Comparing species-temperature relationships of arctic-alpine plants among three altitudinal transects in Svalbard

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Poa arctica ssp. *arctica* (non-viviparous form)

Zeppelinfjellet, Ny-Ålesund, August 2007

Photo: Kathrin Bockmühl

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Abstract

Broad scale data has normally been used to predict vascular plant species responses to global climate change. The aim of this study is to investigate to what extent a high sampling resolution reveals local variations among species-temperature relationships in arctic regions. I recorded vascular plant communities along three altitudinal transects in the arctic archipelago Svalbard (78-80 °N). All species in 25 m^2 - plots were mapped using a simple abundance measure. I performed detrended correspondence analysis to explore how altitude was related to the variation in the species composition. Afterwards, the altitudinal gradients were converted into temperature gradients. Generalised linear models with a binomial distribution and a logit link were used to generate temperature response curves for 40 species and to detect similarities and differences among temperature relationships of 18 species at different sites. For most of the species clear relationships to temperature were found and many of them exhibited unimodal response curves. The comparison of the temperature response curves showed that only a few species responded consistently to temperature at the different study sites, while the majority revealed different relationships to temperature among the locations. This may indicate that populations of arctic species are locally adapted to environmental and climatic conditions. Further, my results show that altitude is even on low mountains a strong and useful tool to detect local species adaptations within arctic regions, which are characterised by strong climate variations. Hence, this study illustrates that small-scale data reveals local variations, which are overlooked when using broad scale data, but which supply important knowledge on how to optimise predictions for arctic-alpine plants under global rising temperatures.

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1. Introduction

Climate affects and determines life on earth. It is a major factor for plant species compositions and distributions all over the world. Temperature decreases on global scale gradually from the equator to the poles. Besides Antarctica, the Arctic is the coldest region in the world. Life in the Arctic is possible although the predominating climate conditions fix its limits. In contrast to animals, plants cannot move and are committed to enduring the local weather conditions. Thus, arctic plant species must be very hardy to tolerate the extreme conditions. In addition to being capable of surviving these harsh environments, they are rather specialised (Körner 2003). Some high arctic species are not able to survive in regions with higher temperatures. If, for example, *Papaver dahlianum* is transplanted into a region at lower latitudes, e.g. from Svalbard to Central Europe, it will die because of overheating (Dahl 1951, Savile 1972). Arctic plants are perfectly adapted to the extreme, and similar species can only be found in alpine regions at lower latitudes. Alpine and arctic plants grow under the same conditions. They use similar techniques to cope with low temperatures, short growing seasons and harsh climatic conditions (Dahl 1951, Billings & Mooney 1968, Körner 2003).

The consequences of global climate change are predicted to be most drastic at high northern latitudes and on the Antarctic Peninsula and will include raised UV radiation, increasing temperatures and altered precipitation patterns (Arctic Climate Impact Assessment [ACIA] 2006, Intergovernmental Panel on Climate Change [IPCC] 2007). Hence, arctic regions are expected to undergo fundamental changes in the following years, with the first impacts (thawing permafrost, etc.) already visible (ACIA 2006). These changes will have serious consequences for arctic plant communities in near future. The predicted warmer temperatures are expected to lead to an earlier onset of spring, an extension of the growing season and to upwards and polewards shifts of vegetation belts and thus, in an expansion of thermophile species to higher altitudes and latitudes (Walther 2004, ACIA 2006, Alsos et al. 2007, IPCC 2007). Different observations and experimental studies supply evidence that arctic and alpine plants and ecosystems react substantially and individualistically to rising temperatures (Birks 1981, Huntley 1991, Walker et al. 2006). Some species show better abilities to cope with a changing climate than others (Erschbamer 2007, Parolo & Rossi 2008). Changes in behaviour, ranges and interactions of different species as result of climate warming have already been observed and documented as so called 'ecological fingerprints' (Grabherr et al. 1994, Parmesan & Yohe 2003, Walther 2004, Araujo & Rahbek 2006). Klanderud & Birks (2003) found considerable changes in species distributions in Norwegian mountains although air temperatures had only increased little over the last decades. Additionally, upwards shifts of vascular plants and increases in species richness under raised temperatures have been detected (Walther 2004, Parolo & Rossi 2008). But still it is not clear which species will become threatened in the following decades. One approach commonly used to assess which species might be threatened is to estimate climatic tolerances or 'envelopes' for specific species (Huntley et al. 1995, Thuiller et al. 2005b). This has been done using broad scale distribution maps (e.g. data from Atlas Flora Europaeae for vascular plants) together with IPCC future scenarios. These methods have been criticised, because they led to under- and overestimations of species distributions and species plasticity (Pearson & Dawson 2003, Thuiller 2004, Guisan & Thuiller 2005, Thuiller et al. 2005a). Researchers have demonstrated a need for models incorporating finer-scale information about species distribution and climate variations especially for mountainous areas, because they are assumed to provide more accurate prediction possibilities (Welk & Bruelheide 2006). Still, no perfect bioclimatic modelling techniques have been developed to make precise predictions for species responses to a global changing climate (Araujo et al. 2005, Araujo & Rahbek 2006, Pearman et al. 2008).

Arctic-alpine plants tolerate little competition (Klanderud & Birks 2003). These cold-adapted and light demanding species, especially those with specific demands and low tolerance limits regarding their habitats (e.g., snow bed species), will be out-competed and replaced, without having refugia to retreat to (Sætersdal & Birks 1997). They may not be able to expand to higher altitudes, simply because the mountains on which they currently grow might not be high enough to provide habitats with appropriate low temperatures under future climates (Holten & Carey 1992). Additionally, they might not either be able to expand to higher latitudes because land shape and geology (bedrock, open water, etc.) might stop them. Hence, temperature is a keystone variable regarding arctic-alpine plants and their responses to climate change. Alsos et al. (2007) suggested that dispersal is unlimited under a changing climate, but concluded that temperature constricts establishment in new habitats and limits thereby distribution. Thus, the prevailing temperature conditions are fundamental for species communities and compositions. It is uncertain if species will be able to shift their climatic niches under changing climate conditions, but if these shifts happen, a fine spatial sampling resolution will be needed to detect them (Pearman et al. 2008).

Under climate warming, the Norwegian mainland and Svalbard may play important roles as last refuges for various arctic-alpine species, providing suitable habitats with appropriate temperature conditions. A work in progress by Grytnes & Randin shows that for many species that today have a wide European distribution, only small areas in Norway will remain climatically suitable in 2080 under some of IPCC future climatic scenarios (Grytnes, personal communication). Therefore, it is important to gain more knowledge and understanding of the tolerance limits within the Norwegian flora.

Altitudinal gradients are useful to study ecological responses of plants to changing temperature and climate conditions (Grytnes 2003, Körner 2007). They are compressed climate gradients and include enormous temperature variations (Körner 2003). Studying and investigating species-temperature relationships along altitudinal gradients will lead to a better knowledge about climate gradients on a larger scale. Because climate variations from the equator to the poles follow a similar pattern to the climate variations from sea level to a mountain top, altitudinal climate variations can be transferred to climatic variations on a latitudinal scale (Körner 2003). Svalbard, as well as the Norwegian mainland, is characterized by a mountainous landscape with strong variations in altitude on a small spatial scale. Species compositions change quickly within short geographical distances. Hence, the sensitive high arctic ecosystems of Svalbard are an ideal location to investigate altitudinal gradients in order to study potential effects of a changing climate on arctic-alpine vascular plant communities.

Assuming that temperature determines species' distribution ranges, it is important to study species abundance along temperature gradients in many differing places. The harsh climatic conditions in arctic environments create geomorphic processes (e.g. cryoturbation) which lead to high habitat and species diversity on local scales (Murray 1997). This causes large variations of species distribution in space and leads to different results when studying the same species at different sites. Assessing and comparing these differences in species temperature relationships can help to reveal niche variations in space, which is important to optimise predictions of species response to climate change (Pearman et al. 2008). Until now, spatial species variations have rarely been studied on local scale. Virtanen et al. (1997) and Law & Dieckmann (2000) investigated, for example, changes in plant communities on a small scale, but they did not focus on species specific variations. To fill this lack of data, I investigated three sites in the High Arctic which provided varying conditions for plant growth. I used species abundance and temperature variations along altitudinal gradients to compare species' relationships to temperature between the different localities. My main aims in this thesis are first, to use altitudinal gradients to estimate species relationships to temperature based on small scale data; second, to reveal variations in species' relationships to temperature among three different places; third, to show that these local variations are overlooked in broad scale 'climatic envelope' approaches; and fourth, to discuss if altitudinal gradients are reliable tools to investigate response possibilities and tendencies towards niche variations of species in space under global climate change.

2. Materials and Methods

2.1 Study Area

The archipelago Svalbard (Figure 2.1) is located in the Atlantic Ocean north of the Norwegian mainland and west of Greenland. It covers an area of approximately 62 160 km^2 and ranges from 74° to 81° North, and from 10° to 35° East. The largest of the islands is called Spitsbergen. The name refers to the peaked and sharp mountains characterizing the landscape.

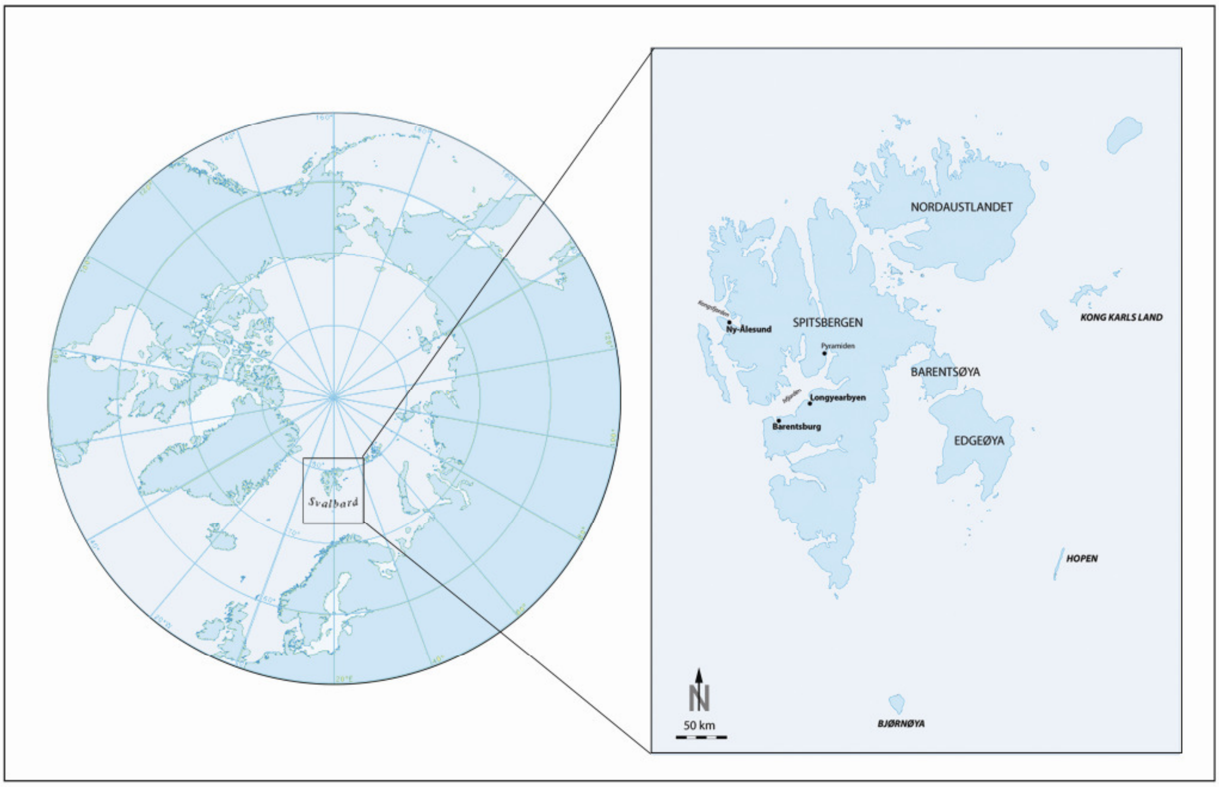

Figure 2.1 Outline map of Svalbard in its circumpolar context. Received and modified from Norwegian Polar Institute (1999b) and www.sikkerhetspolitikk.no (Sikkerhetspolitikk).

Svalbard is known as one of the most easily accessed regions of the high Arctic (Lindner & Meister 2006). This may be due to its geographical position. Although Svalbard is situated above the Arctic Circle, a branch of the Gulf Stream creates a temperate climate at the west coast of Spitsbergen (Rønning et al. 1996). In addition, Svalbard consists of different islands with indented shorelines. Thus, numerous places can be accessed by boat and by hikes during summer time.

During the last glacial maximum in the late Weichselian, 20 000 years before present, almost the entire archipelago was covered with ice (Landvik et al. 2003). The landscape of Svalbard was shaped by advancing and retreating glaciers in the course of recurrent glacial cycles during the Quaternary, which started about 2.6 million years ago and lasts until today. Today 60%

of Svalbard is covered by glaciers and the ground is continuously bedded into permafrost (Ingólfsson 2005). Throughout Svalbard mean annual air temperatures of approximately -6 °C at sea level and -15 °C at high mountain tops have been observed (Ingólfsson 2005). The two highest mountains in Svalbard are Newtontoppen and Perriertoppen with 1717 m a.s.l. each (Hjelle & Brekke 1993).

Svalbard provides harsh environments for plant growth. Nevertheless, Svalbard's flora is surprisingly rich and various in comparison to other arctic regions at the same latitude (Kartesz 1994, Vechov & Kuliev 1996). It contains approximately 165 native vascular plant species (Elven & Elvebakk 1996) and 7 species which are assumed to be introduced (Rønning et al. 1996). Further, more than 300 lichen species and approximately 350 bryophyte species have been documented (Lindner & Meister 2006). Within the archipelago, plant diversity is highest on Spitsbergen, because it is the only island that includes the middle arctic tundra zone (Elvebakk 2005). The rest of Svalbard is characterized by the northern arctic tundra zone and arctic polar desert zone (Elvebakk 2005). The three vegetation zones are explained in Table 2.1. All study sites are located on Spitsbergen in bioclimatic zone C (Figure 2.2).

Table 2.1 *The bioclimatic zones and their mean July temperatures after Elvebakk (2005).*

Bioclimatic Zone	Name	Mean July Temperature / °C
A	Arctic Polar Desert Zone	1 to 3
B	Northern Arctic Tundra Zone	4 to 5
C	Middle Arctic Tundra Zone	6 to 7

2.2 Study Sites

Three sites were investigated in this study. The names are given according to the mountains on which the transects were placed. A summary of the study sites is given in Table 2.2.

Table 2.2 *Sites analysed in this study (* : after Elvebakk (2005)).*

Name	Altitude of highest point / m a. s. l.	Date of sampling	UTM coordinates	Location	Aspect of transect	Bioclimatic zone	Vegetation type*	Number of plots
Zeppelinfjellet	554	07.-11.08.2007	33X 8761548, 433085	coastal	north-east	C	mesic heath	40
Brentskarhaugen	530	19.-23.08.2007	33X 8769514, 543471	continental	north-west	C	mesic heath	41
Platåberget	468	01.-05.09.2007	33X 8681050, 511545	coastal	north-east, south	C	mesic heath	31

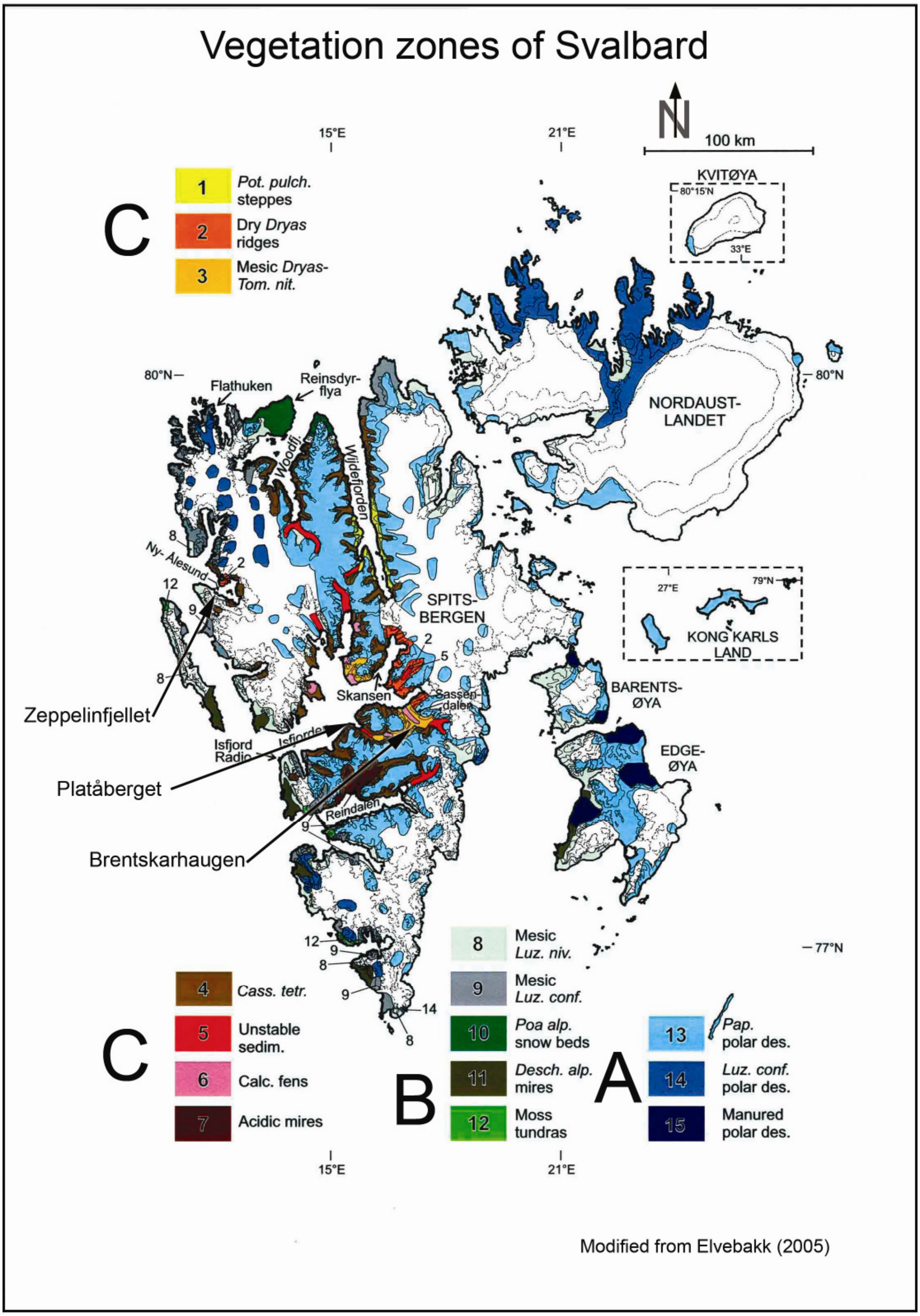

Figure 2.2 *Vegetation map of Svalbard showing vegetation communities in the three bioclimatic zones. The locations of the study sites are included.*

2.2.1 Zeppelinfjellet

The first study site was located in the Kongsfjord area on Brøggerhalvøya (Figure 2.3). It was the northernmost study site. Zeppelinfjellet is situated south of Ny-Ålesund and is flanked by quaternary moraines in the east and west (Hjelle et al. 1999). In the southeast it is linked to a mountain chain leading to Lundryggen and Berteltoppen. The glaciers Austre Brøggerbreen and Vestre Lovénbreen surround this mountain chain and the southern foot of Zeppelinfjellet. Three mines out of operation, a rifle ranch and small paths and roads leading to Ny-Ålesund are situated north of the mountain. At Zeppelinfjellet it is mainly mining, frost action and reindeer grazing which has an impact in the submontane area.

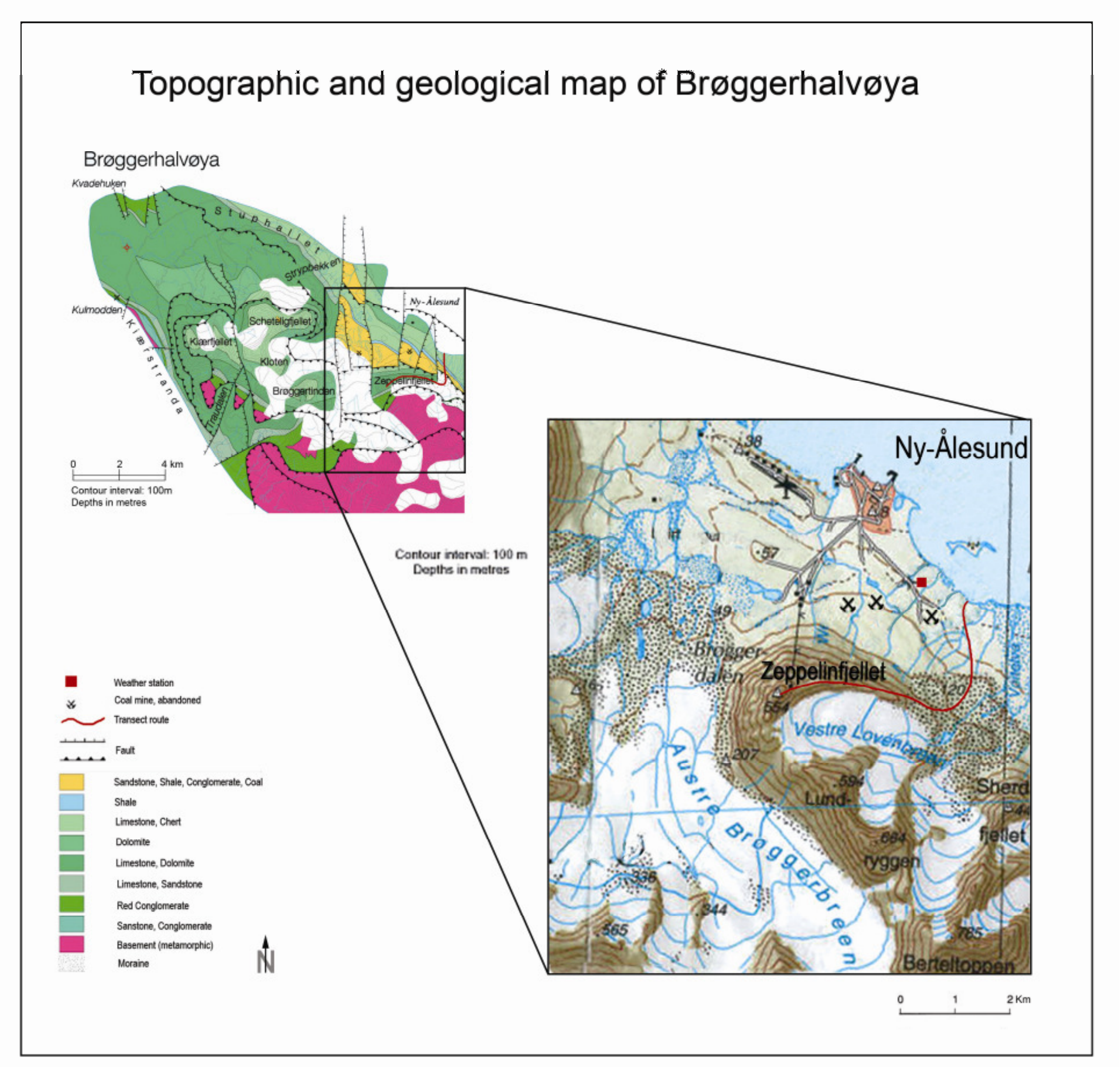

__Figure 2.3__ Bedrock and location of Zeppelinfjellet including the approximate location of the weather station Ny-Ålesund. Modified from Norwegian Polar Institute (2003b, 2004).

Zeppelinfjellet is a steep, narrow and elongated mountain with a pronounced ridge. In comparison with the other two mountains variation in bedrock is highest on Zeppelinfjellet. The submontane area on the northern side of Zeppelinfjellet consists of a conglomerate of mainly shale, sandstone, chert and limestone. The eastern foothill of Zeppelinfjellet is covered by a quaternary moraine (Hjelle et al. 1999) (Figure 2.3), while the ridge and the southern part of the mountain consist of limestone and dolomite. Along the transect, the bedrock from sea level up to approximately 140 m a.s.l. is a conglomerate of alkaline and slightly acidic substrate. Above the moraine, from 275 m a.s.l. until the mountain top the bedrock is calcareous and alkaline. Although the bedrock changes 7 times, limestone and sandstone are predominant in most parts of the transect.

Only the coastline and the submontane provide an organic layer facilitating plant growth, but frost action in the ground prohibits a continuous vegetation cover. Further upwards rubble, scree and boulder dominate and organic material is scarce, resulting in patchy and sparse vegetation. Not only is vascular plant growth limited, but also lichens and mosses. At approximately 100 m altitude I observed the last large vegetation patches. Generally the vegetation alternates between different vegetation types. In the lower part of the transect the vegetation types gradually change from the littoral vegetation zone to *Luzula confusa* lichen heath to *Saxifraga oppositifolia* lichen heath to *Carex rupestris - Dryas octopetala* heath to *Carex nardina - Cassiope tetragona – D. octopetala* heath to *S. oppositifolia* lichen heath and finally to herbal rich moraine vegetation (Brattbakk 1981). The vegetation of Zeppelinfjellet from 200 m a.s.l. upwards is not mapped.

2.2.2 Brentskarhaugen

The second transect was situated on Brentskarhaugen (Figure 2.4). The study site is located in the inner Isfjord-area where Adventdalen meets Sassendalen. Brentskarhaugen is almost surrounded by two rivers flowing through broad valleys. In the west and in the south of Brentskarhaugen lies Adventelva, in the north Eskerelva. In the east Brentskarhaugen is connected over a slight depression to Breikampen, which is almost entirely surrounded and covered by glaciers. Brentskarhaugen is oval in shape and the top is easily accessed over the northern side with its moderate slope. The bedrock consists mainly of sandstone, shale and conglomerate (Major et al. 2000) (Figure 2.4), providing slightly acidic conditions.

In the lower parts of the mountain the vegetation cover is dense. Mosses dominate the plant community and graminoids dominate the vascular plants. The vegetation type is moss tundra and marsh area (Brattbakk 1984). Further upwards the vegetation changes into *S. polaris – D. octopetala* heath with *Equisetum arvense* abundance and finally into *S. polaris – D. octopetala* heath (Brattbakk 1984). Frost disturbance in the soil increases with increasing altitude. The bare ground is exposed to the weather, since rocks and scree are rare. The vegetation density and the thickness of the organic layer decrease gradually towards the mountain top. The soil is calcareous (Brattbakk

1984), and the increasingly patchy vegetation is astonishing variable. Thanks to its remote position, Brentskarhaugen is least disturbed. Frost activity and grazing reindeer are the only factors disturbing the vegetation.

2.2.3 Platåberget

The third study site was located on Platåberget, which is situated in the Isfjord west of Longyearbyen (Figure 2.4). According to its name Platåberget forms a large plateau. In the north the mountain is bordered by the sea, in the east by Longyearbyen and Longyeardalen, and in the west by Bjørndalen and Bjørnelva. In the south it passes into the higher Nordenskiöldfjellet with its glacier, the Longyearbreen. The northern and eastern side of Platåberget are influenced by human activities from the nearby town. A frequently used road connecting Longyearbyen with the airport and the harbour runs along the northern submontane mountainside, accompanied by a ropeway for coal transportation. Two abandoned coal mines are located on the eastern slope, and several small roads run through Longyeardalen in direction of the town. A church, a kindergarten, residential houses, the governor's office and a coal shipping factory are located on the lower part of the north-eastern slope. In comparison to Zeppelinfjellet and Brentskarhaugen, disturbance is most pronounced in the transect on Platåberget in terms of mining, hiking, frost activity and reindeer grazing.

Along the transect on Platåberget the bedrock changes 4 times (Figure 2.4), but sandstone and shale are predominant (Major et al. 2000), resulting in a slightly acidic organic layer. The lowest part contains sandstone, siltstone and shale (Major et al. 2000). As with the other two mountains, the submontane of Platåberget is rich in vegetation. As elevation increases, organic material decreases, scree increases and vegetation decreases gradually. Detailed information about the vegetation on Platåberget is not available, because the vegetation in that area has never been mapped.

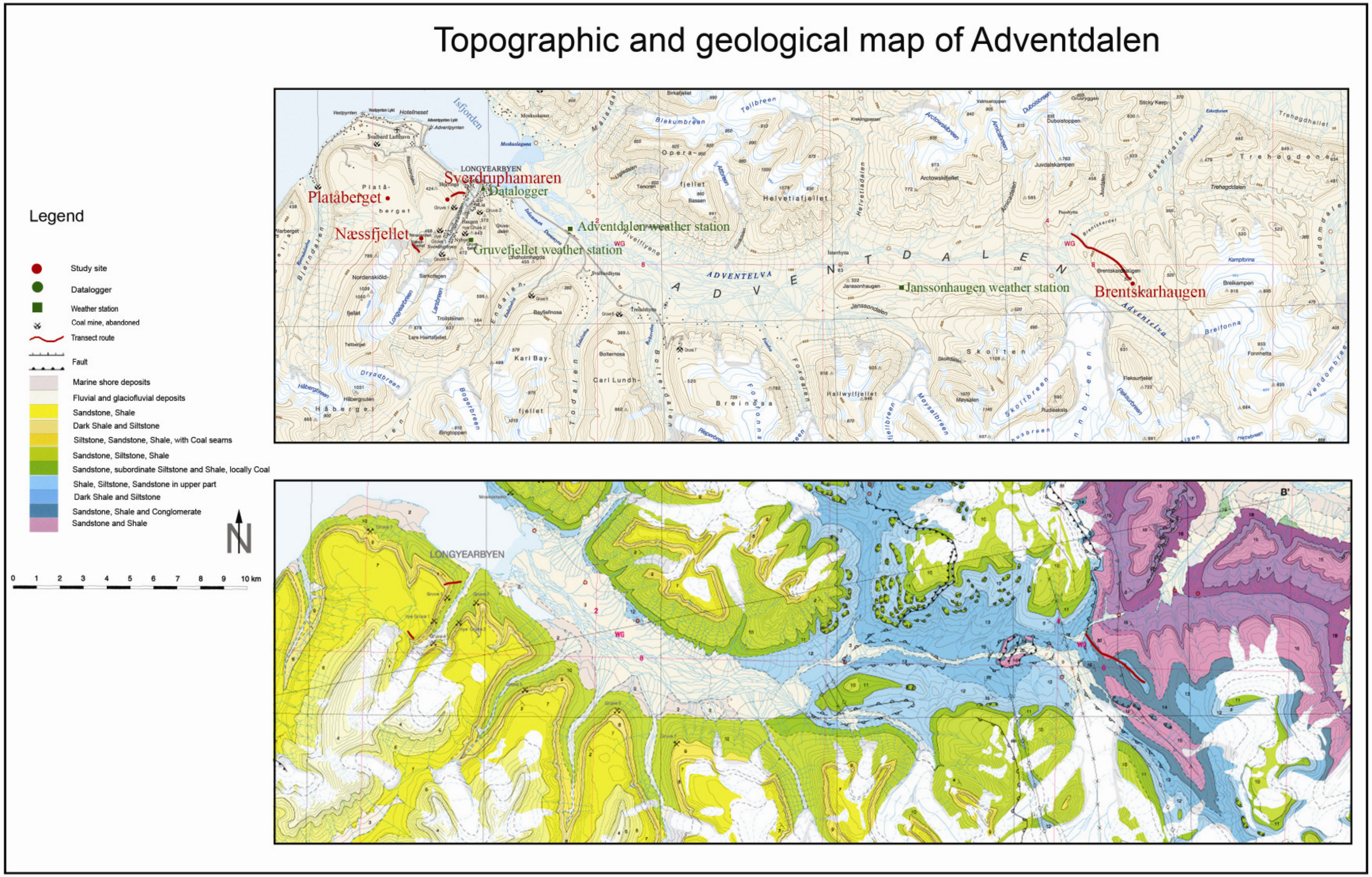

Figure 2.4 *Topographic and geological map of Adventdalen including the study sites and approximate locations of the datalogger and the weather stations. Received and modified from Norwegian Polar Institute (1999a, 2003a).*

2.3 Sampling Methods

I accomplished my field work between 7th August and 5th September 2007. During this time I mapped vascular plant species composition, distribution and diversity by sampling along three altitudinal transects. Each mountain was mapped in approximately one week time and each transect covered one mountain side starting from sea level or valley bottom and ending at the top. The sampling scheme followed Grytnes (2003). With a small plot size of 5 x 5 m my sampling method took variations within plant communities on small spatial scale into account. Thus, the subsequent construction of temperature niches was based on local-scale data (Guisan & Thuiller 2005, Araujo & Guisan 2006). Each plot was bounded by strings fixed with pins in the corners in the ground. When it was possible, the positions of the plots were chosen randomly and ridges and otherwise extreme and differing sites were avoided. However, in the impracticable terrain of Zeppelinfjellet I was obliged to sample along the ridge. For the same reason on Zeppelinfjellet and Platåberget the plots had to be placed close to hiking trails.

