The influence of orography on species composition and phenology at mountain summits of Nuolja and Slåttatjåkka, Sweden.

Bachelor Thesis

B.Sc. Landscape Ecology and Nature Conservation

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List of abbreviations

a.s.l.	above sea level
e.g.	exempli gratia, for example
FFD	first flowering date
i.e.	id est, that is
Mt.	Mountain
LFD	last flowering date

1 Abstract

Plant species inhabiting mountain regions are particularly sensitive to recent rapid climate changes. With a warming climate, range limits of species are extending upwards and polewards which results in shrinking alpine zones. Investigations of mountain summits show the disappearance of some alpine adapted plant species but an increase in species richness which intensifies with acceleration in climate warming. Plants' life and distribution is influenced by abiotic and biotic factors, for example, weather, soil nutrients and competition. In this study the influence of aspect on species distribution and phenology was investigated with the aim of finding out how much regional climate conditions are affecting mountain summit's vegetation. The survey was conducted on two mountain summits in Abisko National Park, Northern Sweden. During the growing season, on each summit presence and phenology data were recorded within five randomly distributed plots in each cardinal direction. Data were analysed to find out the relationship between species distributions and phenology and aspect. Results show that the distribution of plants does not correlate with aspect but an effect of small-scale topography can be assumed. Beginning of flowering is influenced by aspect resulting in differences between the eastern and western slope. However, an additional influence of microclimate variability of slope cannot be excluded. The duration of flowering correlates with the different functional plant groups and certain functional plant groups show a correlation of flowering duration and aspect. In conclusion this study has shown that aspect has an influence on the lives of alpine plants, but small-scale topography of each slope also significantly influences the vegetation on mountain summits. Therefore, the relationship between orography and weather and its influence on alpine plants should be considered when predicting climate change impacts on mountain summits' vegetation.

2 Introduction

Species inhabiting mountain regions are particularly sensitive to recent rapid climate changes (Ernakovich et al. 2014; European Commission 2004) . Here species live close to their distributional limits and must be adapted to harsh environmental conditions. This includes the ability to deal with short growing seasons, low temperatures and strong wind effects. Additionally, plants must be adapted to stochastic frost and snow events. Therefore, many species take advantage of more favourable microclimatic conditions near the surface as low stature life forms (Bliss 1962).

With warming climate, range limits of species are extending upwards and polewards, in altitude and latitude, respectively. This way species try to track their preferred climatic niche (Chen et al. 2011; Klanderud and Birks 2003; Gottfried et al. 1999), resulting in shifts of distribution, vegetation zones (Gottfried et al. 2012) and communities turnover (Thuiller et al. 2005). These effects are especially pronounced on mountain summits, as species cannot expand beyond the summit (Rixen and Wipf 2017). This results in shrinking alpine zones (Rixen and Wipf 2017; Engler et al. 2011; Gottfried et al. 2012) and disappearance of some alpine adapted plant species (Dullinger et al. 2012; Thuiller et al. 2005). However, investigations of mountain summits show an increase in species richness which intensifies with acceleration in climate warming [Steinbauer et al. 2018].

Since 1850 global mean temperatures have increased by 1.1 ± 0.1 °C through 2019 (World Meteorological Organization 2019). High altitude and latitude areas show an average warming rate of 0.8 °C per decade with a likely range of ± 0.2 °C (Hock et al. 2019). It is projected that according to the four fossil fuel emission scenarios the global mean surface temperature will likely increase by 0.3 to 0.7 °C within the next 20 years (IPCC 2013). However, warming in mountain areas will be greater and regardless of the climate scenario, temperatures will likely continue to increase by 0.8 °C per decade until mid-21st century (Hock et al. 2019). The level of warming varies for different regions (IPCC 2013) and different mountain regions are differently intense affected (Engler et al. 2011). Therefore, observations on mountain summits are particularly interesting for climate change research as species occupying them face distributional limits at the summits and dispersal constraints (Rixen and Wipf 2017).

The shape of mountain summits influences the intensity of environmental conditions, e.g. wind, temperature, precipitation, snow accumulation and soil properties and thereby creates microclimatic habitats for plants. This way the near-surface temperature can be considerably higher than the ambient air temperature (Scherrer and Körner 2010). This has even more distinct effects at high mountains and those with rough topography and thus, heavily influences plant’s development (e.g. timing and duration of flowering) and distribution of species on different mountain sides as these conditions can change over short distances (Körner 2003; Opedal et al. 2014; Winkler et al. 2016). The main environmental factors that determine flowering phenology of alpine plants are ambient temperature and timing of snowmelt

(Jia et al. 2011; Kudo and Hirao 2006). As microclimatic conditions differ from macroclimatic conditions, this could mean that the shape, slope and aspect of a mountain influence beside species distribution also the plant's phenological development.

In this study the effects of orography on mountain summit's vegetation are investigated on two peaks found in the north of Sweden. These two adjacent mountain peaks have a similar height and experience the same climatic conditions. However, orographic conditions are different on each peak. The overall aim of this study is to show how vegetation on mountain summits is affected by aspect and to this related regional climate conditions. This could show to which extend regional climate is influencing plants' distribution and development and if specific orographic conditions of the aspect might be important to consider when making predictions on climate change impact on mountain summit's vegetation.

In this study I ask how the aspect affects plant species distributions, species composition and timing of phenology on mountain summits. I hypothesize that the distribution of plant species, the communities and the timing of flowering and duration of flowering is dependent on aspect at mountain summits. I predict that

… the **species number** will be greater on eastern and southern slopes in comparison to northern and western slopes because of more moderate temperature conditions at eastern and southern slopes.

… **species composition** will be most similar between eastern and southern slopes as well as northern and western slopes because they experience more similar temperature conditions, respectively.

… the **beginning of flowering** will be earlier at northern and western slopes as these are the wind-blown areas where little snow accumulates and melts first at the onset of summer. Plants will flower later at eastern and southern slopes where snow melt occurs later.

… the **flowering duration** will be shorter at eastern and southern slopes in comparison to northern and western slopes because a later snow melt in the east and south of the summit means a shorter growing season and consequently a shorter flowering duration.

3 Methods

3.1 Study site description

Figure 1 Location of Abisko National Park in Sweden (Sverige).

Mt. Nuolja (68.37262961°N | 18.69783973°E) and Mt. Slåttatjåkka (68.35662537°N | 18.67856972°E) are located in Abisko National Park (Figure 1, Figure 2), 200 km north of the Arctic Circle in northern Sweden. Due to its location in the east of high mountains, the Abisko National Park is in rain shadow. Thus, the area around Abisko experiences very low precipitation regionally (approximately 310 mm / year) in comparison to the maritime climate only a short distance to the west. Most of the precipitation falls during the summer months. Snow persists in the lowlands usually from October through May, in higher elevation snow cover can be longer or even permanent. (Callaghan et al. 2010, p. 2; Kohler et al. 2006). The landscape is characterized by mountains with similar plant communities, for example low elevation birch forests, shrub zone and alpine habitats.

Mt. Nuolja and Mt. Slåttatjåkka are 1164 m above sea level (a.s.l.) and 1186 m a.s.l., respectively (Lantmäteriet 2020). As they are situated directly next to each other, from north to south, they experience the same regional climate (Figure 2). Prevailing winds are coming from north and west. This leads to more snow accumulation and more moderate winter soil temperatures on eastern and southern slopes in comparison to the other cardinal directions. Snow beds accumulate and remain longer in depressions and behind slope edges. The surface of the summits is partly very rocky and covered with mosses, lichens and low stature plants. The summit of Slåttatjåkka has a very rough and heterogenous surface with a rocky ridge that crosses the summit north to south compared to Nuolja. There, lichens and low stature woody plants, such as *Salix herbacea* and *Salix polaris*, are typical. Next to the ridge on Slåttatjåkka, is a long depression where snow remains long. Solar radiation is highest on southern and western slopes in the spring. However, differences in solar radiation diminish during the 24 hours daylight period and once snow has melted.

