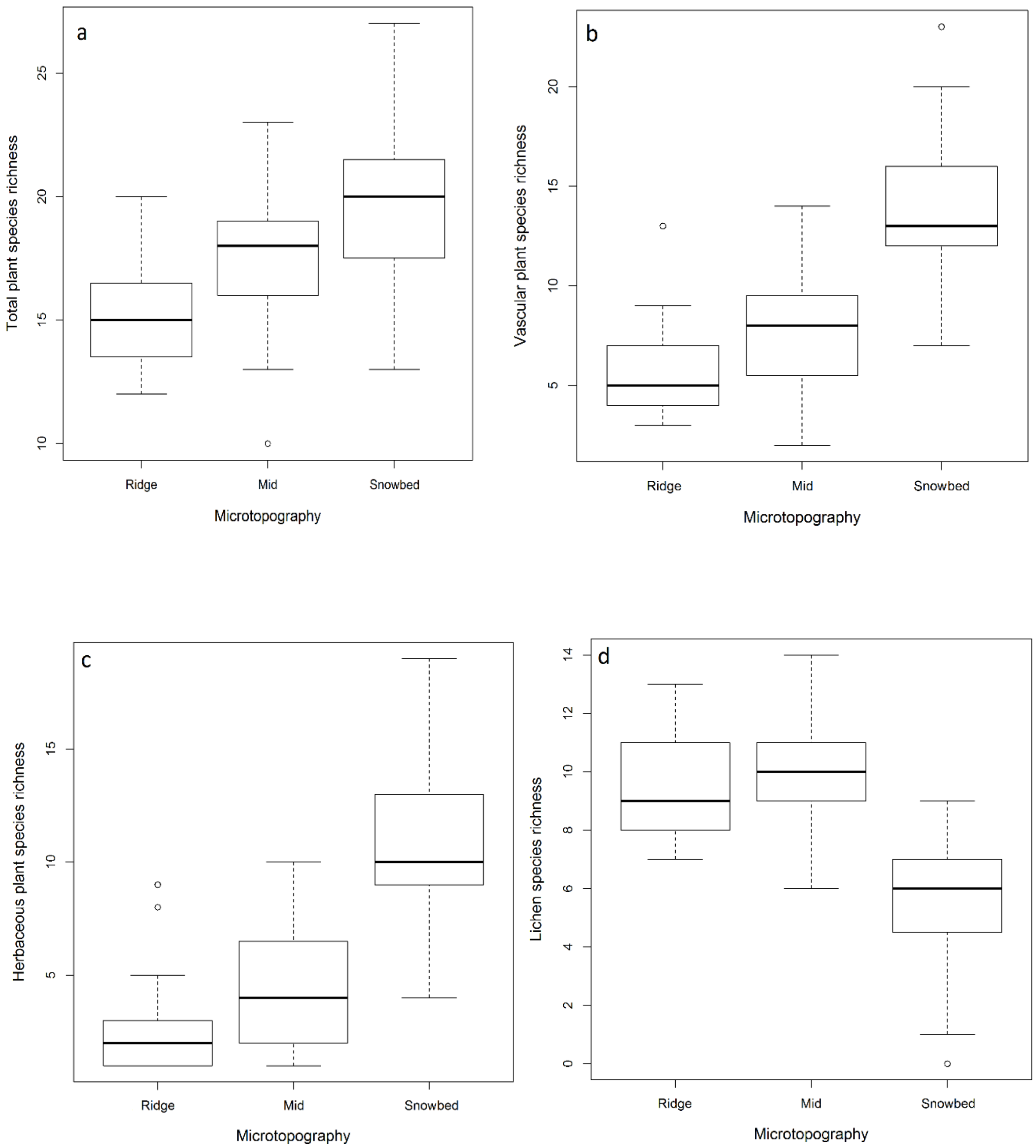


Figure 6. Box plot showing the species richness with micro topography; a) all plant species, b) vascular plant species c) herbaceous plant species and d) lichen species. A total of 69 plots (23 transects), 23 plots from each microtopography (ridge, mid and snowbed) were used.

Table 4. Summary of the statistical analysis (one way ANOVA) with microtopography as environmental factor to examine variability within micro topography. Species richness is the response variable and microtopography is the predictor.

Response Variable	Predictor	DF	Sum Sq	Mean Sq	F value	Pr(>F)
Total plant species	Microtopography	2	236.17	118.08	13.33	<0.001
	Residuals	66	584.26	8.852		
Vascular plant species	Microtopography	2	869.77	434.88	46.89	<0.001
	Residuals	66	612.0	9.27		
Herbaceous plant species	Microtopography	2	899.59	449.80	55.994	<0.001
	Residuals	66	530.17	8.03		
Dwarf shrub plant species	Microtopography	2	1.652	0.829	0.753	0.47
	Residuals	66	72.348	1.096		
Lichen species	Microtopography	2	249.07	124.53	30.413	<0.001
	Residuals	66	270.26	4.095		

Table 5. Summary of the Tukey's HSD test to show the variability within each of the environ mental factor (ridge, mid and snowbed).

Response variable	Micro topography	Estimate	Std. Error	t value	Pr(>|t|)
Total plant species	Ridge - Mid	2.521	0.877	2.874	<0.05
	Snowbed - Ridge	4.521	0.877	5.154	<0.001
	Snowbed - Mid	2.0	0.877	2.280	0.06
Vascular plant species	Ridge - Mid	2.217	0.898	2.469	<0.05
	Snowbed - Ridge	8.391	0.898	9.345	<0.001
	Snowbed – Mid	6.174	0.898	6.876	<0.001
Herbaceous plant species	Ridge - Mid	1.913	0.835	2.289	0.06
	Snowbed - Ridge	8.434	0.835	10.09	<0.001
	Snowbed – Mid	6.521	0.835	7.803	<0.001
Lichen species	Ridge - Mid	0.304	0.596	0.510	0.867
	Snowbed - Mid	-3.869	0.596	-6.485	<0.001
	Snowbed - Ridge	-4.173	0.596	-6.995	<0.001

4. Discussions

The results of the ordination show that there is a separation between ridges and snowbeds in species composition. This relates to the microtopographic gradient that was measured in the field, and explains the differences in species composition along the first axis (Figure 4). The species composition turnover along the first axis indicates a strong species environment relationship, particularly with respect to liquid water availability controlled by snow cover distribution in space (microtopography) and time (growing season) (Elberling et al., 2008). Here, water availability varies vertically along the microtopographical gradient from the positive part of the first axis to the negative part (Figure 3). The negative part of the first axis is characterised by a dry habitat (Figure 3) with low occurrence of available water for plant species. Lichen species were dominant in the dry habitat (ridge) with deep rooted shrub like *Vaccinium vitis-idaea* (Figure 4) but, the short rooted graminoids were absent in dry ridges. Lichen can cope with water deficiency by reducing the rate of transpiration. In lichen, water is stored in the thallus and escapes through the capillaries. As the diameter of the capillaries decreases until the water potential of the plant becomes the same as the surrounding air, rate of transpiration reduces to zero (Larson, 1979, Krog and Østhagen, 1994). The occurrence of deep roots in shrub species (*Vaccinium vitis-idaea*) means it is able to survive in a dry habitat even if moisture at the surface becomes depleted. The deep root system of these shrubs can absorb water from the deeper soil which contains ample moisture. The species composition in the moist part of the first axis contains species that are adapted to an excess of available water.

The second axis represents a gradient from acidic to calcareous soil. Acidophilous species like *Rumex aceotosa*, *Festuca spicata*, *Anthoxanthum odoratum* and *Alchemilla alpine* are characteristic of nutrient poor acidic soil, which is further supported by Lye (1975) and Ellenberg (1988). Calciphilous species like *Bartsia alpina*, *Ranunculus acris, Salix reticulata and S. lapponum* are clustered on the positive side of DCA axis 2 and indicate the nutrient rich calcareous soil (Lye, 1975). This is an effect of schist bed rock, and it is mainly shown in the moist part of the gradient. This may partly relate to the fact that ridges are dominanted by lichen that absorb water from the air (Longton, 1988) and are very specialised to reduce the rate of transpiration (Larson, 1979), and therefore they cannot utilize the nutrient cations from soil (Brooks, 1983). This also indicates that organisms need a certain amount of available water to manage to export the extra nutrient into their system (Karmer and Boyer, 1995).

The separation of species composition between ridges and snowbeds is very clear, and the exposed ridges with rocky soil are mostly dominated by the lichen species such as *Alectoria* *ochroleuca*, *Alectoria nigricans* and *Sphaerophorus globosus*. These species are often the most abundant species on exposed slopes and ridges with rocky soil and are almost absent in the moist snowbeds (Lye, 1975, Ellenberg, 1988, Odland and Munkejord, 2008, Odland et al., 2014). The presence of *Alectoria ochroleuca* and *Alectoria nigricans* is also indicative of oligotrophic, windy and dry habitats where wind frequently blows the snow away (Ellenberg, 1988).

It is likely that the plots in the upper part of the microtopographical gradient are subjected to similar soil disturbance due to continuously triggered wind, ice blast and soil freeze-thaw processes. The intensity and frequency of these disturbance processes could influence the species composition (Körner, 2003) and the diversity of species at a site (Newman, 1973). Moreover, the exposed ridges are the sites where the snow accumulation is almost zero. The thick lichen mats in addition had limited growth of vascular plants by restricting access to light, limiting the availability of substrate for seedling germination, through insulating cooling of the soils and also the chemical inhibition from the lichen species (Brown and Mikola, 1974, Kershaw, 1977)

In contrast, the other end of the snow gradient has moist soils, mostly dominated by vascular plant species like *Anthoxanthum odoratum*, *Bistorta vivipara*, *Festuca spicata*, *Pyrola alpina* and *Rumex acetosa* and the shrubs species *Salix lapponum* and *S. reticulate*. The presence of these species indicates a eutrophic soil with greater productive (Lye, 1975). The sedge species were dominant in the snowbeds and similar findings were observed by Billings (1973) where graminoids were the dominant growth form of the wetter portions of the topographic gradient and contribute more to total biomass in the snowbeds (Walker et al., 1995). These differences between location in their species assembly suggest the difference in environmental factors as well.

Ordination results further indicate that the similarity in species composition between all the three study sites in HNP have revealed that plant assemblages can be classified in two distinct functional groups i.e. lichen dominated and vascular plant dominated (woody species and herbaceous species) based on the microtopographic gradient. It is the latter group which responds to the additional nutrient made available from the schistous baedrock (Pausas, 2001). Therefore, it is the nutrient gradient, which separates acidophilous species from calcareous species which is only shown along half of the main snow-cover gradient along the first axis.