I used a hand held GPS receiver (Garmin eTrex Euro, Garmin Ltd., Olathe, Kansas, USA) to determine the exact geographical position of each plot. The distance between the plots was approximately 10 altitudinal meters and was measured with an altimeter based on atmospheric pressure (Altitronic Professional, Altimeter and Barometer/Thermometer, Revue Thommen AG, Waldenburg, Switzerland). See Appendix II for the exact altitudes and UTM positions of the plots. Since the mountains were low, I chose the short altitudinal distance to ensure that the transects consisted of a sufficient number of plots with minimum 31 on Platåberget. All vascular plants within each plot were determined to species level, apart from individuals without fruits and flowers, commonly graminoids and representatives of the genus *Draba*. These individuals were excluded from the statistical analysis. For species determination in the field I used a magnifying glass (Ruper Viking 10 x / 20 x duel folding lens, Japan) and in the laboratory a dissecting microscope (1.6 x / 4 x, Carl Zeiss, Jena, Germany). Further, I used three floras for species identification by Rønning et al. (1996), Lid et al. (2005) and Mossberg et al. (2005). The Latin nomenclature followed the Pan-Arctic-Flora-Project (PAF) (Elven et al. 2007). Deviations between the Latin names following PAF and the different floras were clarified by making use of online-flora 'The Flora of Svalbard' (Alsos et al. 2005-2008) and Lid et al. (2005).

To estimate species abundance in each plot, a four level abundance scale was developed: 1 = very rare, 2 = rare, 3 = common and 4 = dominating. This abundance scale was used on Zeppelinfjellet and on Brentskarhaugen. On Platåberget early snow fall hampered the accomplishment of the field work. Instead of the abundance scale a presence-absence-scale (1 = present, 0 = absent) was used, because 9 plots contained snow patches. To avoid continuous snow cover the fieldwork on Platåberget had been carried out at two different parts of the mountain called Sverdruphamaren and Næssfjellet (Figure 2.4). Sverdruphamaren is situated in the north-eastern part of Platåberget. In this part the transect covered a northeast facing slope and comprised the 23 lower plots. Næssfjellet is located in the south-eastern part of Platåberget. On Næssfjellet the transect ran along a south facing slope and contained the 8 upper plots, ending at 450 m altitude. The highest elevation (468 m) of Platåberget was covered by snow. In the middle of this transect, from 280 m a.s.l. to 360 m a.s.l., 9 plots are missing because of continuous snow cover. Even though the transect was geographically divided into two parts, it was treated as one single transect.

2.4 Temperature data

Mean July temperature provided the basis for the analysis of species' relationships to temperature. I received daily measured air temperature values for July 2007 from three meteorological stations (Table 2.3). I chose stations which were located as close as possible to the three study sites.

Table 2.3 *The weather stations are presented according to the respective mountain, including altitudinal positions, information on measurements and the distances between study sites and weather stations.*

Study site	Meteorological station, operator	Location / m a.s.l.	Measuring height / m above ground	Measuring interval / hours	Appr. distance to the transect / km
Zeppelinfjellet	Weather Station Ny-Ålesund, Meteorological Institute	8	2	12	2
Brentskarhaugen	Janssonhaugen Weather Station, UNIS	270	3	1	9
Platåberget	Gruvefjellet Weather Station, UNIS	464	3	1	3

Based on the daily mean July air temperatures I calculated the mean July temperature for the position of each meteorological station. The obtained values I used to extrapolate the respective mean July temperatures for each plot based on the altitudinal locations of the weather stations. I used an adiabatic lapse rate of 0,649 K decrease in air temperature with 100 m increase in altitude (Coulson, personal communication).

2.5 Statistical analysis

The main aim of this study was to analyse and to compare differences in species' response to mean July air temperature between habitats with different climatic conditions.

The data analysis was accomplished in three steps, involving two different analyses. First, ordination analysis was performed to describe the variation in species composition in the data set and to explore how altitude was related to this variation. Second, logistic regression was used to relate each species to the temperature gradients. In a first regression analysis I estimated trends and optima in species response to temperature within each transect. Third, in a second regression analysis I tested if there were any differences in species-temperature relationships between the different transects.

The multivariate analysis was implemented using CANOCO for Windows version 4.5 (ter Braak & Šmilauer 2002) and the associated diagrams were produced in CANODRAW version 4.0 (ter Braak & Šmilauer 2002). The regression analyses were carried out in R version 2.6.1 (The R Developement Core Team 2007).

2.5.1 Ordination analysis

Detrended correspondence analysis (DCA) was used to choose the appropriate ordination method (Lepš & Šmilauer 2003). In DCA the species turnover along the gradient is defined in Standard Deviation (SD) units (Hill & Gauch 1980). Usually, a threshold value of 2 – 2.5 SD units is used to decide if a unimodal or a linear method is adequate. The lengths of the first axes were found to be 2.7 SD units on Zeppelinfjellet, and 2.3 SD units on Brentskarhaugen and Platåberget. These values were spread around the threshold. Nevertheless, I selected a unimodal model, because using a unimodal model is more reliable in ambiguous cases, than using a linear model. First, I used correspondence analysis (CA), which is an unconstrained method and based on the assumption that species have a unimodal distribution along environmental gradients (Whittaker 1967, referred to in Gotelli & Ellison 2004). CA is commonly used to relate species compositions to environmental variables (Hill 1973, referred to in Gotelli & Ellison 2004, Jongman et al. 1995). I performed a CA for each transect separately, to explore the species distribution and to find out, if altitude is related to species composition. The CA created an arch effect, clearly visible when plotting the ordination diagram. To remove this effect, I carried out detrended correspondence analysis (DCA) (Hill & Gauch 1980). DCA is a variant of the CA and is also an unconstrained method. In DCA the new axes are detrended and rescaled (Oksanen 2007). Rare species were downweighted to reduce their influence on the display of the relationship between species composition and environmental gradient (Jongman et al. 1995, Gotelli & Ellison 2004, Oksanen 2007). They were also removed from the diagrams to keep the ordination plots clear.

2.5.2 Regression analysis

To explore the relationship between species abundance and temperature, I used logistic regression in two separate analyses. In the first analysis I investigated the response of each species to temperature in each transect separately. In the second analysis I tested if the species had a different response to temperature in the three transects. Some species were too rare to fit regression models. Those species that were observed in less than six plots within one transect were not analysed.

2.5.3 The character of the data set and the use of GLMs

Logistic regression is commonly used to estimate the character of the relationship between a continuous predictor variable and a categorical response variable (Gotelli & Ellison 2004, Crawley 2005). The data set consists of three different variables: 'Temperature', 'transect' and 'species abundance'. 'Temperature' is a continuous and "transect" a factorial predictor variable. 'Species abundance' is a discrete response variable with a simple abundance measure on Zeppelinfjellet and Brentskarhaugen and a presence-absence measure on Platåberget. Hence, in both analyses I used generalised linear models (GLMs) with a logit link function and a quasibinomial distribution on Zeppelinfjellet and Brentskarhaugen and a binomial distribution on Platåberget (Crawley 2005). GLMs have been shown to be useful and transferable regarding bioclimatic modelling, although they are less precise than generalised additive models (Araujo & Rahbek 2006). The GLMs I used are presented below in simplified mathematical equations. The coefficients (β's) actually change from term to term, and the variables (A, M and T) are actually different for each tested species. For explanatory reasons I schematised the models and abandoned the subscripts which indicate these differences. When testing the models for significant differences against each other I used an F-test for the quasi-binomial model and a χ^2-test for the binomial model (Crawley 2005).

2.5.4 Estimating trends in species relationships to temperature

To observe linear and unimodal trends in species response to temperature I created the following three models:

1) $(\text{logit})\text{A} = \beta$ A = species abundance
2) $(\text{logit})\text{A} = \beta + \beta\ \text{T}$ T = temperature in °C
3) $(\text{logit})\text{A} = \beta + \beta\ \text{T} + \beta\ \text{T}^2$ β = parameters

The null model (1) assumed no relationship between species abundance and temperature. The first-order polynomial model (2) assumed a linear relationship between species abundance and temperature, while the second-order polynomial model (3) assumed a unimodal relationship.

First, I tested the first-order polynomial against the null model for statistically significant difference between the models. When the difference was significant, I tested the second-order polynomial against the first-order polynomial model. When the difference was not significant, I tested the second-order polynomial against the null model. I always accepted the more complex model as final model, when the difference was significant. Additionally I plotted the fitted models to visualise the trends of the species in relation to temperature. Afterwards I defined the temperature optima for species with a significant unimodal trend. This was done by estimating the temperature for the point where the highest fitted value in the unimodal model was found. In unimodal models with negative trends, I estimated the temperature for the point where the lowest fitted value was found. In addition, based on my observations, I developed for each of the 73 species in each transect temperature ranges based on highest and lowest altitude where the species were observed. For those species that occurred in more than one transect, the different temperature ranges were summarised into one total range.

2.5.5 Estimating differences in species response to temperature

In the second regression analysis I investigated if individual species respond differently to temperature in the three transects. To make the data comparable between the mountains, I converted all abundance data to presence-absence data and hence used a binomial distribution for all species. A comparison was only possible within species that occurred in at least two transects, and within each transects in more than 6 plots. To compare the different relationships to temperature within the species I created a generalised linear model including five terms:

$$(\text{logit})\text{A} = \beta + \beta\ \text{M} + \beta\ \text{T} + \beta\ \text{T}^2 + \beta\ \text{M}:\text{T} + \beta\ \text{M}:\text{T}^2$$

A = abundance, 0 or 1 (binomial) M = mountain, name of the transect (factorial)
T = temperature in °C (continuous) β = parameter

The first term was used to test if the average abundance of the respective species is different between the transects. The second and the third term gave information on whether the respective species responds linear (second term) or unimodal (third term) to temperature. I used the first interaction term to test if the respective species differs in its linear response between the transects. Finally, the second interaction term gave information about differences in unimodal response between the transects. The interaction terms were of main interest for the comparison. Thus, I created six models to test their explanatory power using a χ^2-test in backward elimination.

Null Model: $(\text{logit})\mathrm{A} = \beta$

1) $(\text{logit})\mathrm{A} = \beta + \beta\,\mathrm{M}$

2) $(\text{logit})\mathrm{A} = \beta + \beta\,\mathrm{M} + \beta\,\mathrm{T}$

3) $(\text{logit})\mathrm{A} = \beta + \beta\,\mathrm{M} + \beta\,\mathrm{T} + \beta\,\mathrm{T}^2$

4) $(\text{logit})\mathrm{A} = \beta + \beta\,\mathrm{M} + \beta\,\mathrm{T} + \beta\,\mathrm{T}^2 + \beta\,\mathrm{M:T}$

5) $(\text{logit})\mathrm{A} = \beta + \beta\,\mathrm{M} + \beta\,\mathrm{T} + \beta\,\mathrm{T}^2 + \beta\,\mathrm{M:T} + \beta\,\mathrm{M:T}^2$

First, I tested the full model (5) against a next simpler one (4). When the difference was significant, I accepted the full model. If not, I continued with testing the simpler model (4) against a next simpler model (3) and so on. A summary of the models is given in Table 2.4. To visualise the differences within the species between the transects, I plotted the final models for each species.

Table 2.4 *Summarised are for each model the characters of the tested terms and their explanatory powers.*

Model	**Character of the tested term**	**Used to test if…**
1)	Factorial	…the average abundance of the species is different in the transects.
2)	1st order polynomial	…the species responds linear to temperature.
3)	2nd order polynomial	…the species responds unimodal to temperature.
4)	Interaction between 1. and 2. term	…the linear response to temperature is different in the transects.
5)	Interaction between 1. and 3. term	…the unimodal response to temperature is different in the transects.

However, this comparison analysis was not appropriate for all species that were observed frequently in two or three transects. *Dryas octopetala*, *Papaver dahlianum*, *Salix polaris*, *Saxifraga cespitosa* ssp. *cespitosa* and *Saxifraga oppositifolia* ssp. *oppositifolia* exhibited in some transects sharp changes between presence in one part of the transect and absence in the other part. In these cases, fitting the complex model did not further illuminate differences between the species-temperature relationships at the different study sites. The differences regarding the five species were obvious in the results of the first regression analysis, thus the second analysis was not accomplished.

3. Results

3.1 Quantitative account of the mapped species

All in all 73 species have been recorded in the three transects. The total species list, including abbreviations, Latin, English, Norwegian and German species names, is provided in Appendix III. I observed 42 species in the transect on Zeppelinfjellet, 55 on Brentskarhaugen and 50 on Platåberget. The separate species lists are given in Appendix IV together with the species records in each plot of each transect. Out of the 73 observed species, 33 species were observed less than 6 times in the transects and were excluded from the two regression analyses. The remaining 40 species were analysed for their relationship to temperature using logistic regression. Out of these 40 species, 23 were observed on a minimum of two mountains and were compared regarding their similarities and differences in response to temperature in the different transects. Out of these 23 species, five were compared visually and 18 were compared in a statistical analysis. Finally, five species responded similarly to temperature in all transects in which they were observed, and 18 species differed in their response to temperature between the transects.

3.2 Species composition and altitude

Focusing on the most abundant species, the DCA revealed changes in species compositions along the transects and their relation to underlying environmental gradients. The results are summarised in Table 3.1. The lengths of the first axes in standard deviation (SD) units presents the degree of compositional turnover (β- diversity) along the gradient. The change in species composition was most pronounced on Zeppelinfjellet (SD = 2.70), and less pronounced on Brentskarhaugen (SD = 2.36) and Platåberget (SD = 2.31). All in all, the axes are short (<3 SD), because the mountains were low (max. 554 m. a.s.l., Zeppelinfjellet). Comparing the eigenvalues of the axes shows that the value for the first axis is in each transect clearly higher than for the remaining ones. This indicates that one main underlying environmental factor determines species composition. The low values of the remaining axes show that the influence of other environmental factors is considerably smaller. Altitude is assumed to be the main environmental variable.

***Table 3.1** Summary of the DCA ordination. SD = standard deviation.*

Transect	Lengths of Axis 1 in SD units	Eigenvalues				Total inertia
		Axis 1	Axis 2	Axis 3	Axis 4	
Zeppelinfjellet	2.706	0.371	0.213	0.162	0.077	1.694
Brentskarhaugen	2.357	0.269	0.109	0.073	0.055	1.129
Platåberget	2.31	0.26	0.103	0.082	0.049	1.282

On Brentskarhaugen and Platåberget altitude correlated clearly with the first axes, indicated by the correlation coefficients close to 1 (Table 3.2). With a coefficient of 0.5729 the correlation was less pronounced on Zeppelinfjellet. But still the correlation between altitude and the first axis was higher than between altitude and the second axis (0.4114). The ordination diagrams of the DCA are given in Figures 3.1, 3.2 and 3.3.

Table 3.2 *The correlation coefficients indicate the levels of correlation between the environmental variable altitude and the different axes.*

	Correlation coefficients				
	1. axis	**2. axis**	**3. axis**	**4. axis**	
Altitude	0.5729	0.4114	0.1134	0.2683	**Zeppelinfjellet**
Altitude	0.8936	0.1953	-0.0028	0.1017	**Brentskarhaugen**
Altitude	0.8706	0.1791	0.0407	0.0664	**Platåberget**

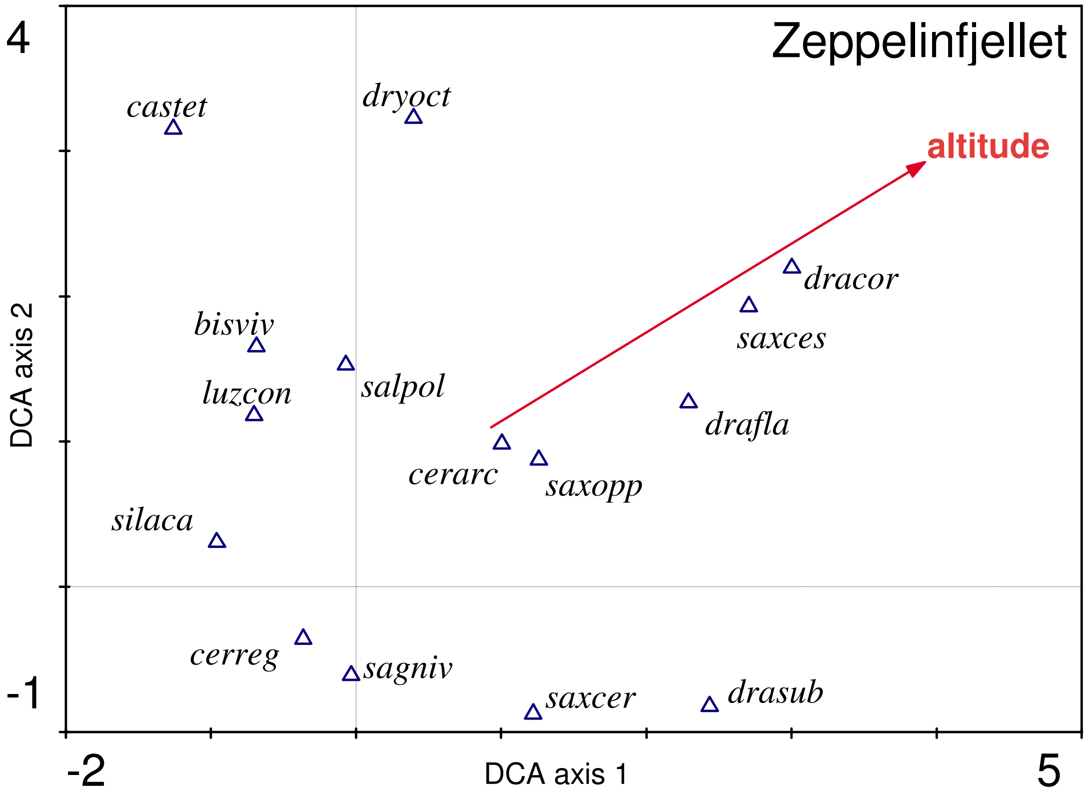

Figure 3.1 *DCA ordination plot of the species observed on Zeppelinfjellet. For species abbreviations see Appendix III. The triangles illustrate species optima. The environmental variable 'altitude' is shown as an arrow and has been rescaled 10 times. Rare species were downweighted and removed from the plot to keep it clear.*

The three DCA biplots display the optima for the most abundant species (triangles) in relation to the environmental variable altitude (arrow). The arrows point in each diagram towards increasing altitude. Since the arrows point to the right in all diagrams species on the right side of the diagrams were most abundant at high elevation, while species on the left side were most abundant in the lowland. On Zeppelinfjellet and Platåberget only few species had their optima at high altitude. The majority of the species on Zeppelinfjellet were most abundant at low elevation. On Platåberget and on Brentskarhaugen however, most of the species had their optima at mid-elevation. In all transects at least one species of the genus *Draba* was found to have its optimum at high altitude. *Bistorta vivipara*, *Cassiope tetragona* ssp. *tetragona*, *Luzula confusa*, *Ranunculus sulphureus* and *Salix polaris* were among the species that were most abundant at low elevation in all transects. *Cerastium arcticum*, *Cerastium regelii*, *Saxifraga cernua*, *Saxifraga cespitosa* ssp. *cespitosa* and *Saxifraga oppositifolia* ssp. *oppositifolia* are examples for species that had their optima in all transects at mid-altitude. However, some species exhibited opposite optima in the transects. *Poa alpina* var. *vivipara* for example was most abundant at high altitude on Platåberget and at low altitude on Brentskarhaugen.

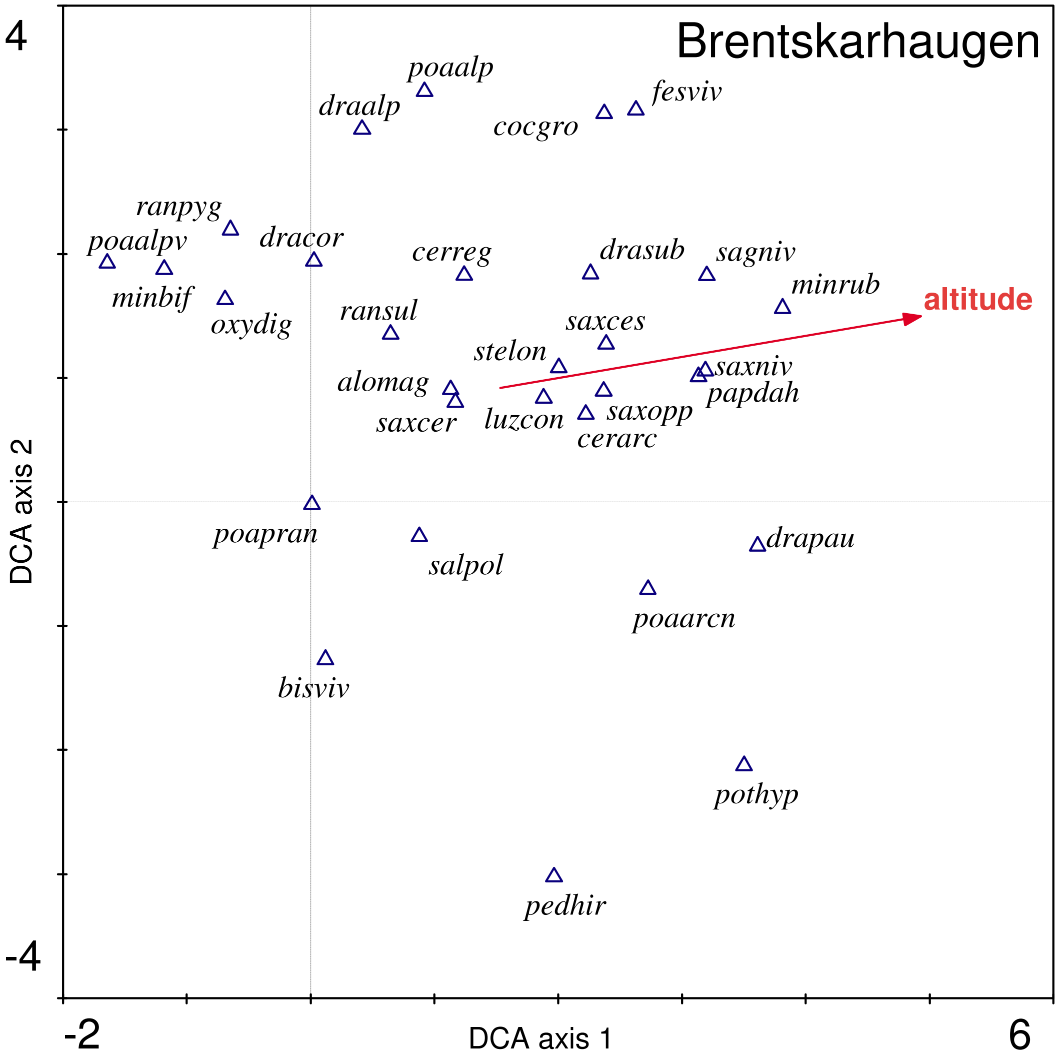

__Figure 3.2__ DCA ordination plot of the species observed on Brentskarhaugen. For species abbreviations see Appendix III. The triangles illustrate species optima. The environmental variable 'altitude' is shown as an arrow and has been rescaled 8 times. Rare species were downweighted and removed from the plot to keep it clear.

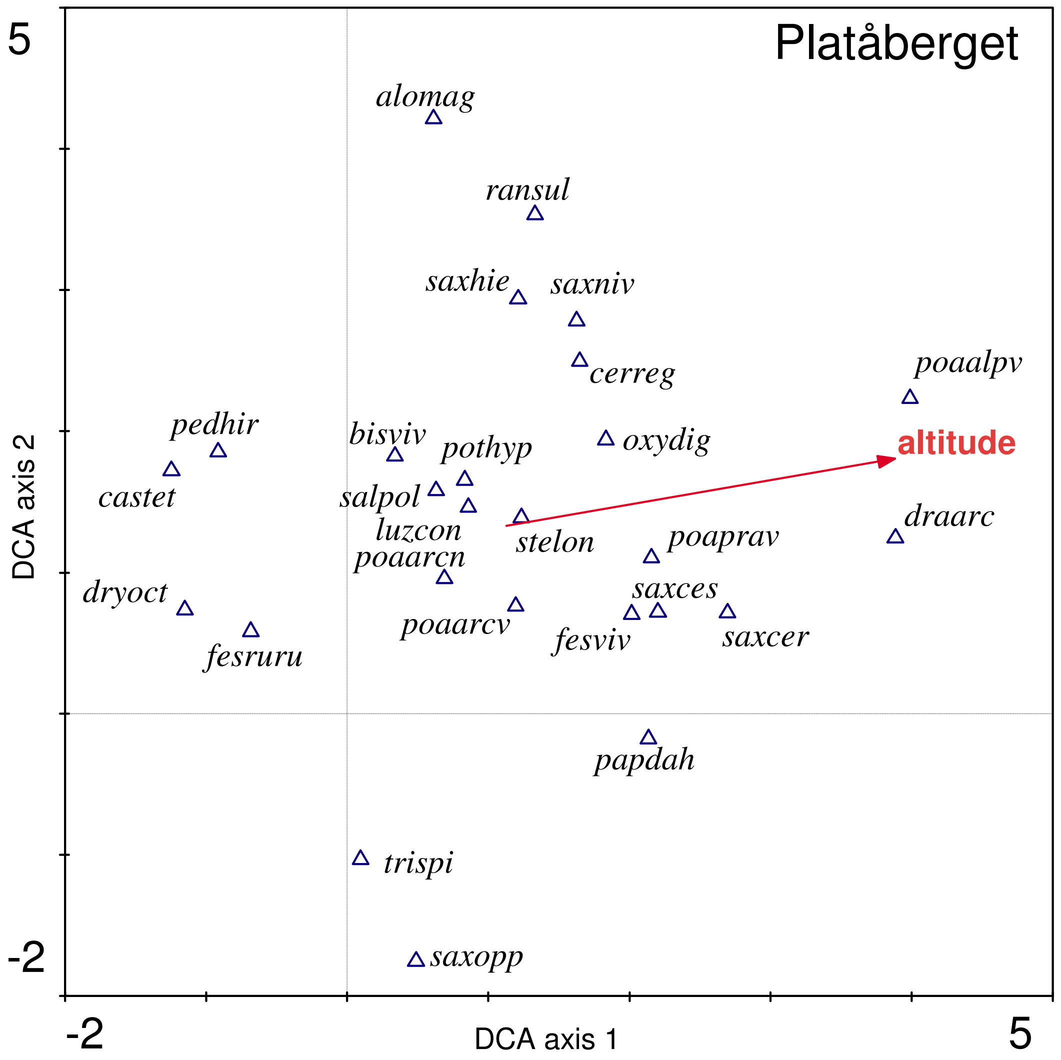

Figure 3.3 *DCA ordination plot of the species observed on Platåberget. For species abbreviations see Appendix III. The triangles illustrate species optima. The environmental variable 'altitude' is shown as an arrow and has been rescaled 7 times. Rare species were downweighted and removed from the plot to keep it clear.*

3.3 Species response to temperature

In the first regression analysis I detected within 40 species the character of their relationship to temperature. Some trends were linear and unimodal, but not significant trends were also observed. All diagrams of the fitted GLMs for all of the 40 species are presented in Appendix V. The associated GLM summary table is presented in Table 3.3. To ease the digestion of the included information, I present the table content supplementary in condensed form in Table 3.4.