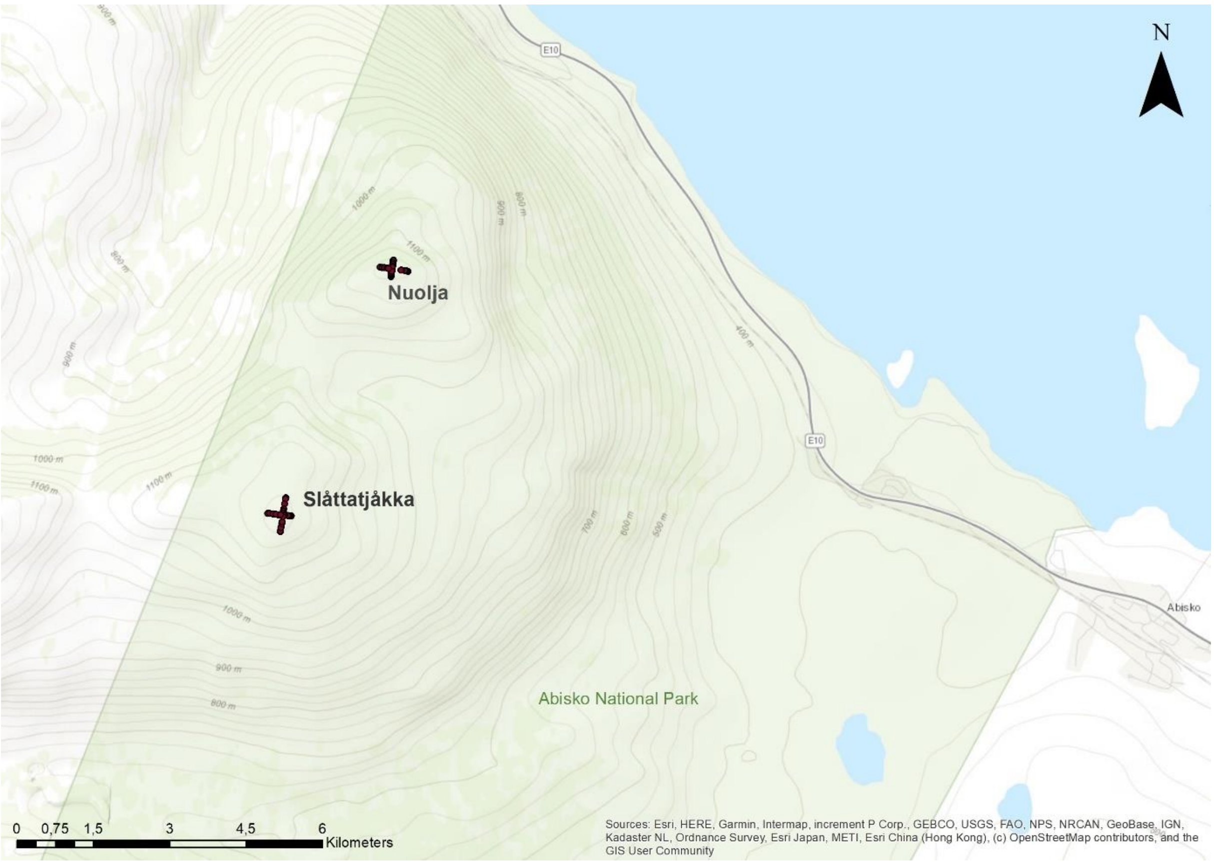

Figure 2 Map of study area. The study was conducted on two adjacent peaks of similar height in Abisko National Park. On each summit and in each cardinal direction five plots were distributed within the top ten metres of elevation.

3.2 Plot design

To find out how aspect affects the vegetation of mountain summits, the approach of this study was to randomly distribute plots in each cardinal direction at two mountain summits. For this, the elevation of the highest point on both summits was measured with the Trimble dGPS, accurate to 8 mm (horizontal) and 15 mm (vertical). As a centre point of each summit were taken obvious landmarks, i.e. the weather station on Nuolja and a stone cairn on Slåttatjåkka. The investigation area was restricted to the top ten metres of elevation (Figure 3). Using a compass and GPS, for each cardinal direction this was marked with a stick. Five 1m by 1m plots were randomly distributed along each line from the "summit" down to the 10 metres contour line for each of the four cardinal directions, i.e. north, east, south, and west (Figure 4, Figure 5). This made 20 plots on each peak (Appendix 2, Appendix 3). In case of very rocky surfaces or lacking vegetation, random locations were excluded and the next random location was chosen.

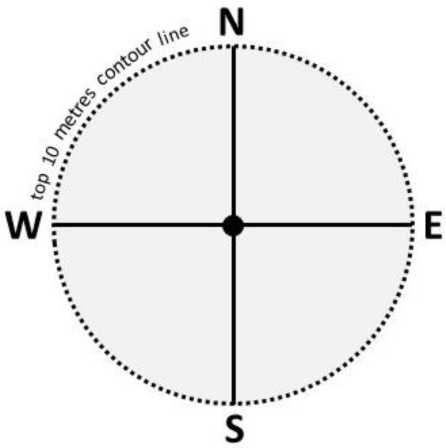

Figure 3 Hypothetical mountain summit. The summit as investigation area is restricted to the top ten metres of elevation

Each plot was square and delineated with corner markers. The corner that was measured with the dGPS, point towards southwest. This way all plots are positioned with the same orientation.

Each plot was named with the appropriate mountain's name plus the cardinal direction and a number. The cardinal directions are abbreviated with *"N"* for north, *"S"* for south, *"W"* for west and *"E"* for east. The numbers were assigned in the following way: *"1"* is the plot which is closest to the summit and *"5"* is the plot which is most distant from the summit, for example *"Nuolja_N1"*.

3.3 Data collection

Sampling was repeated six times at 15 days interval during the growing season, beginning on the 15th June 2019 and ending when each species predominantly finished flowering. For each plot the presence and the current phenological phase of each species was recorded. Only those plants were taken into account that rooted within the square. Branches of plants that just extended into the plot remained disregarded. The phenological state recorded was always the highest state of phenology that a species showed at that time. Here the codes created by Thore C. E. Fries, described in Appendix 1, were used (Fries 1925, p. 10). Lichens and mosses remained disregarded.

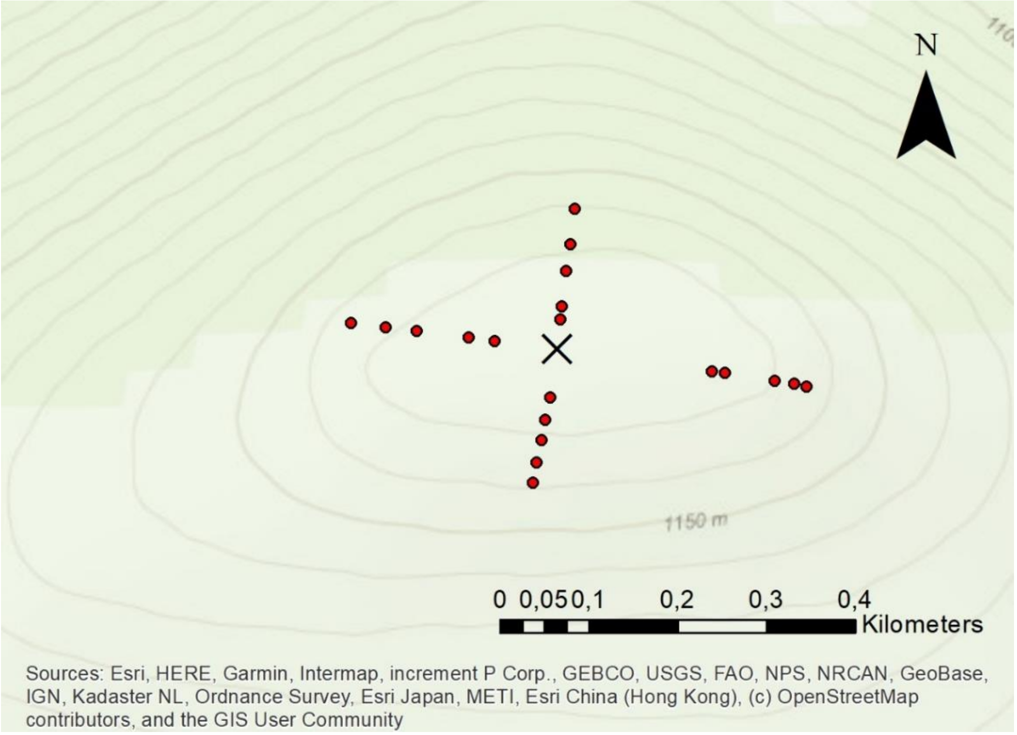

Figure 4 Distribution of plots on Mt. Nuolja. In each cardinal direction, five plots (red dots) were randomly distributed. As a reference point for the summit was taken the weather station. The black cross identifies the summit.