Plant species can be used as potential indicators of environmental conditions, and species indicator values have been applied as a surrogate for environmental parameters throughout Europe (Koerner et al., 1997, Lawesson, 2000, Hill et al., 2000, Wamelink et al., 2002). Weighted average snow indicator values are the easiest way to estimate the environmental variables acting together for the growth and development of species (Diekmann, 2003). The lower scores represent the low snow cover and the snow accumulation increases as the value increases (Odland and Munkejord, 2008).

The relationship between WASI and species richness will vary with different plant functional groups as expected. Regression analysis (GLM) revealed a curvilinear relationship in species richness for total plant species (Figure 5a) and all other life forms (Figure 5b, 5c and 5e) except for dwarf shrub species (Figure 5d) when regressed against weighted average snow indicator values, revealed both expected and unexpected pattern. Species richness for total plant species, vascular plant species and herbaceous plant species increased with an increase in WASI values whereas, species richness for lichen species declined substantially towards the higher WASI values. In contrast, species richness for dwarf shrub species showed a unimodal relationship with a hump shaped pattern against WASI values.

The possible reason for the curvilinear response of species richness, maximum species towards the snowbeds, particularly for total plant species, vascular plant species and herbaceous plant species can be explained by the water energy dynamics hypothesis (O'Brien, 1993, O'Brien, 2006, Vetaas, 2006). Water and energy are the vital climatic components that determine the initial abiotic component (O'Brien, 2006, Vetaas, 2006). In my study, the microtopographical gradient from snowbeds to ridge replicate to some extent an elevation gradient, which often has maximum available water in the lower half (Bhattarai et al., 2004). Energy alone is less efficient in determining the pattern of species richness, however, it effects the available water. In the ridge-snowbed gradient, available water is determined by the snow-cover (Gjærevoll, 1956), i.e. more snow-cover means more moisture. However, in the snowbeds the availability of moisture is constrained by time, which means only a few types of organisms can survive when the growing season is less than one month (Gjærevoll, 1956). Therefore, the available water for plant species increases linearly with maximum WASI values and hence the pattern of total plant species richness, vascular plant species richness and herbaceous species richness increases towards the maximum WASI values. In contrast, the unimodal pattern showed by the dwarf shrub is because, shrub possess a deep root system that can absorb water from deep soil when there is a scarcity of available water in the surface soil layer (Sala et al., 1989). Species richness of lichen is maximum at lower WASI values because lichen can utilise atmospheric water and reduced rate of transpiration through specialised morphological appearance (Larson, 1979) (divided into small capillaries and low stature) and therefore, it can cope with severe drought and wind. On a high WASI values, available water is maximum and the competition increases as the environment is more suitable for other vascular plant species where lichen lack competitive ability in comparison to other vascular plants (Shukla et al., 2014).

Macro lichen have maximum richness at a low WASI values, which is not generated only by ridge specialists (eg. *Alectoria ochroleuca* and *Alectoria nigricans*), but rather by generalist species, which are also common in intermediate snow cover and snowbeds as well, maybe because lichen are small and heliophilic, the richness is supressed by snowbed specialists i.e. forbs and graminoids (Bruun et al., 2006). The possible explanation for the lack of a unimodal pattern of species richness for total plant species as well as for vascular plant species and herbaceous species could relate to the disturbance occurring at the local scale. Ridge and steep slopes are likely the result of greater soil disturbance than flat snowbeds. The ridge and steep slopes which are continuously subjected to many natural disturbances such as wind scouring, frost heaving and solifluction (Johnson and Billings, 1962, Körner, 2003) and these disturbance processes have the ability to uproot seedlings and break off roots from established plants (Körner, 2003).

Rates of erosion and solifluction should increase as the degree of slope increases (Matsuoka, 2001), so the amount of disturbance depends on the variability of local microtopography. In an environment where growth is already limited by cold temperatures, wind scouring and solifluction, only the hardiest, most resistant species can survive, leading to reduced total plant species richness as well as other life forms except lichen in these conditions. In contrast, the snowbeds are less affected by these disturbances but they have a short growing season. Hence species richness is supressed in snowbeds and again species richness should be greater at intermediate WASI values, but this is not supported in my study. However, I did not investigate the very extreme snowbeds where only dark coloured mosses (e.g species form the genus Andrea) are found (Heegaard, 1997).

The possible explanation for this is because, plants in these early-melting plots (i.e. ridge and mid) are exposed to cold nights in absence of snow protection where they undergo violent freeze-thaw alteration. Most of the forbs and graminoids could not tolerate freezing cold (Chen et al., 2008) and get eliminated from the community. Despite, a long growing season in early snowmelt plots associated with plants’ reproduction and growth (Galen and Stanton, 1995), upper parts of the gradient do not contain a maximal number of species. Thus, one of the limiting factors on plant species richness in alpine areas is night temperature (Grabherr et al., 1995, Odland and Birks, 1999, Wohlgemuth, 2002) which determines species richness at fine scale.

In addition, alpine plants are exposed for competition at more productive sites (Choler et al., 2001, Onipchenko et al., 2009) and facilitation between plants at more stressful sites (Choler et al., 2001). Therefore one may expect to see enhanced richness in the more productive, snowbeds (Menge and Sutherland, 1976), which is supported in my analyses. Moreover, the abundance of dwarf shrub supresses the species richness of other growth forms (Bruun et al., 2006) at intermediate WASI value (middle microtopographical gradient), which lead to supressed species richness at middle microtopographical gradient. This may again causes the enhanced species richness in the snowbeds. Moreover, my snowbeds are not the base of continuous mountainside that is covered by black moss (Heegaard, 1997) where snow lasts for most of the summer, rather my snowbeds are the small depressions made by local microtopography. Therefore, my snowbeds are not limited by a very short growing season and thus, account for more species. In addition, half of the snowbeds possess calcareous soil, and a lack of cations is a main limiting factor in the Norwegian alpine zone (Gjærevoll, 1956).

Another factor is browsing and grazing by wild and domestic animals, which is quite common in the Hardangervidda National Park Plateau. The subalpine and low alpine meadows are widely grazed by reindeer and livestock including sheep (Odland et al., 2014). So, these plots are mostly subjected to longer and more serious grazing and trampling by reindeer and livestock. This kind of disturbance could lead to the disappearance of some species and result in lowering species richness at middle and ridge microtopography.

Mostly researchers treat microtopography as a secondary parameter nested in altitude to describe the pattern of species richness for different plant groups (Bruun et al., 2006) and the importance of microtopography is always inaudible. However, I particularly, focus on microtopographical gradient in my analysis to show the effect of microtopography on plant species richness. The overall result is thus explicable from the topographical gradients that operate at local spatial scales. Total plant species, vascular plant species and herbaceous plant species showed regular increase in species numbers from ridge to snowbeds, contrasting to Bruun et at (2006) and Chen et al (2008), because my snowbeds are not limited by short growing season and are richer in available water and nutrients. Also, the WASI value of ca. 6

where the species richness tends to peak in my study fall under the intermediate weighted average snow indicator values in Odland and Munkejordd (2008). The opposite appeared to be the case for lichen species, which only exhibited an increase in species richness on the ridges and steep slopes. These results call for studies of the microtopographical patterns in species richness that include local environmental stress i.e. edaphic factors.

In summary, the ridge possesses more mechanical stress but longer growing season whereas the snowbeds possess suitable temperature and nutrient inflow but exhibit the shorter length of growing season, and middle microtopography between ridge and snowbeds may represents more optimal environment. But my data do not support this hypothesis, except for dwarf shrub, therefore liquid water availability determines species richness in mountains, particularly in my study which is controlled by snow cover and prevalent wind direction. The short growing season limits species richness, although there is enough available water, which shows that time is an important vector that determines the species richness along microtopographical gradients.

5. Conclusions

In this study, species composition between all three study sites in HNP has revealed that plant assemblage samples can be placed in two distinct functional groups i.e. one is lichen-dominated and the other is vascular plant- dominated (woody species and herbaceous species). The differences in species composition are probably caused by the strong micro-climatic variations on fine spatial scale. My findings indicate that local adaptations of different functional groups exist, and are responsible for clustering species with respect to microtopographical gradient. Water-energy dynamics hypothesis (O'Brien, 2006; Vetaas 2006) has been used for the first time to relate species richness and microtopographical gradient from local scale data in Hardangervidda plateau.

Moreover, the pattern of species richness of total plant species and all other life forms with snow cover gradient is shown, weighted average snow indicator value is used as a surrogate of environmental parameters. Species richness revealed both expected and unexpected patterns, and particularly, determined by liquid water availability which is controlled by snow cover and prevalent wind direction. Finally, this master thesis may help to achieve better understanding for relating species richness and species composition with water energy dynamics hypothesis.

The findings of this study provide the basis for continuing investigation, in which species richness could be compared in mountains with extreme snowbeds and explained through water energy dynamics hypothesis. O'Brien (2006) suggests the importance of available water to determine the species richness at both local and regional scale. Water energy dynamics on a microtopographic gradient can be transferred to water energy dynamics on an elevation gradient because dynamics of water energy variation from the lower altitude to the higher altitude follow a similar pattern to that at fine scale study (Vetaas 2006). Finally, repeated sampling in the same transects helps to understand the possible effect of a global changing climate on plant assemblages.

6. References

BHATTA, K. P. & VETAAS, O. R. 2016. Does tree canopy closure moderate the effect of climate warming on plant species composition of temperate Himalayan oak forest? *Journal of Vegetation Science,* 27**,** 948-957.

BHATTARAI, K. R. & VETAAS, O. R. 2003. Variation in plant species richness of different life forms along a subtropical elevation gradient in the Himalayas, east Nepal. *Global Ecology and Biogeography,* 12**,** 327-340.

BHATTARAI, K. R. & VETAAS, O. R. 2006. Can Rapoport's rule explain tree species richness along the Himalayan elevation gradient, Nepal? *Diversity and Distributions,* 12**,** 373-378.

BILLINGS, W. 1973. Arctic and alpine vegetations: similarities, differences, and susceptibility to disturbance. *BioScience,* 23**,** 697-704.

BILLINGS, W. D. & BLISS, L. 1959. An alpine snowbank environment and its effects on vegetation, plant development, and productivity. *Ecology,* 40**,** 388-397.

BILLINGS, W. D. & MOONEY, H. A. 1968. The ecology of arctic and alpine plants. *Biological reviews,* 43**,** 481-529.

BIRDLIFE INTERNATIONAL. 2017. *Important Bird Areas factsheet: Hardangervidda* [Online]. Available: http://www.birdlife.org [Accessed].

BJERKETVEDT, D. K., REIMERS, E., PARKER, H. & BORGSTRØM, R. 2014. The Hardangervidda wild reindeer herd: a problematic management history.

BLISS, L. C. 1963. Alpine plant communities of the presidential range, New Hampshire. *Ecology,* 44**,** 678-697.