Table 3.3 *Summary of the logistic regression models between species abundance and temperature. Linear models were tested against null models for significance, and unimodal models were tested against significant linear models. When the linear trends were not significant, unimodal models were tested against null models. Null deviances, degrees of freedom (D.f.) used in the test, p-values and residual deviances for linear and unimodal models are presented separately for each species in each transect. NS stands for 'not significant'. Empty fields indicate that the species was not observed in the respective transect. The results for the final models are printed in bold.*

Species	**Zeppelinfjellet**							**Brentskarhaugen**							**Platåberget**						
		Linear trend			**Unimodal trend**				**Linear trend**			**Unimodal trend**				**Linear trend**			**Unimodal trend**		
	Null dev.	D.f.	P-value	Res. dev.	D.f.	P-value	Res. dev.	Null dev.	D.f.	P-value	Res. dev.	D.f.	P-value	Res. dev.	Null dev.	D.f.	P-value	Res. dev.	D.f.	P-value	Res. dev.
Alopecurus magellanicus	-	-	-	-	-	-	-	25.4661	1	<0.05	23.4216	**1**	**<0.05**	**20.2968**	38.986	1	NS	-	2	NS	-
Bistorta vivipara	26.958	1	<0.05	16.138	**1**	**<0.05**	**12.5137**	30.841	1	<0.001	19.599	**1**	**<0.001**	**14.9575**	38.986	**1**	**<0.01**	**29.057**	1	NS	-
Cassiope tetragona ssp. *tetragona*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35.403	**1**	**<0.01**	**28.102**	1	NS	-
Cerastium arcticum	26.5627	1	NS	-	2	NS	-	15.9576	1	<0.01	13.2324	**1**	**<0.05**	**11.4231**	-	-	-	-	-	-	-
Cerastium regelii	11.9753	1	<0.001	5.8268	**1**	**<0.05**	**5.2944**	21.8169	1	NS	-	**2**	**<0.001**	**15.9554**	41.381	1	NS	-	2	NS	-
Cochlearia groenlandica	-	-	-	-	-	-	-	9.6947	1	<0.05	8.3851	**1**	**<0.01**	**6.8151**	-	-	-	-	-	-	-
Draba alpina	-	-	-	-	-	-	-	12.5298	1	NS	-	2	NS	-	-	-	-	-	-	-	-
Draba arctica ssp. *arctica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35.403	1	<0.001	21.686	**1**	**<0.05**	**17.5759**
Draba corymbosa	21.1837	1	NS	-	2	NS	-	18.823	1	NS	-	2	NS	-	-	-	-	-	-	-	-
Draba fladnizensis	11.4321	1	NS	-	2	NS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Draba pauciflora	-	-	-	-	-	-	-	17.5887	**1**	**<0.001**	**12.2755**	1	NS	-	-	-	-	-	-	-	-
Draba subcapitata	16.486	1	NS	-	2	NS	-	13.6702	1	NS	-	2	NS	-	-	-	-	-	-	-	-
Dryas octopetala	34.489	1	NS	-	2	NS	-	-	-	-	-	-	-	-	42.165	1	<0.001	23.046	**1**	**<0.01**	**12.4241**
Festuca rubra ssp. *rubra*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41.381	1	<0.05	35.519	**1**	**<0.001**	**22.843**
Festuca viviparoidea	-	-	-	-	-	-	-	30.3845	1	<0.05	27.1999	**1**	**<0.05**	**21.334**	40.324	**1**	**<0.05**	**34.578**	1	NS	-
Luzula confusa	19.2155	**1**	**<0.05**	**14.1254**	1	NS	-	29.135	**1**	**<0.01**	**24.011**	1	NS	-	27.3918	**1**	**<0.05**	**21.5208**	1	NS	-
Minuartia biflora	-	-	-	-	-	-	-	22.9756	**1**	**<0.01**	**18.5878**	1	NS	-	-	-	-	-	-	-	-
Minuartia rubella	-	-	-	-	-	-	-	16.574	**1**	**<0.001**	**8.6416**	1	NS	-	-	-	-	-	-	-	-
Oxyria digyna	-	-	-	-	-	-	-	26.5128	**1**	**<0.001**	**19.391**	1	NS	-	40.324	1	NS	-	**2**	**<0.05**	**31.84**
Papaver dahlianum	-	-	-	-	-	-	-	35.803	1	<0.001	7.399	**1**	**<0.001**	**4.858**	42.943	1	NS	-	2	NS	-
Pedicularis hirsuta	-	-	-	-	-	-	-	9.9032	1	NS	-	**2**	**<0.001**	**4.9194**	42.684	1	<0.001	28.589	**1**	**<0.05**	**23.9896**
Poa alpina var. *alpina*	-	-	-	-	-	-	-	29.1397	1	NS	-	**2**	**<0.05**	**23.6282**	-	-	-	-	-	-	-
Poa alpina var. *vivipara*	-	-	-	-	-	-	-	18.9434	**1**	**<0.01**	**14.7468**	1	NS	-	30.462	**1**	**<0.001**	**10.139**	1	NS	-
Poa arctica ssp. *arctica* (non-viv.)	-	-	-	-	-	-	-	31.991	1	NS	-	2	NS	-	41.381	**1**	**<0.05**	**35.493**	1	NS	-
Poa arctica ssp. *arctica* (viv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42.165	1	NS	-	2	NS	-
Poa pratensis ssp. *alpigena* (non-viv.)	-	-	-	-	-	-	-	39.451	**1**	**<0.01**	**33.307**	1	NS	-	-	-	-	-	-	-	-
Poa pratensis ssp. *alpigena* (viv.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42.165	1	NS	-	**2**	**<0.01**	**27.711**
Potentilla hyparctica ssp. *hyparctica*	-	-	-	-	-	-	-	7.8482	**1**	**<0.05**	**6.7732**	1	NS	-	41.381	1	NS	-	2	NS	-
Ranunculus pygmaeus	-	-	-	-	-	-	-	16.1655	**1**	**<0.05**	**13.8981**	1	NS	-	-	-	-	-	-	-	-
Ranunculus sulphureus	-	-	-	-	-	-	-	21.9771	1	<0.01	18.6083	**1**	**<0.01**	**15.7692**	35.403	1	NS	-	2	NS	-
Sagina nivalis	16.5993	**1**	**<0.001**	**6.6048**	1	NS	-	18.4391	1	<0.05	15.9075	**1**	**<0.05**	**14.0793**	-	-	-	-	-	-	-
Salix polaris	38.681	**1**	**<0.01**	**30.958**	1	NS	-	29.407	**1**	**<0.01**	**23.841**	1	NS	-	33.118	**1**	**<0.01**	**24.802**	1	NS	-
Saxifraga cernua	19.859	1	NS	-	2	NS	-	7.091	1	NS	-	**2**	**<0.01**	**5.7145**	42.943	**1**	**<0.001**	**29.313**	1	NS	-
Saxifraga cespitosa ssp. *cespitosa*	24.2386	1	NS	-	2	NS	-	16.2944	1	<0.001	10.2716	**1**	**<0.001**	**5.266**	37.351	1	<0.01	27.396	**1**	**<0.01**	**19.041**
Saxifraga hieracifolia ssp. *hieracifolia*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.118	1	NS	-	2	NS	-
Saxifraga nivalis	-	-	-	-	-	-	-	23.589	1	<0.001	11.405	**1**	**<0.01**	**9.4382**	37.351	1	NS	-	**2**	**<0.05**	**30.621**
Saxifraga oppositifolia ssp. *oppositifolia*	16.9758	**1**	**<0.05**	**15.2252**	1	NS	-	17.9746	1	<0.001	8.8587	**1**	**<0.05**	**7.8501**	33.118	1	NS	-	2	NS	-
Silene acaulis	20.7582	1	<0.001	7.1687	**1**	**<0.001**	**2.1647**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longipes	-	-	-	-	-	-	-	20.388	1	<0.05	18.806	**1**	**<0.001**	**13.7427**	37.351	1	NS	-	**2**	**<0.05**	**28.516**
Trisetum spicatum ssp. *spicatum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38.986	**1**	**<0.01**	**31.477**	1	NS	-

Table 3.4 *Condensed version of Table 3.3. Summarised are the final models for each of the 40 species. The species are grouped and ranked according to their trends in response to temperature: 1) species with a linear trend on one mountain, 2) species with a linear trend on minimum two mountains, 3) species with a unimodal trend on one mountain, 4) species with a unimodal trend on minimum two mountains, 5) species with a change in their trends between the mountains and 6) species without a significant response to temperature.*

Final model	**Function**
1	linear
2	unimodal

-	Not observed or observed less than 6 times
NS	No significant trend
🟧	Positive linear trend
🟦	Negative linear trend
🟪	Negative unimodal trend

Species name	**Zeppelinfjellet**	**Brentskarhaugen**	**Platåberget**
Cassiope tetragona ssp. *tetragona*	-	-	🟧 **1**
Minuartia biflora	-	🟧 **1**	-
Poa arctica ssp. *arctica* (non-viv.)	-	NS	🟧 **1**
Poa pratensis ssp. *alpigena* (non-viv.)	-	🟧 **1**	-
Ranunculus pygmaeus	-	🟧 **1**	-
Trisetum spicatum ssp. *spicatum*	-	-	🟧 **1**
Draba pauciflora	-	🟦 **1**	-
Minuartia rubella	-	🟦 **1**	-
Potentilla hyparctica ssp. *hyparctica*	-	🟦 **1**	NS
Salix polaris	🟧 **1**	🟧 **1**	🟧 **1**
Luzula confusa	🟧 **1**	🟦 **1**	🟧 **1**
Poa alpina var. *vivipara*	-	🟧 **1**	🟦 **1**
Silene acaulis	**2**	-	-
Dryas octopetala	NS	-	**2**
Ranunculus sulphureus	-	**2**	NS
Alopecurus magellanicus	-	**2**	NS
Poa alpina var. *alpina*	-	**2**	-
Poa pratensis ssp. *alpigena* (viv.)	-	-	**2**
Cerastium arcticum	NS	**2**	-
Cochlearia groenlandica	-	**2**	-
Draba arctica ssp. *arctica*	-	-	**2**
Papaver dahlianum	-	**2**	NS
Festuca rubra ssp. *rubra*	-	-	🟪 **2**
Cerastium regelii	**2**	**2**	NS
Pedicularis hirsuta	-	**2**	**2**
Stellaria longipes	-	**2**	**2**
Saxifraga cespitosa ssp. *cespitosa*	NS	**2**	**2**
Saxifraga nivalis	-	**2**	**2**
Oxyria digyna	-	🟧 **1**	**2**
Sagina nivalis	🟧 **1**	**2**	-
Saxifraga oppositifolia ssp. *oppositifolia*	🟧 **1**	**2**	NS
Bistorta vivipara	🟪 **2**	**2**	🟧 **1**
Festuca viviparoidea	-	**2**	🟦 **1**
Saxifraga cernua	NS	**2**	🟦 **1**
Draba alpina	-	NS	-
Draba corymbosa	NS	NS	-
Draba fladnizensis	NS	-	-
Draba subcapitata	NS	NS	-
Poa arctica ssp. *arctica* (viv.)	-	-	NS
Saxifraga hieracifolia ssp. *hieracifolia*	-	-	NS

Out of 40 species, 12 had a linear relationship to temperature in all transects in which they were found (Table 3.4). *Luzula confusa* and *Salix polaris* are two examples of these species. They exhibited linear trends in all of the transects (Figure 3.4). Sixteen species had a unimodal or no significant relationship to temperature in the transects in which they were found. *Saxifraga cespitosa* ssp. *cespitosa* and *Stellaria longipes* for example responded unimodal on Brentskarhaugen and Platåfjellet (Figure 3.5). Six species changed between linear and unimodal relationship to temperature between the transects. *Bistorta vivipara* and *Festuca viviparoidea* exemplify these differences in response to temperature in Figure 3.6. Finally, 6 species did not have a significant relationship to temperature. *Draba corymbosa* is presented as an example in Figure 3.7.

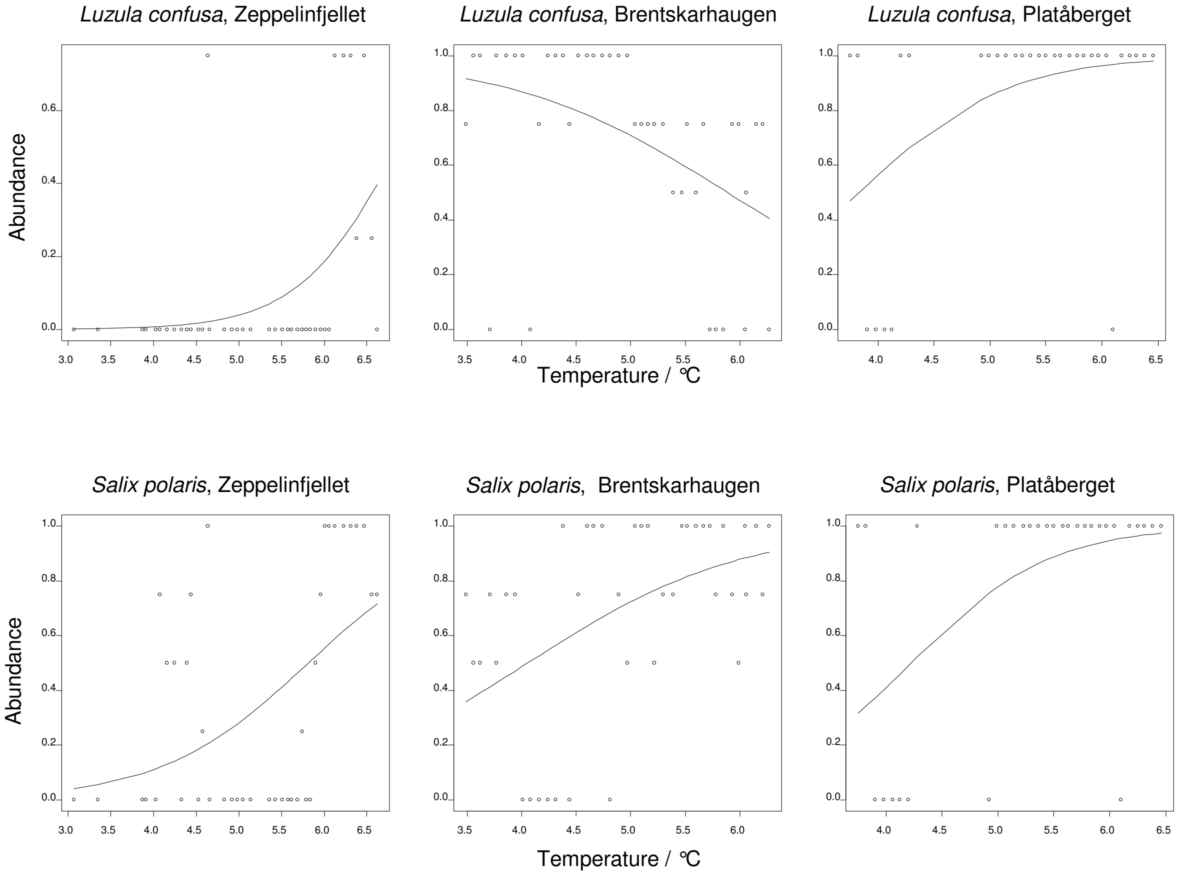

Figure 3.4 Luzula confusa *and* Salix polaris *are two out of 12 species which responded linear to temperature.*

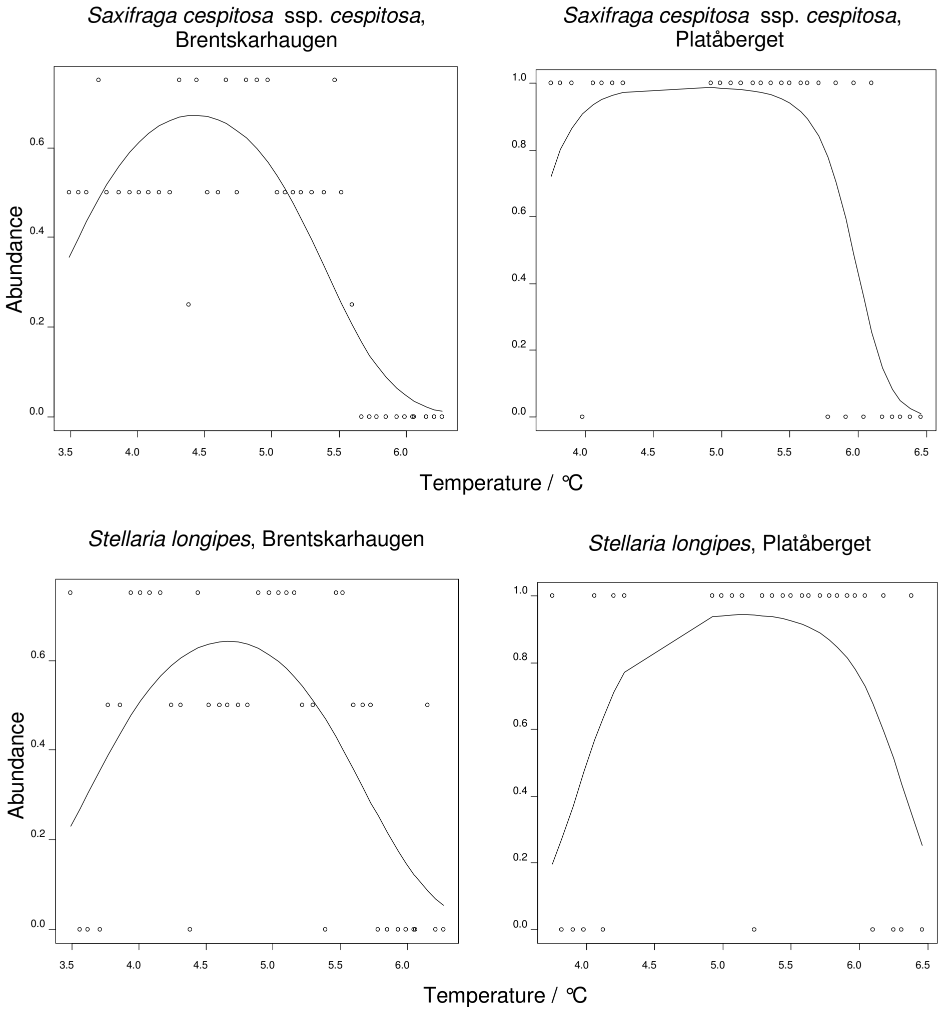

Figure 3.5 Saxifraga cespitosa *ssp.* cespitosa *and* Stellaria longipes *are two examples out of 16 species with a unimodal relationship to temperature.*

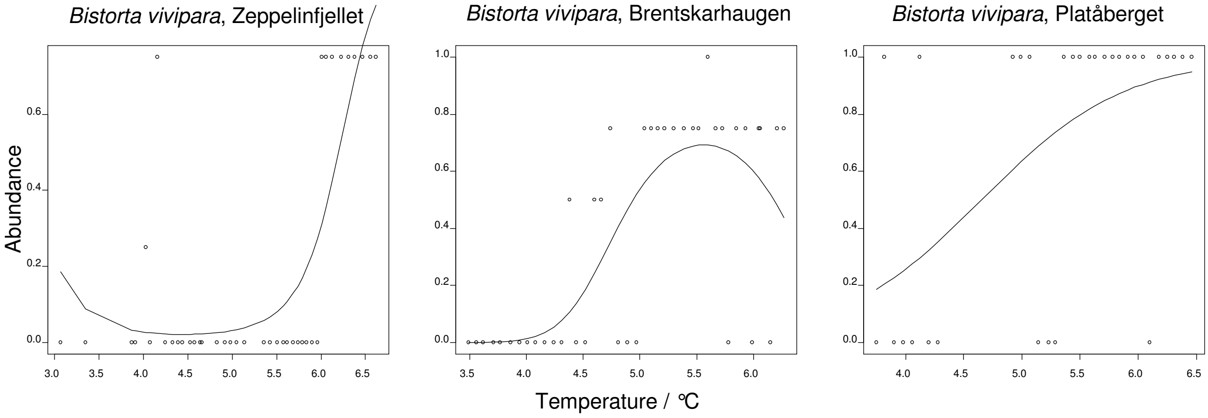

Figure 3.6 (part I) Bistorta vivipara *is one example out of six species that responded in one transect linear to temperature and unimodal in at least one other.*

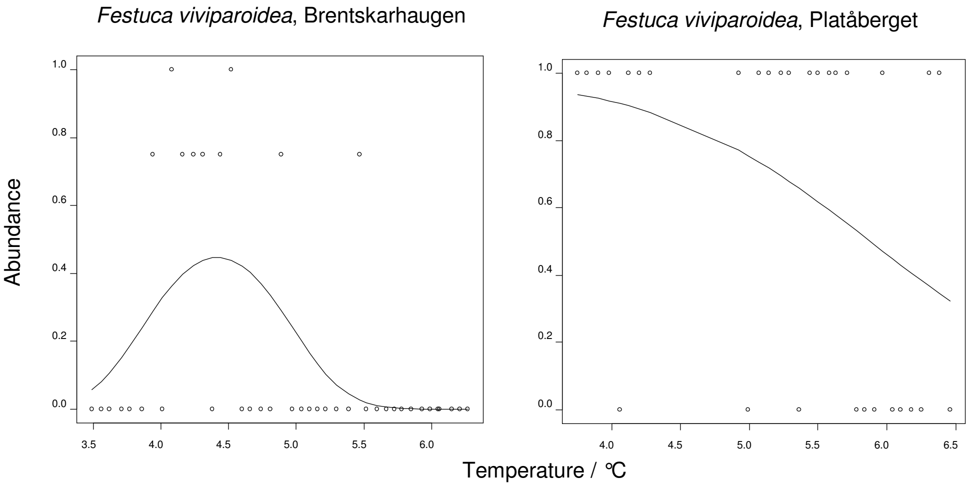

Figure 3.6 (part II) Festuca viviparoidea *is one example out of six species that responded in one transect linear to temperature and unimodal in another.*

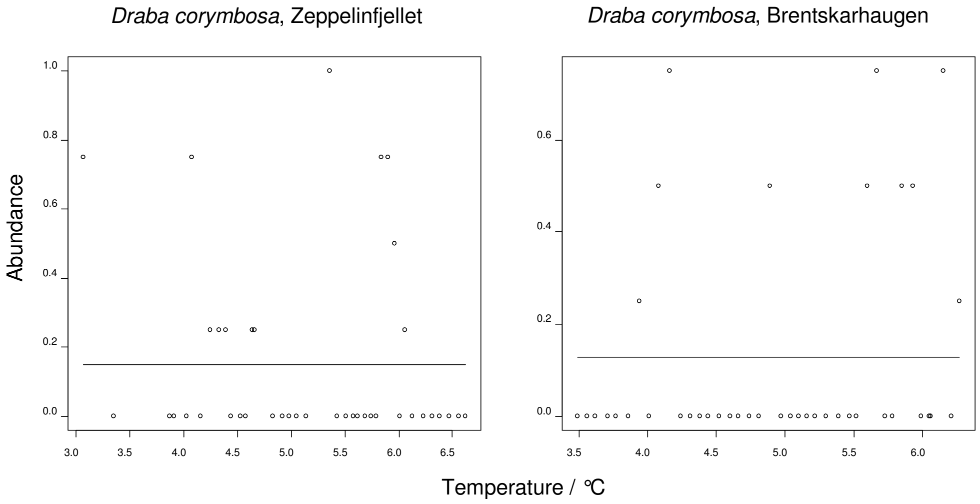

Figure 3.7 *The diagrams for* Draba corymbosa *exemplify no significant response to temperature.*

According to the results presented in Table 3.4, the determined optima and trends in temperature response are presented in Table 3.5. Seven species had a positive linear trend to be more abundant at higher temperatures in the respective transect. Three species had a negative linear trend indicating a tendency to prefer low temperatures in the respective transect. *Luzula confusa* and *Poa alpina* var. *vivipara* exhibited a change in the linear trend between the transects. Their different tendencies in response to temperature are documented in Table 3.5. For 21 species optima in temperature response could be defined. *Cerastium regelii* and *Silene acaulis* had among these the highest optima. *Papaver dahlianum* and *Saxifraga nivalis* exhibited the lowest optima. *Festuca rubra* ssp. *rubra* was found to have a negative unimodal trend, indicating that it was present in the lowland and at the top, but absent at mid-altitude. The temperature ranges for all

73 observed species are grouped into four tables according to the species' trends in temperature response and are provided in Appendix VI.

***Table 3.5** Trends in response to temperature and temperature optima (°C).*

-	Not observed or observed less than 6 times
NS	No significant trend
Warm	Linear trend towards higher temperatures
Cold	Linear trend towards low temperatures
🟪	Negative unimodal trend

Species name	Zeppelinfjellet	Brentskarhaugen	Platåberget
Cassiope tetragona ssp. *tetragona*	-	-	**Warm**
Minuartia biflora	-	**Warm**	-
Poa arctica ssp. *arctica* (non-viv.)	-	NS	**Warm**
Poa pratensis ssp. *alpigena* (non-viv.)	-	**Warm**	-
Ranunculus pygmaeus	-	**Warm**	-
Trisetum spicatum ssp. *spicatum*	-	-	**Warm**
Draba pauciflora	-	**Cold**	-
Minuartia rubella	-	**Cold**	-
Potentilla hyparctica ssp. *hyparctica*	-	**Cold**	NS
Salix polaris	**Warm**	**Warm**	**Warm**
Luzula confusa	**Warm**	**Cold**	**Warm**
Poa alpina var. *vivipara*	-	**Warm**	**Cold**
Silene acaulis	**6.3**	-	-
Dryas octopetala	NS	-	**5.9**
Ranunculus sulphureus	-	**5.3**	NS
Alopecurus magellanicus	-	**5.2**	NS
Poa alpina var. *alpina*	-	**5**	-
Poa pratensis ssp. *alpigena* (viv.)	-	-	**4.9**
Cerastium arcticum	NS	**4.4**	-
Cochlearia groenlandica	-	**4.4**	-
Draba arctica ssp. *arctica*	-	-	**4.3**
Papaver dahlianum	-	**4**	NS
Festuca rubra ssp. *rubra*	-	-	**3.8**
Cerastium regelii	**6.5**	**4.9**	NS
Pedicularis hirsuta	-	**5.1**	**5.9**
Stellaria longipes	-	**4.7**	**5.1**
Saxifraga cespitosa ssp. *cespitosa*	NS	**4.4**	**4.9**
Saxifraga nivalis	-	**3.9**	**5**
Oxyria digyna	-	**Warm**	**4.9**
Sagina nivalis	**Warm**	**4.3**	-
Saxifraga oppositifolia ssp. *oppositifolia*	**Warm**	**3.9**	NS
Bistorta vivipara	**6.6**	**5.6**	**Warm**
Festuca viviparoidea	-	**4.4**	**Cold**
Saxifraga cernua	NS	**5**	**Cold**

3.4 Similarities and differences in species response to temperature

In the second regression analysis 18 species have been compared regarding their similarities and differences in response to temperature between the transects. An overview over the results of the comparison is given in Table 3.6.

***Table 3.6** Listed are 18 species that were observed in at least two transects and analysed regarding their similarities and differences in response to temperature. The numbers indicate the final models and thus if the species responded different to temperature between the transects. The species are sorted from no response to temperature (model 0) to a difference in unimodal trends between the transects (model 5). A detailed summary of the results including p-values and residual deviances is provided in AppendixVII.*

-	Not observed or observed less than 6 times
🟨	Observed in two transects
🟩	Observed in all transects

Species name	**Final model**		
	Zeppelinfjellet	**Brentskarhaugen**	**Platåberget**
Draba corymbosa	**0**		**-**
Alopecurus magellanicus	-	**1**	
Draba subcapitata	**3**		-
Festuca viviparoidea	-	**3**	
Cerastium arcticum	**4**		-
Sagina nivalis	**4**		-
Oxyria digyna	-	**4**	
Pedicularis hirsuta	-	**4**	
Poa alpina var. *vivipara*	-	**4**	
Poa arctica ssp. *arctica* (non-viv.)	-	**4**	
Potentilla hyparctica ssp. *hyparctica*	-	**4**	
Saxifraga nivalis	-	**4**	
Stellaria longipes	-	**4**	
Luzula confusa	**4**		
Ranunculus sulphureus	-	**5**	
Cerastium regelii	-	**5**	
Bistorta vivipara	**5**		
Saxifraga cernua	**5**		

Further, five species have been visually compared regarding their similarities and differences in response to temperature based on the results of the first regression analysis. *Salix polaris*, *Dryas octopetala*, *Papaver dahlianum*, *Saxifraga cespitosa* ssp. *cespitosa* and *Saxifraga oppositifolia* ssp. *oppositifolia* were frequently observed and showed clear similarities and differences in their relationship to temperature between the different mountains. Because of their sharp changes from presence to absence in some transects it was not reasonable to use the same GLM as for the other 18 species to compare their responses to temperature. The graphs of the fitted models from the first regression analysis were sufficient to illustrate the similarities and differences between the mountains. *S. polaris* is the only species showing similar trends in all transects. On all mountains it increased in abundance with increasing temperature (Figure 3.8). The other species exhibited differences in their relationships to temperature between the transects. All of them had a unimodal response in at least one transect and exhibited no significant trends in one other transect. *D. octopetala* was almost absent in the transect on Zeppelinfjellet and did not show a significant response to temperature. On Platåberget it was very abundant from 5.3 °C upwards and responded unimodally to temperature (Figure 3.9). *P. dahlianum* increased on Brentskarhaugen gradually with decreasing temperature. On Platåberget it exhibited no significant relationship to temperature (Figure 3.10). *S. cespitosa* ssp. *cespitosa* revealed on Brentskarhaugen and Platåberget a unimodal trend with temperature optima of 4.4 and 4.9 °C respectively. The species was frequently observed on Zeppelinfjellet, but did not show a significant trend in response to temperature (Figure 3.11). *S. oppositifolia* ssp. *oppositifolia* was observed in almost every plot on Zeppelinfjellet and had a linear trend towards increasing temperatures. On Brentskarhaugen it showed an increase with decreasing temperature, while it was almost absent and showing no significant response on Platåberget (Figure 3.12).