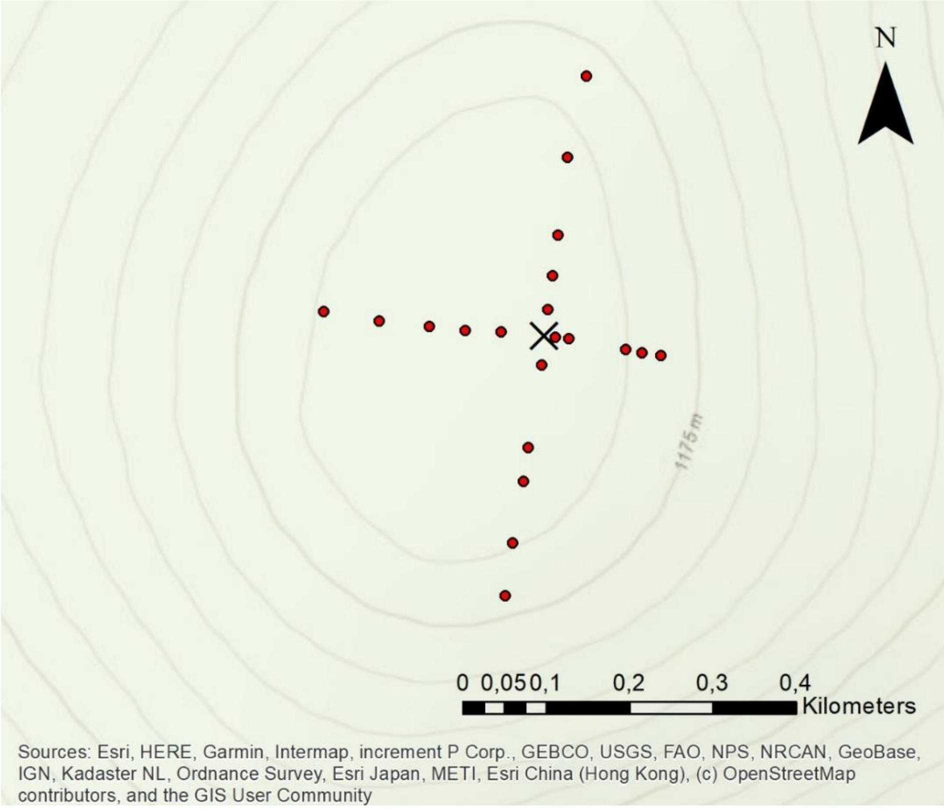

Figure 5 Distribution of plots on Mt. Slåttatjåkka. In each cardinal direction, five plots (red dots) were randomly distributed. As a reference point for the summit was taken a stone cairn. The black cross identifies the summit.

3.4 Data Analysis

Data analysis was conducted using the programmes Mircosoft Excel 2019 and R version 3.5.2 (R Core Team 2018).

3.4.1 Species distribution

Species richness

A dataset including plot number, peak, aspect and species number was created. Species number ~ aspect with random effect of peaks was statistically analysed with a linear mixed effect model and ANOVA using the R packages *lme4* (Bates et al. 2015) and *lmerTest* (Kuznetsova et al. 2017). Data of all plots on each summit and aspect were pooled and plotted in stacked bar charts using the R package *ggplot2* (Wickham 2016) and show the distribution of species richness and the proportion of functional plant groups by peak and aspect.

Similarity of species composition

For the analysis of similarity of species composition between the aspects, data sets were created showing for each species the number of plots which they inhabited at each aspect and summit. The Jaccard Index C_J measures the similarity of species composition between two samples. The more complementary two samples are, the higher is the beta diversity (Magurran 2004). The index can take values in the range 0 to 1. Zero means that two samples do not share any species and 1 means that species composition of two samples is completely the same.

$$C_J = \frac{a}{a + b + c}$$

- a = total number of species found in both samples
- b = total number of species only found in sample 1
- c = total number of species only found in sample 2

The index was calculated in R using the package *vegan* (Oksanen 2013).

3.4.2 Flowering phenology

I chose flowering phenology because this life history trait is typically correlated with environmental variables, such as snow melt and accumulation of solar radiation (Kudo and Hirao 2006). Specifically, first flowering date (FFD) and duration were investigated. All plots on each summit and cardinal direction were pooled for data analysis. A summarizing data set of flowering phenology was created that includes for each peak and aspect the functional group, FFD, last flowering date (LFD), flowering duration and flowering code of each recorded species.

First Flowering Date

FFD ~ aspect with random effect of peak was analysed with a linear mixed effect model and ANOVA using the R packages *lme4* (Bates et al. 2015)and *lmerTest* (Kuznetsova et al. 2017). Additionally, contrasts were computed for FFD ~ aspect using the R package *emmeans* (Lenth 2020). For visualization and analysis of the FFD the flowering data were plotted in stacked bar charts using the R package *ggplot2* (Wickham 2016) and show the distribution of FFD and proportion of functional plant group by peak and aspect.

Flowering Duration

Duration is defined as the difference between FFD and LFD. Duration data were statistically analysed with a linear mixed effect model and ANOVA using the R packages *lme4* (Bates et al. 2015) and *lmerTest* (Kuznetsova et al. 2017). Duration ~ aspect * functional group with random effect of peak was calculated. For visualization the data were plotted in stacked bar charts with the R package *ggplot2* (Wickham 2016) and show the distribution of flowering durations and proportion of functional plant groups by peak and aspect.

4 Results

4.1 Species distribution

4.1.1 Species richness

Nuolja had the highest species numbers in the East (19 species) and South (18 species). Plots in the West (10 species) showed a smaller species number in comparison to the other aspects (Figure 6). In contrast, highest species numbers on Slåttatjåkka were found in the East (16 species) and West (17 species) compared to slopes in the North (9 species) and South (8 species) (Figure 6). However, differences between the aspects are not significant (P > 0.05, Appendix 4.1). Species distribution and species richness of each plot by peak and aspect is shown in Appendix 5 and Appendix 6, respectively.

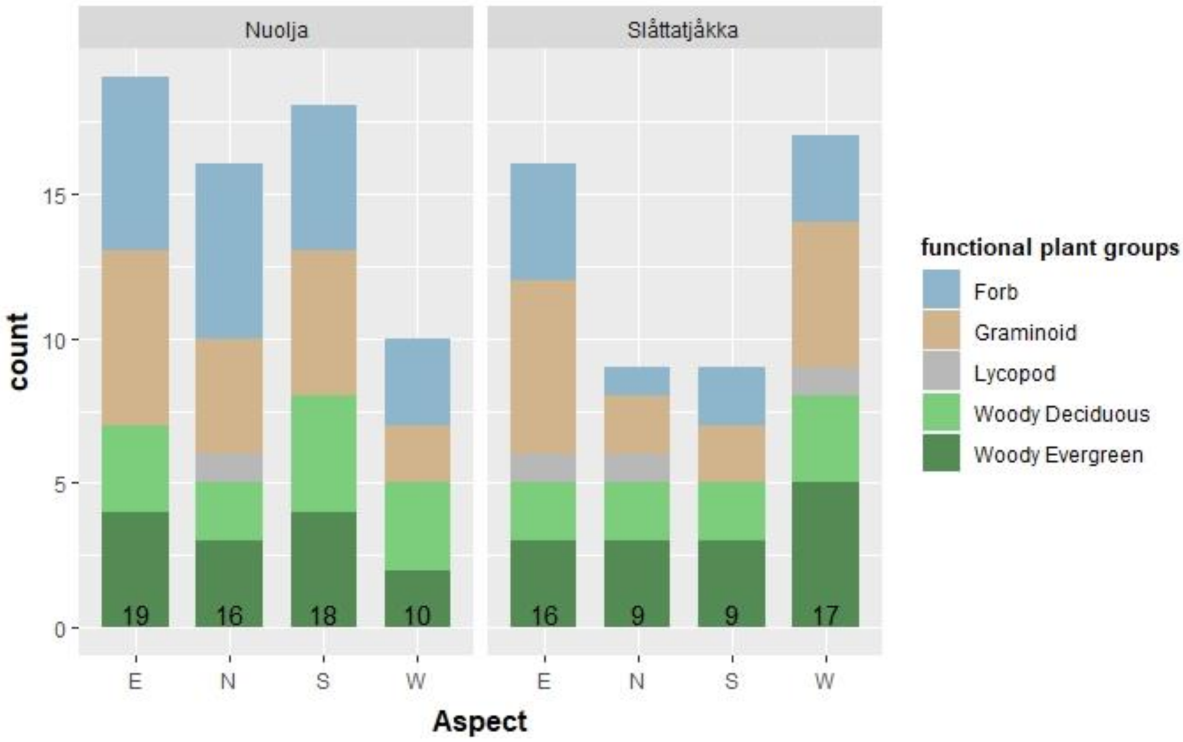

Figure 6 Species richness of each aspect for the summits of Mt. Nuolja and Mt. Slåttatjåkka. The x-axis shows the aspects north east (E), north (N), south (S) and west (W). The y-axis shows the count of each species. Each bar shows the proportion (in counts) of functional plant groups of the total amount of species.

4.1.2 Similarity of species composition

The comparison of similarity of species composition between the aspects shows index values between 0.424 and 0.553. The lowest similarities were calculated for east ~ south and north ~ west. The highest similarity was calculated for north ~ south. (Table 1)

Table 1 Jaccard Index of similarity calculated for the aspects north (N), east (E), south (S) and west (W). The index can take values in the range 0 to 1. Zero means that two samples do not share any species and 1 means that species composition of two samples is completely the same. The table shows the similarity of species composition between two aspects.

Aspect		N	E	S
Aspect	E	0.500		
	S	0.553	0.424	
	W	0.425	0.442	0.489

On Nuolja, the index takes values from 0.421 (east ~ south) to 0.656 (north ~ south). On Slåttatjåkka values range from 0.44 (north ~ south) to 0.514 (north ~ west). This shows that aspects on Slåttatjåkka were less similar than on Nuolja. On Slåttatjåkka, eastern and western slopes as well as northern and southern slopes were most dissimilar. On Nuolja, the lowest similarity was calculated for the eastern and southern slope as well as for the northern and western slope. The comparison of aspects of both peaks shows that Nuolja's western slope and Slåttatjåkka's eastern as well as southern slope shared less than 50% same species. The same accounts for Nuolja's northern slope and Slåttatjåkka's eastern slope (Table 2).