BLISS, L. C. 1971. Arctic and alpine plant life cycles. *Annual Review of Ecology and Systematics,* 2**,** 405-438.

BOSSUYT, B. & HERMY, M. 2001. Influence of land use history on seed banks in European temperate forest ecosystems: a review. *Ecography,* 24**,** 225-238.

BRAUN-BLANQUET, J. 1932. Plant sociology. The study of plant communities. *Plant sociology. The study of plant communities. First ed.*

BROOKS, R. R. 1983. *Biological methods of prospecting for minerals*, Wiley.

BROWN, R. T. & MIKOLA, P. 1974. *The influence of fruticose soil lichens upon the mycorrhizae and seedling growth of forest trees*, Suomen metsätieteellinen seura.

BRUNET, J. & TYLER, G. 2000. Interannual variability in abundance of field layer species in a south Swedish deciduous wood. *Flora,* 195**,** 97-103.

BRUUN, H. H., MOEN, J., VIRTANEN, R., GRYTNES, J.-A., OKSANEN, L., ANGERBJÖRN, A. & EZCURRA, E. 2006. Effects of altitude and topography on species richness of vascular plants, bryophytes and lichens in alpine communities. *Journal of Vegetation Science,* 17**,** 37-46.

BUCCI, G. & BORGHETTI, M. 1997. Understory vegetation as a useful predictor of natural regeneration and canopy dynamics in Pinus sylvestris forests in Italy. *Acta Oecologica,* 18**,** 485-501.

CHEN, W., WU, Y., WU, N. & LUO, P. 2008. Effect of snow-cover duration on plant species diversity of alpine meadows on the eastern Qinghai-Tibetan Plateau. *Journal of Mountain Science,* 5**,** 327-339.

CHOLER, P., MICHALET, R. & CALLAWAY, R. M. 2001. Facilitation and competition on gradients in alpine plant communities. *Ecology,* 82**,** 3295-3308.

CORREA-METRIO, A., DECHNIK, Y., LOZANO-GARCÍA, S. & CABALLERO, M. 2014. Detrended correspondence analysis: A useful tool to quantify ecological changes from fossil data sets. *Boletín de la Sociedad Geológica Mexicana,* 66**,** 135-143.

CRAWLEY, M. J. 2012. *The R book,* John Wiley & Sons.

DIEKMANN, M. 1994. *Deciduous forest vegetation in Boreo-nemoral Scandinavia,* Opulus Press AB.

DIEKMANN, M. 1995. Use and improvement of Ellenberg's indicator values in deciduous forests of the Boreo-nemoral zone in Sweden. *Ecography,* 18**,** 178-189.

DIEKMANN, M. 2003. Species indicator values as an important tool in applied plant ecology– a review. *Basic and applied ecology,* 4**,** 493-506.

DIEKMANN, M., BRUNET, J., RÜHLING, Å. & FALKENGREN-GRERUP, U. 1999. Effects of nitrogen deposition: results of a temporal-spatial analysis of deciduous forests in South Sweden. *Plant Biology,* 1**,** 471-481.

DIRNAT 2003. Forvaltningsplan for Hardangervidda nasjonalpark med landskapsvernområder.

DOBSON, A. J. & BARNETT, A. 2008. *An introduction to generalized linear models*, CRC press.

DUPRÉ, C. 2000. How to determine a regional species pool: a study in two Swedish regions. *Oikos,* 89**,** 128-136.

ELBERLING, B., NORDSTRØM, C., GRØNDAHL, L., SØGAARD, H., FRIBORG, T., CHRISTENSEN, T. R., STRÖM, L., MARCHAND, F. & NIJS, I. 2008. High-Arctic Soil CO 2 and CH 4 Production Controlled by Temperature, Water, Freezing and Snow. *Advances in Ecological Research,* 40**,** 441-472.

ELLENBERG, H. 1950. Ackerunkraut-Gemeinschaften als Bodenzeiger. Landwirtschaftlicher Zentraldienst (Stuttgart-Hohenheim). *Merkblatt,* 1959.

ELLENBERG, H. 1974. Zeigerwerte der Gefässpflanzen Mitteleuropas. Scripta Geobot. 9. *Univ. Göttingen*.

ELLENBERG, H. 1988. *Vegetation ecology of central Europe*, Cambridge University Press.

ELLENBERG, H. 1992. Zeigerwerte der Gefäßpflanzen (ohne Rubus). *Scripta Geobotanica,* 18**,** 9-166.

EVANS, R. & FONDA, R. 1990. The influence of snow on subalpine meadow community pattern, North Cascades, Washington. *Canadian Journal of Botany,* 68**,** 212-220.

EWALD, J. 1999. Relationships between floristic and micro site variability in coniferous forests of the Bavarian Alps. *Phytocoenologia***,** 327-344.

FALLDORF, T., STRAND, O., PANZACCHI, M. & TØMMERVIK, H. 2014. Estimating lichen volume and reindeer winter pasture quality from Landsat imagery. *Remote Sensing of Environment,* 140**,** 573-579.

FRANCIS, A. P. & CURRIE, D. J. 2003. A globally consistent richness-climate relationship for angiosperms. *The American Naturalist,* 161**,** 523-536.

FRASER, R. H. & CURRIE, D. J. 1996. The species richness-energy hypothesis in a system where historical factors are thought to prevail: coral reefs. *The American Naturalist,* 148**,** 138-159.

GALEN, C. & STANTON, M. L. 1995. Responses of Snowbed Plant Species to Changes in Growing-Season Length. *Ecology,* 76**,** 1546-1557.

GAUCH, H. G. 1982. Noise reduction by eigenvector ordinations. *Ecology,* 63**,** 1643-1649.

GJÆREVOLL, O. 1956. *The plant communities of the Scandinavian alpine snow-beds,* F. Bruns.

GRABHERR, G., GOTTFRIED, M., GRUBER, A. & PAULI, H. 1995. Patterns and current changes in alpine plant diversity. *Arctic and alpine biodiversity: patterns, causes and ecosystem consequences.* Springer.

HAWKINS, B. A., FIELD, R., CORNELL, H. V., CURRIE, D. J., GUÉGAN, J.-F., KAUFMAN, D. M., KERR, J. T., MITTELBACH, G. G., OBERDORFF, T. & O'BRIEN, E. M. 2003. Energy, water, and broad-scale geographic patterns of species richness. *Ecology,* 84**,** 3105-3117.

HEEGAARD, E. 1997. Ecology of Andreaea in western Norway. *Journal of Bryology,* 19**,** 527-636.

HILL, M. & CAREY, P. 1997. Prediction of yield in the Rothamsted Park Grass Experiment by Ellenberg indicator values. *Journal of Vegetation Science,* 8**,** 579-586.

HILL, M. O. & GAUCH, H. G. 1980. Detrended correspondence analysis: an improved ordination technique. *Vegetatio,* 42**,** 47-58.

HILL, M. O., ROY, D. B., MOUNTFORD, J. O. & BUNCE, R. G. 2000. Extending Ellenberg's indicator values to a new area: an algorithmic approach. *Journal of applied Ecology,* 37**,** 3-15.

HILLER, B., NUEBEL, A., BROLL, G. & HOLTMEIER, F.-K. 2005. Snowbeds on silicate rocks in the Upper Engadine (Central Alps, Switzerland)—pedogenesis and interactions among soil, vegetation, and snow cover. *Arctic, antarctic, and alpine research,* 37**,** 465-476.

HUSTON, M. A. 1999. Local processes and regional patterns: appropriate scales for understanding variation in the diversity of plants and animals. *Oikos***,** 393-401.

JOHNSON, P. L. & BILLINGS, W. D. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. *Ecological Monographs,* 32**,** 105-135.

KARLSON, R. H., CORNELL, H. V. & HUGHES, T. P. 2004. Coral communities are regionally enriched along an oceanic biodiversity gradient. *Nature,* 429**,** 867-870.

KARMER, P. & BOYER, J. 1995. Water relations of plant and soils. *Academic, Waltham*.

KELLY, A. E. & GOULDEN, M. L. 2008. Rapid shifts in plant distribution with recent climate change. *Proceedings of the National Academy of Sciences,* 105**,** 11823-11826.

KERSHAW, K. 1977. Studies on lichen-dominated systems. XX. An examination of some aspects of the northern boreal lichen woodlands in Canada. *Canadian Journal of Botany,* 55**,** 393-410.

KOERNER, W., DUPOUEY, J., DAMBRINE, E. & BENOIT, M. 1997. Influence of past land use on the vegetation and soils of present day forest in the Vosges mountains, France. *Journal of ecology***,** 351-358.

KÖRNER, C. 2003. *Alpine plant life: functional plant ecology of high mountain ecosystems; with 47 tables,* Springer Science & Business Media.

KÖRNER, C. 2011. Coldest places on earth with angiosperm plant life. *Alpine Botany,* 121**,** 11-22.

LARSON, D. 1979. Lichen water relations under drying conditions. *New Phytologist,* 82**,** 713-731.

LAWESSON, J. E. 2000. Danish deciduous forest types. *Plant Ecology,* 151**,** 199-221.

LEE, T. D. & LA ROI, G. H. 1979. Gradient analysis of bryophytes in Jasper National Park, Alberta. *Canadian Journal of Botany,* 57**,** 914-925.

LID, J. & LID, D. 2005. Norsk flora. 7 utgåve ved R. *Elven. Det Norske Samlaget, Oslo, Norway*.

LONGTON, R. E. 1988. *Biology of polar bryophytes and lichens,* CUP Archive.

LYE, K. 1975. Survey of the main plant communities on Hardangervidda. *Fennoscandian tundra ecosystems.* Springer.

MATSUOKA, N. 2001. Solifluction rates, processes and landforms: a global review. *Earth-Science Reviews,* 55**,** 107-134.

MCCULLAGH, P. & NELDER, J. A. 1989. Generalized Linear Models, no. 37 in Monograph on Statistics and Applied Probability. Chapman & Hall.

MENGE, B. A. & SUTHERLAND, J. P. 1976. Species diversity gradients: synthesis of the roles of predation, competition, and temporal heterogeneity. *The American Naturalist,* 110**,** 351-369.

MICHALET, R., GANDOY, C., JOUD, D., PAGES, J.-P. & CHOLER, P. 2002. Plant community composition and biomass on calcareous and siliceous substrates in the northern French Alps: comparative effects of soil chemistry and water status. *Arctic, Antarctic, and Alpine Research***,** 102-113.

MOEN, A. 1999. National atlas of Norway: vegetation.

NAGY, L., GRABHERR, G., KÖRNER, C. & THOMPSON, D. 2003. Alpine biodiversity in space and time: a synthesis. *Alpine Biodiversity in Europe.* Springer.