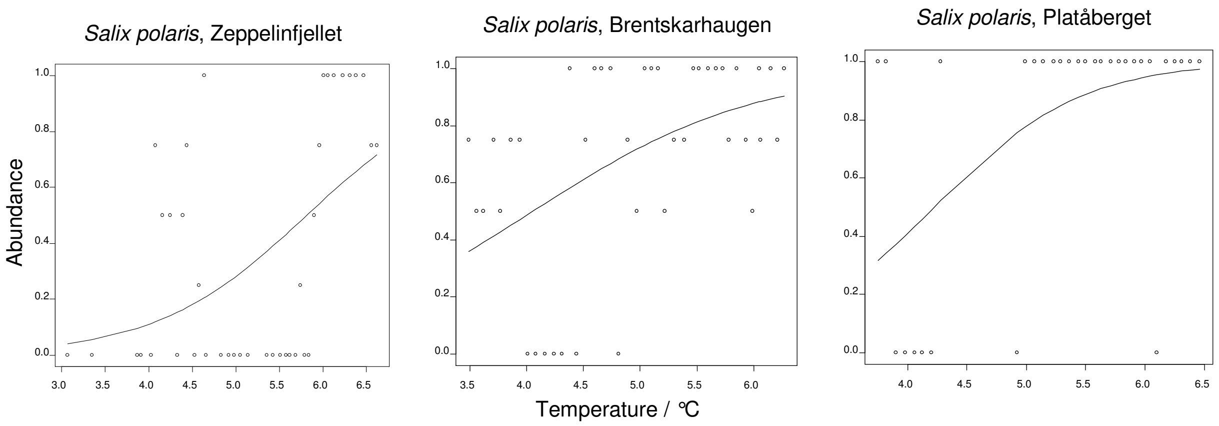

Figure 3.8 Salix polaris *responded on all mountains linear to temperature. The results of the analysis are summarised in Table 3.3.*

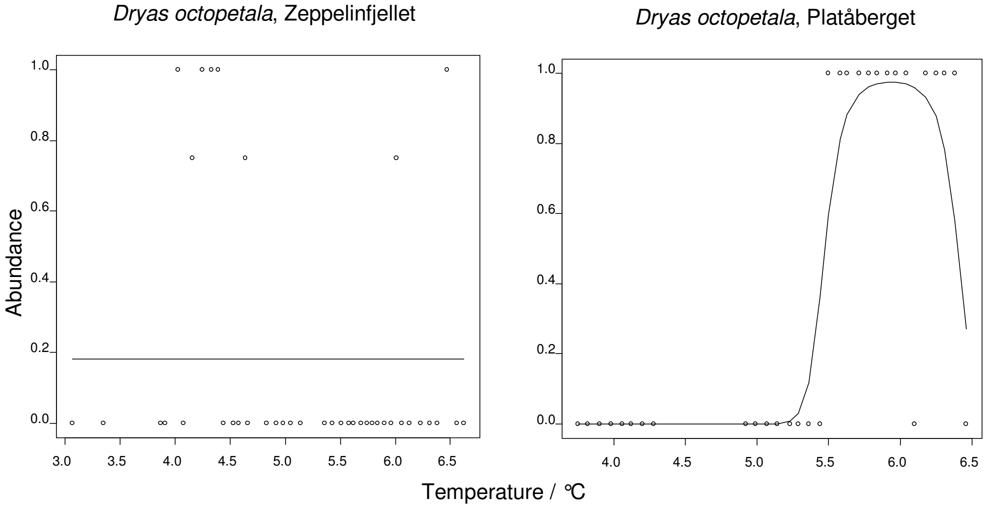

Figure 3.9 Dryas octopetala *did not have a significant relationship to temperature on Zeppelinfjellet, but showed a unimodal relationship to temperature on Platåberget. The results of the analysis are summarised in Table 3.3.*

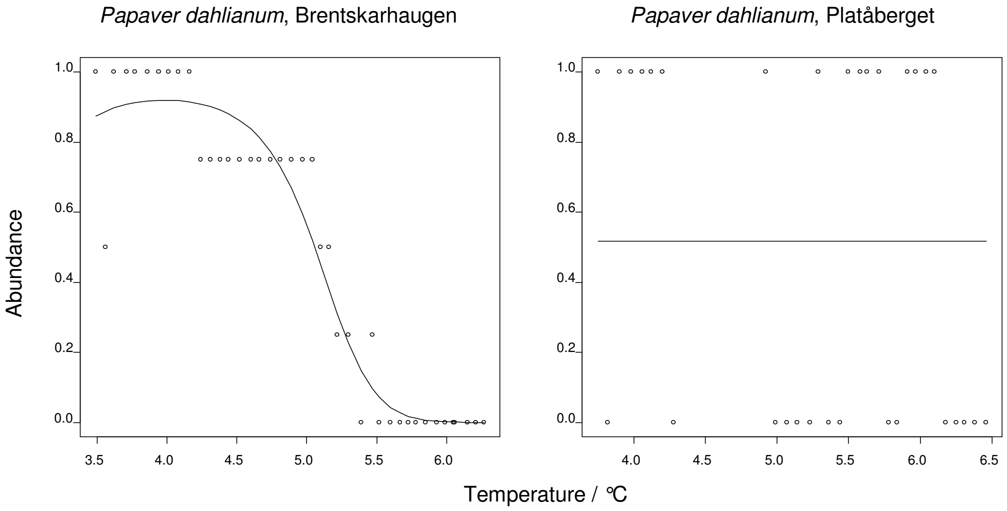

Figure 3.10 Papaver dahlianum *had a unimodal relationship to temperature on Brentskarhaugen and no significant relationship on Platåberget. The results of the analysis are summarised in Table 3.3.*

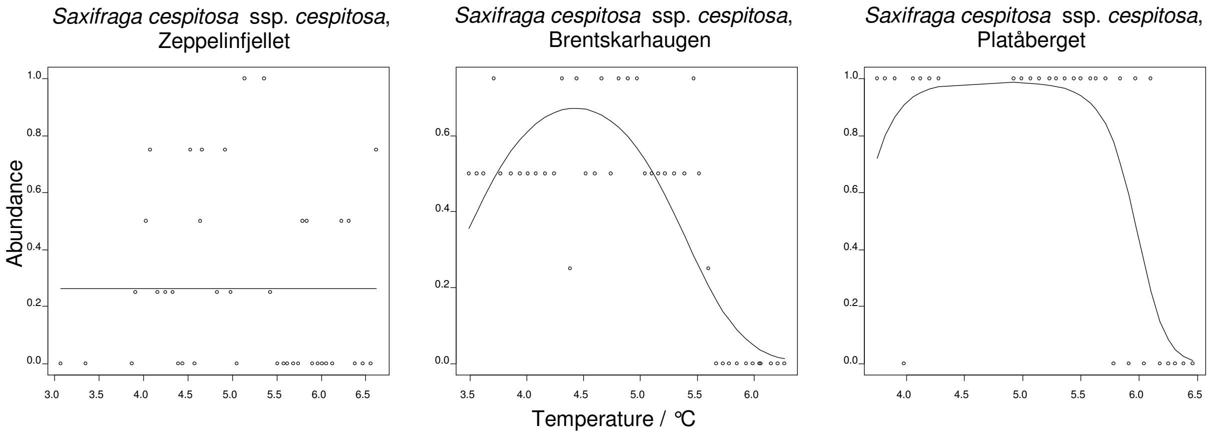

Figure 3.11 Saxifraga cespitosa *ssp.* cespitosa *responded on Brentskarhaugen and Platåberget unimodal to temperature, while it had no significant relationship to temperature on Zeppelinfjellet. The results of the analysis are summarised in Table 3.3.*

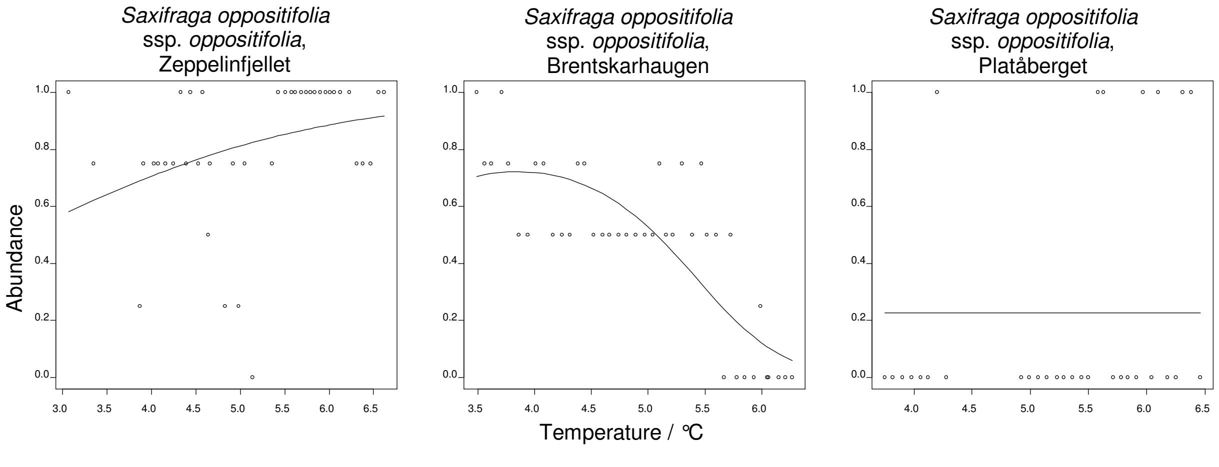

Figure 3.12 *The relationship of* Saxifraga oppositifolia *ssp.* oppositifolia *to temperature was linear on Zeppelinfjellet, unimodal on Brentskarhaugen and not significant on Platåberget. The results of the analysis are summarised in Table 3.3.*

When using the GLMs to determine if and in which way the 18 species differed between the mountains, 4 species responded similarly to temperature in the transects. The remaining 14 species revealed differences in linear or unimodal response between the transects. *Draba corymbosa* did not respond significantly in any of the transects to temperature (Figure 3.13).

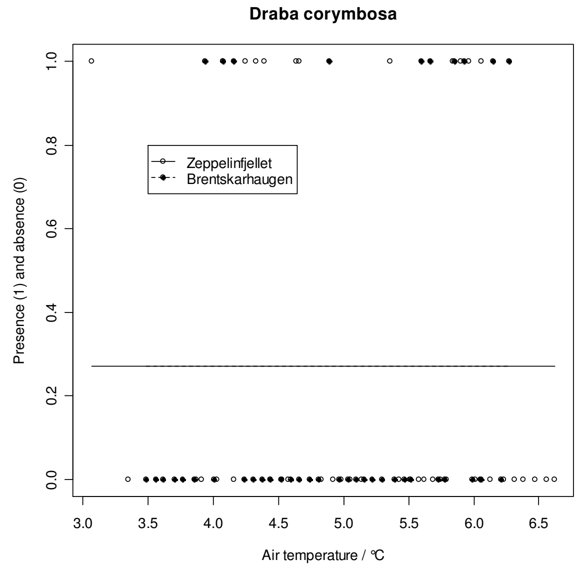

Figure 3.13 *Diagram of the null model for* Draba corymbosa. *Since there is no significant difference between the average abundance between the transects the lines for the null models lie on top of each other. The results of the analysis are provided in Appendix VII.*

Alopecurus magellanicus differed between the transects in average abundance, but not in response to temperature. Figure 3.14 shows that the species was more abundant on Brentskarhaugen than on Platåberget.

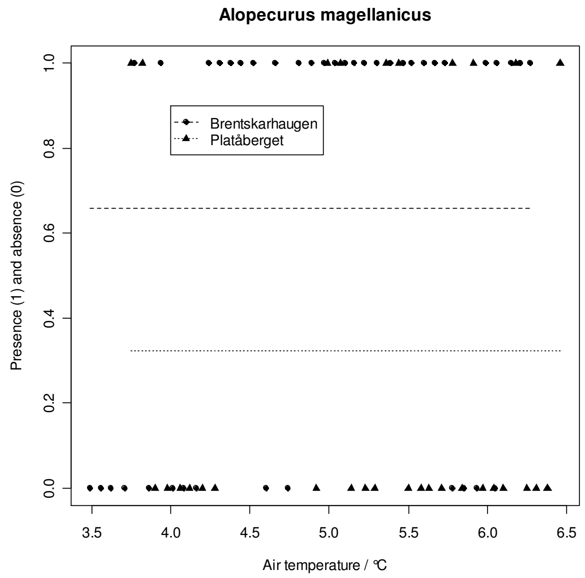

Figure 3.14 *The diagram presents the minimal model for the abundance of* Alopecurus magellanicus. *The results of the analysis are provided in Appendix VII.*

Draba subcapitata and *Festuca viviparoidea* were observed in two transects, and responded unimodally to temperature without significant differences between the transects (Figure 3.15).

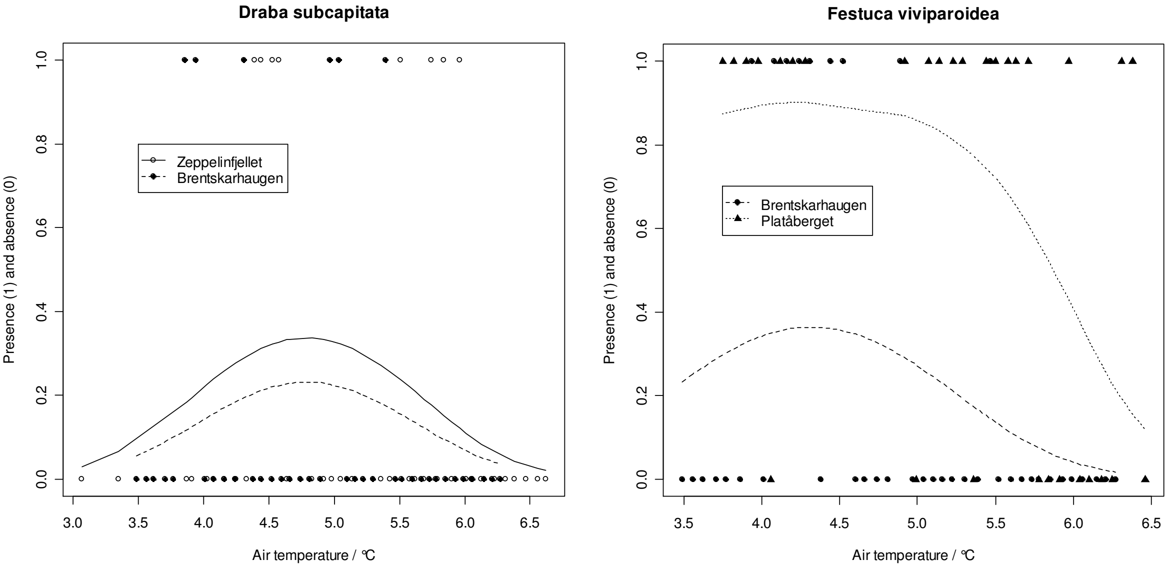

Figure 3.15 *Illustrated are the temperature response curves of* Draba subcapitata *and* Festuca viviparoidea. *Both show consistence in their relationships to temperature in the transects. The results of the analysis are provided in Appendix VII.*

The majority, 10 out of 18 species, differed in the linear response to temperature between the transects (Figure 3.16). *Luzula confusa* was the only species out of 10 which was observed and analysed within three transects. On Zeppelinfjellet and Platåberget it increased with increasing temperature, while it increased with decreasing temperature on Brentskarhaugen. The remaining species showed opposing trends between two mountains.

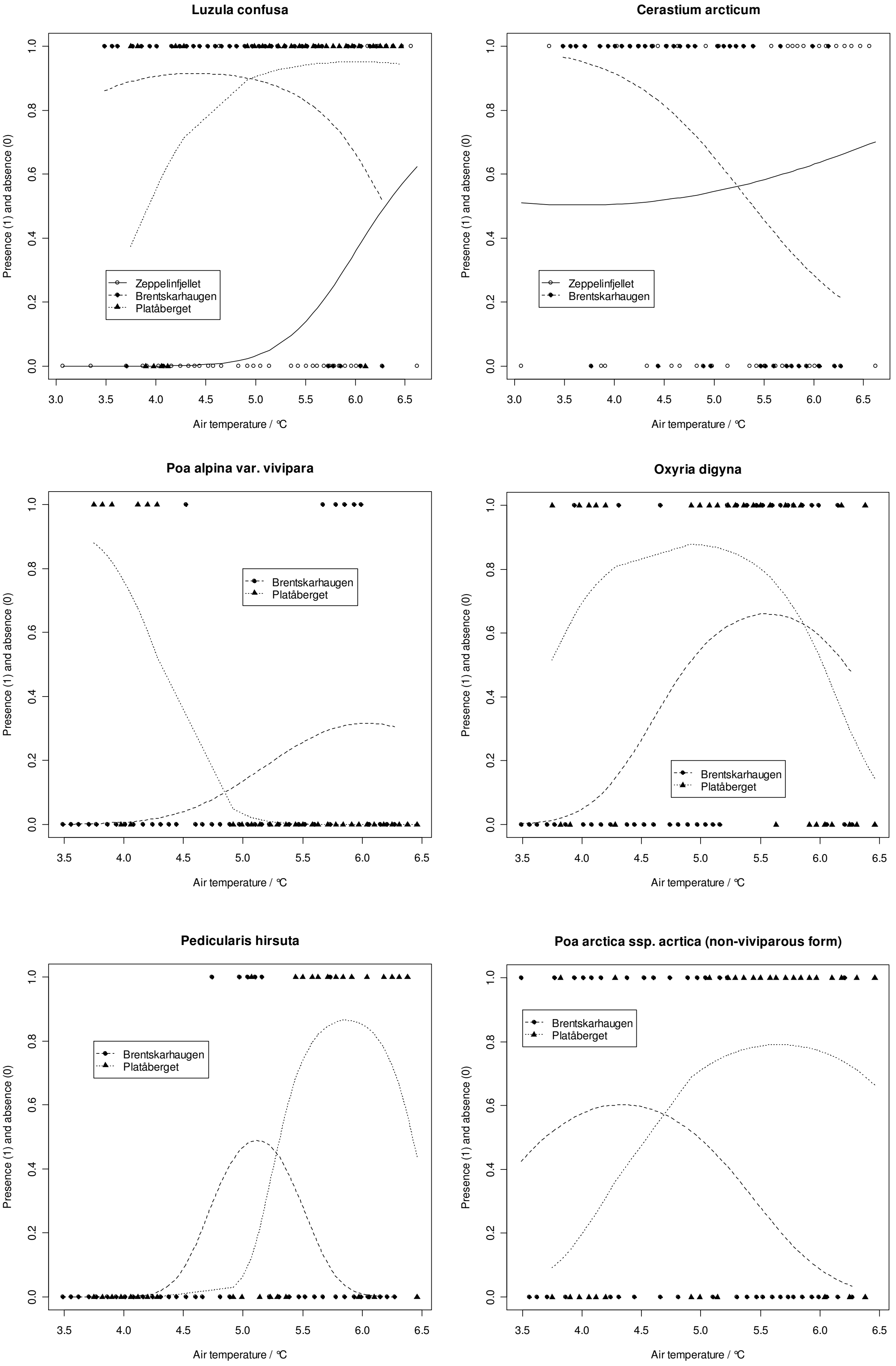

Figure 3.16 (part I) *Illustrated are the graphs of 10 species which exhibited significant differences in their linear responses to temperature among the transects. The results of the analysis are provided in Appendix VII.*

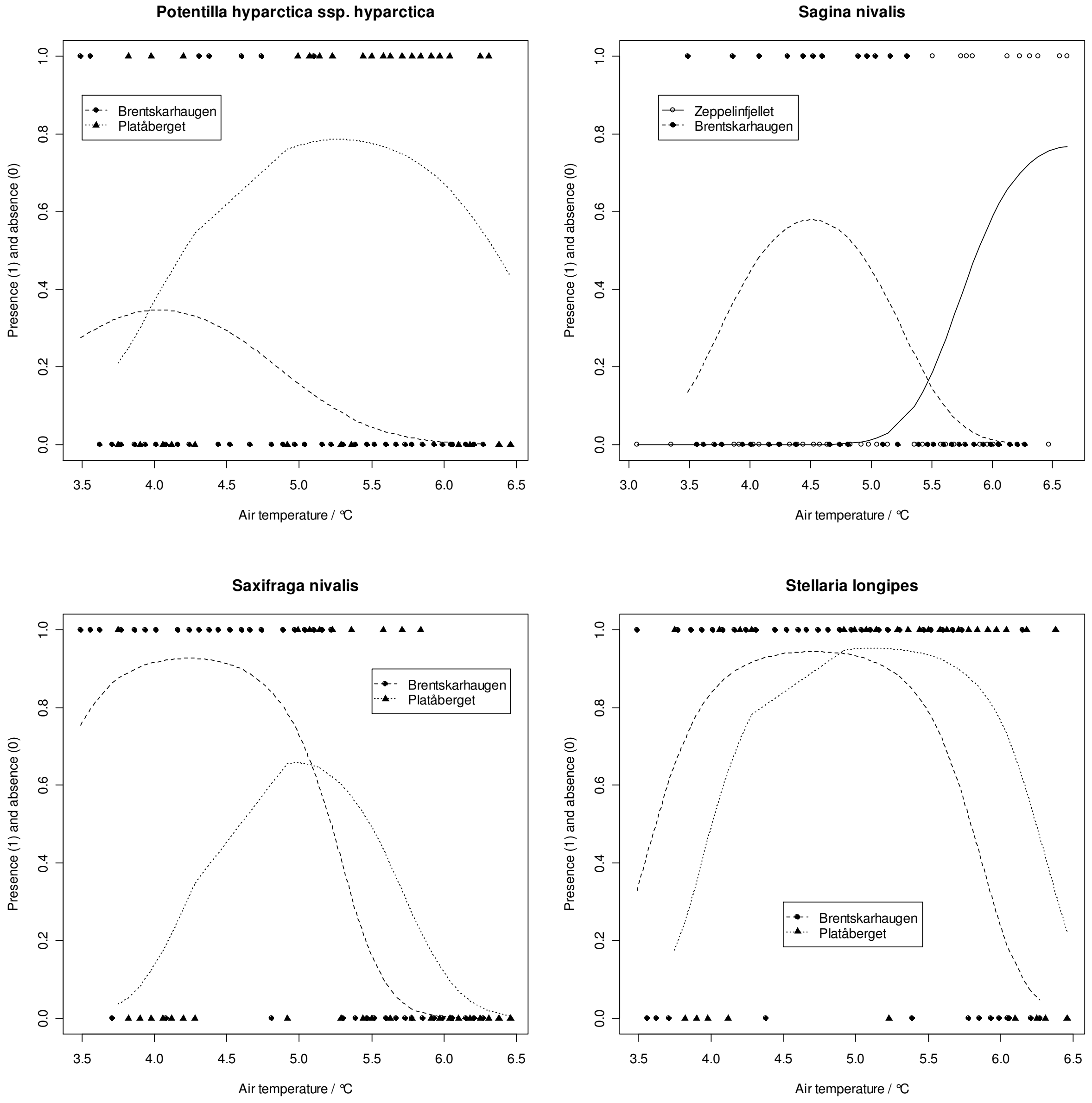

Figure 3.16 (part II) *Illustrated are the graphs of 10 species which exhibited significant differences in their linear responses to temperature among the transects. The results of the analysis are provided in Appendix VII.*

Four species differed in the unimodal response to temperature (Figure 3.17). *Cerastium regelii* and *Ranunculus sulphureus* were observed in two transects. Both species exhibited a positive unimodal trend on Brentskarhaugen and a negative unimodal trend on Platåberget. *Bistorta vivipara* and *Saxifraga cernua* were observed in three transects. On Brentskarhaugen both species showed positive unimodal trends. On Platåberget they exhibited a linear trend, which was positive for *Bistorta vivipara* and negative for *Saxifraga cernua*. On Zeppelinfjellet both species responded negative unimodal.

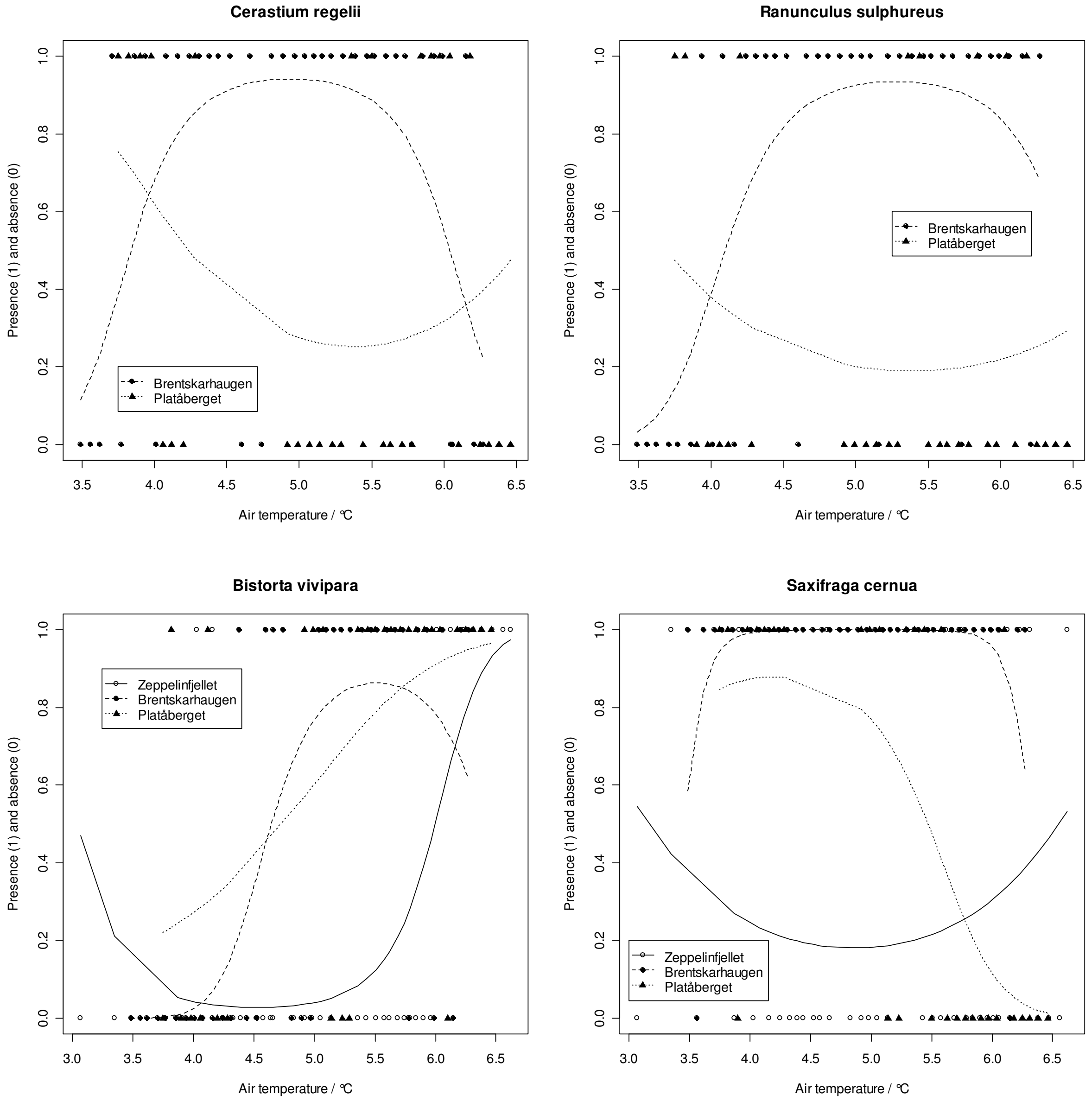

Figure 3.17 *Illustrated are the graphs of 4 species which exhibited significant differences in their unimodal responses to temperature among the transects. The results of the analysis are provided in Appendix VII.*

4. Discussion

Temperature is assumed to be a major factor in determining vascular plant species distribution (Woodward & Williams 1987, Karlsen & Elvebakk 2003, Alsos et al. 2007). Thus, it is important to investigate species' relationships to temperature when predicting species' responses to global climate change. This project was motivated by the enormous potential altitudinal gradients offer to study how vascular plant species abundance is related to temperature (Körner 2007). Using the decrease in mean July temperature with increasing altitude, I investigated species' temperature relationships on a small spatial scale. Thus, my results fill the gap between experimental and broad scale data (Huntley et al. 1995, Jonsdottir et al. 2005, Thuiller et al. 2005b, Walker et al. 2006, Klanderud 2008) and provide urgently needed species-specific small-scale data, which supplies knowledge that is important for the conservation of arctic-alpine vegetation (Parolo & Rossi 2008). As far as I know, no study with a similar approach in arctic regions is yet published. Altitudinal distributions and limits of vascular plants have been studied before on Greenland and in Svalbard (Sunding 1962, Virtanen et al. 1997, Schwarzenbach 2000), but not with a fine spatial sampling resolution as I used. None of these studies assessed the extent to which species differ in their response to temperature between different study sites in the Arctic. Pearman et al. (2008) pointed out that single populations can be locally adapted to climatic conditions and that species, therefore, can differ in their fundamental niches. My aim was to detect differences and similarities in species-temperature relationships among different places, to evaluate if local variations are important and to which degree these variations need to be taken into account when predicting species responses to climate change in arctic regions (Pearman et al. 2008).

For most of the analysed species, I found clear relationships to temperature, despite the short altitudinal gradients. Many of these relationships were significantly unimodal. Most of the species differed considerably in their relationships to temperature among the locations, while only a few of the analysed species responded consistently to temperature at the study sites.

The majority of the 73 investigated species revealed linear and unimodal temperature response curves. Hence, my findings confirm what already has been demonstrated by other researchers who investigated species temperature relationships along altitudinal gradients (Vetaas 2000, Guisan et al. 2002). Species normally respond linearly or unimodally to long and distinct environmental gradients (Sætersdal & Birks 1997). The difference between my findings and earlier studies is that I found that these relationships also hold true on short gradients. Detecting these local variations is important for harsh arctic environments, where climate conditions vary quickly on a small scale (Murray 1997), and where temperature is an important determining factor. The unimodal species temperature relationships I found could indicate that species track their optimal habitats or niches within these strong environmental variations on small spatial scale. These local adaptations will be overlooked when using a low spatial sampling resolution or distribution maps to predict local presences of species.

The variations I found among the temperature response curves at the different sites may indicate that local adaptations of arctic plant species populations exist, and that they could be related to the varying climatic and environmental conditions at the respective sites. Each population I investigated has to cope with the local biotic and abiotic challenges of its habitat, and might have developed adaptations to establish and live successfully under the respective conditions. Only five of 23 species were consistent in their relationships to temperature among the different study sites. Vetaas (2000) showed, using a similar technique to mine, strong similarities in temperature response curves for the species *Rhododendron arboreum* in the Himalayas. But the Vetaas study took place in an alpine region at lower latitudes. The differences between my and Vetaas' findings may illustrate that arctic ecosystems provide stronger local climate variations than alpine ecosystems at lower latitudes (Murray 1997). Ten of the species I analysed revealed opposing linear trends among the study sites, which may reflect these environmental variations. The temperature response curves of *Luzula confusa*, *Poa alpina* var. *vivipara*, *Poa arctica* ssp. *arctica* (non-viviparous form) and *Sagina nivalis* exemplify these differences. On one mountain they increased in abundance with increasing temperature while they increased on another mountain with decreasing temperature. For *Bistorta vivipara*, *Cerastium regelii*, *Ranunculus sulphureus* and *Saxifraga cernua* I found contrasting unimodal relationships to temperature, which might illustrate differences among local optima for these species.

My findings suggest that arctic plants respond clearly to the local climate variability in arctic environments. But even though temperature is a strong environmental variable, various, interacting environmental factors can contribute to the variations among the temperature response curves. Different macro- and micro-climatic conditions at each location I investigated may have caused large parts of the variations I found among the temperature response curves. Zeppelinfjellet differed considerably from the other two mountains, which were more similar to each other. The main differences between the sites were bedrock type, amount of organic material and type of disturbance. Virtually surrounded by glaciers, Zeppelinfjellet provided the harshest conditions for plant growth. Hence, I expected to find similar temperature response curves for most of the species on Brentskarhaugen and Platåberget, and a different response curve on Zeppelinfjellet. Solely, *Saxifraga cespitosa* ssp. *cespitosa*, a hardy and not demanding species (Rønning et al. 1996), showed this pattern. The majority of species differed between the two mountains providing similar conditions. In the following I will discuss several of the environmental variables, which might have caused the differences.

Bedrock could have had an influence on the response curves, because some species prefer or are dependent on a specific bedrock type, and for logistical reasons, it was not possible to avoid the bedrock changing to a certain extent along the transects. On Zeppelinfjellet the bedrock was calcareous along the ridge, where most of my sampling took place, and it was a conglomerate towards the bottom. On Brentskarhaugen and Platåberget the bedrock was constantly slightly acidic. Although *Salix polaris*, *Draba corymbosa* and *D. subcapitata* were found at study sites with different bedrock types, they were consistent in their responses to temperature. *S. polaris* does not have demands regarding the bedrock in Svalbard (Lid et al. 2005), but *D. corymbosa* and *D. subcapitata* are, according to Lid et al. (2005), restricted to alkaline substrates. However, in my findings these species showed similar trends on alkaline and slightly acidic substrate, indicating that the bedrock type did not influence their response curves. Eight species out of 18 showed different response curves on different bedrock types. Only one of these species, *Sagina nivalis*, prefers alkaline substrate and gravel (Lid et al. 2005), both of which can be found on Zeppelinfjellet. Contrasting to its preferences, *S. nivalis* decreased on Zeppelinfjellet from the slightly acidic foot of the mountain towards the alkaline ridge. This indicates that bedrock has no influence on the observed temperature response curves of *S. nivalis*. The other seven species do not have any specific demands regarding the substrate (Rønning et al. 1996, Lid et al. 2005). Hence, the differences in their relationships to temperature are probably not caused by differences in bedrock types. All in all, the majority of the species with differing temperature response curves varied among the sites with similar substrates, Brentskarhaugen and Platåberget. I conclude that bedrock probably is only a minor factor influencing the temperature response curves along the transects studied here.