Table 2 Jaccard Index of similarity calculated for each aspect of the two summits of Mt. Nuolja and Mt. Slåttatjåkka. Aspects are abbreviated like the following: north (N), east (E), south (S) and west (W). The index can take values in the range 0 to 1. Zero means that two samples do not share any species and 1 means that species composition of two samples is completely the same. The table shows the similarity of species composition between two aspects.

		Nuolja				Slåttatjåkka		
		N	E	S	W	N	E	S
Nuolja	E	0.600						
	S	0.656	0.421					
	W	0.467	0.625	0.611				
Slåttatjåkka	N	0.634	0.720	0.735	0.639			
	E	0.489	0.509	0.672	0.476	0.500		
	S	0.525	0.604	0.617	0.471	0.440	0.500	
	W	0.585	0.569	0.627	0.583	0.514	0.444	0.513

4.2 Flowering phenology

4.2.1 First Flowering Date (FFD)

On both peaks and each aspect, most species showed FFD at the first survey date of each peak (Figure 7). Eastern slopes showed FFD on every sampling day, means early and late FFD. On the other slopes were not found any or only a small number of species with late FFD. At northern and southern slopes on Slåttatjåkka only species were found that flowered early. In the same cardinal directions on Nuolja species additionally started flowering in the mid of the sample period. Western slopes of both peaks show mainly species with early FFD except for one species on Slåttatjåkka that started flowering later. Analysis shows that differences in FFD among the aspects are significant ($P < 0.01$, Appendix 4.2). When contrasting two aspects, significant difference was found for eastern and western slopes ($P < 0.05$, Appendix 4.3).

Min, max and mean FFD for all species by functional plant group, peak and aspect are shown in Appendix 7.

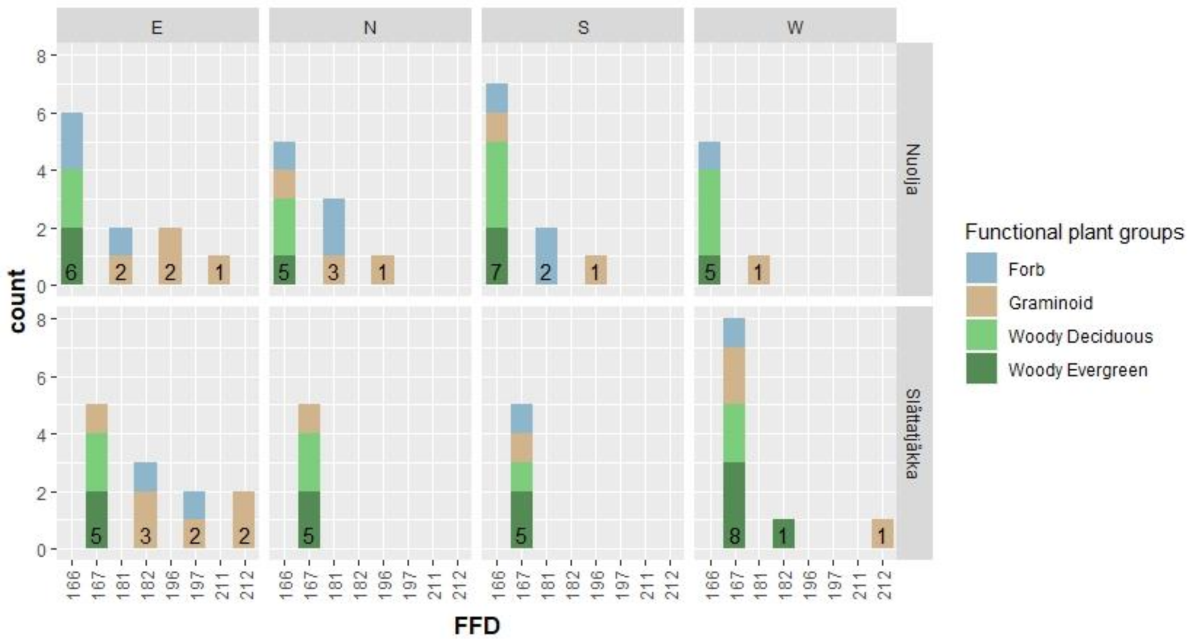

Figure 7 Distribution of first flowering dates (FFD) by aspects on Mt. Nuolja and Mt. Slåttatjåkka. The FFD is the observation date when a species flowered first in the season. The number of FFD on each sampling day is shown for each aspect east (E), north (N), south (S) and west (W) on Nuolja's and Slåttatjåkka's summit. Sampling days are shown as day of year on the x-axis. The number of first flowering dates is shown as counts on the y-axis. Bars show the proportion (in counts) of each functional plant group of the total count on that sampling day.

4.2.2 Flowering Duration

On each aspect the majority of species flowered between 30 and 75 days (Figure 8). Species flowered on Nuolja for at least 30 days, except for one species at the north slope. The maximum flowering duration on Nuolja ‘s aspects was 75 days, except for the western slope where the maximum flowering duration was 60 days. The eastern and western slopes of Slåttatjåkka showed flowering durations within a range from less than 15 days to 75 days. Most of these flowered between 30 and 45 days. On Slåttatjåkka ’s northern slope flowered most species 30 days except for one species flowering 60 and one species flowering 75 days. On the southern slope of Slåttatjåkka, species flowered at least for 30 days and up to 75 days at maximum. Differences between flowering duration among aspects are not significant (P > 0.5, Appendix 4.4).

However, there is a significant interaction of aspect and functional group (P < 0.001, Appendix 4.4). Flowering duration of forbs and graminoids varies more among the aspects than the flowering durations of woody plants which flowered rather long. Furthermore, functional plant groups show significant differences in flowering duration (P < 0.05, Appendix 4.4). In general, graminoids showed the shortest flowering duration (15 and less days) and evergreen woody plants the longest durations (75 days).

Durations of all species by functional plant group, peak and aspect are shown in Appendix 8.

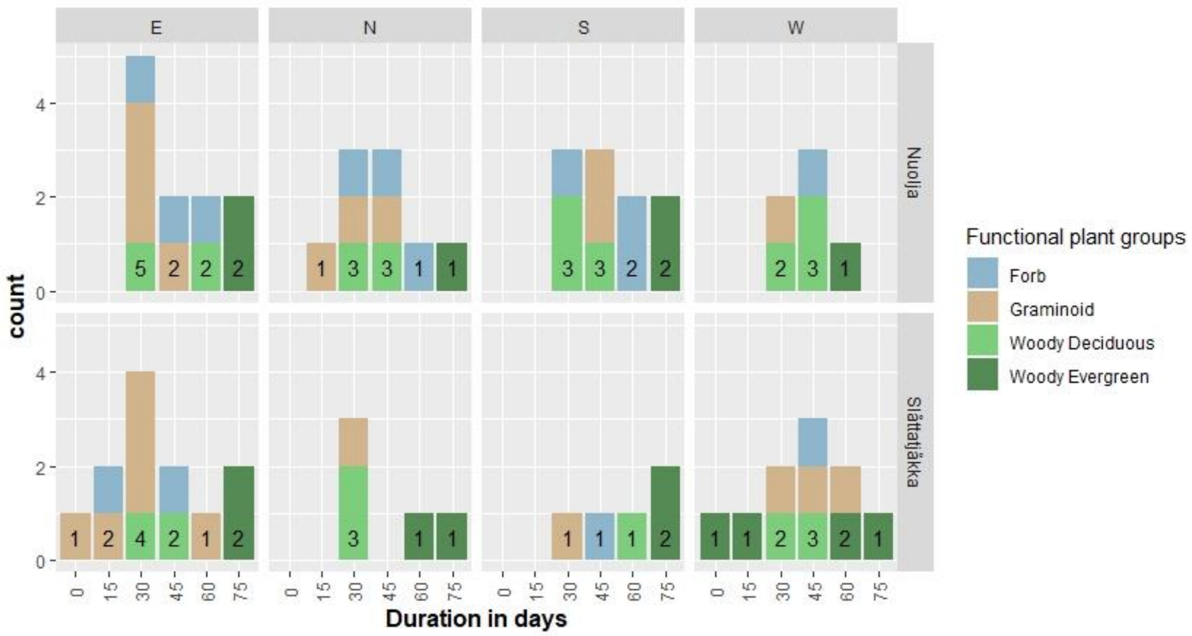

Figure 8 Flowering Duration by aspects on Mt. Nuolja and Mt. Slåttatjåkka. The number of species that flowered for the corresponding duration is shown for each aspect north (N), east (E), south (S) and west (W) on the summits of Nuolja and Slåttatjåkka. Bars show the proportion (in counts) of functional plant groups of the total species number for this duration. The x-axis shows the duration in days. The y-axis shows the count of each species for the corresponding duration.