NATERSTAD, J. 1988. Haukelisæter 1414 IV. *Berggrunnsgeologisk M,* 1.

NEWMAN, E. 1973. Competition and diversity in herbaceous vegetation. *Nature,* 244**,** 310-310.

O'BRIEN, E. 1998. Water-energy dynamics, climate, and prediction of woody plant species richness: an interim general model. *Journal of Biogeography,* 25**,** 379-398.

O'BRIEN, E. M. 1993. Climatic gradients in woody plant species richness: towards an explanation based on an analysis of southern Africa's woody flora. *Journal of Biogeography***,** 181-198.

O'BRIEN, E. M. 2006. Biological relativity to water–energy dynamics. *Journal of Biogeography,* 33**,** 1868-1888.

ODLAND, A. & BIRKS, H. 1999. The altitudinal gradient of vascular plant richness in Aurland, western Norway. *Ecography,* 22**,** 548-566.

ODLAND, A. & MUNKEJORD, H. K. 2008. Plants as indicators of snow layer duration in southern Norwegian mountains. *Ecological indicators,* 8**,** 57-68.

ODLAND, A., SANDVIK, S. M., BJERKETVEDT, D. K. & MYRVOLD, L. L. 2014. Estimation of lichen biomass with emphasis on reindeer winter pastures at Hardangervidda, S Norway. *Rangifer,* 34**,** 95-110.

ØKLAND, R. H. 1990. *Vegetation ecology: theory, method and applications with reference to Fennoscandia*, Botanical Garden and Museum, University of Oslo.

ONIPCHENKO, V. G., BLINNIKOV, M. S., GERASIMOVA, M. A., VOLKOVA, E. V. & CORNELISSEN, J. H. 2009. Experimental comparison of competition and facilitation in alpine communities varying in productivity. *Journal of Vegetation Science,* 20**,** 718-727.

ØSTBYE, E., BERG, A., BLEHR, O., ESPELAND, M., GAARE, E., HAGEN, A., HESJEDAL, O., HAGVAR, S., KJELVIK, S. & LIEN, L. 1975. Hardangervidda, Norway. *Structure and function of tundra ecosystems. Ecol Bull,* 20**,** 225-264.

ØVSTEDAL, D., TØNSBERG, T. & ELVEBAKK, A. 2009. The lichen flora of Svalbard. *Sommerfeltia,* 33**,** 3-393.

PÄRTEL, M. 2002. Local plant diversity patterns and evolutionary history at the regional scale. *Ecology,* 83**,** 2361-2366.

PÄRTEL, M., ZOBEL, M., ZOBEL, K. & VAN DER MAAREL, E. 1996. The species pool and its relation to species richness: evidence from Estonian plant communities. *Oikos***,** 111-117.

PAUSAS, J. G. 2001. Resprouting vs seeding–a Mediterranean perspective. *Oikos,* 94**,** 193-194.

PROULX, M. & MAZUMDER, A. 1998. Reversal of grazing impact on plant species richness in nutrient-poor vs. nutrient-rich ecosystems. *Ecology,* 79**,** 2581-2592.

R CORE TEAM 2016. R: A language and environment for statistical computing.: R Foundation for Statistical Computing, Vienna, Austria.

RANNOW, S. 2013. Do shifting forest limits in south-west Norway keep up with climate change? *Scandinavian Journal of Forest Research,* 28**,** 574-580.

REINHARDT, S. 2013. The importance of snow for mountain vegetation in the Hardangervidda area (Southern Norway): plant distribution, plant phenology, plant diversity, and effects of global climate change.

RICKLEFS, R. E. 2004. A comprehensive framework for global patterns in biodiversity. *Ecology letters,* 7**,** 1-15.

SALA, O., GOLLUSCIO, R., LAUENROTH, W. & SORIANO, A. 1989. Resource partitioning between shrubs and grasses in the Patagonian steppe. *Oecologia,* 81**,** 501-505.

SAVILE, D. 1961. The botany of the northwestern Queen Elizabeth Islands. *Canadian Journal of Botany,* 39**,** 909-942.

SHUKLA, V., UPRETI, D. & BAJPAI, R. 2014. Introduction. *Lichens to Biomonitor the Environment.* Springer.

SZYMURA, T. H., SZYMURA, M. & MACIOŁ, A. 2014. Bioindication with Ellenberg's indicator values: A comparison with measured parameters in Central European oak forests. *Ecological indicators,* 46**,** 495-503.

THOMPSON, K., HODGSON, J., GRIME, J., RORISON, I., BAND, S. & SPENCER, R. 1993. Ellenberg numbers revisited. *Phytocoenologia***,** 277-289.

TUKEY, J. W. 1953. Section of mathematics and engineering: Some selected quick and easy methods of statistical analysis. *Transactions of the New York Academy of Sciences,* 16**,** 88-97.

VAN DER WELLE, M. E., VERMEULEN, P. J., SHAVER, G. R., BERENDSE, F. & WHITE, P. 2003. Factors determining plant species richness in Alaskan arctic tundra. *Journal of Vegetation Science,* 14**,** 711-720.

VETAAS, O. R. 2006. Biological relativity to water–energy dynamics: a potential unifying theory? *Journal of Biogeography,* 33**,** 1866-1867.

VIRTANEN, R., LUNDBERG, P., MOEN, J. & OKSANEN, L. 1997. Topographic and altitudinal patterns in plant communities on European arctic islands. *Polar Biology,* 17**,** 95-113.

VITTOZ, P., CAMENISCH, M., MAYOR, R., MISERERE, L., VUST, M. & THEURILLAT, J.-P. 2010. Subalpine-nival gradient of species richness for vascular plants, bryophytes and lichens in the Swiss Inner Alps. *Botanica Helvetica,* 120**,** 139-149.

VONLANTHEN, C., BÜHLER, A., VEIT, H., KAMMER, P. & EUGSTER, W. 2006. Alpine plant communities: a statistical assessment of their relation to microclimatological, pedological, geomorphological, and other factors. *Physical Geography,* 27**,** 137-154.

WALKER, M. D., INGERSOLL, R. C. & WEBBER, P. J. 1995. Effects of interannual climate variation on phenology and growth of two alpine forbs. *Ecology,* 76**,** 1067-1083.

WAMELINK, G. W. W., JOOSTEN, V., VAN DOBBEN, H., BERENDSE, F. & BRUELHEIDE, H. 2002. Validity of Ellenberg indicator values judged from physico-chemical field measurements. *Journal of vegetation science,* 13**,** 269-278.

WHITTAKER, R. H. 1967. Gradient analysis of vegetation. *Biological reviews,* 42**,** 207-264.

WHITTAKER, R. J., NOGUÉS-BRAVO, D. & ARAÚJO, M. B. 2007. Geographical gradients of species richness: a test of the water-energy conjecture of Hawkins et al.(2003) using European data for five taxa. *Global Ecology and Biogeography,* 16**,** 76-89.

WILLIAMS, M. N. 2015. *How well do psychologists' research methods equip them to identify the impacts of climate change on behaviour?: a methodological investigation with particular reference to the effects of temperature on violent behaviour: a thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Psychology at Massey University, Albany, New Zealand.* Massey University.

WISZ, M. S., POTTIER, J., KISSLING, W. D., PELLISSIER, L., LENOIR, J., DAMGAARD, C. F., DORMANN, C. F., FORCHHAMMER, M. C., GRYTNES, J. A. & GUISAN, A. 2013. The role of biotic interactions in shaping distributions and realised assemblages of species: implications for species distribution modelling. *Biological Reviews,* 88**,** 15-30.

WOHLGEMUTH, T. 2002. Environmental determinants of vascular plant species richness in the Swiss alpine zone. *Mountain biodiversity: a global assessment***,** 103-116.

Appendices

Appendix I. Species recorded in all plots (151 plots of 4m^2).

Species Name	Abbreviation	Plot Number																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Alchemilla alpina	Alc_alp	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0
Alchemilla vulgaris	Alc_vul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0
Alectoria ochroleuca	Ale_och	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1
Antennaria alpina	Ant_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avenella flexuosa	Ave_fle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia alpina	Bar_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula nana	Bet_nan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Bistorta vivipara	Bis_viv	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0
Carex bigelowii	Car_big	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1
Carex canescens	Car_can	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Carex nigra	Car_nig	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cetraria islandica	Cet_isl	0	0	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	1

Cetraria nivalis	Cet_niv	1	1	1	1	0	0	0	1	1	1	1	1	0	0	1	1	1	1	1	0	0	0	1	1	1
Cetraria spp	Cet_spp	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1
Cladonia arbuscula	Cla_arb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia gracilis	Cla_gra	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
Cladonia mitis	Cla_mit	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladonia rangiferina	Cla_ran	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia spp	Cla_spp	0	1	1	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1	1	0	1	0	1
Cladonia stricta	Cla_str	1	0	1	1	1	1	1	1	1	0	0	0	1	0	1	1	1	1	0	1	1	0	0	0	1
Cladonia uncialis	Cla_unc	1	1	0	1	1	1	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1	1	0	1	0
Deschampsia alpina	Des_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	1	1	0	0	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1
Festuca spicata	Fes_spi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hieracium alpinum	Hie_alp	0	0	0	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	1	0	0	0
Juncus trifidus	Jun_tri	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	0	1
Juniperus communis	Jun_com	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Luzula frigida	Luz_fri	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	1	0	0	0	0
Lycopodium alpinum	Lyc_alp	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0
Lycopodium selago	Lyc_sel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nardus stricta	Nar_str	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola minor	Pyr_min	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Ranunculus acris	Ran_acr	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Rumex acetosa	Rum_ace	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1	0	1	0	0	0
Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix herbacea	Sal_her	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	0	0	0
Salix lapponica	Sal_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix reticulata	Sal_ret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. virgaurea	Sol_vir	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0
Sphaerophorus globosus	Sph_glo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stereocaulon spp	Ste_spp	0	0	0	0	1	1	0	0	1	1	0	1	1	0	0	0	0	1	1	1	1	0	0	0	0
Taraxacum spp	Tar_spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Trientalis europaea	Tri_eur	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	1	1	0	1	0	0	0	0	0
Vaccinium myrtillus	Vac_myr	0	0	0	0	1	1	1	0	1	0	1	1	1	0	1	0	0	0	1	1	0	0	0	0	0
Vaccinium uliginosum	Vac_uli	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Vaccinium vitis-idaea	Vac_vit	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont...