Variations in the thickness of the organic layer may also have had an impact on the shape of the response curves, because it facilitates seedling establishment and plant growth and hence determines presence and absence of species. On Zeppelinfjellet organic material decreased rapidly within the first third of the gradient from the bottom in upwards direction, while it was more constant on the other two mountains (personal observation in the field). *L. confusa* is the only species that illustrates that the absence of organic material could have had an influence on the temperature response curves. On Zeppelinfjellet it declined rapidly with increasing altitude and decreasing organic matter, while it was abundant all along the transects on Brentskarhaugen and Platåberget. *L. confusa* is a typical tundra species, depending on a certain amount of organic substrate (Lid et al. 2005, Lindner & Meister 2006). Both mountains, Brentskarhaugen and Platåberget, also provided more organic material than Zeppelinfjellet in scree areas in the transect, which may explain the pattern of the species' response curves. Among the 23 species, which differed in their temperature response curves, only *S. nivalis* showed the same decreasing pattern on Zeppelinfjellet. But as mentioned above, *S. nivalis* prefers gravel. The decrease of *S. nivalis* on Zeppelinfjellet must have been due to other reasons than the decreasing organic layer. Hence, the amount of substrate might have had an impact on the differences in the temperature response curves for *L. confusa*, but it is unlikely to have had any effect for the other species.

Numerous disturbance factors could have contributed to the differences in the temperature response curves. All study sites were influenced by grazing reindeer and cryoturbation in the lower parts. On Brentskarhaugen the main disturbance factor was cryoturbation. Otherwise, due to its remote location, Brentskarhaugen was least disturbed by human influence. This might be reflected by the fact that I found the largest amount of species in this transect, and among them a considerable amount with unimodal response curves. Zeppelinfjellet and Platåberget were to higher degrees influenced by mining and hiking activities. It is likely that the different degrees of disturbance have contributed to the differences among the temperature response curves. *C. regelii* and *R. sulphureus* exemplify to what extent disturbance might have caused the different unimodal response curves for the species on Brentskarhaugen and Platåberget.

I conclude that various, interacting biotic and abiotic factors, including temperature, may have resulted in varying micro- and macro-climatic conditions along the transects (cf. Appendix I). These variations on small spatial scale may have caused the differences among the temperature response curves.

Some of my results are consistent with findings of other researchers. Karlsen & Elvebakk (2003) estimated summer temperature threshold values for arctic plants using circumpolar distribution maps to determine local climatic variations in East Greenland. When I compared my findings with the lower threshold values Karlsen & Elvebakk defined I found concordances for *Minuartia biflora* and *M. rubella*. *M. biflora* exhibited on Brentskarhaugen a positive linear trend between abundance and temperature, indicating a preference for mild temperatures. This corresponds to Karlsen & Elvebakk, who allocated *M. biflora* a mean July threshold temperature as high as 5 – 6 °C. In contrast, *M. rubella* revealed a negative linear trend between abundance and temperature on Brentskarhaugen, indicating a high tolerance towards low temperatures. This corresponds again to Karlsen & Elvebakk, who determined a low mean July threshold temperature of 3 – 4 °C for *M. rubella*. However, for *Ranunculus pygmaeus* and *Trisetum spicatum* ssp. *spicatum* I found contrasting trends to what Karlsen & Elvebakk estimated. Further, Karlsen & Elvebakk's estimations of threshold values for species on Greenland differ from Sætersdal & Birks' (1997) estimations for the same species from the Norwegian mainland. Sætersdal & Birks allocated to the identical species generally lower mean July temperature threshold values then Karlsen & Elvebakk. I expected different threshold values for arctic and alpine populations of the same species, since local adaptations to temperature within the same species in arctic and alpine regions have been shown earlier (Mooney & Billings 1961). Mooney & Billings (1961) showed arctic populations of *Oxyria digyna* have higher photosynthetic rates at lower temperatures than alpine populations of the same species. Hence, when comparing Karlsen & Elvebakk's with Sætersdal & Birks' findings, I would have expected the arctic population to have lower tolerance values than the alpine population. However, their investigations revealed the opposite. From this I conclude, methods, using a combination of species distribution maps, local species observations, temperature data from weather stations and geographical temperature thermoclines, are suitable to study species distributions in relation to temperature, but they can lead to varying results. These differences indicate that one should be careful when predicting local presences of species from response curves derived from distribution maps, and vice versa. This might lead to wrong estimations when transferring and predicting species data from one study area to another or from one sampling scale to another. Karlsen & Elvebakk (2003) stated that plant-temperature relationships need to be studied connected to scale, because topography influences temperature conditions (cf. Appendix I). My findings illustrate that it is important to study the same species in different areas to reveal local variations, especially in the Arctic. The above drawn comparison with Vetaas' (2000) findings for *R. arboreum* from the Himalayas might indicate that local variations are more important in arctic regions. But Vetaas sampled on a much larger scale than I. Additionally, he mapped one single species, a tree, while I investigated small species on community level. The comparison between Karlsen & Elvebakk and Sætersdal & Birks revealed on a large scale similar differences as I found on a small scale. Hence, the small scale variations I revealed are probably not only related to arctic environments, characterised by short gradients, they might also exist within environments comprising long and less variable gradients. These local variations could even be a universal phenomenon, but further investigations would be necessary to proof this hypothesis.

My investigations revealed contrasting species temperature relationships, because my sampling method took local variations into account. These variations are overlooked, when using large scale data which has normally been used for the construction of 'climatic envelopes' for possibly threatened species. Hence, my method presents a possibility to reveal local adaptations of populations within species in the Arctic or in other regions, which have not yet been found (Karlsen & Elvebakk 2003) and which will continuously be overlooked in future when using exclusively the climatic envelope approach. Assuming that arctic-alpine species react distinctly to changing climate conditions (Birks 1981, Huntley 1991, Jonsdottir et al. 2005, Walker et al. 2006, Erschbamer 2007, Klanderud 2008, Parolo & Rossi 2008), small scale data will reveal which response possibilities under global warming threatened species might have. This information might help to optimise predictive models of arctic plants under global climate change.

5. Conclusion

In this study altitudinal gradients have been used for the first time to generate species' temperature response curves from local-scale data in Svalbard. Only a few species were found to be consistent in their response to temperature among different study sites, while the majority of the investigated species showed different temperature response curves among different locations. These different relationships to temperature are probably caused by the strong micro- and macro-climatic variations on small spatial scale within arctic environments. My findings indicate that local adaptations of populations exist, and that small scale data from different locations is necessary to detect these variations. In this study, I showed that a high sampling resolution is especially important when collecting data in arctic regions in order to predict future fates of plants under global rising temperatures. Finally, this master thesis may help to achieve better data for predicting species' future responses to global rising temperatures and for identifying vulnerable species and places, which may help managing the biological diversity in alpine and arctic areas.

The findings of this study provide the basis for a continuing investigation, in which species temperature response curves could be compared between to different climatic regions, Svalbard and the Norwegian mainland. Körner (2007) postulated the demand for a 'consistent altitude concept'. He suggested a comparison between an arctic region with short altitudinal gradients and an alpine region with long altitudinal gradients regarding species-temperature relationships. An understanding of the relationships between altitudinal and latitudinal gradients will help to form a more complex picture of the possible effects of a global changing climate on plant communities. Finally, a comparison with previous broad-scale 'climatic envelopes' will give information about how to optimally identify species that may be critically endangered by climate warming.

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Appendix I

The relationship between micro- and macroclimate

Macroclimate is assumed to determine plant distribution in terms of mean July temperature thermoclines (Huntley et al. 1995, Sætersdal & Birks 1997, Moen 1999, Karlsen & Elvebakk 2003). However, when studying plant response to temperature, the microclimate plants experience can not be ignored, because it determines plant growth. Some alpine and arctic vascular plant species have developed techniques to raise their internal ambient temperature about 15 K above the surrounding air temperature (Körner 2003). *Silene acaulis*, a cushion plant, was observed by Gauslaa (1984) (referred to in Körner 2003) to raise its leaf temperature 24.5 K above the air temperature. The ability to create an appropriate microclimate that ensures growth and reproduction enables numerous arctic-alpine plant species to grow in their cold and harsh habitats (Billings & Mooney 1968).

The interaction of four factors, namely solar radiation, slope, exposure and growth form, creates the microclimate (Körner 2003). These main drivers of the microclimate are conditioned by the macroclimate, in terms of moisture availability, soil quality, surface structure, wind velocity, thermal conductivity and air temperature (Körner 2003). In my master thesis I focus on one of these macroclimatic drivers. I assume mean July air temperature as characteristic and determining for the temperature in the main growing season (Körner 2007), and also as the overall macroclimatic driver for the microclimate. To show this relationship I measured microclimatic temperature conditions in the vegetation in Longyearbyen over a period from 14 July to 9 September 2007. A datalogger (Tinytag Plus 2, Gemini Data Loggers Ltd, UK) was located in the tundra vegetation at the UTM position 33X 8683145, 514933 approximately 20 m a. s. l. (Figure 2.4). The temperature was measured hourly on the soil surface in the vegetation and in 10 cm depth in the ground (Figure 1). In addition I received air temperature data for the same time period from a weather station located southeast of Longyearbyen in Adventdalen approximately 20 m a. s. l. (Figure 2.4). The air temperature was measured hourly 0.5 m and 4 m above the ground (Figure 2). The two locations of the micro- and macroclimatic temperature measurements have a distance of approximately 3.5 km. The distances between the study sites and the respective weather stations vary between 2 and 9 km (Figure 2.4). The July air temperature data I received from these weather stations and the air temperatures I extrapolated for each plot using the adiabatic lapse rate do not tell anything about the actual microclimatic conditions the plants experienced in the plots I sampled. However, the graphs for the microclimate and the macroclimate (Figures 1 and 2) show similar patterns which indicates that one depends on the other. All of the four measured temperatures, in the soil in 10 cm depth, on

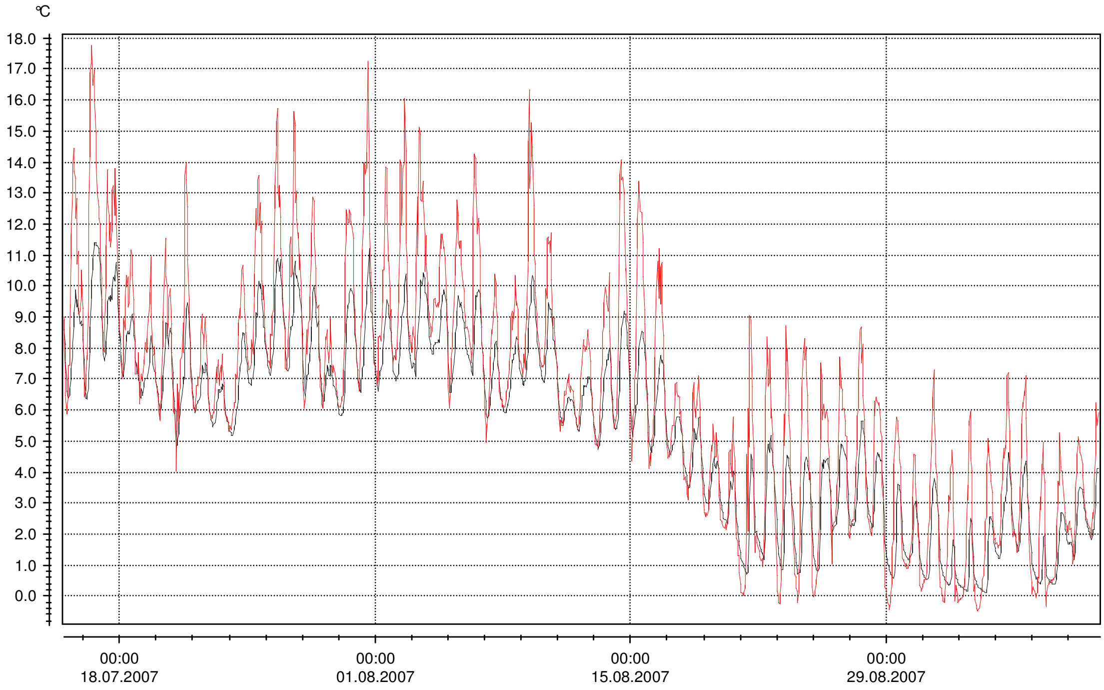

Figure 1 *Microclimatic ground temperature variations in Longyearbyen measured from 14.07.2007, 21:41 h until 09.09.2007, 14:42 h every hour. The black line represents the temperature measured in 10 cm depth in the soil. The red line shows the temperature measured on the soil surface in the vegetation.*

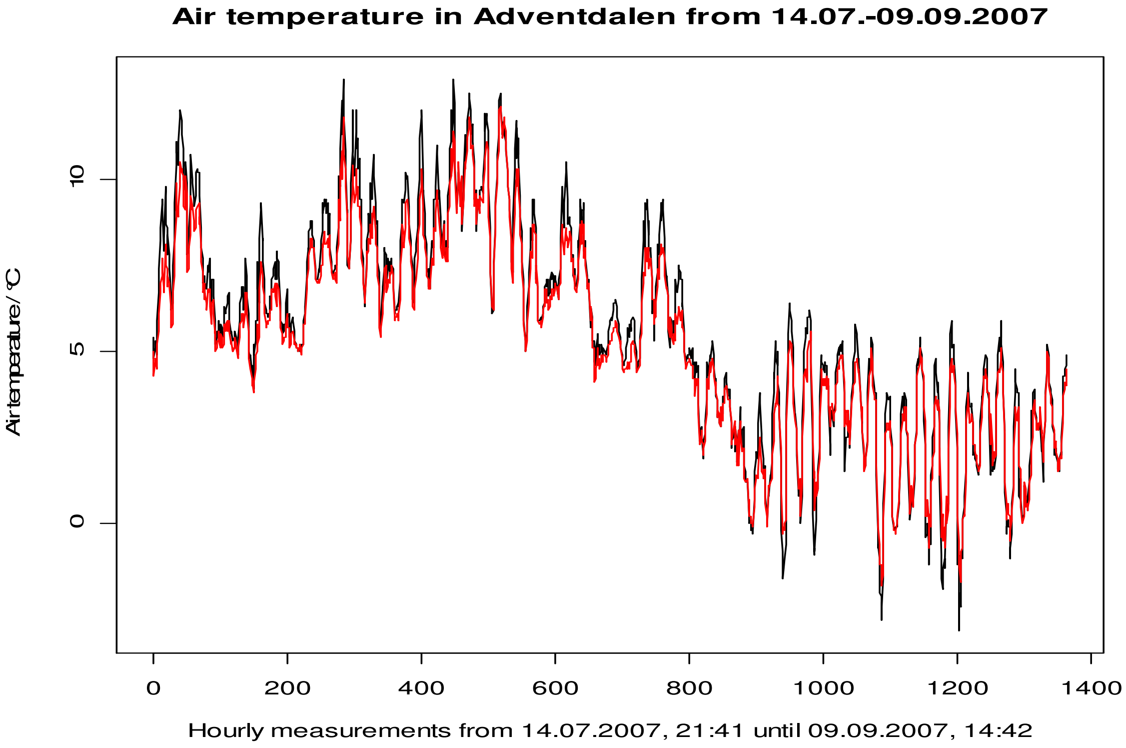

Figure 2 *Air temperatures at Adventdalen weather station, measured from 14.07.2007, 21:41 h until 09.09.2007, 14:42 h every hour. The x-axis shows the number of hourly measurements. The black line represents the air temperature measured 0.5 m above the ground and the red line represents the air temperature measured 4 m above the ground.*

the soil surface, 0.5 m and 4 m above the ground, show an overall declining trend from midsummer to early autumn. The iterative fluctuations result from the daily oscillations in air temperature. These daily fluctuations and also the weekly temperature variations match almost perfectly in the microclimatic and macroclimatic temperature curve. The temperatures in the soil and on the soil surface are generally higher than the air temperatures measured above the ground. Thus, the plant individuals I mapped experienced a warmer climate than I allocated to their respective position. The soil surface temperature shows the largest amplitude of all measured temperatures. The highest peak is on 16 July at 11:41 h with 17.7 °C and the lowest trough with -0.5 °C on 3 September at 00:41 h. The amplitude of the soil temperature in comparison is dampened and more stable. It never exceeds 11.35 °C and never drops below 0 °C. The difference between soil, surface and air temperature and the difference in the amplitude widths between soil and surface temperature are caused by thermal conductivity and thermal radiation. The soil surface acts as insulation layer. It heats up easily and loses warmth quickly again but protects the soil below against strong temperature fluctuations. The air temperatures measured in two different heights above the ground are almost congruent. This indicates that the two different measuring heights of the three meteorological stations I used to extrapolate plot temperatures are minor for my results. The oscillations are only slightly stronger in the air temperature measured in 0.5 m distance to the ground. This could be caused by the interplay between wind and surface structure, which decreases with increasing distance from the ground. All in all, the main trend in temperature fluctuations, changes and shifts is the same in, on and above the ground. Hence, the data received from the datalogger and from Adventdalen weather station indicate a close relationship between macroclimatic and microclimatic conditions. Nevertheless, I cannot assume that the microclimatic and macroclimatic conditions change consistent and ‘parallel’ along an altitudinal gradient.

Temperature gradients within arctic plants

Arctic and alpine plants live under and survive because of strong microclimatic temperature gradients in their direct environment and also within themselves (Körner 2003). The ground temperature curve (Figure 1) exemplifies these microclimatic conditions by showing large temperature variations on minimal spatial scale. The distance between the places of the microclimatic measurements was 10 cm, while the distance between the points of the macroclimatic measurements was 3.5 m. The temperature curves (Figures 1 and 2) show that air temperature is lower and varies less on a larger spatial scale, than the temperatures under which plants grow. Measuring these variations is a challenge. The climate plants experience is influenced by numerous variables, and not alone by altitude (Körner 2007). It is not feasible to measure all of these variations when mapping vegetation on community level. How could one measure all of the temperature variations within each 25 m ^{2} -plot within each tuft, cushion and individual plant throughout the entire growth season? Measuring while sampling would only reflect the current situation, and it would not be representative for the growth conditions throughout the season. To make this study feasible I focused exclusively on the decrease in mean July air temperature with increasing altitude.

Temperature decrease with altitude

My results show that air temperature also decreases with increasing altitude along short gradients. The differences in July air temperatures measured at the three different weather stations support this fact. The weather station in Ny-Ålesund is located 8 m a. s. l. (Table 2.3). It has the lowest altitudinal position and measured the highest air temperatures during July 2007. It is followed with lower July air temperatures by Janssonhaugen weather station, which is situated 270 m a.s.l. Gruvefjellet weather station is situated highest (464 m a.s.l.) and presents the lowest air temperatures during July 2007. Figure 3 and the boxplot (Figure 4) illustrate the considerable difference in mean July air temperature with altitudinal position. Altitude is a reliable variable regarding macroclimatic temperature variations.

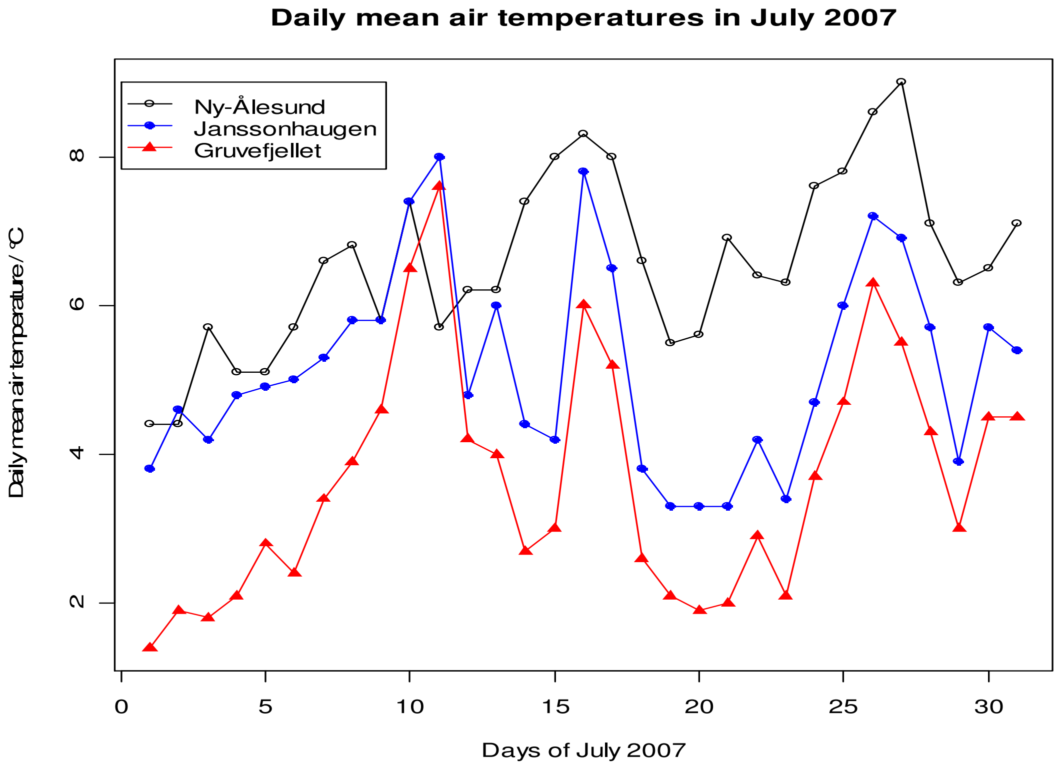

Figure 3 *Daily mean air temperatures for July 2007 measured at the three weather stations nearby the three study sites.*

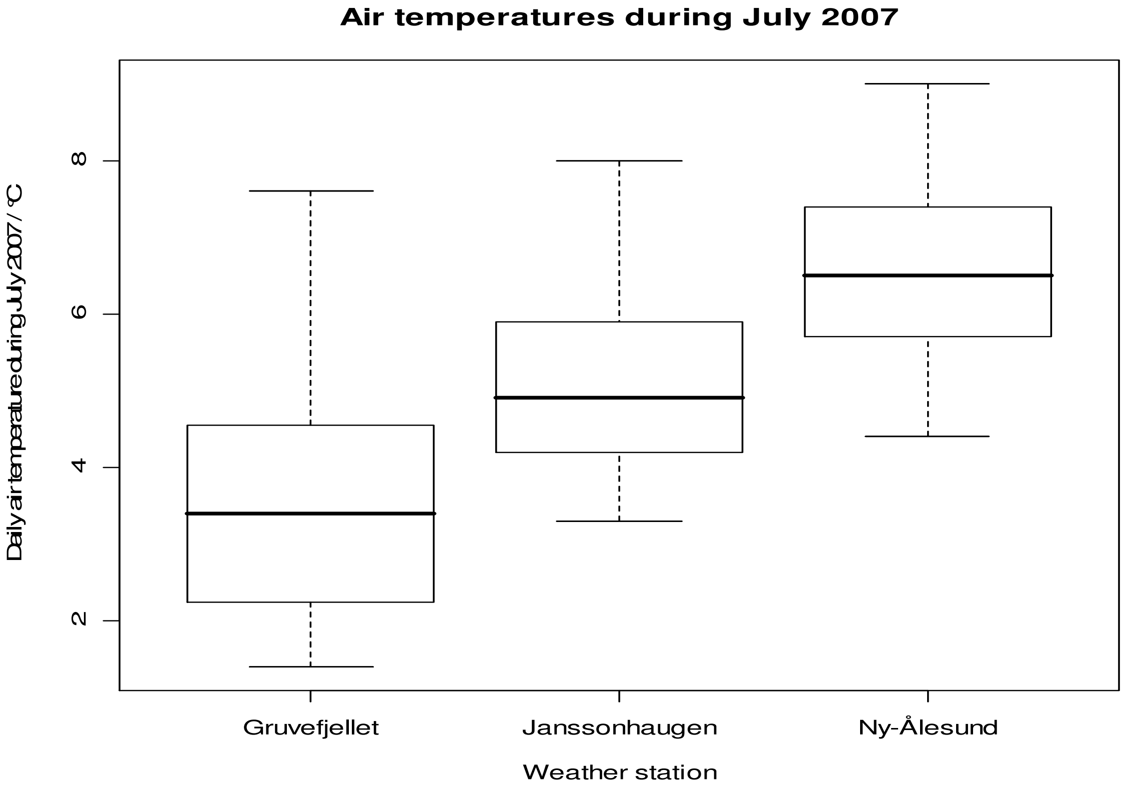

Figure 4 *Differences in mean day air temperatures during July 2007 measured at the three weather stations nearby the three study sites.*

Temperature and geographical position

The temperature data I extrapolated for each plot along each transect are given in Figure 5. While Zeppelinfjellet and Platåberget show similar temperature conditions, Brentskarhaugen tends to have a slightly higher mean July temperature. This might refer to the different geographical positions. While Zeppelinfjellet and Platåberget have coastal positions, Brentskarhaugen has a continental location. The mountains surrounding Brentskarhaugen have a sheltering function ('mass elevation effect') and slightly raise the mean July temperature (Moen 1999, Körner 2003).

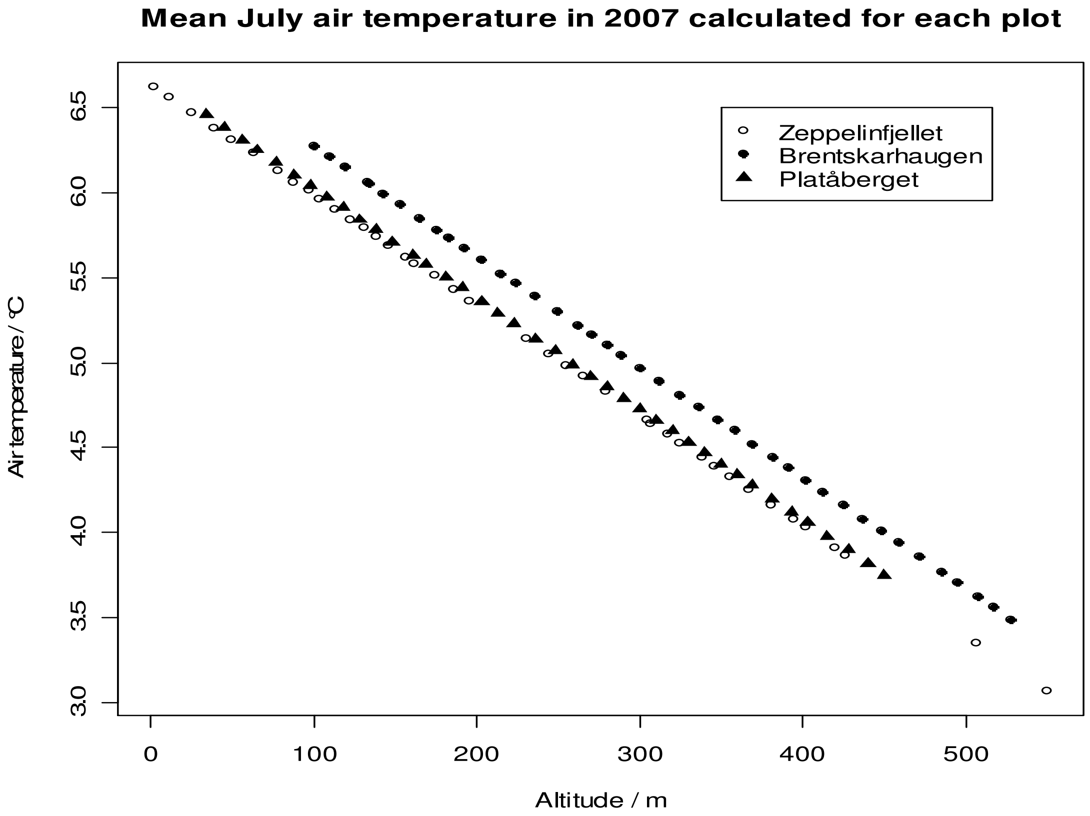

Figure 5 *Mean July air temperature extrapolated from the temperature data received from the weather stations for each plot using an adiabatic lapse rate of 0.0649 K decrease in temperature with 10 m increase in altitude.*

Conclusion

When I used the adiabatic lapse rate to calculate the temperatures in the plots along the transects, I generalised and approximated the actual air temperatures. With this technique I developed a scale I could use to compare species relationship to temperature between the three study sites. Using a generalised adiabatic lapse rate is actually not reliable, because it varies with terrain, height above ground, altitude, latitude and season (Stone & Carlson 1979). Thus, it should not be used in climate models. But when working with climate change, which happens on a global scale, the actual air temperature needs to be studied because it influences the conditions under which the studied plant species grow. It is not only the microclimate which determines plant growth per se. But still, when using this method, errors are to be expected. Nevertheless, my results show visible trends and patterns which indicate that macroclimate can be used as parameter for vascular plant response to rising temperatures.

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Appendix II

Altitudinal and UTM positions of the sampled plots sorted by transect.