5 Discussion

5.1 Discussion of results

5.1.1 Species distribution

"I predict that ***species number*** *will be greater on eastern and southern slopes in comparison to northern and western slopes."*

Results have shown that in contrast to predictions the aspect does not explain the current distribution of plant species on the summits of Nuolja and Slåttatjåkka. This could be explained by the fact that diurnal differences in solar radiation and temperature among aspects are less distinct in arctic regions because of long daylight and lower sun angles (Winkler et al. 2016). In contrast, temperate mountain regions, e.g. the Alps, show more distinct differences in species richness between the aspects that often results in a pattern of higher species richness on eastern slopes. Here, diurnal differences in solar radiation and air temperature are higher and lead to higher thermal input on eastern slopes in comparison to other slopes and favour a greater accumulation of plant species (Winkler et al. 2016; Vittoz et al. 2010). As there are less differences in thermal input among mountain aspects in the Arctic, the variation of micro-climates, mainly driven by rough and heterogeneous topography, might be more crucial for plant's distribution and species richness (Scherrer and Körner 2010; Opedal et al. 2014). The western slope of Nuolja seems to be less topographically heterogeneous in comparison to the other aspects. This offered less availability of various microclimates and therefore fewer species were recorded here, mainly due to lower species numbers in forbs and graminoids. Their distribution is more affected by topography than the distribution of woody evergreen and deciduous plants (Bruun et al. 2006). In addition, southern and eastern slopes tend to be more wind protected. The topography on Slåttatjåkka is different to Nuolja and therefore, the distribution of species richness showed a different pattern. On Slåttatjåkka, a ridge crosses the summit from north to south whose surface is less heterogeneous and very exposed to winds. This led to less species accumulation and became mainly apparent in the number of forbs and graminoids like on the species-poor west slope of Nuolja. Slåttatjåkka's eastern slope is wind-shadowed and has a heterogenous topography. The western slope is exposed to winds and the surface is less heterogeneous but includes a big depression next to the already described ridge. It can be assumed that plots located in this depression primarily led to the higher observed species richness because of wind protection, greater snow accumlation and later snow melt within this depression which offers favourable microclimatic conditions (Essery and Pomeroy 2004; Opedal et al. 2014; Körner 2003). Especially the comparison of differing species numbers of slopes in the same cardinal direction shows that the expositions to main prevailing wind directions and solar radiation do not seem to be decisive but topographic heterogenous surfaces offering various microclimates favoured accumulation of higher species numbers. This is also supported by Opedal et al. (2014) who suggest in their study that species richness increases with increasing soil and surface temperature. This, in turn, is influenced by microtopography and slope exposure as the interaction of wind and relief is especially influencing microclimatic conditions (Scherrer and Körner 2010, 2011; Körner 2003). These findings further support the assumption that different functional plant groups respond differently sensitive to changes in microtopography. Woody plants are less affected by topography than other groups, which was found out in a study by Bruun et al. (2006), and also found in this study, especially on Slåttatjåkka.

"I predict that ***species composition*** *will be most similar between eastern and southern slopes as well as northern and western slopes"*

Comparing the species distribution among aspects of each summit in terms of similarity reveals that aspects with a similar number of species, showed the highest beta-diversity. This means that on the east and south slope of Nuolja as well as the east and west slope of Slåttatjåkka was recorded a high number of species but less than 50% of species were shared between these slopes. Therefore, most of the species, that were recorded, live on these aspects. Furthermore, this means that aspects with less species richness, i.e. the western slope of Nuolja and northern and southern slopes of Slåttatjåkka, do not show the same species composition. Summarizing both peaks, each aspect shared at least 42% same species but not more than 55%. Thus, it could be assumed that the aspect had an influence on the distribution of some but not all species. However, this assumption is disproved by the similarity results for aspects of each mountain. If aspect would influence the distribution of single species, this would mean that slopes in the same cardinal direction must have shown the highest similarity but they did not. The highest similarities were calculated between Nuolja's eastern and Slåttatjåkka's northern slope as well as Nuolja's southern and Slåttatjåkka's northern slope. These aspects shared more than 70% same species. However, it was predicted that especially east or south slopes will differ most in comparison to north slopes. This again clearly shows that aspect cannot be the primary determining factor for species distribution in total nor for single ones and matches the study of Löffler and Pape (2008) who stated that a high level of species turnover and beta-diversities is due to topographic heterogeneity and is not determined by regional conditions.

5.1.2 Flowering Phenology

“I predict that the ***beginning of flowering*** *will be earlier at northern and western slopes and plants will flower later at eastern and southern slopes.”*

The hypothesis that the FFD is depending on the aspect can be corroborated. On eastern slopes, most species with later FFD were found, as predicted, but also a high amount of species with early FFD. Northern and western slopes showed mainly species with early FFD as it was also predicted. Southern slopes did not fit to the predictions as these showed the same pattern of FFD distribution like northern and western slopes. The FFD of eastern and western slopes differed significantly. The dependency of FFD on aspect can be explained by snow accumulation and melt because snow melt and temperature influence the timing of flowering (Kudo and Hirao 2006). Snow accumulation is higher and snow fields stay longer at the lee-sides of mountains ,which are the east and south slope of Nuolja and Slåttatjåkka (Essery and Pomeroy 2004). Therefore, snow has melted on the windblown northern and western slopes at first because less snow accumulates here. This explains why less species with late FFD were found at these wind-exposed slopes, i.e. western slopes, in comparison to the wind protected slopes where snow fields remain longer, i.e. eastern slopes. However, the question is why eastern slopes also showed species with early FFD and why the FFD’s at southern slopes are more similar to those in the west and north.

When looking at the peaks itself, it is visible that the FFD is not only influenced by the aspect. It seems that beginning of flowering also responds to the small-scale topography of slopes because greater snow accumulation and long remaining snow fields can be also found in wind protected depressions and behind slope edges (Essery and Pomeroy 2004). Thus, the different timing of snowmelt on each aspect is also influenced by topography (Blöschl et al. 1991) and snow does not only melt earlier at wind-exposed aspects but also on less topographic heterogeneous slopes. Results have shown that aspects with less heterogeneous topography showed almost only early FFD, i.e. western slopes and the northern and southern slope of Slåttatjåkka, whereas those aspects that seemed to provide a greater variation of microclimates were inhabited by species with early as well as late FFD, i.e. eastern slopes and the southern and northern slope of Nuolja. Species distribution and composition is influenced by small scale topography and therefore, timing of flowering as this is also species-specific (Kudo and Hirao 2006; Jia et al. 2011; Körner 2003). Some functional plant groups flowered in general rather early or late independent from aspect. Regardless of which aspect, woody deciduous and evergreen plants were always early flowering because they are less sensitive to topography changes means that they have less preferences of certain microhabitats and are simultaneously less sensitive to low temperatures (Bruun et al. 2006; Körner 2003). Furthermore, woody plants need less time to start flowering because in contrast to forbs and graminoids, they have to put less energy in vegetative growth before flowering (Jia et al. 2011). This could be an explanation why forbs and graminoids showed more species with late FFD and a higher variation of FFD in general. However, beginning of flowering is also influenced by environmental factors, i.e. ambient temperature and snow melt (Kudo and Hirao 2006). Therefore, species will start flowering earlier at windblown as well as less topographic heterogenous slopes because less snow accumulates and snow is gone earlier. This explains why the wind-exposed aspects and those with less variation in microclimate, i.e. western slopes as well as the northern and southern slope of Slåttatjåkka, only showed early FFD in contrast to the wind protected and microclimate-rich areas, primary eastern slopes, where snow fields remain longer and most of the late FFD were recorded, even though on these slopes were also recorded early FFD.

"I predict that the ***flowering duration*** *will be shorter at eastern and southern slopes in comparison to northern and western slopes."*

The analysis of flowering duration has shown that the aspect was not the influencing factor in general but the flowering duration of certain functional plant groups was influenced by the aspect. Furthermore, the flowering duration correlated with functional plant group independent from aspect. Forbs flowered for medium durations, even though there were also some rather short or long flowering species. Graminoids included the shortest but an overall great variation in flowering durations. Woody deciduous plants flowered for medium durations except for one observation of rather long flowering duration on eastern and southern slopes, respectively. Except for the western slope where shorter flowering duration was recorded, evergreen woody plants flowered for the longest time which might result out of their early FFD. Forbs and graminoids showed a higher variation in flowering durations as they did for FFD. The FFD is among other things species-specific and thus, this could also account for the flowering duration as alpine plant species show a high variation of different reproductive strategies that also affect the length of flowering (Molau 1993; Jia et al. 2011). Furthermore, different functional plant groups show different sensitivity to low temperatures which might explain why woody plants flowered for similar durations regardless of aspect but forbs and graminoids showed more different flowering durations depending on the slope (Bruun et al. 2006; Körner 2003) Another explanation for the difference in "long" flowering durations might be the abundance of functional plant groups. Woody plants often showed more or bigger individuals which means that there were more observable flowers of these groups than of single individuals which often represented forbs and graminoids. These different numbers of flowers per species could have led to the differences in flowering duration, too. The different potential reasons show that it is necessary to make additional measurements, e.g. floral counts, on how flowering duration is determined to get reliable explanations for this.