Species Name	**Abbreviation**	**Plot Number**																						
		26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Alchemilla alpina	Alc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla vulgaris	Alc_vul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	1	1
Alectoria ochroleuca	Ale_och	1	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	1	1
Antennaria alpina	Ant_alp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	0	1	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avenella flexuosa	Ave_fle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Bartsia alpina	Bar_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula nana	Bet_nan	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Bistorta vivipara	Bis_viv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex bigelowii	Car_big	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carex canescens	Car_can	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex nigra	Car_nig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	0	0	0	0	1	1	1	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	1
Cetraria islandica	Cet_isl	1	1	1	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0
Cetraria nivalis	Cet_niv	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	1	1
Cetraria spp	Cet_spp	0	1	0	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	0	1	1
Cladonia arbuscula	Cla_arb	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Cladonia gracilis	Cla_gra	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1	1	1	0
Cladonia mitis	Cla_mit	0	0	0	0	1	1	1	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0
Cladonia rangiferina	Cla_ran	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia spp	Cla_spp	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	0
Cladonia stricta	Cla_str	0	0	0	0	0	1	1	0	1	1	0	1	1	1	0	0	1	1	1	1	0	1	0
Cladonia uncialis	Cla_unc	1	1	1	0	0	0	0	1	1	0	0	0	1	1	1	1	0	0	1	1	0	0	1
Deschampsia alpina	Des_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	0	1	0	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	0	1
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Festuca spicata	Fes_spi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hieracium alpinum	Hie_alp	1	1	1	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	1	1	1	0	0
Juncus trifidus	Jun_tri	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0
Juniperus communis	Jun_com	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luzula frigida	Luz_fri	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Lycopodium alpinum	Lyc_alp	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Lycopodium selago	Lyc_sel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Nardus stricta	Nar_str	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Pyrola minor	Pyr_min	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus acris	Ran_acr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex acetosa	Rum_ace	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix herbacea	Sal_her	0	1	1	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	1	1	1	0	0
Salix lapponica	Sal_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix reticulata	Sal_ret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. Virgaurea	Sol_vir	1	1	1	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	1	0	0	0
Sphaerophorus globosus	Sph_glo	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Stereocaulon spp	Ste_spp	1	1	0	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	0	1
Taraxacum spp	Tar_spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1
Trientalis europaea	Tri_eur	0	1	1	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Vaccinium myrtillus	Vac_myr	0	1	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0
Vaccinium uliginosum	Vac_uli	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Vaccinium vitis-idaea	Vac_vit	1	1	0	1	1	0	1	0	0	1	1	1	1	0	0	1	1	0	1	1	0	1	1
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont...

Species Name	**Abbreviation**	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Alchemilla alpina	Alc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Alchemilla vulgaris	Alc_vul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1
Alectoria ochroleuca	Ale_och	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	1
Antennaria alpina	Ant_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	1	0
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avenella flexuosa	Ave_fle	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia alpina	Bar_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula nana	Bet_nan	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Bistorta vivipara	Bis_viv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Carex bigelowii	Car_big	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Carex canescens	Car_can	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex nigra	Car_nig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria islandica	Cet_isl	1	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	1
Cetraria nivalis	Cet_niv	1	1	0	0	1	1	1	1	0	0	1	1	1	0	0	0	1	1	1	1	0	0	1
Cetraria spp	Cet_spp	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1
Cladonia arbuscula	Cla_arb	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Cladonia gracilis	Cla_gra	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1
Cladonia mitis	Cla_mit	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladonia rangiferina	Cla_ran	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia spp	Cla_spp	1	1	0	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1
Cladonia stricta	Cla_str	1	0	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1
Cladonia uncialis	Cla_unc	1	1	1	1	0	0	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1
Deschampsia alpina	Des_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Festuca spicata	Fes_spi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
Hieracium alpinum	Hie_alp	1	1	0	1	1	0	1	0	1	1	0	0	0	1	0	1	0	0	0	0	1	1	0
Juncus trifidus	Jun_tri	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1	0
Juniperus communis	Jun_com	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Luzula frigida	Luz_fri	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	1	0
Lycopodium alpinum	Lyc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0
Lycopodium selago	Lyc_sel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nardus stricta	Nar_str	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1	0
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Pyrola minor	Pyr_min	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ranunculus acris	Ran_acr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex acetosa	Rum_ace	0	0	1	1	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0	1	0	1	0
Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix herbacea	Sal_her	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	1	1	0
Salix lapponica	Sal_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix reticulata	Sal_ret	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. Virgaurea	Sol_vir	1	1	1	1	0	0	0	0	1	1	0	0	0	1	0	1	0	0	0	0	1	1	0
Sphaerophorus globosus	Sph_glo	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stereocaulon spp	Ste_spp	0	1	0	0	0	0	0	1	0	0	0	1	1	1	0	0	1	1	0	0	1	1	0
Taraxacum spp	Tar_spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trientalis europaea	Tri_eur	0	1	1	0	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0
Vaccinium myrtillus	Vac_myr	1	1	1	0	1	0	0	1	1	1	0	0	0	1	1	1	0	0	0	1	0	0	0
Vaccinium uliginosum	Vac_uli	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	0	1
Vaccinium vitis-idaea	Vac_vit	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	0	1
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont...

Species Name	**Abbreviation**																							
		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
Alchemilla alpina	Alc_alp	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla vulgaris	Alc_vul	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0
Alectoria ochroleuca	Ale_och	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0
Antennaria alpina	Ant_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	0	0	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	1	0	0
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avenella flexuosa	Ave_fle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia alpina	Bar_alp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Betula nana	Bet_nan	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Bistorta vivipara	Bis_viv	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Carex bigelowii	Car_big	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
Carex canescens	Car_can	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Carex nigra	Car_nig	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
Cetraria islandica	Cet_isl	1	1	1	1	1	0	0	1	1	1	0	0	0	1	1	1	0	1	1	1	0	0	1
Cetraria nivalis	Cet_niv	0	1	0	0	0	1	1	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0
Cetraria spp	Cet_spp	1	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0	1	1	1	1	1	0	0
Cladonia arbuscula	Cla_arb	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0

Cladonia gracilis	Cla_gra	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
Cladonia mitis	Cla_mit	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	1	0	1	1	1	1	0	0
Cladonia rangiferina	Cla_ran	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
Cladonia spp	Cla_spp	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1
Cladonia stricta	Cla_str	1	1	1	1	0	0	1	1	0	1	0	1	1	0	0	0	1	1	0	1	1	0	0
Cladonia uncialis	Cla_unc	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Deschampsia alpina	Des_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1
Festuca spicata	Fes_spi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Hieracium alpinum	Hie_alp	1	1	1	1	1	0	0	1	1	1	0	0	0	1	1	1	0	1	1	0	1	1	1
Juncus trifidus	Jun_tri	1	1	1	0	0	0	0	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	0
Juniperus communis	Jun_com	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Luzula frigida	Luz_fri	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1
Lycopodium alpinum	Lyc_alp	0	0	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	1	0
Lycopodium selago	Lyc_sel	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Nardus stricta	Nar_str	0	0	0	1	1	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Pyrola minor	Pyr_min	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus acris	Ran_acr	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Rumex acetosa	Rum_ace	0	0	0	1	1	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0
Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Salix herbacea	Sal_her	0	1	1	1	1	0	0	0	0	0	1	0	0	0	1	1	0	1	0	1	1	1	1
Salix lapponica	Sal_lap	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Salix reticulata	Sal_ret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. virgaurea	Sol_vir	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1
Sphaerophorus globosus	Sph_glo	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
Stereocaulon spp	Ste_spp	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Taraxacum spp	Tar_spp	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	1	1	0	0	0	1	1	1	0	0	0	1	1	0	1	1	1	0	0	1	0	0	0
Trientalis europaea	Tri_eur	0	0	1	0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	1	1	1
Vaccinium myrtillus	Vac_myr	1	1	1	1	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	1	1	1
Vaccinium uliginosum	Vac_uli	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0
Vaccinium vitis-idaea	Vac_vit	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	1	0	1	1	1	0	0
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Appendix 1 cont...

Species Name	**Abbreviation**	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114
Alchemilla alpina	Alc_alp	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Alchemilla vulgaris	Alc_vul	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Alectoria ochroleuca	Ale_och	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Antennaria alpina	Ant_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avenella flexuosa	Ave_fle	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0
Bartsia alpina	Bar_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula nana	Bet_nan	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	1	1	1	1
Bistorta vivipara	Bis_viv	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0
Carex bigelowii	Car_big	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1
Carex canescens	Car_can	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Carex nigra	Car_nig	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1
Cetraria islandica	Cet_isl	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1
Cetraria nivalis	Cet_niv	0	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	1
Cetraria spp	Cet_spp	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1
Cladonia arbuscula	Cla_arb	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia gracilis	Cla_gra	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0

Cladonia mitis	Cla_mit	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1
Cladonia rangiferina	Cla_ran	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia spp	Cla_spp	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0
Cladonia stricta	Cla_str	0	0	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Cladonia uncialis	Cla_unc	0	0	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1
Deschampsia alpina	Des_alp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Festuca spicata	Fes_spi	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hieracium alpinum	Hie_alp	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	0	0	0	0
Juncus trifidus	Jun_tri	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1
Juniperus communis	Jun_com	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luzula frigida	Luz_fri	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lycopodium alpinum	Lyc_alp	0	1	1	1	1	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
Lycopodium selago	Lyc_sel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nardus stricta	Nar_str	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	0	0	0	0
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola minor	Pyr_min	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus acris	Ran_acr	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Rumex acetosa	Rum_ace	1	1	1	1	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0
Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix herbacea	Sal_her	1	1	0	1	1	1	1	1	1	0	1	0	0	0	1	1	0	0	0	0
Salix lapponica	Sal_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix reticulata	Sal_ret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. virgaurea	Sol_vir	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Sphaerophorus globosus	Sph_glo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Stereocaulon spp	Ste_spp	0	0	1	1	1	1	0	1	0	0	1	0	1	1	1	0	0	0	1	1
Taraxacum spp	Tar_spp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	0	0	1	0	0	1	1	1	0	1	1	1	0	0	0	0	1	1	1	0
Trientalis europaea	Tri_eur	0	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0
Vaccinium myrtillus	Vac_myr	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0
Vaccinium uliginosum	Vac_uli	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium vitis-idaea	Vac_vit	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1 cont...