Zeppelinfjellet					Brentskarhaugen					Platåberget				
Plot number	**Altitude / m a.s.l.**	**UTM zone**	**UTM North**	**UTM East**	**Plot number**	**Altitude / m a.s.l.**	**UTM zone**	**UTM North**	**UTM East**	**Plot number**	**Altitude / m a.s.l.**	**UTM zone**	**UTM North**	**UTM East**
1	2	33X	8762404	435298	1	100	33X	8681470	541179	1	34	33X	8683232	514222
2	11	33X	8762152	435167	2	110	33X	8681282	541353	2	45	33X	8683274	514141
3	25	33X	8762078	435089	3	119	33X	8681240	541433	3	56	33X	8683374	514094
4	39	33X	8761968	435029	4	133	33X	8681148	541533	4	65	33X	8683460	514043
5	50	33X	8761906	434960	5	134	33X	8681064	541613	5	77	33X	8683474	513983
6	63	33X	8761834	434950	6	143	33X	8680978	541709	6	88	33X	8683490	513956
7	78	33X	8761786	434906	7	153	33X	8680852	541779	7	98	33X	8683510	513918
8	88	33X	8761782	434954	8	165	33X	8680850	541821	8	108	33X	8683530	513880
9	97	33X	8761712	434896	9	175	33X	8680836	541910	9	118	33X	8683488	513821
10	104	33X	8761668	434880	10	183	33X	8680812	541950	10	128	33X	8683476	513776
11	113	33X	8761650	434869	11	192	33X	8680948	542031	11	138	33X	8683462	513755
12	123	33X	8761638	434855	12	203	33X	8680908	542118	12	148	33X	8683372	513774
13	131	33X	8761629	434841	13	215	33X	8680882	542176	13	161	33X	8683348	513745
14	138	33X	8761612	434831	14	224	33X	8680804	542200	14	169	33X	8683336	513708
15	146	33X	8761490	434714	15	236	33X	8680852	542252	15	181	33X	8683326	513675
16	156	33X	8761580	434556	16	250	33X	8680336	542282	16	191	33X	8683300	513651
17	162	33X	8761346	434810	17	262	33X	8680338	542328	17	203	33X	8683286	513627
18	174	33X	8761328	434797	18	271	33X	8680322	542366	18	213	33X	8683278	513598
19	186	33X	8761302	434736	19	280	33X	8680800	542386	19	223	33X	8683254	513597
20	196	33X	8761304	434689	20	289	33X	8680778	542420	20	236	33X	8683238	513585
21	NA				21	300	33X	8680758	542452	21	248	33X	8683228	513552
22	NA				22	312	33X	8680736	542467	22	259	33X	8683220	513529
23	231	33X	8761302	434493	23	325	33X	8680718	542486	23	270	33X	8683218	513493
24	244	33X	8761340	434433	24	336	33X	8680704	542498	24	NA			
25	255	33X	8761362	434441	25	348	33X	8680662	542505	25	NA			
26	265	33X	8761378	434419	26	358	33X	8680634	542519	26	NA			
27	279	33X	8761424	434354	27	369	33X	8680584	542551	27	NA			
28	292	33X	8761462	434365	28	382	33X	8680544	542578	28	NA			
29	301	33X	8761464	434335	29	391	33X	8680534	542517	29	NA			
30	305	33X	8761470	434323	30	402	33X	8680498	542546	30	NA			
31	307	33X	8761486	434305	31	413	33X	8680462	542581	31	NA			
32	317	33X	8761520	434225	32	425	33X	8680442	542611	32	NA			
33	325	33X	8761524	434194	33	437	33X	8680414	542644	33	369	33X	8680875	511745
34	338	33X	8761544	434131	34	448	33X	8680378	542717	34	381	33X	8680040	511687
35	346	33X	8761554	434103	35	459	33X	8680348	542754	35	393	33X	8680926	511689
36	355	33X	8761566	434019	36	472	33X	8680278	542820	36	403	33X	8680940	511677
37	367	33X	8761582	433983	37	485	33X	8680194	542880	37	415	33X	8680960	511654
38	381	33X	8761586	433951	38	495	33X	8680106	542959	38	428	33X	8680980	511630
39	394	33X	8761606	433892	39	508	33X	8680010	543051	39	440	33X	8681010	511623
40	402	33X	8761604	433851	40	517	33X	8679768	543242	40	450	33X	8681050	511545
41	420	33X	8761616	433435	41	528	33X	8679514	543471	-	-	-	-	-
42	426	33X	8761608	433487	-	-	-	-	-	-	-	-	-	-
43	436	33X	8761604	433444	-	-	-	-	-	-	-	-	-	-
44	448	33X	8761600	433304	-	-	-	-	-	-	-	-	-	-
45	461	33X	8761602	433270	-	-	-	-	-	-	-	-	-	-
46	485	33X	8761604	433194	-	-	-	-	-	-	-	-	-	-
47	493	33X	8761600	433177	-	-	-	-	-	-	-	-	-	-
48	507	33X	8761594	433153	-	-	-	-	-	-	-	-	-	-
49	524	33X	8761588	433129	-	-	-	-	-	-	-	-	-	-
50	539	33X	8761578	433111	-	-	-	-	-	-	-	-	-	-
51	550	33X	8761548	433085	-	-	-	-	-	-	-	-	-	-

Appendix III

Total species list (part I). The blue names are chosen at my own discretion, since no direct translation could be found.

Scientific name	**Abbreviation**	**English name**	**Norwegian name**	**German name**
Alopecurus magellanicus Lam.	*alomag*	Polar Foxtail	Polarreverumpe	Nordischer Fuchsschwanz
Arenaria pseudofrigida (Ostenf. & Dahl) Juz.	*arepse*	Fringed Sandwort	Kalkarve	Kalksandkraut
Bistorta vivipara (L.) S. F. Gray	*bisviv*	Alpine Bistort	Harerug	Knöllchenknöterich
Cardamine bellidifolia L. ssp. *bellidifolia*	*carbel*	High Alpine Cress	Høgfjellskarse	Nordisches Schaumkraut
Cardamine pratensis L. ssp. *angustifolia* (Hook.) O. E. Schulz	*carpra*	Polar Cress (Cuckooflower)	Polarkarse	Wiesenschaumkraut
Carex fuliginosa Schkuhr ssp. *misandra* (R. Br.) Nyman	*carful*	Nodding Sedge	Dubbestarr	Ruß-Segge
Carex lachenalii Schkuhr	*carlac*	Arctic Hare's-foot	Rypestarr	Lachenals Segge
Carex nardina Fr. ssp. *hepburnii* (Boott.) Á. Löve, D. Löve & B. M. Kapoor	*carnar*	Cushion Segde, Nard Sedge	Skjeggstarr	Bartsegge
Cassiope tetragona L. D. Don ssp. *tetragona* L.	*castet*	White Arctic Bell-heather	Kantlyng	Vierkantige Moorheide
Cerastium arcticum Lange coll.	*cerarc*	Arctic Mouse-ear	Snøarve	Arktisches Hornkraut
Cerastium arcticum Lange coll. x *Cerastium regelii* Ostenf.	*ceraxr*	-	-	-
Cerastium regelii Ostenf.	*cerreg*	Polar Mouse-ear	Polararve	Polarhornkraut
Cochlearia groenlandica L. coll.	*cocgro*	Polar Scurvygrass	Polarskjørbuksurt	Grönländisches Löffelkraut
Deschampsia alpina (L.) Roem & Schultes	*desalp*	Alpine Hair-grass	Fjellbunke	Alpenschmiele
Draba alpina L.	*draalp*	Golden Whitlow-grass, Alpine Whitlow-grass	Gullrublom	Alpenfelsenblümchen
Draba arctica J. Vahl ssp. *arctica*	*drarc*	Mealy Whitlow-grass	Mjølrublom	Arktisches Felsenblümchen
Draba corymbosa R. Br. ex DC.	*dracor*	Cushioned Whitlow-grass	Puterublom	Kissenfelsenblümchen
Draba fladnizensis Wulf.	*drafla*	White Arctic Whitlow-grass	Alperublom	Fladnitzer Felsenblümchen
Draba glabella Pursh	*dragla*	Scree Whitlow-grass	Skredrublom	Geröllfelsenblümchen
Draba lactea Adams	*dralac*	Lappland Whitlow-grass	Lapprublom	Lapplandfelsenblümchen
Draba micropetala Hook.	*dramic*	Polar Whitlow-grass	Polarrublom	
Draba nivalis Liljebl.	*draniv*	Snow Whitlow-grass	Snørublom	Schneehungerblümchen
Draba oxycarpa Sommerf.	*draoxy*	Pale Whitlow-grass	Bleikrublom	Blasses Felsenblümchen
Draba pauciflora R. Br.	*drapau*	Tundra Whitlow-grass	Tundrarublom	Tundrafelsenblümchen
Draba spec.	*draspe*	-	-	-
Draba subcapitata Simm.	*drasub*	Hemispherical Whitlow-grass	Halvkulerublom	Halbkugelfelsenblümchen
Dryas octopetala L.	*dryoct*	Mountain Avens	Reinrose	Silberwurz
Equisetum arvense L. ssp. *alpestre*	*equarv*	Field Horsetail, Polar Horsetail	Polarsnelle, Åkersnelle	Ackerschachtelhalm
Equisetum scirpoides Michx.	*equsci*	Dwarf Horsetail	Dvergsnelle	Zwergschachtelhalm
Eriophorum scheuchzeri Hoppe ssp. *arcticum* Novoselova	*erisch*	Arctic Cottongrass	Snøull	Scheuchzers Wollgras
Festuca rubra L. ssp. *richardsonii* (Hook.) Hultén	*fesruri*	-	-	-
Festuca rubra L. ssp. *rubra*	*fesruru*	Red Fescue	Rødsvingel	Rotschwingel
Festuca spec.	*fesspe*	-	-	-
Huperzia arctica (Grossh. ex Tolm.) Sipliv.	*huparc*	Polar Fir Clubmoss	Polarlusegress	Tannenbärlapp
Juncus biglumis L.	*junbig*	Two-flowered Rush	Tvillingssiv	Zweiblütige Binse
Koenigia islandica L.	*koeisl*	Iceland-purslane	Dvergsyre	
Luzula confusa Lindeb.	*luzcon*	Northern Wood-rush	Vardefrytle	Wartehainsimse

Total species list (part II). The blue names are chosen at my own discretion, since no direct translation could be found.

Scientific name	**Abbreviation**	**English name**	**Norwegian name**	**German name**
Luzula nivalis (Laest.) Spreng.	*luzniv*	Arctic Wood-rush	Snøfrytle	Arktische Hainsimse
Minuartia biflora (L.) Schnitz & Thellung	*minbif*	Tufted Sandwort	Tuearve	Zweiblüten-Miere
Minuartia rubella (Wahlenb.) Hiern	*minrub*	Mountain Sandwort	Nålearve	Rötliche Miere
Oxyria digyna (L.) Hill	*oxydig*	Mountain Sorrel	Fjellsyre	Säuerling
Papaver dahlianum Nordh.	*papdah*	Svalbard Poppy	Svalbardvalmue	Spitzbergenmohn
Pedicularis dasyantha (Trautv.) Hadac	*peddas*	Wooly Louseworth	Ullmyrklegg	Wolliges Läusekraut
Pedicularis hirsuta L.	*pedhir*	Hairy Lousewort	Lodnemyrklegg	Rauhes Läusekraut
Poa abbreviata R. Br. ssp. *abbreviata*	*poaabb*	Cushioned Meadow-grass	Puterapp	Kissenrispengras
Poa alpina L. var. *alpina*	*poaalp*	Alpine Meadow-grass	Fjellrapp	Alpenrispengras
Poa alpina L. var. *vivipara* L.	*poaalpv*	Alpine Meadow-grass	Fjellrapp	Alpenrispengras
Poa arctica R. Br. ssp. *arctica* (non-viviparous form)	*poaarcn*	Arctic Meadow-grass	Jervrapp	Arktisches Rispengras
Poa arctica R. Br. ssp. *arctica* (viviparous form)	*poaarcv*	Arctic Meadow-grass	Jervrapp	Arktisches Rispengras
Poa hartzii Gand. ssp. *hartzii*	*poahar*	Wire Meadow-grass	Strirapp	Drahtrispengras
Poa pratensis L. ssp. *alpigena* (Fr.) Hiit. (non-viviparous form)	*poapran*	Smooth Meadow-grass	Engrapp	Wiesen-Rispengras
Poa pratensis L. ssp. *alpigena* (Fr.) Hiit. (viviparous form)	*poaprav*	Smooth Meadow-grass	Engrapp	Wiesen-Rispengras
Potentilla hyparctica Malte ssp. *hyparctica*	*pothyp*	Arctic Conquefoil	Raggmure	Polarfingerkraut
Ranunculus nivalis L.	*ranniv*	Snow Buttercup	Snøsoleie	Arktischer Hahnenfuß
Ranunculus pygmaeus Wahlenb.	*ranpyg*	Pygmy Buttercup	Dvergsoleie	Zwerghahnenfuß
Ranunculus sulphureus Sol.	*ransul*	Sulphur-coloured Buttercup	Polarsoleie	Schwefelgelber Hahnenfuß
Sagina cespitosa (J. Vahl) Lange	*sagces*	-	-	-
Sagina nivalis (Lindbl.) Fr.	*sagniv*	Snow Pearlwort	Jøkelarve	Schneemastkraut
Salix polaris Wahlenb.	*salpol*	Polar Willow	Polarvier	Polarweide
Saxifraga aizoides L. coll.	*saxaiz*	Yellow Saxifrage	Gulsildre	Fetthennensteinbrech
Saxifraga cernua L.	*saxcer*	Drooping Saxifrage	Knoppsildre	Nickender Steinbrech
Saxifraga cespitosa L. ssp. *cespitosa*	*saxces*	Tufted Saxifrage	Tuesildre	Kissensteinbrech
Saxifraga foliolosa R. Br.	*saxfol*	Foliolose Saxifrage	Grynsildre	-
Saxifraga hieracifolia Waldst. & Kit. ex Willd. ssp. *hieracifolia*	*saxhie*	Hawkweed-leaved Saxifrage	Stivsildre	Habichtskrautsteinbrech
Saxifraga hirculus L. ssp. *compacta* Hedberg	*saxhir*	Marsh Saxifrage	Myrsildre	Moorsteinbrech
Saxifraga hyperborea R. Br.	*saxhyp*	Polar Saxifrage	Polarsildre	Polarsteinbrech
Saxifraga nivalis L.	*saxniv*	Alpine Saxifrage	Snøsildre	Schneesteinbrech
Saxifraga oppositifolia L. ssp. *oppositifolia*	*saxopp*	Purple Saxifrage	Rødsildre	Gegenblättriger Steinbrech
Saxifraga platysepala (Trautv.) Tolm.	*saxpla*	Polar Stoloniferous Saxifrage	Trådsildre	Schlangensteinbrech
Saxifraga tenuis (Wahlenb.) H. Sm.	*saxten*	Dwarf Saxifrage	Grannsildre	Schlanker Steinbrech
Silene acaulis L. Jacq.	*silaca*	Moss Campion	Fjellsmelle	Stengelloses Leimkraut
Silene uralensis (Rupr.) Bocquet ssp. *arctica* (Th. Fr.) Bocquet	*silura*	Apetalous Catchfly, Polar Campion	Blindurt	Kronlose Nelke
Stellaria longipes Goldie coll.	*stelon*	Tundra Chickweed	Snøstjerneblom	Schneesternmiere
Trisetum spicatum (L.) K. Richt. ssp. *spicatum*	*trispi*	Northern Oat-grass	Svartaks	Ästiger Goldhafer
unknown graminoid	*unkgra*	-	-	-

Appendix IV

Separate species lists for each transect (part I).

Zeppelinfjellet	**Brentskarhaugen**	**Platåberget**
Arenaria pseudofrigida (Ostenf. & Dahl) Juz.	*Alopecurus magellanicus* Lam.	*Alopecurus magellanicus* Lam.
Bistorta vivipara (L.) S. F. Gray	*Bistorta vivipara* (L.) S. F. Gray	*Bistorta vivipara* (L.) S. F. Gray
Cardamine pratensis L. ssp. *angustifolia* (Hook.) O. E. Schulz	*Cardamine bellidifolia* L. ssp. *bellidifolia*	*Cardamine bellidifolia* L. ssp. *bellidifolia*
Carex fuliginosa Schkuhr ssp. *misandra* (R. Br.) Nyman	*Cardamine pratensis* L. ssp. *angustifolia* (Hook.) O. E. Schulz	*Cassiope tetragona* L. D. Don ssp. *tetragona* L.
Carex nardina Fr. ssp. *hepburnii* (Boott.) Á. Löve, D. Löve & B. M. Kapoor	*Carex lachenalii* Schkuhr	*Cerastium arcticum* Lange coll.
Cassiope tetragona L. D. Don ssp. *tetragona* L.	*Cerastium arcticum* Lange coll.	*Cerastium regelii* Ostenf.
Cerastium arcticum Lange coll.	*Cerastium arcticum* Lange coll. x *Cerastium regelii* Ostenf.	*Deschampsia alpina* (L.) Roem & Schultes
Cerastium regelii Ostenf.	*Cerastium regelii* Ostenf.	*Draba arctica* J. Vahl ssp. *arctica*
Cochlearia groenlandica L. coll.	*Cochlearia groenlandica* L. coll.	*Draba fladnizensis* Wulf.
Deschampsia alpina (L.) Roem & Schultes	*Draba alpina* L.	*Draba glabella* Pursh
Draba arctica J. Vahl ssp. *arctica*	*Draba arctica* J. Vahl ssp. *arctica*	*Draba lactea* Adams
Draba corymbosa R. Br. ex DC.	*Draba corymbosa* R. Br. ex DC.	*Draba nivalis* Liljebl.
Draba fladnizensis Wulf.	*Draba fladnizensis* Wulf.	*Draba oxycarpa* Sommerf.
Draba oxycarpa Sommerf.	*Draba micropetala* Hook.	*Draba pauciflora* R. Br.
Draba pauciflora R. Br.	*Draba oxycarpa* Sommerf.	*Draba spec.*
Draba spec.	*Draba pauciflora* R. Br.	*Dryas octopetala* L.
Draba subcapitata Simm.	*Draba spec.*	*Equisetum arvense* L. ssp. *alpestre*
Dryas octopetala L.	*Draba subcapitata* Simm.	*Equisetum scirpoides* Michx.
Equisetum arvense L. ssp. *alpestre*	*Equisetum arvense* L. ssp. *alpestre*	*Festuca rubra* L. ssp. *rubra*
Equisetum scirpoides Michx.	*Equisetum scirpoides* Michx.	*Festuca viviparoidea* Krajina ex Pavlick
Juncus biglumis L.	*Eriophorum scheuchzeri* Hoppe ssp. *arcticum* Novoselova	*Huperzia arctica* (Grossh. ex Tolm.) Sipliv.
Luzula confusa Lindeb.	*Festuca rubra* L. ssp. *richardsonii* (Hook.) Hultén	*Luzula confusa* Lindeb.
Minuartia biflora (L.) Schnitz & Thellung	*Festuca* spec.	*Minuartia biflora* (L.) Schnitz & Thellung
Minuartia rubella (Wahlenb.) Hiern	*Festuca viviparoidea* Krajina ex Pavlick	*Oxyria digyna* (L.) Hill
Oxyria digyna (L.) Hill	*Juncus biglumis* L.	*Papaver dahlianum* Nordh.
Papaver dahlianum Nordh.	*Koenigia islandica* L.	*Pedicularis dasyantha* (Trautv.) Hadac
Pedicularis dasyantha (Trautv.) Hadac	*Luzula confusa* Lindeb.	*Pedicularis hirsuta* L.
Poa abbreviata R. Br. ssp. *abbreviata*	*Luzula nivalis* (Laest.) Spreng.	*Poa alpina* L. var. *alpina*
Poa alpina L. var. *vivipara* L.	*Minuartia biflora* (L.) Schnitz & Thellung	*Poa alpina* L. var. *vivipara* L.
Poa arctica R. Br. ssp. *arctica* (non-viviparous form)	*Minuartia rubella* (Wahlenb.) Hiern	*Poa arctica* R. Br. ssp. *arctica* (non-viviparous form)
Poa hartzii Gand. ssp. *hartzii*	*Oxyria digyna* (L.) Hill	*Poa arctica* R. Br. ssp. *arctica* (viviparous form)
Poa pratensis L. ssp. *alpigena* (Fr.) Hiit. (non-viviparous form)	*Papaver dahlianum* Nordh.	*Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit. (non-viviparous form)
Sagina nivalis (Lindbl.) Fr.	*Pedicularis hirsuta* L.	*Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit. (viviparous form)
Salix polaris Wahlenb.	*Poa abbreviata* R. Br. ssp. *abbreviata*	*Potentilla hyparctica* Malte ssp. *hyparctica*
Saxifraga aizoides L. coll.	*Poa alpina* L. var. *alpina*	*Ranunculus nivalis* L.
Saxifraga cernua L.	*Poa alpina* L. var. *vivipara* L.	*Ranunculus pygmaeus* Wahlenb.
Saxifraga cespitosa L. ssp. *cespitosa*	*Poa arctica* R. Br. ssp. *arctica* (non-viviparous form)	*Ranunculus sulphureus* Sol.

Separate species lists for each transect (partII).

Zeppelinfjellet	**Brentskarhaugen**	**Platåberget**
Saxifraga foliolosa R. Br.	*Poa arctica* R. Br. ssp. *arctica* (viviparous form)	*Sagina cespitosa* (J. Vahl) Lange
Saxifraga hieracifolia Waldst. & Kit. ex Willd. ssp. *hieracifolia*	*Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit. (non-viviparous form)	*Sagina nivalis* (Lindbl.) Fr.
Saxifraga oppositifolia L. ssp. *oppositifolia*	*Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit. (viviparous form)	*Salix polaris* Wahlenb.
Saxifraga tenuis (Wahlenb.) H. Sm.	*Potentilla hyparctica* Malte ssp. *hyparctica*	*Saxifraga cernua* L.
Silene acaulis L. Jacq.	*Ranunculus nivalis* L.	*Saxifraga cespitosa* L. ssp. *cespitosa*
Silene uralensis (Rupr.) Bocquet ssp. *arctica* (Th. Fr.) Bocquet	*Ranunculus pygmaeus* Wahlenb.	*Saxifraga foliolosa* R. Br.
unknown graminoid	*Ranunculus sulphureus* Sol.	*Saxifraga hieracifolia* Waldst. & Kit. ex Willd. ssp. *hieracifolia*
	Sagina nivalis (Lindbl.) Fr.	*Saxifraga hirculus* L. ssp. *compacta* Hedberg
	Salix polaris Wahlenb.	*Saxifraga nivalis* L.
	Saxifraga cernua L.	*Saxifraga oppositifolia* L. ssp. *oppositifolia*
	Saxifraga cespitosa L. ssp. *cespitosa*	*Saxifraga platysepala* (Trautv.) Tolm.
	Saxifraga foliolosa R. Br.	*Silene acaulis* L. Jacq.
	Saxifraga hieracifolia Waldst. & Kit. ex Willd. ssp. *hieracifolia*	*Stellaria longipes* Goldie coll.
	Saxifraga hyperborea R. Br.	*Trisetum spicatum* (L.) K. Richt. ssp. *spicatum*
	Saxifraga nivalis L.	
	Saxifraga oppositifolia L. ssp. *oppositifolia*	
	Saxifraga platysepala (Trautv.) Tolm.	
	Saxifraga tenuis (Wahlenb.) H. Sm.	
	Stellaria longipes Goldie coll.	
	Trisetum spicatum (L.) K. Richt. ssp. *spicatum*	
	unknown graminoid	

Species record of Zeppelinfjellet (part I).

temp / °C	m a.s.l.	*arepse*	*bisviv*	*carpra*	*carful*	*carnar*	*castet*	*cerarc*	*cerreg*	*cocgro*	*desalp*	*draarc*	*dracor*	*drafla*	*draoxy*	*drapau*	*draspe*	*drasub*	*dryoct*	*equarv*	*equsci*	*junbig*	*luzcon*	*minbif*	*minrub*	*oxydig*	*papdah*	*peddas*	*poaabb*	*poaalpv*	*poaarcn*	*poahar*	*poapran*	*sagniv*	*salpol*	*saxaiz*	*saxcer*	*saxces*	*saxfol*	*saxhie*	*saxopp*	*saxten*	*silaca*	*silura*	*unkgra*
6.6	2	0	3	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	3	2	2	3	0	0	4	1	0	0	0
6.6	11	0	3	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	2	3	0	0	0	0	0	4	0	3	0	0
6.5	25	0	3	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0	4	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	4	0	0	0	0	0	3	0	3	0	0
6.4	39	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	2	4	0	0	0	0	0	3	0	2	0	0
6.3	50	0	3	0	3	0	0	3	0	0	1	0	0	0	0	0	0	0	0	2	0	3	3	0	0	3	0	1	2	0	2	0	2	3	4	0	2	2	2	2	3	1	3	0	0
6.2	63	0	3	0	3	0	0	2	1	0	0	0	0	0	0	1	0	0	0	0	1	3	3	0	0	3	0	0	2	1	0	0	0	2	4	0	2	2	0	0	4	0	3	0	0
6.1	78	0	3	0	3	0	0	3	2	0	1	0	0	1	0	1	0	0	0	0	1	0	3	2	0	3	0	0	1	0	0	0	0	2	4	0	2	0	0	0	4	0	3	1	0
6.1	88	0	3	0	4	0	0	1	2	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	4	0	2	1	0
6	97	0	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	2	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0
6	104	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4	0	0	0	0
5.9	113	0	0	0	0	0	0	2	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0
5.8	123	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	4	0	0	0	0
5.8	131	0	0	0	0	0	0	3	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	4	0	0	0	0
5.7	138	0	0	0	0	0	0	4	0	1	0	3	0	0	2	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	1	0	2	0	0	0	4	0	0	0	1
5.7	146	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
5.6	156	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	0	0	0	1	0	0	0	0	0	0	4	0	0	0	4	0	0	0	0
5.6	162	0	0	0	0	0	0	3	0	0	0	2	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	0	0	0	4	0	0	0	0
5.5	174	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	0	0
5.4	186	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	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0
5.4	196	0	0	0	0	0	0	0	0	0	0	3	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0	3	0	0	0	0
5.1	231	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	3	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
5.1	244	0	0	0	0	0	0	4	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	0	0	0	0	0	0	0	3	0	0	0	0
5	255	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	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
4.9	265	0	0	0	0	0	0	4	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	0	0	0	0	3	0	0	3	0	0	0	0
4.8	279	0	0	0	0	0	0	0	0	0	0	2	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	1	0	0	1	0	0	0	0
4.7	292	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.7	301	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.7	305	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	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0	0	0	0
4.6	307	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	4	0	1	2	0	0	2	0	0	0	0
4.6	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0
4.4	338	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4	0	0	0	0
4.4	346	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0
4.3	355	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0
4.3	367	0	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	3	0	0	0	0
4.2	381	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	1	0	0	3	0	0	0	0
4.1	394	0	0	0	0	0	0	3	0	0	0	0	3	2	0	0	2	0	0	0	0	0	0	0	1	0	2	0	0	0	1	2	0	0	3	0	1	3	0	0	3	0	0	0	0

Species record Zeppelinfjellet (part II).

temp / °C	m a.s.l.	*arepse*	*bisviv*	*carpra*	*carful*	*carnar*	*castet*	*cerarc*	*cerreg*	*cocgro*	*desalp*	*draarc*	*dracor*	*drafla*	*draoxy*	*drapau*	*draspe*	*drasub*	*dryoct*	*equarv*	*equsci*	*junbig*	*luzcon*	*minbif*	*minrub*	*oxydig*	*papdah*	*peddas*	*poaabb*	*poaalpv*	*poaarcn*	*poahar*	*poapran*	*sagniv*	*salpol*	*saxaiz*	*saxcer*	*saxces*	*saxfol*	*saxhie*	*saxopp*	*saxten*	*silaca*	*silura*	*unkgra*
4	402	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	3	0	0	0	1
3.9	420	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	2	1	0	0	3	0	0	0	0
3.9	426	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
3.8	436	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.7	448	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.6	461	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	485	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.4	493	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.4	507	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0
3.3	524	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1	539	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.1	550	0	0	0	0	0	0	0	0	0	0	0	3	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	0	0	4	0	0	0	0

Species record Brentskarhaugen.

temp / °C	m a.s.l.	*alomag*	*bisviv*	*carbel*	*carpra*	*carlac*	*cerarc*	*ceraxr*	*cerreg*	*cocgro*	*draalp*	*draarc*	*dracor*	*drafla*	*dramic*	*draoxy*	*drapau*	*draspe*	*drasub*	*equarv*	*equsci*	*erisch*	*fesruri*	*fesspe*	*fesviv*	*junbig*	*koeisl*	*luzcon*	*luzniv*	*minbif*	*minrub*	*oxydig*	*papdah*	*pedhir*	*poaabb*	*poaalp*	*poaalpv*	*poaarcn*	*poaarcv*	*poapran*	*poaprav*	*pothyp*	*ranniv*	*ranpyg*	*ransul*	*sagniv*	*salpol*	*saxcer*	*saxces*	*saxfol*	*saxhie*	*saxhyp*	*saxniv*	*saxopp*	*saxpla*	*saxspe*	*saxten*	*stelon*	*trispi*	*unkgra*
6.3	100	3	3	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0
6.2	110	3	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	2	3	0	0	0	0	0	0	3	2	0	0	0	2	0	0	0	0	0	0	0	0
6.2	119	3	0	0	0	0	1	0	2	0	0	0	3	0	0	0	0	3	0	4	0	0	0	0	0	0	0	3	0	3	0	3	0	0	0	0	0	0	0	0	0	0	3	0	3	0	4	0	0	0	1	2	0	0	0	0	0	2	3	0
6.1	133	3	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	3	3	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	3	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
6.1	134	0	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	2	0	3	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0
6	143	2	0	0	0	4	2	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	3	0	0	0	0	0	2	2	3	0	2	3	0	0	0	0	0	1	0	0	0	0	3	3
5.9	153	0	3	0	1	4	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	3	0	0	0	0	3	0	0	0	0	0	0	0	2	0	3	3	0	0	0	0	0	0	0	1	0	0	3	3
5.9	165	0	3	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	3	0	0	0	0	0	0	2	3	0	4	2	0	0	0	0	0	0	0	0	0	0	0	4
5.8	175	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	4	3	0	0	3	0	0	0	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	0	4
5.7	183	3	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	3	0	0	0	0	0	0	4	3	0	0	0	0	0	2	0	0	0	2	0	4
5.7	192	2	3	0	0	0	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	4	0	0	0	0	3	0	3	0	3	0	0	0	0	2	0	0	4	0	0	0	0	3	0	4	2	0	0	0	0	0	0	0	0	0	2	0	0
5.6	203	2	4	0	0	0	0	2	3	0	0	0	2	0	0	0	0	3	0	0	1	0	0	0	0	0	0	2	0	2	0	3	0	0	0	3	0	0	0	4	0	0	0	0	2	0	4	2	1	0	0	0	0	2	0	0	0	2	0	4
5.5	215	3	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3	2	0	0	2	0	0	0	0	0	0	0	4	0	0	0	0	2	0	4	2	2	0	0	0	0	2	0	0	0	3	0	4
5.5	224	3	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	2	2	0	0	2	1	0	0	0	0	0	0	4	0	0	0	0	3	0	4	3	3	0	0	0	0	3	0	0	0	3	0	4
5.4	236	2	3	0	0	0	1	0	3	0	2	2	0	0	2	0	0	2	2	0	0	0	0	3	0	0	0	2	0	3	0	3	0	0	0	2	0	0	0	4	0	0	0	0	3	0	3	3	2	0	0	0	0	2	0	0	0	0	0	3
5.3	250	3	3	0	0	0	2	2	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	3	0	1	0	3	1	0	0	3	0	0	0	0	0	0	0	0	3	1	3	3	2	0	0	0	0	3	0	0	0	2	0	4
5.2	262	3	3	0	0	0	2	0	3	1	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	3	0	2	0	3	1	0	0	2	0	3	0	0	0	0	0	1	3	0	2	3	2	0	0	0	3	2	0	0	0	2	0	4
5.2	271	3	3	0	0	0	2	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	0	0	3	0	0	0	0	2	2	0	0	0	3	0	0	0	0	0	0	0	1	4	3	2	0	0	0	1	2	0	0	0	3	0	4
5.1	280	2	3	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	0	2	2	0	0	0	0	0	0	0	1	0	0	2	0	4	2	2	0	0	0	1	3	0	0	0	3	0	4
5	289	3	3	0	0	0	2	0	3	0	0	0	0	0	0	0	2	0	2	0	2	0	0	0	0	1	0	3	0	0	1	0	3	2	0	0	0	4	0	0	0	0	0	0	2	2	4	2	2	0	0	0	1	2	0	0	0	3	0	0
5	300	4	0	0	0	0	0	0	3	1	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	4	0	0	1	0	3	1	0	3	0	4	0	0	0	0	0	3	3	2	2	2	3	0	0	0	2	2	0	0	2	3	0	0
4.9	312	3	0	0	0	0	0	0	3	1	1	0	2	0	1	1	1	2	0	0	0	0	0	0	3	0	0	4	0	0	2	0	3	0	0	3	0	3	0	0	0	0	0	0	3	2	3	3	3	0	0	0	2	2	0	0	0	3	0	0
4.8	325	2	0	0	0	0	2	0	3	1	2	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	4	0	0	0	0	3	0	0	4	0	0	0	0	0	0	0	2	3	0	0	2	3	0	0	0	0	2	0	0	3	2	0	4
4.7	336	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	4	0	0	0	0	4	0	0	0	0	3	1	0	0	0	3	3	3	0	1	0	0	2	0	4	2	2	0	1	0	2	2	0	0	0	2	0	0
4.7	348	3	2	0	0	0	2	0	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	4	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	3	0	4	2	3	0	0	0	2	2	0	0	0	2	0	3
4.6	358	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	3	0	0	0	4	0	0	0	0	3	0	0	0	0	3	0	0	0	2	0	0	0	1	4	2	2	0	2	0	2	2	0	0	0	2	0	0
4.5	369	3	0	0	0	0	1	0	3	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	4	0	0	4	2	0	1	0	3	0	0	0	2	2	0	0	0	0	0	0	3	2	3	2	2	0	0	0	2	2	1	0	0	2	0	0
4.4	382	3	0	0	0	0	0	0	3	1	1	0	0	0	1	0	0	2	0	0	0	0	0	0	3	0	0	3	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	3	2	0	3	3	0	0	0	3	3	0	0	0	3	0	3
4.4	391	3	2	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	4	0	0	0	0	3	0	0	0	0	3	0	0	0	1	0	0	2	0	4	1	1	0	0	0	2	3	0	0	0	0	0	3
4.3	402	3	0	0	0	0	1	0	3	0	0	2	0	0	0	0	0	2	2	0	0	0	0	0	3	0	0	4	0	0	2	1	3	0	0	2	0	0	0	3	0	1	0	0	3	3	0	3	3	0	0	0	2	2	3	0	0	2	0	0
4.2	413	3	0	0	0	0	2	4	4	2	0	0	0	0	2	0	0	2	0	0	0	0	0	0	3	0	0	4	0	0	0	0	3	0	0	3	0	0	0	3	0	0	0	0	3	0	0	3	2	0	0	0	3	2	1	0	0	2	0	0
4.2	425	0	0	0	0	0	3	0	2	0	0	0	3	0	0	2	1	0	0	0	0	0	0	0	3	0	0	3	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	2	0	0	0	1	2	0	0	0	3	0	0
4.1	437	0	0	0	0	0	3	0	3	0	0	0	2	0	0	0	2	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	2	1	0	2	2	0	0	0	0	3	0	0	0	3	0	0
4	448	0	0	0	0	0	2	0	0	0	0	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	4	0	0	1	0	4	0	0	0	0	2	0	2	0	0	0	0	0	0	0	2	2	0	0	0	3	3	1	0	0	3	0	0
3.9	459	3	0	1	0	0	2	2	3	2	1	0	1	2	0	0	2	0	1	0	0	0	0	0	3	0	0	4	0	0	1	2	4	0	0	0	0	2	0	0	0	0	0	0	3	0	3	2	2	0	0	0	3	2	3	0	1	3	0	0
3.9	472	0	0	0	0	0	2	2	2	1	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	4	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	2	3	0	0	3	2	0	0	0	2	0	0
3.8	485	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	4	0	0	2	0	4	0	0	0	0	4	0	2	0	0	0	0	0	0	2	2	2	0	0	0	3	3	0	0	0	2	0	0
3.7	495	0	0	0	0	0	2	0	2	1	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2	3	0	4	0	0	1	0	0	2	0	0	0	0	0	0	0	3	2	3	0	0	0	0	4	0	0	0	0	0	0
3.6	508	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	0	3	3	0	0	0	0	0	0
3.6	517	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	0	2	0	2	0	2	0	0	0	0	0	0	1	0	0	0	0	2	0	2	0	0	0	3	3	0	0	0	0	0	0
3.5	528	0	0	0	1	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	2	0	0	0	0	3	0	0	3	0	4	0	0	0	0	2	0	0	0	1	0	0	0	3	3	1	2	0	1	0	3	4	0	0	0	3	0	0	0	0