In general, aspects with higher species numbers showed higher variation in FFD and flowering duration. This supports the assumption that flowering phenology on the one hand was influenced by environmental factors but on the other hand, was a specific to each plant species (Jia et al. 2011; Kudo and Hirao 2006).

5.2 Discussion of methods

5.2.1 Investigation area and plot design

Restricting the summit to the top 10 metres, is a general approach of summit surveys that investigate alpine plant communities on mountain summits (European Commission 2004). In this study the cardinal directions north, east, south and west were investigated. An additional investigation of the cardinal directions northeast, southeast, southwest and northwest might have shown how small-scale topography affects species distribution and phenology. Furthermore, investigation of summits in other regions could show how much results are specific for the Abisko National Park that is characterized by very low precipitation due the rain shadow of the mountain ranges to the west (Callaghan et al. 2010). Therefore, it might be interesting to find out how aspect affects species distribution and phenology on mountain summits that experience higher mean annual or summer precipitation.

The random distribution of plots is a useful method to collect data that give a general overview over the investigated factors within a bigger study area, like a mountain summit. Setting the plot size to 1 by 1m made it easy to capture all plant species and their current phenological phase and reduced the risk of overlooking species or phenology features within the plot. The limitation of plot size and therefore the limit of data collection is sometimes difficult as some plants may extend in- or outside the plot. In this study I decided to regard only those plants that root within the plot. This means that parts of bigger plants extending into the plot, were not regarded. For small plants this would not have made a difference but considering bigger crawling plants, such as *Betula nana*, this could have meant to collect phenology data up to one metre away from the original plot.

Even though the distribution of plots was random, during the data collection it became obvious that these cover less sites with possibly special microhabitats. For example, it was visible that especially slope edges and small cliffs are inhabited by a variety of different species but placing a 1 by 1m plot on a small cliff is difficult. This could have been solved by bigger plots but in turn this would have increased the already described risk of overlooking plants and their phenology.

5.2.2 Data collection

To investigate the influence of environmental factors on plants phenology, several sampling efforts were necessary during the growing season. In this study sampling campaigns were conducted every 15 days but this does not cover completely or exactly the phenological phases. For most species the FFD was recorded on the first sampling date which shows that the study should have been initiated earlier to capture this dimension. This means that the FFD and LFD as well as flowering durations should be considered as relative to each other and not absolute. These data are only in comparison to each other meaningful. By conducting more samplings within the same period but also earlier and later samplings, this effect could have been minimized.

The application of phenology classification system of Thore C. E. Fries (Appendix 1) (Fries 1925) is an overall good practice to record data on plant's phenology. However, during the sampling it turned out that for some species the change from flowering (code b1, b2, b3) to the end of flowering (code b4) was not always easy to identify and classify into Fries' coding system and might not be independent from the observer. This influence on data quality was tried to minimize by having always two observers per sampling campaign who could control each other.

Data quality always depends on several conditions during the sampling, like weather or knowledge of observers. I tried to decrease bias by starting and ending every sampling campaign at another cardinal direction. Due to increasing experience, the knowledge of observers increased simultaneously during the field season. This also could have had an influence on data quality.

5.2.3 Data analysis

The recorded species richness has to be regarded as number of present species that were found within the plots. Thus, it is a comparison of species' presence but not of absence. Even though certain species were not found within the plots, does not mean that they do not occur on a certain aspect or peak at all. Therefore, the recorded species numbers represent only the general distributions on each peak and aspect and might not include rare or less abundant species.

Analysing species distribution by using a biodiversity index represents species diversity in numerical values. This is an easy and advantageous approach to analyse differences in the spatial distribution of species. Using a similarity index, such as the Jaccard Index, is an easy and familiar way to analyse the beta-diversity of two sites (Magurran 2004). But indices can be hard to interpret because they condense complex systems into a single number.

6 Conclusion

Vegetation changes on mountain summits are predicted to intensify with accelerating climate change including an increase in species richness and simultaneously the loss of species (Steinbauer et al. 2018; Dullinger et al. 2012; Thuiller et al. 2005). This study has shown that beside the aspect and the regional climate that is related to this, it seems that microclimatic conditions additionally affect species distribution and phenology on mountain summits. The aspect influences the beginning of flowering and the flowering duration of certain functional plant groups, i.e. forbs and graminoids. The influence of aspect on the flowering duration of certain functional groups show that flowering phenology is to some extent species-specific and cannot be related only to environmental factors. This is something that has to be investigated in further studies to make reliable predictions for future climate changes. Aspect did not influence species richness and composition. In fact, it seems that this is more affected by small-scale topography and roughness of the slope's surface. Furthermore, it is apparent that small-scale topography also influences the timing of flowering. The variability of microclimate is controlled by the topography of the mountain's surface and a can buffer alpine vegetation against increasing temperatures due to climate change (Scherrer and Körner 2011). This study supports that microclimate is a crucial factor for species distribution and that the beginning of flowering seems to be partly influenced by microclimate variability. This highlights the importance to include the effect of the heterogeneity of microclimate in investigations when predicting climate change impacts on mountain's vegetation.

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9 Appendix

Appendix 1 Phenological codes that were used for flower development during data collection.

Code	Description of code	Analysis code	
	flower development		
K	a flower bud is visible	3	
As	a developing spike is visible	2	**only graminoids**
Af	a free and completely developed spike is visible that is not flowering yet	2.1	**only graminoids**
Rs	a developing panicle is visible	2.3	**only graminoids**
Rf	a developing panicle is visible that is free from covering leaves	2.4	**only graminoids**
Ra	a developed panicle is visible that is free and spread out and is not flowering yet	2.5	**only graminoids**
b1	one flowering individual is visible	3.1	
b2	two flowering individuals are visible	3.2	
b3	three or more flowering individuals are visible	3.3	
b4	the majority of individuals has stopped flowering	3.4	

Appendix 2 GPS data of plots and positions on the summit of Mount Nuolja. The altitudes that were measured with the Trimble dGPS are adjusted to the height of the summit measured by *Lantmäteriet.*

plot name / position	latitude	longitude	altitude in metres	adjusted altitude in metres
summit (weather station)	68.37262961N	18.69783973E	1195.125	1164
Nuolja_N1	68.37273845N	18.69786279E	1193.603	1162.478
Nuolja_N2	68.37278699N	18.69787718E	1192.763	1161.638
Nuolja_N3	68.37292050N	18.69792567E	1190.650	1159.525
Nuolja_N4	68.37301943N	18.69796635E	1188.442	1157.317
Nuolja_N5	68.37315027N	18.69801244E	1186.289	1155.164
North 10m contour line	68.37317947N	18.69801563E	1185.484	1154.359
Nuolja_E1	68.37254623N	18.69939674E	1193.386	1162.261
Nuolja_E2	68.37253985N	18.69953022E	1192.841	1161.716
Nuolja_E3	68.37250957N	18.70003387E	1188.633	1157.508
Nuolja_E4	68.37249836N	18.70022774E	1187.077	1155.952
Nuolja_E5	68.37254623N	18.70035414E	1186.674	1155.549
East 10m contour line	68.37247239N	18.70061375E	1185.161	1154.036
Nuolja_S1	68.37244792N	18.69776369E	1194.557	1163.432
Nuolja_S2	68.37236490N	18.69771189E	1193.058	1161.933
Nuolja_S3	68.37228941N	18.69767360E	1190.920	1159.795
Nuolja_S4	68.37220583N	18.69762506E	1188.629	1157.504
Nuolja_S5	68.37213165N	18.69758523E	1186.074	1154.949
South 10m contour line	68.37211279N	18.69757865E	1185.154	1154.029
Nuolja_W1	68.37265890N	18.69720058E	1192.854	1161.729
Nuolja_W2	68.37267273N	18.69693838E	1191.904	1160.779
Nuolja_W3	68.37269505N	18.69641288E	1189.417	1158.292
Nuolja_W4	68.37270982N	18.69609928E	1187.584	1156.459
Nuolja_W5	68.37272561N	18.69574788E	1185.378	1154.253
West 10m contour line	68.37272623N	18.69572666E	1185.277	1154.152