Species Name	**Abbreviation**	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133
Alchemilla alpina	Alc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla vulgaris	Alc_vul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1
Alectoria ochroleuca	Ale_och	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	1
Antennaria alpina	Ant_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Avenella flexuosa	Ave_fle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia alpina	Bar_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula nana	Bet_nan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Bistorta vivipara	Bis_viv	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Carex bigelowii	Car_big	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Carex canescens	Car_can	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex nigra	Car_nig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	1	0	0	1	1	1	1	1	0	0	1	1	1	1	0	0	0	0	1
Cetraria islandica	Cet_isl	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	1	1	1
Cetraria nivalis	Cet_niv	1	0	0	1	1	1	1	1	0	1	1	1	1	1	0	0	0	1	1
Cetraria spp	Cet_spp	1	1	0	1	1	0	1	0	0	1	1	0	1	1	1	0	0	1	1
Cladonia arbuscula	Cla_arb	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia gracilis	Cla_gra	1	1	1	0	1	0	0	1	1	1	0	1	1	1	0	1	1	1	0
Cladonia mitis	Cla_mit	1	1	1	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0

Cladonia rangiferina	Cla_ran	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cladonia spp	Cla_spp	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0
Cladonia stricta	Cla_str	1	1	0	0	1	1	1	1	0	1	0	1	1	1	0	1	1	1	1
Cladonia uncialis	Cla_unc	1	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1	0	0
Deschampsia alpina	Des_alp	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	0	0	0	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1
Festuca spicata	Fes_spi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0
Hieracium alpinum	Hie_alp	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0
Juncus trifidus	Jun_tri	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Juniperus communis	Jun_com	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luzula frigida	Luz_fri	0	0	0	0	0	1	0	0	0	0	1	1	0	1	0	0	0	0	0
Lycopodium alpinum	Lyc_alp	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lycopodium selago	Lyc_sel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nardus stricta	Nar_str	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	1	1	0
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola minor	Pyr_min	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus acris	Ran_acr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex acetosa	Rum_ace	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0

Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix herbacea	Sal_her	0	0	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	0
Salix lapponica	Sal_lap	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Salix reticulata	Sal_ret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. virgaurea	Sol_vir	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Sphaerophorus globosus	Sph_glo	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Stereocaulon spp	Ste_spp	1	1	0	1	1	1	1	1	1	0	0	0	0	0	1	0	0	1	1
Taraxacum spp	Tar_spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0	0	0	1
Trientalis europaea	Tri_eur	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0
Vaccinium myrtillus	Vac_myr	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium uliginosum	Vac_uli	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Vaccinium vitis-idaea	Vac_vit	1	1	0	1	0	1	1	1	0	0	1	1	1	1	1	0	0	0	1
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species Name	**Abbreviation**																		
		134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151
Alchemilla alpina	Alc_alp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Alchemilla vulgaris	Alc_vul	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alectoria nigricans	Ale_nig	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	0	0	0
Alectoria ochroleuca	Ale_och	0	1	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0
Antennaria alpina	Ant_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum odoratum	Ant_odo	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Arctous alpinus	Arc_alp	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Arctuostaphylla uva-ursi	Arc_uva	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Astragalus norvegicus	Ast_nor	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Avenella flexuosa	Ave_fle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia alpina	Bar_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Betula nana	Bet_nan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1
Bistorta vivipara	Bis_viv	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Carex bigelowii	Car_big	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
Carex canescens	Car_can	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Carex nigra	Car_nig	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cerastium cerastoides	Cer_cer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetraria cucullata	Cet_cuc	1	1	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0
Cetraria islandica	Cet_isl	1	1	1	1	1	0	1	1	1	0	0	1	0	0	1	1	1	1
Cetraria nivalis	Cet_niv	1	1	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0
Cetraria spp	Cet_spp	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	0
Cladonia arbuscula	Cla_arb	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
Cladonia gracilis	Cla_gra	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	0

Cladonia mitis	Cla_mit	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Cladonia rangiferina	Cla_ran	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
Cladonia spp	Cla_spp	1	1	1	1	0	0	1	1	1	1	0	1	0	1	0	1	1	0
Cladonia stricta	Cla_str	1	1	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	0
Cladonia uncialis	Cla_unc	1	1	1	1	1	0	1	0	1	1	0	1	0	1	0	1	1	0
Deschampsia alpina	Des_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empetrum nigrum ssp. hermaphroditum	Emp_nig	1	1	1	1	1	0	1	0	1	1	1	0	1	1	1	0	1	0
Eriphorum scheuchzeri	Eri_sch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca ovina ssp. ovina	Fes_ovi	0	0	0	0	1	1	0	1	0	1	1	1	0	0	1	0	0	0
Festuca spicata	Fes_spi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gentiana purpurea	Gen_pur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium alpinum	Gna_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Gnaphalium norvegicum	Gna_nor	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Hieracium alpinum	Hie_alp	0	0	1	1	1	0	0	0	0	1	1	1	0	0	0	0	0	0
Juncus trifidus	Jun_tri	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	1	0
Juniperus communis	Jun_com	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luzula frigida	Luz_fri	0	0	0	0	1	1	0	0	0	1	1	1	0	1	0	0	1	1
Lycopodium alpinum	Lyc_alp	0	0	1	1	0	0	0	0	0	1	1	1	0	0	0	1	1	1
Lycopodium selago	Lyc_sel	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nardus stricta	Nar_str	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1
Nephroma arcticum	Nep_arc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxyria digyna	Oxy_dig	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pedicularis lapponica	Ped_lap	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola alpina	Pyr_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrola minor	Pyr_min	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ranunculus acris	Ran_acr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Rumex acetosa	Rum_ace	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	0	1
Salix glauca	Sal_gla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Salix herbacea	Sal_her	0	0	1	1	1	0	0	1	1	1	1	1	0	1	1	0	1	1
Salix lapponica	Sal_lap	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Salix reticulata	Sal_ret	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saussurea alpina	Sau_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sibbaldia procumbens	Sib_pro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene acaulis	Sil_aca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene dioica	Sil_dio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solidago virgaurea ssp. virgaurea	Sol_vir	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerophorus globosus	Sph_glo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stereocaulon spp	Ste_spp	1	1	1	1	1	0	1	0	1	1	1	1	0	0	1	0	1	0
Taraxacum spp	Tar_spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalictrum alpinum	Tha_alp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnolia vermiculata	Tha_ver	1	1	0	0	0	1	0	1	1	0	0	0	1	1	1	0	0	0
Trientalis europaea	Tri_eur	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	1
Vaccinium myrtillus	Vac_myr	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Vaccinium uliginosum	Vac_uli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vaccinium vitis-idaea	Vac_vit	1	1	1	0	0	1	1	1	1	0	0	0	1	1	1	0	1	0
Viola palustris	Vio_pal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 2. Plotwise environmental parameters.

Plot.No	Site	Latitude	Longitude	Altitude	Aspect	Slope	WASI*	RD**	Plot location	Soil type	Lichen cover	Herb cover	Shrub cover	Grass cover	Moss cover	Bare land cover
1	Tronsbu	60.28466667	7.558333333	1227	70	4	2.2	0.00	Ridge	Poor	70	5	10	5	0	10
2	Tronsbu	60.28469444	7.558416667	1226	68	4	2.36	16.67	Ridge	Poor	70	5	30	5	0	5
3	Tronsbu	60.28458333	7.558472222	1215	70	6	2.66	33.33	Between	Poor	80	5	5	10	0	10
4	Tronsbu	60.28472222	7.558527778	1217	70	6	3	50.00	Between	Poor	70	0	5	10	0	10
5	Tronsbu	60.28472222	7.558555556	1217	70	7	4	66.67	Between	Poor	50	5	20	10	0	10
6	Tronsbu	60.28475	7.558583333	1213	70	11	3.45	83.33	Between	Poor	40	40	30	10	10	10
7	Tronsbu	60.28475	7.558694444	1213	70	5	3.7	100	Snowbed	Poor	10	10	20	40	20	10
8	Tronsbu	60.28555556	7.548388889	1225	58	2	2.45	0.00	Ridge	Poor	80	0	10	10	0	5
9	Tronsbu	60.28558333	7.548388889	1226	58	4	3.45	16.67	Ridge	Poor	50	5	5	40	0	5
10	Tronsbu	60.28561111	7.548472222	1229	58	7	3.27	33.33	Between	Poor	50	5	5	40	0	5
11	Tronsbu	60.28561111	7.548527778	1227	58	9	4.09	50.00	Between	Poor	50	5	5	40	0	0
12	Tronsbu	60.28563889	7.548583333	1227	58	12	3.61	66.67	Between	Poor	40	10	20	20	0	0
13	Tronsbu	60.28563889	7.548638889	1226	58	21	4.58	83.33	Between	Poor	20	30	30	20	0	0
14	Tronsbu	60.28563889	7.548722222	1226	58	8	4.71	100	Snowbed	Poor	10	5	50	10	20	20
15	Tronsbu	60.28619444	7.550027778	1225	54	2	2.64	0.00	Ridge	Poor	80	0	10	5	0	10
16	Tronsbu	60.28619444	7.550083333	1221	54	3	2.36	14.29	Ridge	Poor	90	0	5	5	0	5
17	Tronsbu	60.28619444	7.550138889	1220	54	20	3.75	28.57	Between	Poor	50	5	40	5	0	10
18	Tronsbu	60.28622222	7.550222222	1218	54	18	3.8	42.86	Between	Poor	60	5	20	5	0	10
19	Tronsbu	60.28625	7.550277778	1220	54	18	3.81	57.14	Between	Poor	50	5	30	5	0	20
20	Tronsbu	60.28627778	7.550305556	1222	54	12	4.26	71.43	Between	Poor	30	5	50	5	0	20