Species record Platåberget.

temp / °C	m a.s.l.	*alomag*	*bisviv*	*carbel*	*castet*	*cerarc*	*cerreg*	*desalp*	*draarc*	*drafla*	*dragla*	*dralac*	*draniv*	*draoxy*	*drapau*	*draspe*	*dryoct*	*equarv*	*equsci*	*fesruru*	*fesviv*	*huparc*	*luzcon*	*minbif*	*oxydig*	*papdah*	*peddas*	*pedhir*	*poaalp*	*poaalpv*	*poaarcn*	*poaarcv*	*poapran*	*poaprav*	*pothyp*	*ranniv*	*ranpyg*	*ransul*	*sagces*	*sagniv*	*salpol*	*saxcer*	*saxces*	*saxfol*	*saxhie*	*saxhir*	*saxniv*	*saxopp*	*saxpla*	*silaca*	*stelon*	*trispi*
6.5	34	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
6.4	45	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	0
6.3	56	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	0	1
6.3	65	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1
6.2	77	1	1	0	1	1	1	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	1	0	0	1	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0
6.1	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1
6	98	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	1
6	108	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	1	1
5.9	118	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
5.8	128	0	1	1	0	1	1	0	0	1	0	1	0	1	0	0	1	0	0	1	0	0	1	1	1	0	0	1	0	0	1	1	0	1	1	0	0	1	0	1	1	0	1	0	1	0	1	0	0	0	1	1
5.8	138	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
5.7	148	0	1	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	1	0	1	1	0	1	0	0	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
5.6	161	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	0	1	0	1	0	0	1	1	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	1
5.6	169	0	1	0	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	1	1	0	1	0	0	1	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	1	1
5.5	181	0	1	0	1	1	1	0	0	1	0	0	1	0	0	0	1	0	0	0	1	1	1	0	1	1	0	1	0	0	1	0	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0
5.4	191	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	1	1	0	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	0
5.4	203	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	0	0	0	1	0	0	0	1	0
5.3	213	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1
5.2	223	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0
5.1	236	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	1
5.1	248	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1	0	1	0	1	0	0	0	1	0
5	259	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	1	0
4.9	270	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	0
4.3	369	0	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	0
4.2	381	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	1	0	0	0	1	1	1	0	1	0	0	0	1	1	0	1	0	0	1	0	0	1	0
4.1	393	0	1	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
4.1	403	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0
4	415	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3.9	428	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
3.8	440	1	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	1	1	0	0	0	1	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0
3.8	450	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	1	1	0	0	1	1	1	1	0	0	1	0	0	0	1	0

Table over the species that were excluded from the analyses.

Listed are species that occurred less than 6 times in at least one transect. The first 33 species were observed less than 6 times, and thus excluded from any analyses. Underlined species were observed more than 6 times in at least one transect, were hence analysed regarding their response to temperature within the respective transect. Bold printed species were only analysed in the transects in which they occurred more than 6 times.

Species observed <6 times in at least one transect			
Species name	**Transect**		
	Zeppelinfjellet	**Brentskarhaugen**	**Platåberget**
Arenaria pseudofrigida	<6	-	-
Cardamine bellidifolia ssp. *bellidifolia*	-	<6	<6
Cardamine pratensis ssp. *angustifolia*	<6	<6	-
Carex fuliginosa ssp. *misandra*	<6	-	-
Carex lachenalii	-	<6	-
Carex nardina ssp. *hepburnii*	<6	-	-
Cerastium arcticum x *Cerastium regelii*	-	<6	-
Deschampsia alpina	<6	-	<6
Draba glabella	-	-	<6
Draba lactea	-	-	<6
Draba micropetala	-	<6	-
Draba nivalis	-	-	<6
Draba oxycarpa	-	<6	-
Equisetum arvense ssp. *alpestre*	<6	<6	<6
Equisetum scirpoides	<6	<6	<6
Eriophorum scheuchzeri ssp. *arcticum*	-	<6	-
Festuca rubra ssp. *richardsonii*	-	<6	-
Huperzia arctica	-	-	<6
Juncus biglumis	<6	-	-
Koenigia islandica	-	<6	-
Luzula nivalis	-	<6	-
Pedicularis dasyantha	<6	-	<6
Poa abbreviata ssp. *abbreviata*	<6	-	-
Poa hartzii ssp. *hartzii*	<6	-	-
Ranunculus nivalis	-	<6	<6
Sagina cespitosa	-	-	<6
Saxifraga aizoides	<6	-	-
Saxifraga foliolosa	<6	<6	<6
Saxifraga hirculus ssp. *compacta*	-	-	<6
Saxifraga hyperborea	-	<6	-
Saxifraga platysepala	-	<6	-
Saxifraga tenuis	<6	<6	-
Silene uralensis ssp. *arctica*	<6	-	-
Draba arctica ssp. *arctica*	<6	-	**>6**
Draba pauciflora	<6	**>6**	-
Minuartia biflora	-	**>6**	<6
Saxifraga hieracifolia ssp. *hieracifolia*	-	<6	**>6**
Silene acaulis	**>6**	-	<6
Oxyria digyna	<6	**>6**	**>6**
Papaver dahlianum	<6	**>6**	**>6**
***Poa arctica* ssp. *arctica* (non-viviparous form)**	<6	**>6**	**>6**

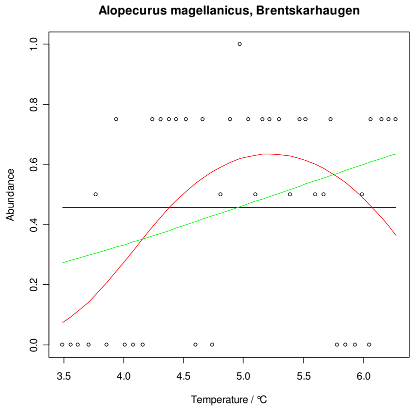
Table over the analysed species.

Listed are the 40 species that were statistically analysed. The left column comprises species, that were only analysed regarding their response to temperature in one transect. The central and the right column contain species, that were additionally analysed regarding their differences in response to temperature between the transects.

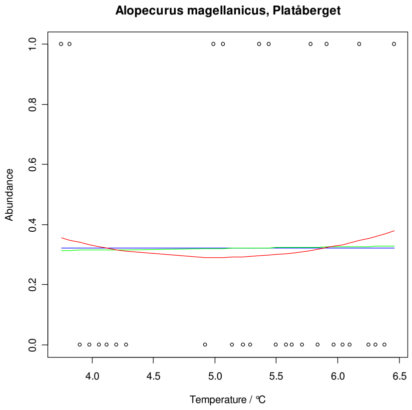
In 1 transect	**In 2 transects**	**In 3 transects**
Cassiope tetragona ssp. *tetragona*	*Alopecurus magellanicus*	*Bistorta vivipara*
Cochlearia groenlandica	*Cerastium arcticum*	*Cerastium regelii*
Draba arctica ssp. *arctica*	*Draba corymbosa*	*Luzula confusa*
Draba alpina	*Draba subcapitata*	*Salix polaris*
Draba fladnizensis	*Dryas octopetala*	*Saxifraga cernua*
Draba pauciflora	*Festuca viviparoidea*	*Saxifraga cespitosa* ssp. *cespitosa*
Festuca rubra ssp. *rubra*	*Oxyria digyna*	*Saxifraga oppositifolia* ssp. *oppositifolia*
Minuartia biflora	*Papaver dahlianum*	
Minuartia rubella	*Pedicularis hirsuta*	
Poa alpina var. *alpina*	*Poa alpina* var. *vivipara*	
Poa arctica ssp. *arctica* (viv.)	*Poa arctica* ssp. *arctica* (non-viv.)	
Poa pratensis ssp. *alpigena* (non-viv.)	*Potentilla hyparctica ssp. hyparctica*	
Poa pratensis ssp. *alpigena* (viv.)	*Ranunculus sulphureus*	
Ranunculus pygmaeus	*Sagina nivalis*	
Saxifraga hieracifolia ssp. *hieracifolia*	*Saxifraga nivalis*	
Trisetum spicatum ssp. *spicatum*	*Silene acaulis*	
	Stellaria longipes	

Appendix V

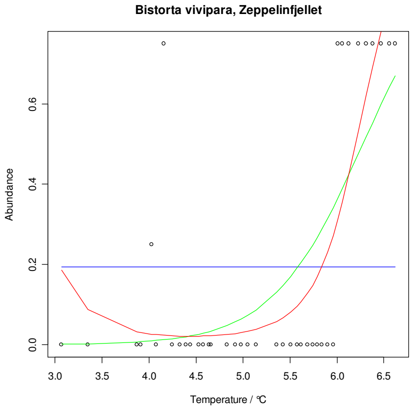
Illustrated are the plotted GLMs fitted to the distribution of each species along the transects. Trends in the models indicate trends in response to temperature. The blue line represents the null model, the green the linear and the red the unimodal model. The results of the analysis are provided in Table 3.3. The diagrams are displayed in alphabetical order of the species. When a species occurred in more than one transect, the diagrams have been aligned in the order Zeppelinfjellet, Brentskarhaugen and Platåberget from the left to the right.



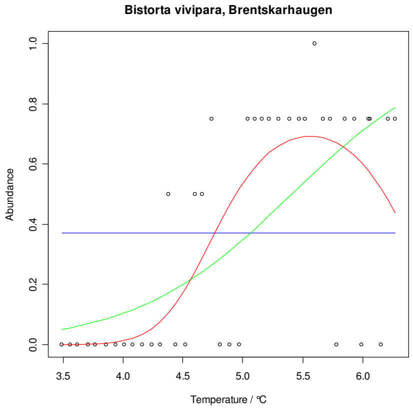
Alopecurus magellanicus, Brentskarhaugen



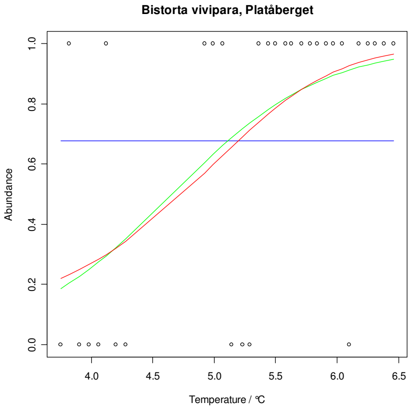
Alopecurus magellanicus, Platåberget



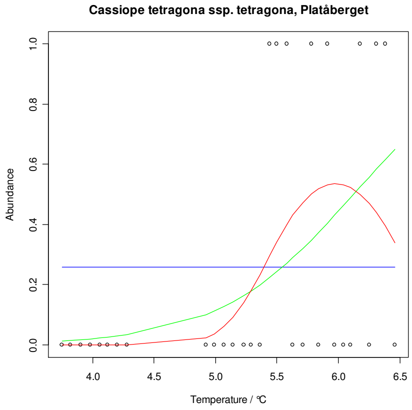
Bistorta vivipara, Zeppelinfjellet



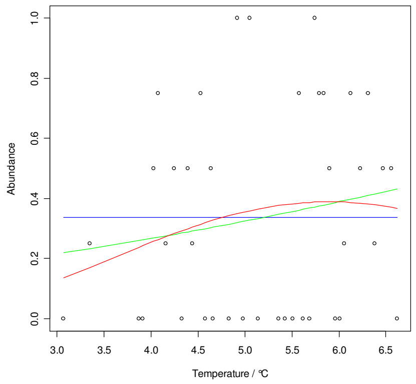
Bistorta vivipara, Brentskarhaugen



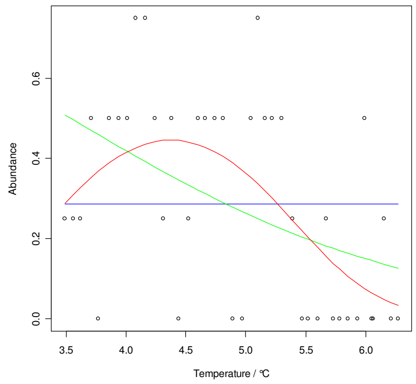
Bistorta vivipara, Platåberget



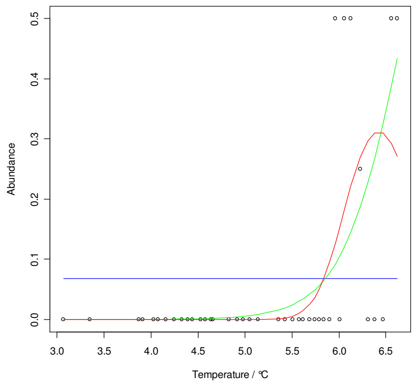
Cassiope tetragona ssp. tetragona, Platåberget



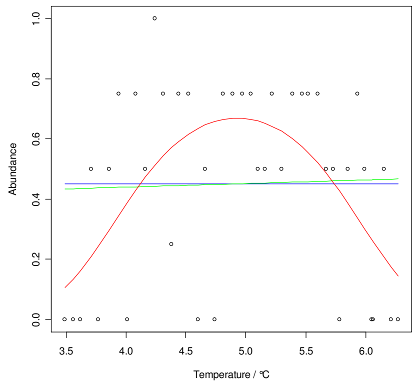
Cerastium arcticum, Zeppelinfjellet



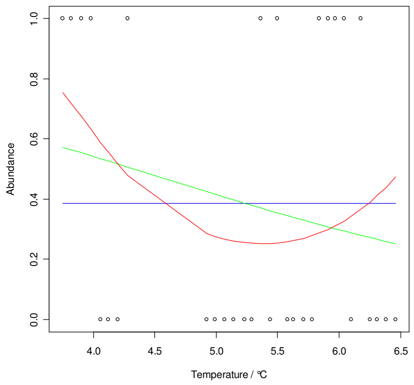
Cerastium arcticum, Brentskarhaugen



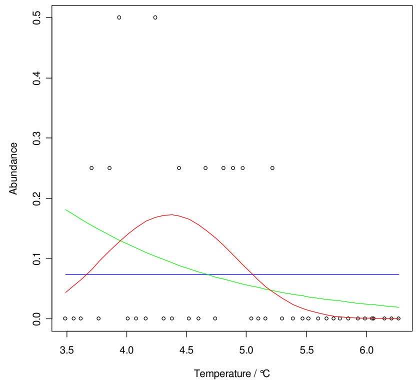
Cerastium regelii, Zeppelinfjellet



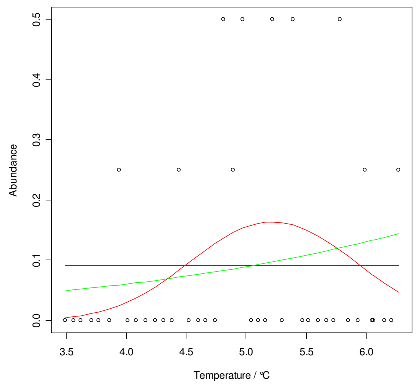
Cerastium regelii, Brentskarhaugen



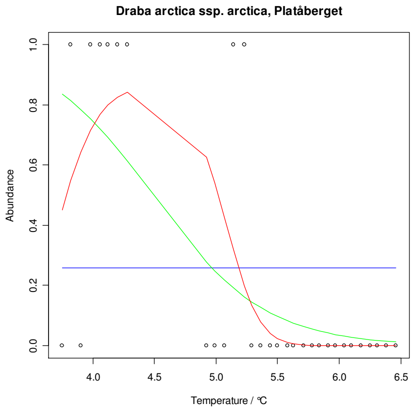
Cerastium regelii, Platåberget



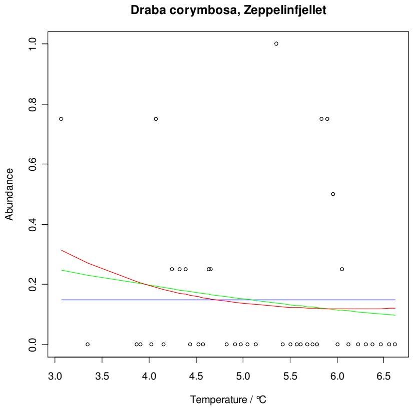
Cochlearia groenlandica, Brentskarhaugen



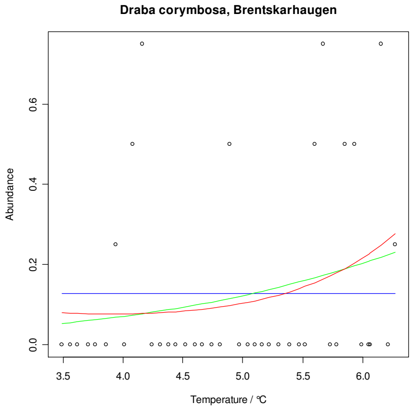
Draba alpina, Brentskarhaugen



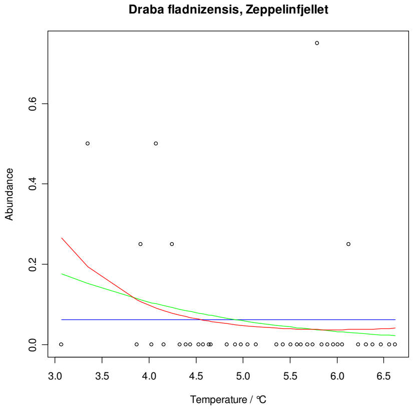
Draba arctica ssp. arctica, Platåberget



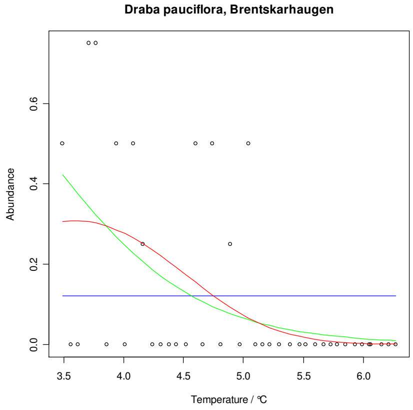
Draba corymbosa, Zeppelinfjellet



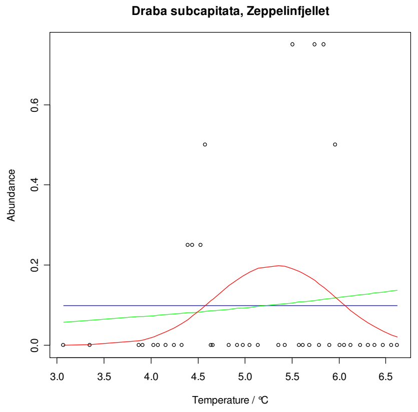
Draba corymbosa, Brentskarhaugen



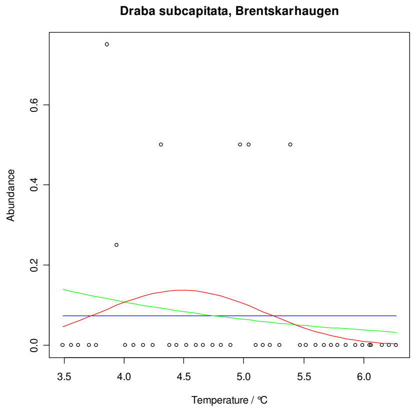
Draba fladnizensis, Zeppelinfjellet



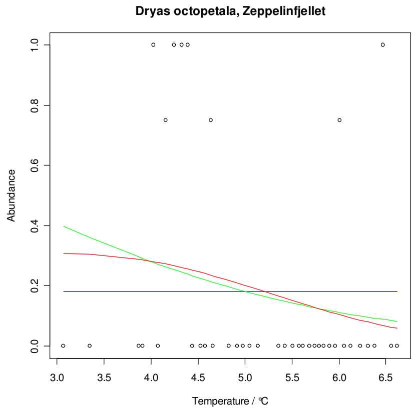
Draba pauciflora, Brentskarhaugen



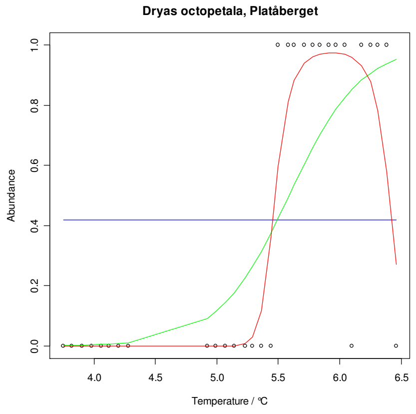
Draba subcapitata, Zeppelinfjellet



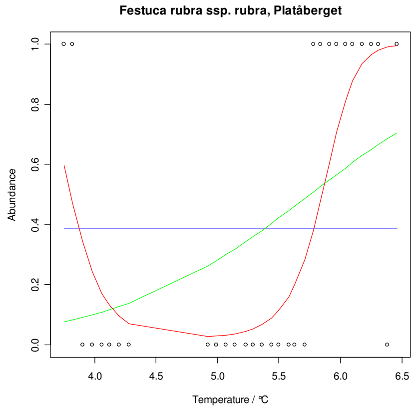
Draba subcapitata, Brentskarhaugen



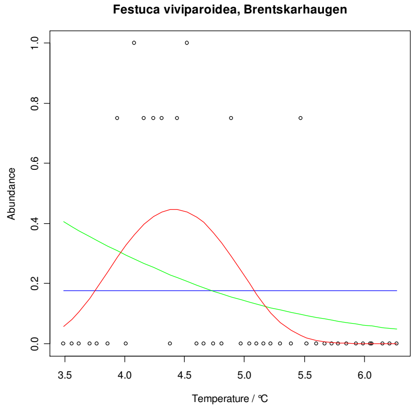
Dryas octopetala, Zeppelinfjellet



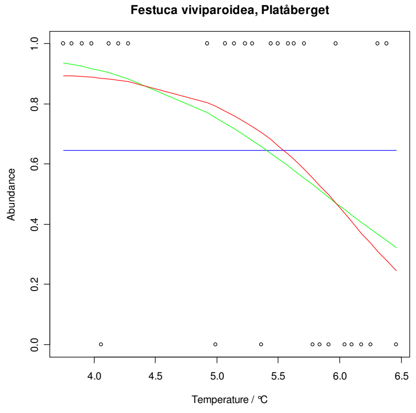
Dryas octopetala, Platåberget



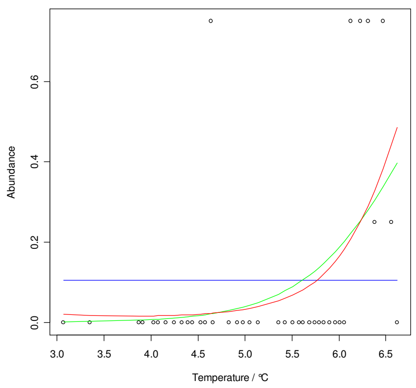
Festuca rubra ssp. rubra, Platåberget

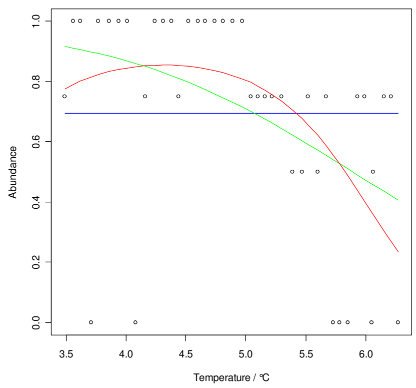


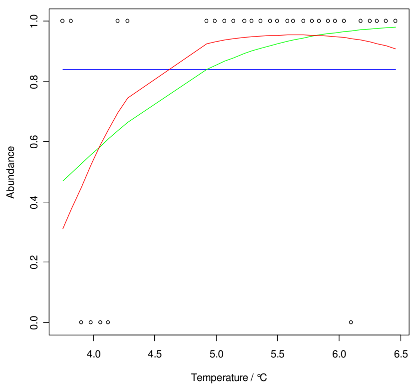
Festuca viviparoidea, Brentskarhaugen

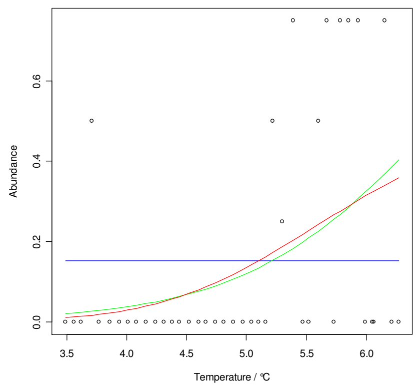


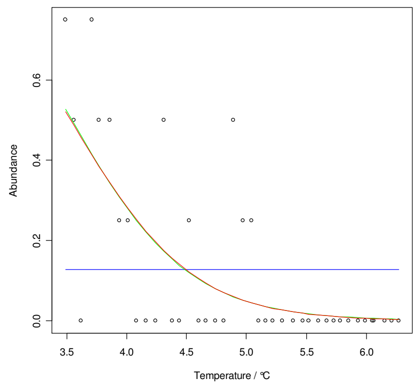
Festuca viviparoidea, Platåberget

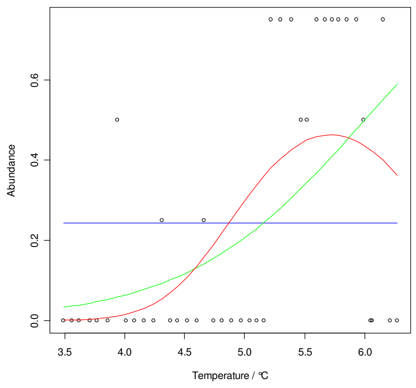

Luzula confusa, Zeppelinfjellet

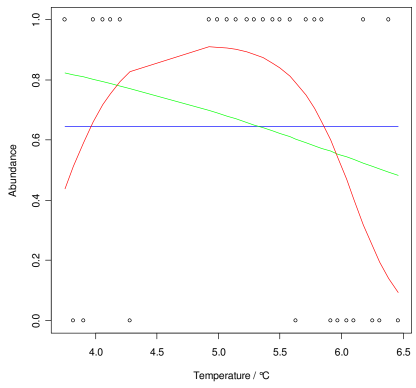

Luzula confusa, Brentskarhaugen

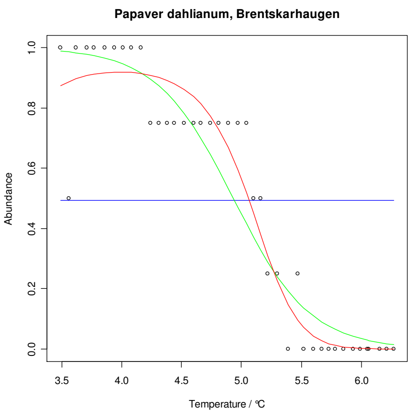

Luzula confusa, Platåberget


Minuartia biflora, Brentskarhaugen

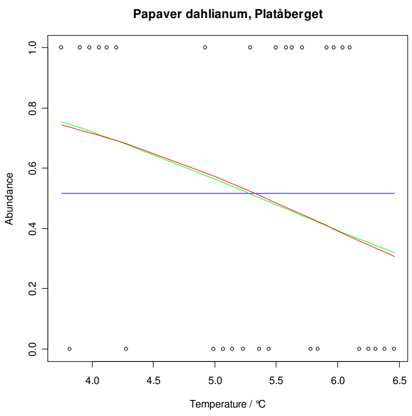

Minuartia rubella, Brentskarhaugen


Oxyria digyna, Brentskarhaugen

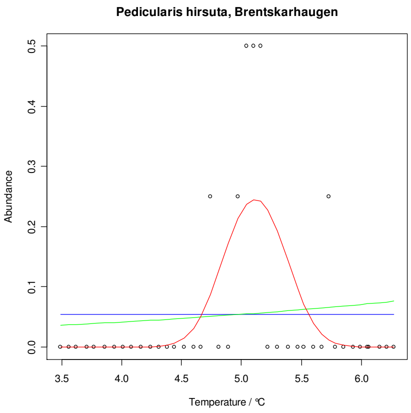

Oxyria digyna, Platåberget



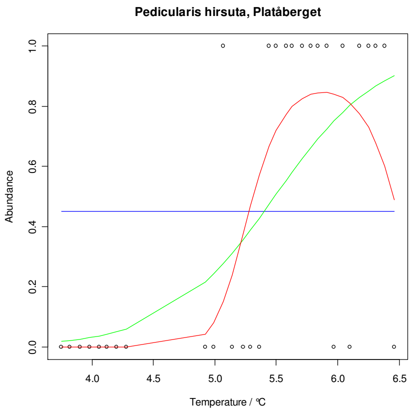
Papaver dahlianum, Brentskarhaugen



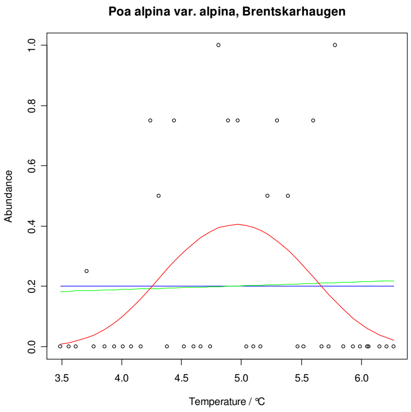
Papaver dahlianum, Platåberget



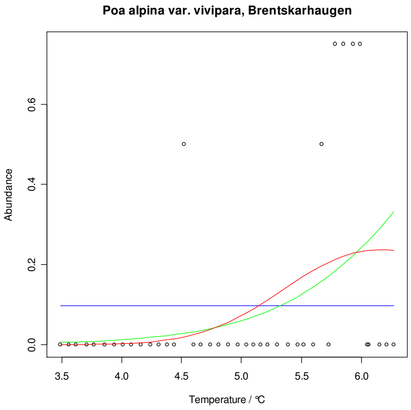
Pedicularis hirsuta, Brentskarhaugen



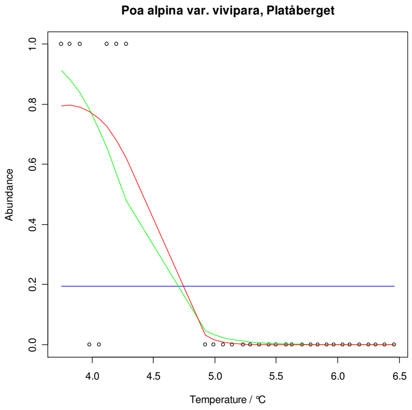
Pedicularis hirsuta, Platåberget



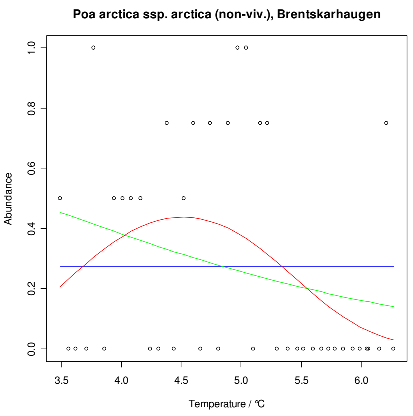
Poa alpina var. alpina, Brentskarhaugen



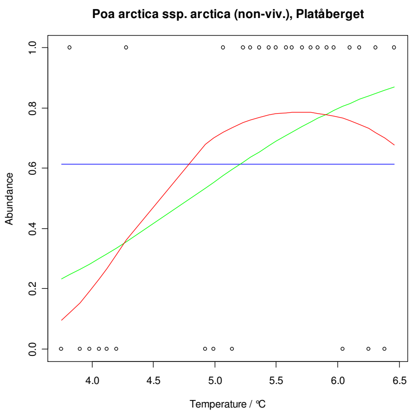
Poa alpina var. vivipara, Brentskarhaugen