Appendix 3 GPS data of plots and positions on the summit of Mount Slåttatjåkka. The altitudes that were measured with the Trimble dGPS are adjusted to the height of the summit measured by *Lantmäteriet.*

plot name / position	latitude	longitude	altitude in metres	adjusted altitude in metres
Summit (stone cairn)	68.35662537N	18.67856972E	1217.422	1186
Slåttatjåkka_N1	68.35673135N	18.67860406E	1216.410	1184.988
Slåttatjåkka_N2	68.35686549N	18.67865834E	1216.946	1185.524
Slåttatjåkka_N3	68.35702614N	18.67871305E	1216.072	1184.65
Slåttatjåkka_N4	68.35733610N	18.67881747E	1213.253	1181.831
Slåttatjåkka_N5	68.35766020N	18.67902142E	1207.882	1176.46
North 10m contour line	68.35774574N	18.67909613E	1207.277	1175.855
Slåttatjåkka_E1	68.35662081N	18.67868613E	1215.447	1184.025
Slåttatjåkka_E2	68.35661469N	18.67883083E	1214.799	1183.377
Slåttatjåkka_E3	68.35657039N	18.67944629E	1210.017	1178.595
Slåttatjåkka_E4	68.35655936N	18.67962138E	1209.433	1178.011
Slåttatjåkka_E5	68.35654774N	18.67982554E	1208.257	1176.835
East 10m contour line	68.35654527N	18.67999449E	1207.337	1175.915
Slåttatjåkka_S1	68.35651082N	18.67853823E	1216.309	1184.887
Slåttatjåkka_S2	68.35618078N	18.67839749E	1213.188	1181.766
Slåttatjåkka_S3	68.35604611N	18.67834159E	1212.129	1180.707
Slåttatjåkka_S4	68.35580217N	18.67822931E	1210.039	1178.617
Slåttatjåkka_S5	68.35559103N	18.67814697E	1208.252	1176.83
South 10m contour line	68.35553573N	18.67812689E	1207.430	1176.008
Slåttatjåkka_W1	68.35664113N	18.67810353E	1214.974	1183.552
Slåttatjåkka_W2	68.35664746N	18.67771734E	1215.080	1183.658
Slåttatjåkka_W3	68.35666431N	18.67732897E	1216.048	1184.626
Slåttatjåkka_W4	68.35668460N	18.67678830E	1214.671	1183.249
Slåttatjåkka_W5	68.35672168N	18.67619041E	1209.248	1177.826
West 10m contour line	68.35672970N	18.67589207E	1207.450	1176.028

Appendix 4 Statistical Results. 1. Species number ~ aspect, 2. FFD ~ aspect, 3. contrasting FFD ~ aspect, 4. Duration ~ aspect * functional plant group

1

Type III Analysis of Variance Table with Satterthwaite's method

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr (>F)
aspect	24.4	8.133	3	38	1.0022	0.4024

2

Type III Analysis of Variance Table with Satterthwaite's method

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr (>F)	
aspect	2513.1	837.69	3	83	4.7361	0.004238	**

3

contrast		estimate	SE	df	t.ratio	p.value
E - N	effect	5.76	4.4	79	1.31	0.1942
E - S	effect	5.53	3.27	79	1.692	0.1942
E - W	effect	6.13	2.19	79	2.805	0.038
N - S	effect	-6.29	4.24	79	-1.483	0.1942
N - W	effect	-5.68	3.47	79	-1.636	0.1942
S - W	effect	-5.45	4.07	79	-1.339	0.1942

4

Type III Analysis of Variance Table with Satterthwaite's method

	Sum Sq	Mean Sq	NumDF	DenDF	F value	Pr (>F)	
aspect	475.9	158.6	3	83	0.6371	0.59325	
functional group	10662.6	3554.2	3	83	14.2741	1.39E-07	***
aspect : functional group	5107.6	567.5	9	83	2.2792	0.02451	*

Significance codes 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix 5 Species distribution on the mountain summits of Nuolja, Slåttatjåkka and in total of both summits. Additionally, the species number in total within the plots are listed.

functional plant group	species name	Nuolja				Slåttatjåkka				both			
		East	North	South	West	East	North	South	West	East	North	South	West
forb	Antennaria alpina	x		x						x		x	
forb	Astragalus alpinus		x								x		
forb	Bistorta vivipara	x	x	x	x	x			x	x	x	x	x
forb	Cardamine bellidifolia					x				x			
forb	Hieracium alpinum						x		x		x		x
forb	Pedicularis hirsuta	x	x	x	x	x		x	x	x	x	x	x
forb	Pedicularis lapponica	x	x		x	x				x	x		x
forb	Saussurea alpina	x		x						x		x	
forb	Saxifraga cernua		x								x		
forb	Silene acaulis	x	x	x				x		x	x	x	
graminoid	Calamagrostis lapponica	x		x		x	x		x	x	x	x	x
graminoid	Carex bigelowii								x				x
graminoid	Carex rupestris		x								x		
graminoid	Festuca ovina	x		x					x	x		x	x
graminoid	Festuca vivipara	x	x	x		x				x	x	x	
graminoid	Hierochloe alpina		x		x	x				x	x		x
graminoid	Luzula arcuata	x	x	x	x	x	x	x	x	x	x	x	x
graminoid	Luzula multiflora			x								x	
graminoid	Poa alpina	x				x			x	x			x
graminoid	Trisetum spicatum	x				x				x			
lycopod	Huperzia selago		x			x	x		x	x	x		x
woody deciduous	Betula nana			x	x							x	x
woody deciduous	Salix herbacea	x	x	x	x	x	x	x	x	x	x	x	x
woody deciduous	Salix polaris	x	x	x	x	x	x	x	x	x	x	x	x
woody deciduous	Vaccinium uliginosum	x		x					x	x		x	x
woody evergreen	Cassiope hypnoides	x		x					x	x		x	x
woody evergreen	Cassiope tetragona	x	x	x	x	x	x	x	x	x	x	x	x
woody evergreen	Diapensia lapponica								x				x
woody evergreen	Empetrum nigrum	x		x		x	x	x	x	x	x	x	x
woody evergreen	Saxifraga oppositifolia		x								x		
woody evergreen	Vaccinium vitis-idaea	x	x	x	x	x	x	x	x	x	x	x	x
	Total per aspect	**19**	**16**	**18**	**10**	**16**	**9**	**8**	**17**	**22**	**19**	**18**	**20**
	Total per summit		**27**				**23**				**31**		

Appendix 6 Recorded species richness (number of species) of each plot by peak and aspect.

Peak	Aspect	Plot number	Species richness
Nuolja	North	Nuolja_N1	5
Nuolja	North	Nuolja_N2	6
Nuolja	North	Nuolja_N3	7
Nuolja	North	Nuolja_N4	8
Nuolja	North	Nuolja_N5	12
Nuolja	East	Nuolja_E1	5
Nuolja	East	Nuolja_E2	3
Nuolja	East	Nuolja_E3	13
Nuolja	East	Nuolja_E4	11
Nuolja	East	Nuolja_E5	13
Nuolja	South	Nuolja_S1	5
Nuolja	South	Nuolja_S2	5
Nuolja	South	Nuolja_S3	10
Nuolja	South	Nuolja_S4	12
Nuolja	South	Nuolja_S5	12
Nuolja	West	Nuolja_W1	8
Nuolja	West	Nuolja_W2	8
Nuolja	West	Nuolja_W3	3
Nuolja	West	Nuolja_W4	5
Nuolja	West	Nuolja_W5	7
Slåttatjåkka	North	Slåttatjåkka_N1	7
Slåttatjåkka	North	Slåttatjåkka_N2	2
Slåttatjåkka	North	Slåttatjåkka_N3	3
Slåttatjåkka	North	Slåttatjåkka_N4	2
Slåttatjåkka	North	Slåttatjåkka_N5	4
Slåttatjåkka	East	Slåttatjåkka_E1	6
Slåttatjåkka	East	Slåttatjåkka_E2	6
Slåttatjåkka	East	Slåttatjåkka_E3	7
Slåttatjåkka	East	Slåttatjåkka_E4	5
Slåttatjåkka	East	Slåttatjåkka_E5	9
Slåttatjåkka	South	Slåttatjåkka_S1	2
Slåttatjåkka	South	Slåttatjåkka_S2	5
Slåttatjåkka	South	Slåttatjåkka_S3	5
Slåttatjåkka	South	Slåttatjåkka_S4	2
Slåttatjåkka	South	Slåttatjåkka_S5	8
Slåttatjåkka	West	Slåttatjåkka_W1	7
Slåttatjåkka	West	Slåttatjåkka_W2	6
Slåttatjåkka	West	Slåttatjåkka_W3	11
Slåttatjåkka	West	Slåttatjåkka_W4	8
Slåttatjåkka	West	Slåttatjåkka_W5	5

Appendix 7 Minimum, maximum and mean FFD for each species by peak, aspect and functional plant group.