21	Tronsbu	60.28630556	7.550361111	1218	54	14	4.13	85.71	Between	Poor	30	5	40	10	0	20
22	Tronsbu	60.28630556	7.550416667	1217	54	4	4.36	100	Snowbed	Poor	10	5	40	20	20	30
23	Tronsbu	60.28669444	7.543611111	1231	74	4	2.4	0.00	Ridge	Poor	70	0	20	5	0	0
24	Tronsbu	60.27108333	7.571083333	1217	310	6	2.15	20.00	Ridge	Poor	70	0	20	5	0	10
25	Tronsbu	60.27113889	7.571	1218	310	8	2.27	40.00	Between	Poor	70	0	20	10	5	5
26	Tronsbu	60.27113889	7.570944444	1218	310	16	3.15	60.00	Between	Poor	60	5	20	20	5	5
27	Tronsbu	60.27116667	7.570944444	1215	310	16	3.87	80.00	Between	Poor	40	5	60	5	0	0
28	Tronsbu	60.27119444	7.570861111	1214	310	12	4.41	100	Snowbed	Poor	20	20	20	30	5	10
29	Tronsbu	60.27033333	7.572194444	1224	102	2	2.16	0.00	Ridge	Poor	70	0	30	5	0	10
30	Tronsbu	60.27030556	7.572194444	1223	102	4	1.72	20.00	Ridge	Poor	50	0	50	5	0	5
31	Tronsbu	60.27030556	7.57225	1221	102	6	2.27	40.00	Between	Poor	60	5	30	5	10	0
32	Tronsbu	60.27033333	7.572305556	1224	102	16	2.83	60.00	Between	Poor	60	0	30	10	0	0
33	Tronsbu	60.27030556	7.572416667	1219	102	16	4.12	80.00	Between	Poor	10	5	70	10	0	0
34	Tronsbu	60.27033333	7.572444444	1218	102	6	4.26	100	Snowbed	Poor	10	10	20	50	5	10
35	Tronsbu	60.26808333	7.575027778	1224	106	6	2.33	0.00	Ridge	Poor	70	0	20	5	0	5
36	Tronsbu	60.26811111	7.575083333	1224	106	4	2.08	20.00	Ridge	Poor	70	0	10	10	0	10
37	Tronsbu	60.26811111	7.575194444	1226	106	12	3.6	40.00	Between	Poor	50	5	30	10	0	10
38	Tronsbu	60.26808333	7.57525	1227	106	16	3.68	60.00	Between	Poor	40	5	50	10	0	5
39	Tronsbu	60.26808333	7.575333333	1224	106	12	4.35	80.00	Between	Poor	40	10	20	30	0	5
40	Tronsbu	60.26808333	7.575361111	1223	106	8	4.07	100	Snowbed	Poor	10	20	30	30	10	10
41	Tronsbu	60.26711111	7.5755	1224	350	2	2.25	0.00	Ridge	Poor	80	0	20	5	0	5
42	Tronsbu	60.26716667	7.5755	1221	350	4	2.2	20.00	Ridge	Poor	80	0	10	5	0	10
43	Tronsbu	60.26719444	7.5755	1218	350	4	2.33	40.00	Between	Poor	60	0	30	5	0	10
44	Tronsbu	60.26722222	7.5755	1220	350	16	3.26	60.00	Between	Poor	60	0	40	5	0	5
45	Tronsbu	60.26727778	7.575472222	1219	350	28	4.06	80.00	Between	Poor	20	5	60	5	10	10
46	Tronsbu	60.26730556	7.575472222	1216	350	12	4.2	100	Snowbed	Poor	5	10	60	20	10	0
47	Tronsbu	60.26519444	7.574777778	1223	40	2	2.3	0.00	Ridge	Poor	80	0	20	5	0	5

48	Tronsbu	60.26516667	7.574861111	1220	40	4	2.21	20.00	Ridge	Poor	70	0	30	5	0	10
49	Tronsbu	60.26511111	7.574861111	1219	40	12	3.46	40.00	Between	Poor	60	0	20	5	0	20
50	Tronsbu	60.26508333	7.574861111	1219	40	12	3.75	60.00	Between	Poor	20	10	50	20	0	10
51	Tronsbu	60.26505556	7.574916667	1222	40	14	3.7	80.00	Between	Poor	20	10	40	30	0	10
52	Tronsbu	60.26502778	7.574944444	1221	40	6	4.64	100	Snowbed	Poor	5	10	40	40	10	10
53	Tronsbu	60.27397222	7.563444444	1218	50	4	3.46	0.00	Ridge	Poor	70	0	20	5	0	10
54	Tronsbu	60.27397222	7.5635	1221	50	10	2.81	20.00	Ridge	Poor	70	0	20	5	0	10
55	Tronsbu	60.27397222	7.5635	1221	50	18	3	40.00	Between	Poor	50	0	20	10	20	5
56	Tronsbu	60.27402778	7.563638889	1219	50	18	3.26	60.00	Between	Poor	40	5	40	20	5	10
57	Tronsbu	60.27402778	7.563694444	1220	50	24	4.06	80.00	Between	Poor	20	5	50	10	0	20
58	Tronsbu	60.27405556	7.563722222	1220	50	8	4.4	100	Snowbed	Poor	5	20	30	40	10	10
59	Sanhau	60.19111111	7.479027778	1303	170	10	2.4	0.00	Ridge	Rich	70	0	10	5	0	20
60	Sanhau	60.19111111	7.479055556	1307	170	8	2.23	20.00	Between	Rich	50	0	30	5	0	20
61	Sanhau	60.19108333	7.479083333	1306	170	24	2.5	40.00	Between	Rich	60	0	30	5	0	10
62	Sanhau	60.191	7.479111111	1299	170	22	3.85	60.00	Between	Rich	40	5	40	10	0	5
63	Sanhau	60.19094444	7.479166667	1301	170	14	4.3	80.00	Snowbed	Rich	10	5	40	50	10	0
64	Sanhau	60.19094444	7.479083333	1299	170	12	5.53	100	Snowbed	Rich	10	5	20	70	10	0
65	Sanhau	60.191	7.476611111	1283	206	12	2.46	0.00	Ridge	Rich	60	0	40	5	0	0
66	Sanhau	60.191	7.476555556	1286	206	12	2.45	20.00	Ridge	Poor	50	0	40	5	0	10
67	Sanhau	60.19097222	7.476555556	1281	206	16	2.6	40.00	Between	Poor	60	0	40	5	0	5
68	Sanhau	60.19094444	7.476472222	1282	206	20	3.08	60.00	Between	Poor	50	5	50	5	0	5
69	Sanhau	60.19088889	7.476472222	1280	206	20	3.91	80.00	Between	Poor	30	5	60	10	0	5
70	Sanhau	60.19088889	7.476416667	1275	206	10	4.93	100	Snowbed	Poor	20	5	40	50	10	5
71	Sanhau	60.19241667	7.477055556	1298	256	10	2.33	0.00	Ridge	Rich	60	0	40	5	0	5
72	Sanhau	60.19241667	7.476972222	1298	256	18	3.33	20.00	Between	Rich	50	10	30	5	0	10
73	Sanhau	60.19238889	7.476916667	1295	256	18	3.3	40.00	Between	Rich	60	5	30	5	0	10
74	Sanhau	60.19238889	7.476833333	1294	256	22	3.84	60.00	Between	Rich	40	5	50	5	0	0

75	Sanhau	60.19238889	7.476805556	1292	256	20	4.88	80.00	Between	Rich	5	10	30	60	0	5
76	Sanhau	60.19238889	7.476694444	1290	256	4	6.13	100	Snowbed	Rich	5	10	20	60	10	5
77	Sanhau	60.19452778	7.477222222	1309	200	2	2.25	0.00	Ridge	Rich	80	0	10	10	0	0
78	Sanhau	60.19447222	7.477166667	1307	200	5	2.35	20.00	Between	Rich	40	0	60	5	0	10
79	Sanhau	60.19447222	7.477111111	1307	200	25	2.91	40.00	Between	Rich	70	5	30	0	0	0
80	Sanhau	60.19441667	7.477055556	1306	200	20	3.11	60.00	Between	Rich	50	0	40	10	0	0
81	Sanhau	60.19438889	7.477027778	1305	200	18	3.75	80.00	Between	Rich	40	0	10	50	0	0
82	Sanhau	60.19438889	7.476972222	1303	200	20	4.92	100	Snowbed	Rich	5	10	0	90	10	0
83	Sanhau	60.19419444	7.477861111	1309	240	2	2.14	0.00	Ridge	Rich	80	0	10	5	0	5
84	Sanhau	60.19419444	7.47775	1312	240	16	2.23	25.00	Ridge	Rich	80	0	10	5	0	10
85	Sanhau	60.19419444	7.477694444	1312	240	14	3.36	50.00	Between	Rich	50	5	40	10	0	0
86	Sanhau	60.19416667	7.477583333	1311	240	8	4.37	75.00	Between	Rich	20	10	10	60	0	0
87	Sanhau	60.19413889	7.477555556	1308	240	4	4.47	100	Snowbed	Rich	30	5	40	40	0	0
88	Sanhau	60.19011111	7.472888889	1262	240	4	2.15	0.00	Ridge	Poor	80	0	20	5	5	0
89	Sanhau	60.19008333	7.472861111	1261	240	10	3.27	14.29	Between	Poor	70	0	20	10	5	0
90	Sanhau	60.19005556	7.47275	1254	240	8	3.4	28.57	Between	Poor	30	5	60	10	5	5
91	Sanhau	60.19002778	7.472694444	1254	240	6	3.1	42.86	Between	Poor	40	0	60	5	0	0
92	Sanhau	60.19	7.472611111	1251	240	16	4.2	57.14	Between	Poor	50	5	30	20	5	5
93	Sanhau	60.18997222	7.472611111	1254	240	2	4.21	71.43	Between	Poor	5	5	30	70	10	0
94	Sanhau	60.18997222	7.472527778	1250	240	2	4.58	85.71	Snowbed	Poor	5	5	10	90	10	0
95	Sanhau	60.18991667	7.472472222	1252	240	2	6.16	100	Snowbed	Poor	0	10	5	90	5	0
96	Sanhau	60.19094444	7.472638889	1263	230	10	3.84	0.00	Ridge	Poor	70	0	20	10	0	0
97	Sanhau	60.19091667	7.472583333	1259	230	14	3.33	14.29	Between	Poor	50	5	30	10	0	5
98	Sanhau	60.19088889	7.4725	1263	230	8	3.78	28.57	Between	Poor	40	5	50	10	5	5
99	Sanhau	60.19088889	7.472444444	1259	230	10	4	42.86	Between	Poor	40	5	60	5	5	5
100	Sanhau	60.19086111	7.472388889	1258	230	12	4.17	57.14	Between	Poor	30	5	50	20	5	5
101	Sanhau	60.19086111	7.472305556	1255	230	12	3.8	71.43	Between	Poor	10	10	40	40	0	10