Species	Functional Plant Group	Peak	Aspect	min FFD	max FFD	mean FFD
Antennaria alpina	Forb	Nuolja	S	166	166	166
Bistorta vivipara	Forb	Nuolja	E	181	196	188.5
Bistorta vivipara	Forb	Nuolja	S	181	181	181
Pedicularis hirsuta	Forb	Nuolja	E	166	166	166
Pedicularis hirsuta	Forb	Nuolja	N	166	196	181
Pedicularis hirsuta	Forb	Nuolja	W	166	196	181
Saxifraga cernua	Forb	Nuolja	N	181	181	181
Silene acaulis	Forb	Nuolja	E	166	166	166
Silene acaulis	Forb	Nuolja	N	181	181	181
Silene acaulis	Forb	Nuolja	S	181	181	181
Calamagrostis lapponica	Graminoid	Nuolja	E	211	211	211
Carex rupestris	Graminoid	Nuolja	N	166	166	166
Festuca ovina	Graminoid	Nuolja	E	196	196	196
Festuca ovina	Graminoid	Nuolja	S	196	196	196
Festuca vivipara	Graminoid	Nuolja	N	196	196	196
Luzula arcuata	Graminoid	Nuolja	E	181	181	181
Luzula arcuata	Graminoid	Nuolja	N	181	181	181
Luzula arcuata	Graminoid	Nuolja	W	181	196	188.5
Luzula multiflora	Graminoid	Nuolja	S	166	166	166
Trisetum spicatum	Graminoid	Nuolja	E	196	196	196
Betula nana	Woody Deciduous	Nuolja	W	166	166	166
Salix herbacea	Woody Deciduous	Nuolja	E	166	196	181
Salix herbacea	Woody Deciduous	Nuolja	N	166	181	173.5
Salix herbacea	Woody Deciduous	Nuolja	S	166	166	166
Salix herbacea	Woody Deciduous	Nuolja	W	166	181	173.5
Salix polaris	Woody Deciduous	Nuolja	E	166	181	173.5
Salix polaris	Woody Deciduous	Nuolja	N	166	166	166
Salix polaris	Woody Deciduous	Nuolja	S	166	166	166
Salix polaris	Woody Deciduous	Nuolja	W	166	166	166
Vaccinium uliginosum	Woody Deciduous	Nuolja	S	166	181	173.5
Cassiope hypnoides	Woody Evergreen	Nuolja	E	166	166	166
Cassiope hypnoides	Woody Evergreen	Nuolja	S	166	166	166
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	E	166	166	166
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	N	166	166	166
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	S	166	166	166
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	W	166	166	166
Bistorta vivipara	Forb	Slåttatjåkka	E	197	197	197
Pedicularis hirsuta	Forb	Slåttatjåkka	E	182	182	182
Pedicularis hirsuta	Forb	Slåttatjåkka	S	167	167	167
Pedicularis hirsuta	Forb	Slåttatjåkka	W	167	167	167
Calamagrostis lapponica	Graminoid	Slåttatjåkka	E	212	212	212
Carex bigelowii	Graminoid	Slåttatjåkka	W	167	182	174.5
Festuca ovina	Graminoid	Slåttatjåkka	W	212	212	212
Festuca vivipara	Graminoid	Slåttatjåkka	E	197	197	197
Hierochloe alpina	Graminoid	Slåttatjåkka	E	167	167	167

Luzula arcuata	Graminoid	Slåttatjåkka	E	182	182	182
Luzula arcuata	Graminoid	Slåttatjåkka	N	167	167	167
Luzula arcuata	Graminoid	Slåttatjåkka	S	167	167	167
Luzula arcuata	Graminoid	Slåttatjåkka	W	167	197	182
Poa alpina	Graminoid	Slåttatjåkka	E	182	182	182
Trisetum spicatum	Graminoid	Slåttatjåkka	E	212	212	212
Salix herbacea	Woody Deciduous	Slåttatjåkka	E	167	182	174.5
Salix herbacea	Woody Deciduous	Slåttatjåkka	N	167	167	167
Salix herbacea	Woody Deciduous	Slåttatjåkka	S	167	182	174.5
Salix herbacea	Woody Deciduous	Slåttatjåkka	W	167	182	174.5
Salix polaris	Woody Deciduous	Slåttatjåkka	E	167	167	167
Salix polaris	Woody Deciduous	Slåttatjåkka	N	167	167	167
Salix polaris	Woody Deciduous	Slåttatjåkka	W	167	182	174.5
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	E	167	167	167
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	N	167	167	167
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	S	167	167	167
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	W	167	182	174.5
Diapensia lapponica	Woody Evergreen	Slåttatjåkka	W	182	182	182
Empetrum nigrum	Woody Evergreen	Slåttatjåkka	W	167	167	167
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	E	167	197	182
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	N	167	167	167
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	S	167	167	167
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	W	167	167	167

Appendix 8 Flowering duration of each species by functional plant group, peak and aspect.

Species	Functional Plant Group	Peak	Aspect	FFD	LFD	Duration in days
Antennaria alpina	Forb	Nuolja	S	166	226	60
Bistorta vivipara	Forb	Nuolja	E	181	241	60
Bistorta vivipara	Forb	Nuolja	S	181	211	30
Pedicularis hirsuta	Forb	Nuolja	E	166	211	45
Pedicularis hirsuta	Forb	Nuolja	N	166	211	45
Pedicularis hirsuta	Forb	Nuolja	W	166	211	45
Saxifraga cernua	Forb	Nuolja	N	181	211	30
Silene acaulis	Forb	Nuolja	N	181	241	60
Silene acaulis	Forb	Nuolja	E	166	196	30
Silene acaulis	Forb	Nuolja	S	181	241	60
Calamagrostis lapponica	Graminoid	Nuolja	E	211	241	30
Carex rupestris	Graminoid	Nuolja	N	166	211	45
Festuca ovina	Graminoid	Nuolja	S	196	241	45
Festuca ovina	Graminoid	Nuolja	E	196	241	45
Festuca vivipara	Graminoid	Nuolja	N	196	211	15
Luzula arcuata	Graminoid	Nuolja	W	181	211	30
Luzula arcuata	Graminoid	Nuolja	E	181	211	30
Luzula arcuata	Graminoid	Nuolja	N	181	211	30
Luzula multiflora	Graminoid	Nuolja	S	166	211	45
Trisetum spicatum	Graminoid	Nuolja	E	196	226	30

Betula nana	Woody Deciduous	Nuolja	W	166	211	45
Salix herbacea	Woody Deciduous	Nuolja	W	166	196	30
Salix herbacea	Woody Deciduous	Nuolja	S	166	196	30
Salix herbacea	Woody Deciduous	Nuolja	E	166	226	60
Salix herbacea	Woody Deciduous	Nuolja	N	166	211	45
Salix polaris	Woody Deciduous	Nuolja	W	166	211	45
Salix polaris	Woody Deciduous	Nuolja	E	166	196	30
Salix polaris	Woody Deciduous	Nuolja	N	166	196	30
Salix polaris	Woody Deciduous	Nuolja	S	166	196	30
Vaccinium uliginosum	Woody Deciduous	Nuolja	S	166	211	45
Cassiope hypnoides	Woody Evergreen	Nuolja	E	166	241	75
Cassiope hypnoides	Woody Evergreen	Nuolja	S	166	241	75
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	W	166	226	60
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	N	166	241	75
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	S	166	241	75
Vaccinium vitis-idaea	Woody Evergreen	Nuolja	E	166	241	75
Bistorta vivipara	Forb	Slåttatjåkka	E	197	242	45
Pedicularis hirsuta	Forb	Slåttatjåkka	E	182	197	15
Pedicularis hirsuta	Forb	Slåttatjåkka	S	167	212	45
Pedicularis hirsuta	Forb	Slåttatjåkka	W	167	212	45
Calamagrostis lapponica	Graminoid	Slåttatjåkka	E	212	242	30
Carex bigelowii	Graminoid	Slåttatjåkka	W	167	228	60
Festuca ovina	Graminoid	Slåttatjåkka	W	212	242	30
Festuca vivipara	Graminoid	Slåttatjåkka	E	197	197	0
Hierochloe alpina	Graminoid	Slåttatjåkka	E	167	197	30
Luzula arcuata	Graminoid	Slåttatjåkka	N	167	197	30
Luzula arcuata	Graminoid	Slåttatjåkka	E	182	212	30
Luzula arcuata	Graminoid	Slåttatjåkka	S	167	197	30
Luzula arcuata	Graminoid	Slåttatjåkka	W	167	212	45
Poa alpina	Graminoid	Slåttatjåkka	E	182	242	60
Trisetum spicatum	Graminoid	Slåttatjåkka	E	212	228	15
Salix herbacea	Woody Deciduous	Slåttatjåkka	S	167	228	60
Salix herbacea	Woody Deciduous	Slåttatjåkka	N	167	197	30
Salix herbacea	Woody Deciduous	Slåttatjåkka	E	167	212	45
Salix herbacea	Woody Deciduous	Slåttatjåkka	W	167	212	45
Salix polaris	Woody Deciduous	Slåttatjåkka	N	167	197	30
Salix polaris	Woody Deciduous	Slåttatjåkka	W	167	197	30
Salix polaris	Woody Deciduous	Slåttatjåkka	E	167	197	30
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	N	167	228	60
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	E	167	242	75
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	W	167	228	60
Cassiope tetragona	Woody Evergreen	Slåttatjåkka	S	167	242	75
Diapensia lapponica	Woody Evergreen	Slåttatjåkka	W	182	197	15
Empetrum nigrum	Woody Evergreen	Slåttatjåkka	W	167	167	0
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	E	167	242	75
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	N	167	242	75
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	S	167	242	75
Vaccinium vitis-idaea	Woody Evergreen	Slåttatjåkka	W	167	242	75