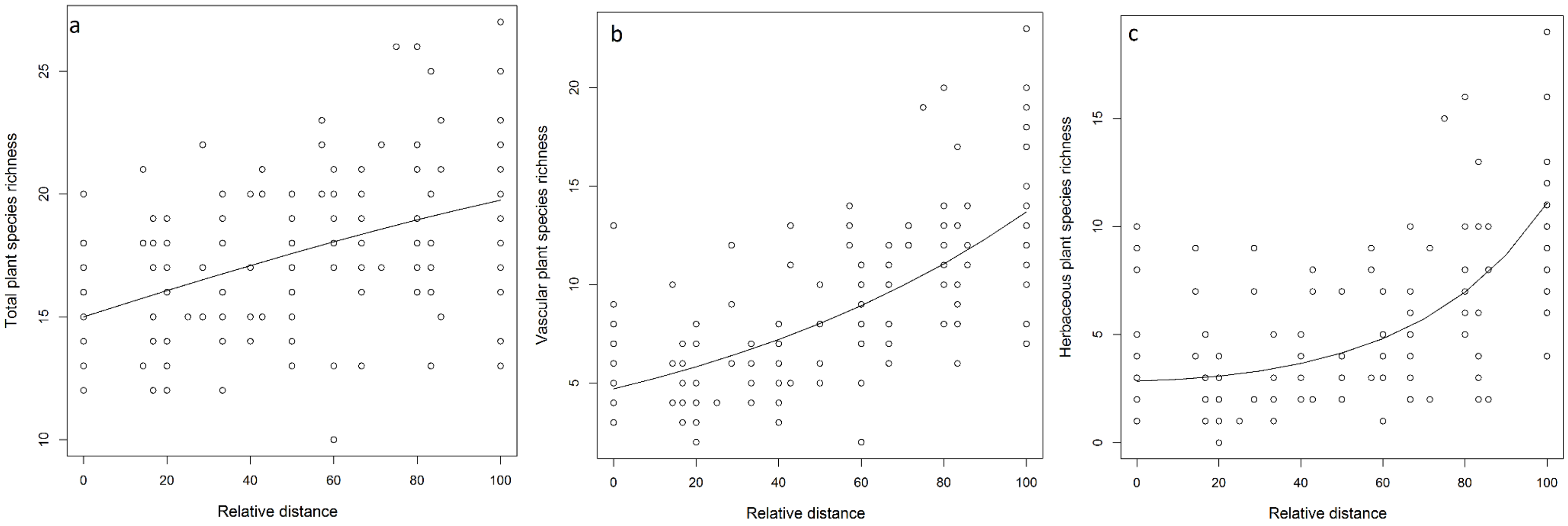
102	Sanhau	60.19083333	7.47225	1255	230	14	4.11	85.71	Between	Poor	50	5	40	5	0	0
103	Sanhau	60.19077778	7.472166667	1259	230	4	4.88	100	Snowbed	Poor	10	10	10	70	5	5
104	Sanhau	60.19519444	7.4725	1290	260	4	2.5	0.00	Ridge	Poor	80	0	20	5	0	5
105	Sanhau	60.19516667	7.472444444	1286	260	10	3	16.67	Ridge	Poor	70	0	30	5	0	5
106	Sanhau	60.19516667	7.472361111	1284	260	10	2.5	33.33	Between	Poor	60	0	5	5	0	0
107	Sanhau	60.19516667	7.472305556	1282	260	12	2.9	50.00	Between	Poor	60	0	40	5	0	0
108	Sanhau	60.19516667	7.472194444	1284	260	12	3.36	66.67	Between	Poor	40	0	60	5	5	0
109	Sanhau	60.19513889	7.472138889	1281	260	22	4	83.33	Between	Poor	30	0	70	10	0	0
110	Sanhau	60.19513889	7.472083333	1281	260	4	4.87	100	Snowbed	Poor	10	40	10	40	10	0
111	Besso	60.18480556	7.398138889	1263	146	4	2.27	0.00	Ridge	Rich	80	0	20	5	5	5
112	Besso	60.18477778	7.398166667	1266	146	4	2.27	16.67	Between	Rich	40	0	60	5	0	0
113	Besso	60.18475	7.398194444	1267	146	6	2.28	33.33	Between	Rich	60	0	40	5	5	0
114	Besso	60.18475	7.39825	1269	146	12	2.25	50.00	Between	Rich	60	0	40	5	0	0
115	Besso	60.18469444	7.398277778	1266	146	20	2.5	66.67	Between	Rich	40	0	60	5	5	5
116	Besso	60.18469444	7.398361111	1264	146	24	2.83	83.33	Between	Rich	50	0	50	5	0	5
117	Besso	60.18461111	7.398361111	1261	146	14	5.07	100	Snowbed	Rich	5	10	60	30	5	0
118	Besso	60.186	7.3945	1288	300	2	2.86	0.00	Ridge	Rich	80	0	20	0	0	0
119	Besso	60.18602778	7.394444444	1290	300	6	2.8	16.67	Ridge	Rich	70	0	20	0	0	10
120	Besso	60.18602778	7.394444444	1293	300	4	2.56	33.33	Between	Rich	70	0	20	5	0	10
121	Besso	60.18602778	7.394388889	1290	300	8	2.76	50.00	Between	Rich	60	0	20	5	0	20
122	Besso	60.18605556	7.394277778	1295	300	28	3.25	66.67	Between	Rich	30	0	60	0	30	0
123	Besso	60.18608333	7.394222222	1290	300	16	3.75	83.33	Between	Rich	5	5	80	10	10	0
124	Besso	60.18611111	7.394166667	1289	300	10	3.69	100	Snowbed	Rich	10	5	80	5	5	10
125	Besso	60.18613889	7.390888889	1298	340	2	2.8	0.00	Ridge	Rich	50	0	40	5	0	10
126	Besso	60.18616667	7.390861111	1296	340	8	2.5	16.67	Ridge	Rich	50	0	40	5	5	10
127	Besso	60.18619444	7.390833333	1296	340	12	2	33.33	Between	Rich	50	0	50	5	5	5
128	Besso	60.18625	7.390861111	1298	340	16	3	50.00	Between	Rich	30	0	70	10	5	0

129	Besso	60.18625	7.390638889	1293	340	20	3.45	66.67	Between	Rich	40	0	60	5	5	0
130	Besso	60.18630556	7.390805556	1294	340	24	4.66	83.33	Between	Rich	10	10	70	10	10	5
131	Besso	60.18633333	7.390805556	1293	340	4	4.66	100	Snowbed	Rich	5	20	40	30	10	0
132	Besso	60.17666667	7.383111111	1304	340	4	4.46	0.00	Ridge	Rich	60	0	30	5	10	5
133	Besso	60.17669444	7.383194444	1305	340	8	2.41	16.67	Between	Rich	30	5	60	5	10	5
134	Besso	60.17669444	7.383277778	1307	340	8	2.5	33.33	Between	Rich	40	0	60	5	10	5
135	Besso	60.17669444	7.383305556	1302	340	6	2.35	50.00	Between	Rich	30	0	30	5	10	30
136	Besso	60.17669444	7.383388889	1299	340	18	3.64	66.67	Between	Rich	40	5	60	5	5	5
137	Besso	60.17672222	7.383444444	1298	340	18	3.83	83.33	Between	Rich	5	5	20	70	10	0
138	Besso	60.17672222	7.383527778	1297	340	2	4.12	100	Snowbed	Rich	10	10	40	40	5	10
139	Besso	60.17794444	7.386833333	1304	274	6	2.69	0.00	Ridge	Rich	70	5	20	10	0	5
140	Besso	60.17797222	7.38675	1309	274	12	2.35	16.67	Between	Rich	60	0	30	5	5	10
141	Besso	60.17797222	7.386722222	1305	274	14	2.8	33.33	Between	Rich	20	0	80	5	0	10
142	Besso	60.17797222	7.386638889	1307	274	18	2.73	50.00	Between	Rich	40	0	50	5	0	5
143	Besso	60.17797222	7.386583333	1305	274	16	3.64	66.67	Between	Rich	60	0	30	10	5	5
144	Besso	60.17794444	7.3865	1298	274	12	4.3	83.33	Between	Rich	40	5	40	20	5	0
145	Besso	60.17797222	7.386416667	1299	274	2	5.08	100	Snowbed	Rich	5	5	30	70	0	5
146	Besso	60.17847222	7.389472222	1312	120	6	2.23	0.00	Ridge	Rich	50	5	50	5	5	5
147	Besso	60.17847222	7.3895	1313	120	6	2.57	20.00	Between	Rich	40	0	50	5	5	10
148	Besso	60.17844444	7.389555556	1314	120	18	2.37	40.00	Between	Rich	70	0	30	5	5	5
149	Besso	60.17841667	7.389583333	1313	120	20	2.5	60.00	Between	Rich	20	0	80	5	0	0
150	Besso	60.17838889	7.389611111	1309	120	26	3.86	80.00	Between	Rich	20	5	40	40	5	5
151	Besso	60.17833333	7.389666667	1306	120	6	6	100	Snowbed	Rich	5	10	20	70	0	0

*WASI- Weighted average snow indicator value

**RD- Relative distance

Appendix 3. Species richness of total plant species and different life forms with relative distance.



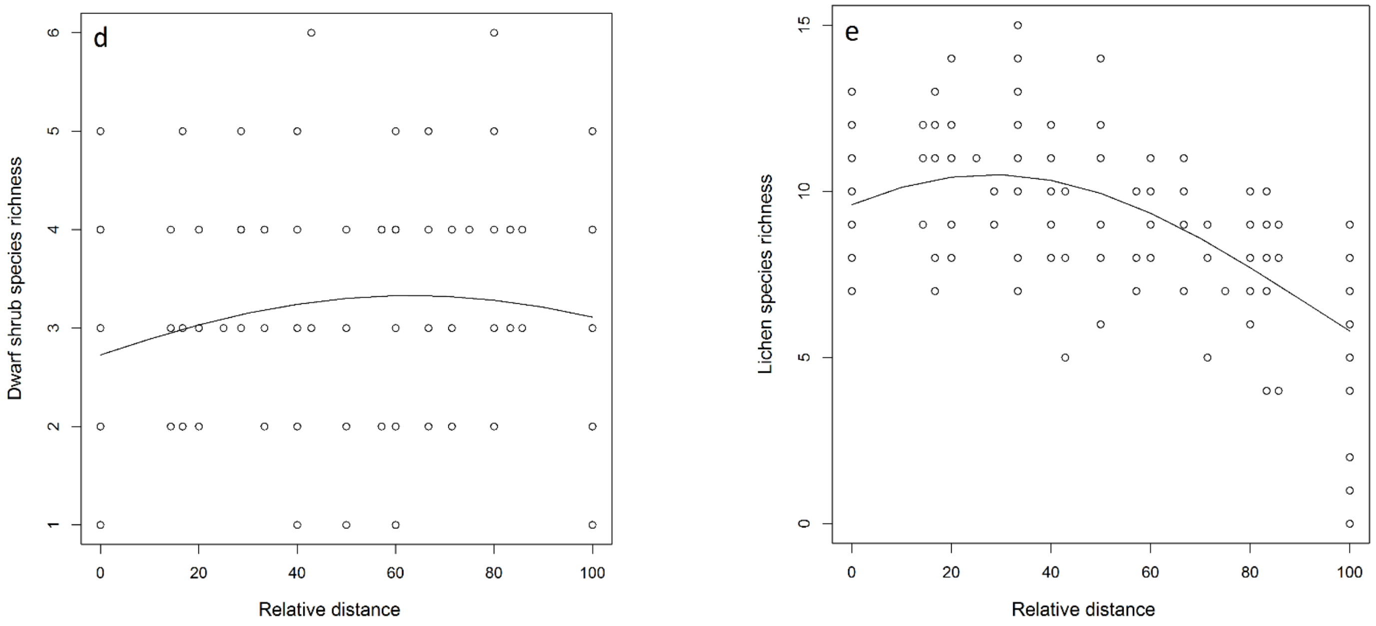


Figure 7. Species richness of: a) total plant species, b) vascular plant species c) herbaceous plant species, d) dwarf shrub species and e) lichen species with relative distance.