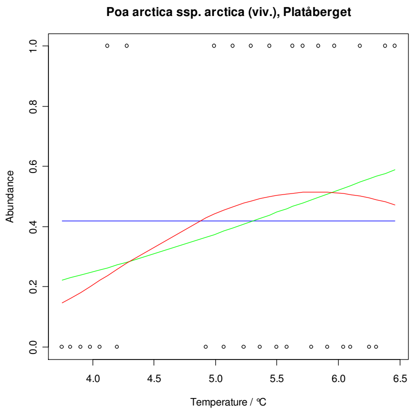
Poa alpina var. vivipara, Platåberget



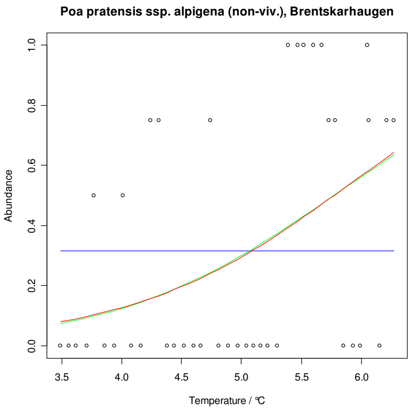
Poa arctica ssp. arctica (non-viv.), Brentskarhaugen



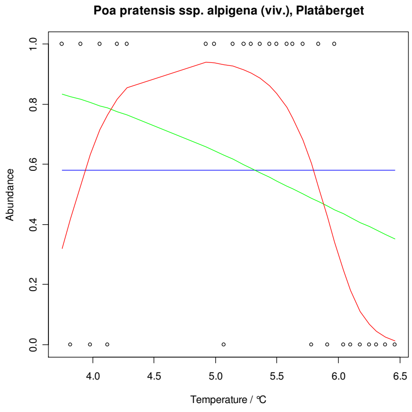
Poa arctica ssp. arctica (non-viv.), Platåberget



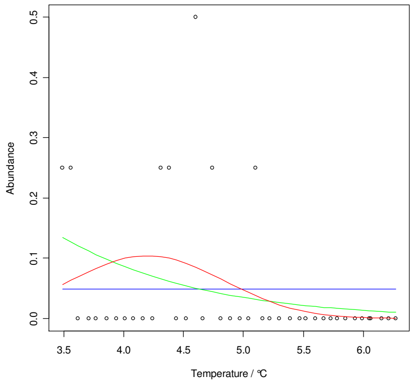
Poa arctica ssp. arctica (viv.), Platåberget



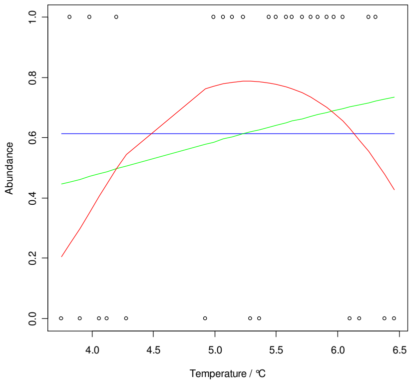
Poa pratensis ssp. alpigena (non-viv.), Brentskarhaugen



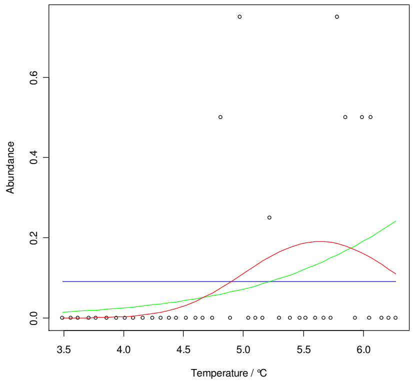
Poa pratensis ssp. alpigena (viv.), Platåberget



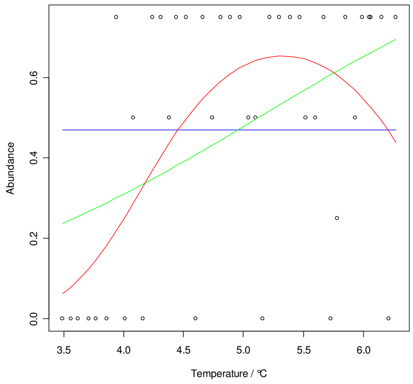
Potentilla hyparctica ssp. hyparctica, Brentskarhaugen



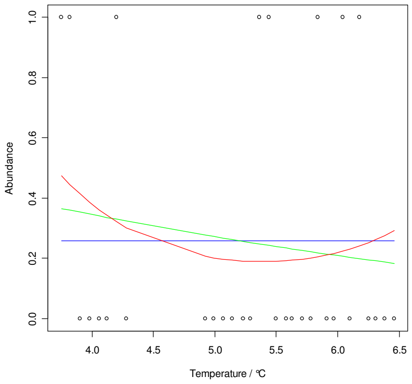
Potentilla hyparctica ssp. hyparctica, Platåberget



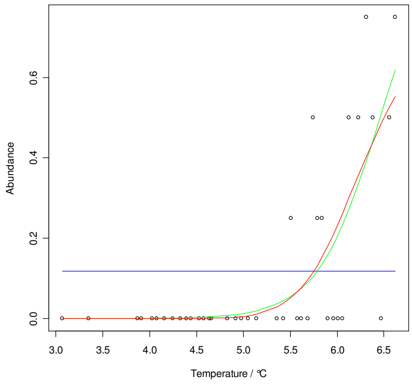
Ranunculus pygmaeus, Brentskarhaugen



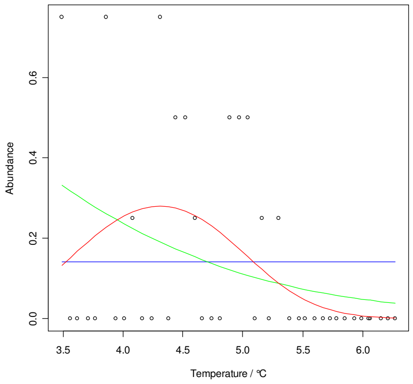
Ranunculus sulphureus, Brentskarhaugen



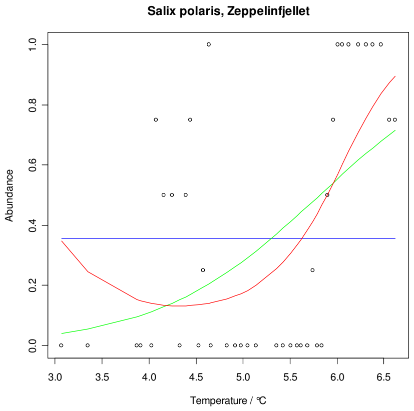
Ranunculus sulphureus, Platåberget

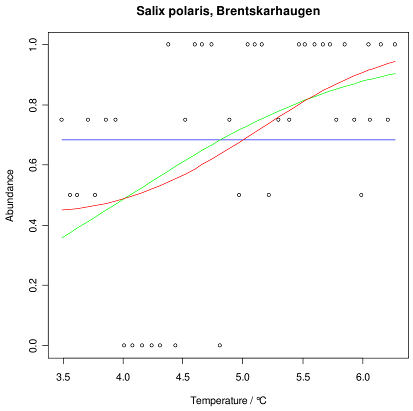


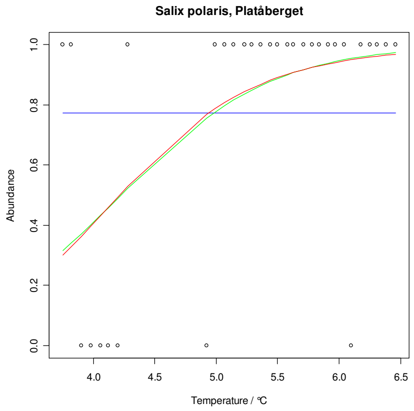
Sagina nivalis, Zeppelinfjellet

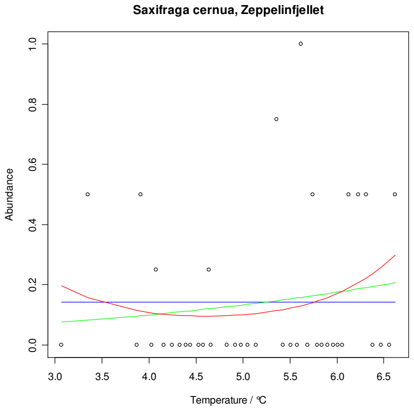


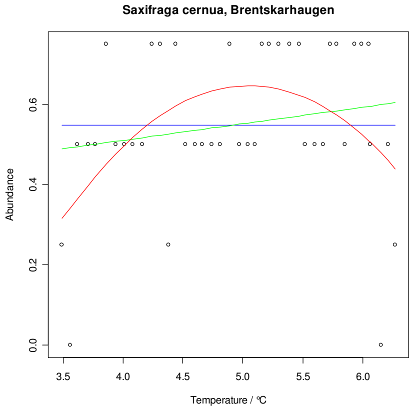
Sagina nivalis, Brentskarhaugen

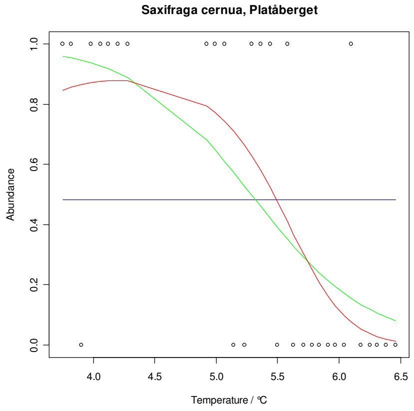

Salix polaris, Zeppelinfjellet

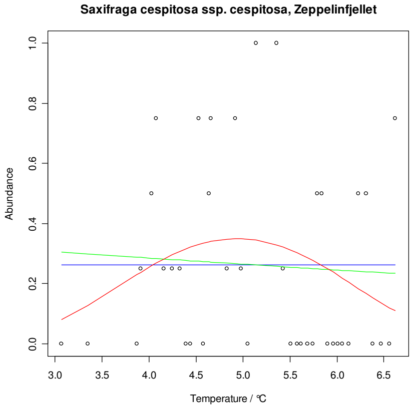

Salix polaris, Brentskarhaugen

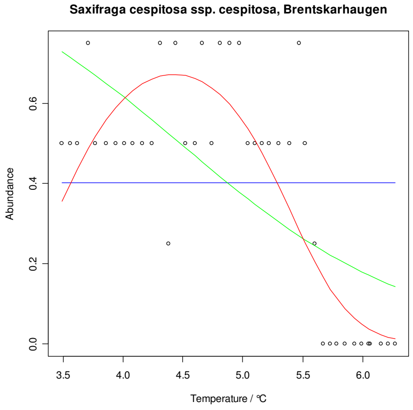

Salix polaris, Platåberget

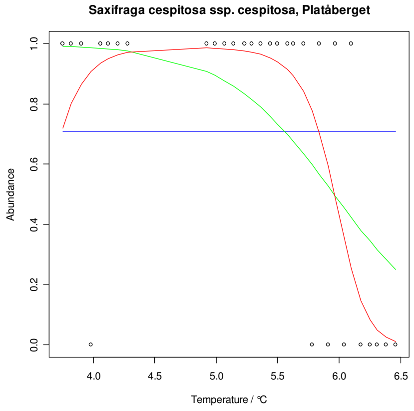

Saxifraga cernua, Zeppelinfjellet

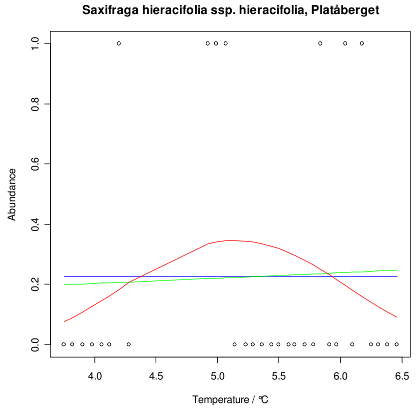

Saxifraga cernua, Brentskarhaugen


Saxifraga cernua, Platåberget

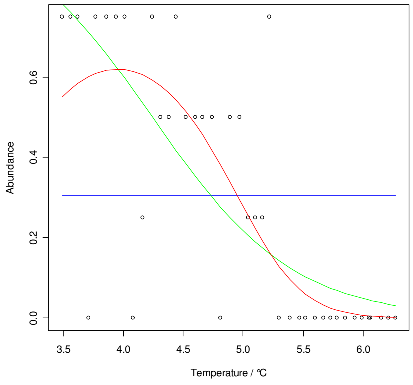

Saxifraga cespitosa ssp. cespitosa, Zeppelinfjellet


Saxifraga cespitosa ssp. cespitosa, Brentskarhaugen

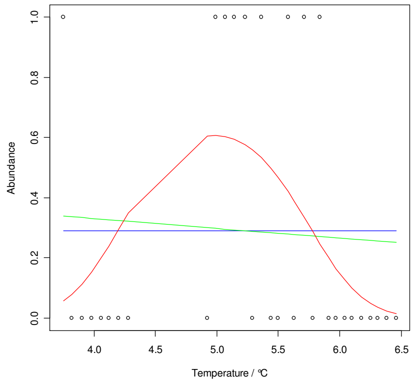

Saxifraga cespitosa ssp. cespitosa, Platåberget


Saxifraga hieracifolia ssp. hieracifolia, Platåberget

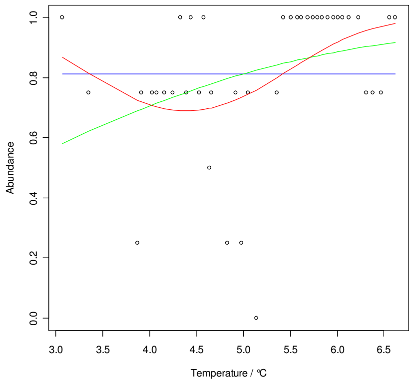
Saxifraga nivalis, Brentskarhaugen



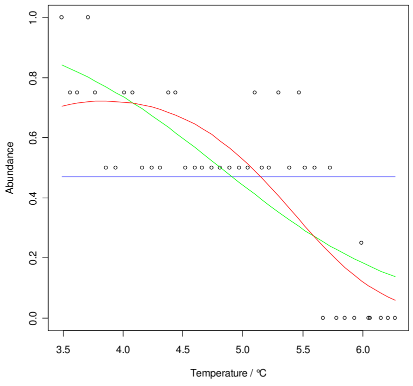
Saxifraga nivalis, Platåberget



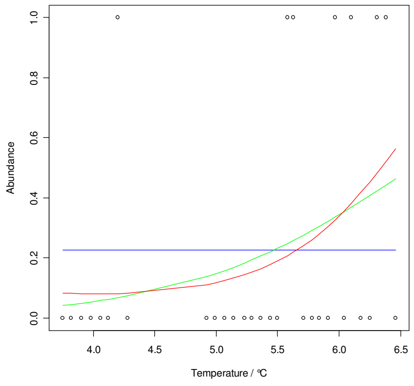
Saxifraga oppositifolia ssp. oppositifolia, Zeppelinfjellet



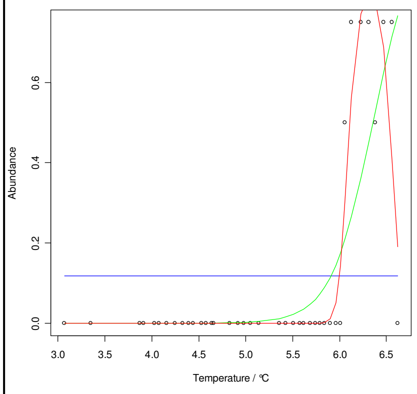
Saxifraga oppositifolia ssp. oppositifolia, Brentskarhaugen



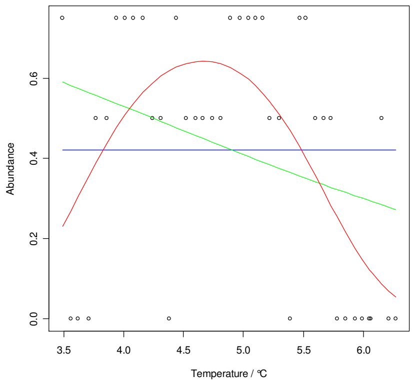
Saxifraga oppositifolia ssp. oppositifolia, Platåberget



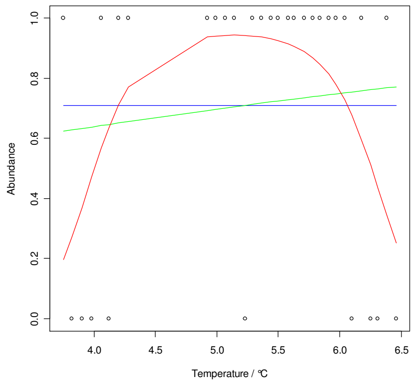
Silene acaulis, Zeppelinfjellet

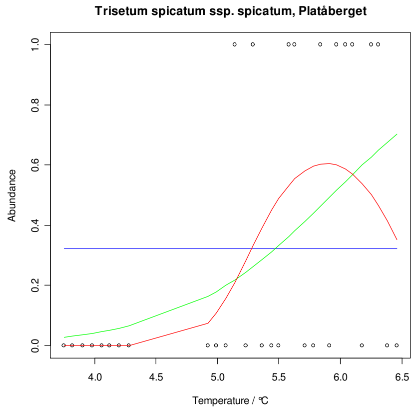


Stellaria longipes, Brentskarhaugen



Stellaria longipes, Platåberget




Trisetum spicatum ssp. spicatum, Platåberget
Abundance
0.0
0.2
0.4
0.6
0.8
1.0
4.0
4.5
5.0
5.5
6.0
6.5
Temperature / ℃

Appendix VI:

Temperature ranges for all 73 observed species. Lowest and highest temperatures, where a species was observed, provided the limiting values for each temperature range. For each species the temperature ranges in the different transects are summarised into a total range. The species were grouped into four tables:

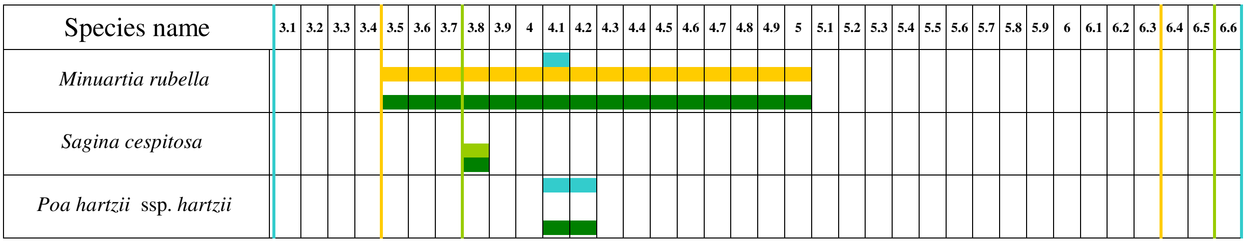
1) Species observed only towards the mountain tops and thus at low temperatures.
2) Species observed only at medium altitudes and thus at medium temperatures.
3) Species observed solely towards the mountain foots, and hence at mild temperatures.
4) Species observed along vast parts of the transects, and thus along large temperature gradients.

🟦 ***Zeppelinfjellet***
🟨 ***Brentskarhaugen***
🟩 ***Platåberget***
🟩 ***Summarised total range***

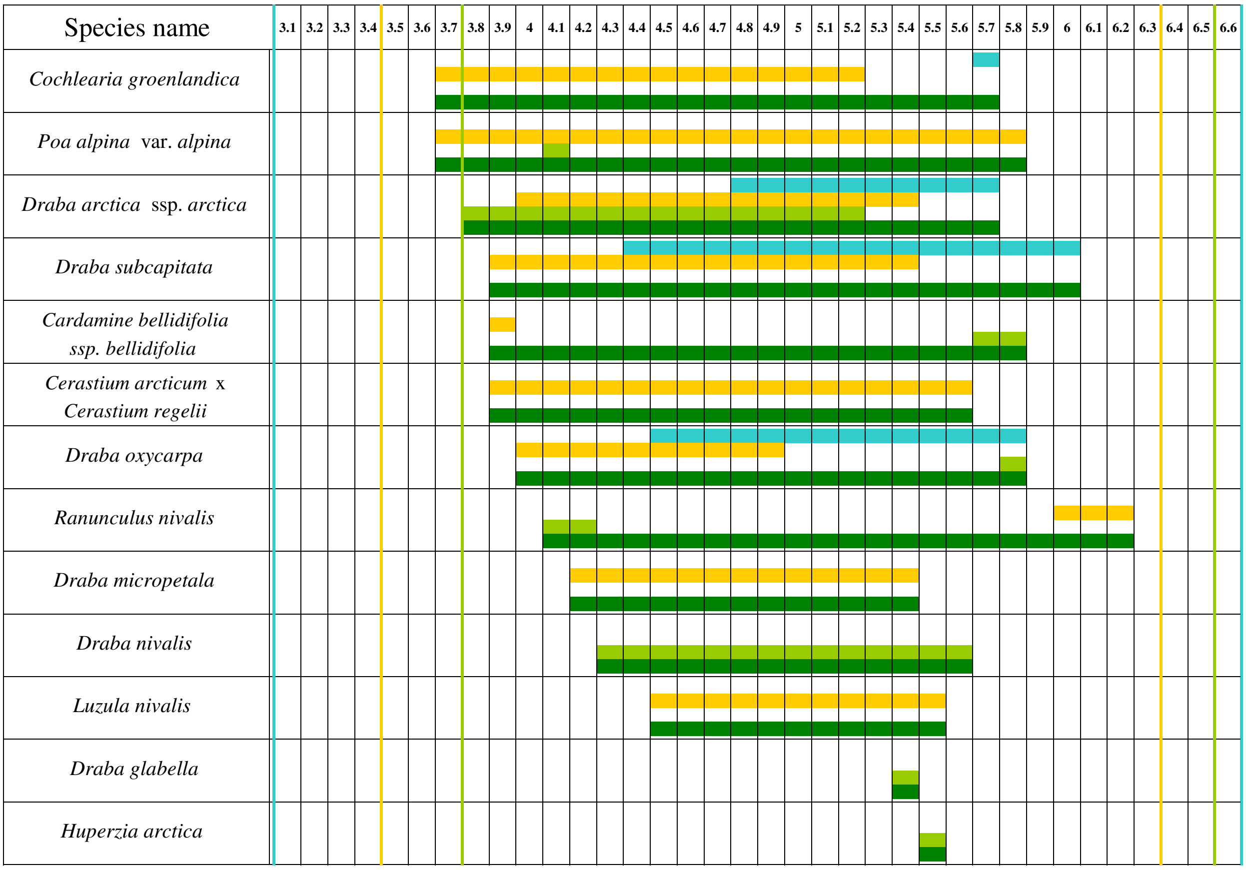
| | | | ***Upper and lower temperature limits of the transects***

3.1-6.6 = Air temperature in °C

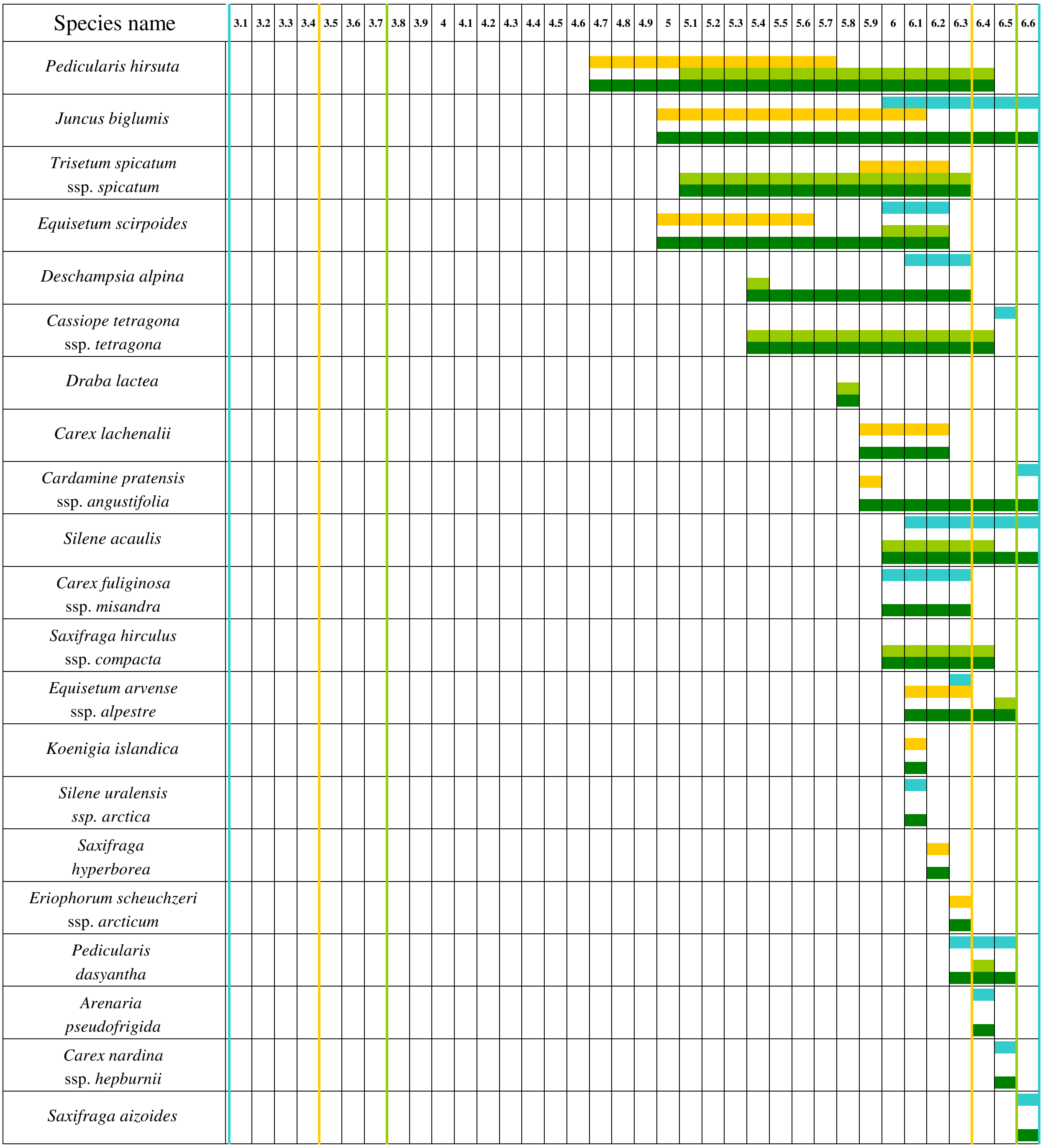
1) Species observed at low temperatures:



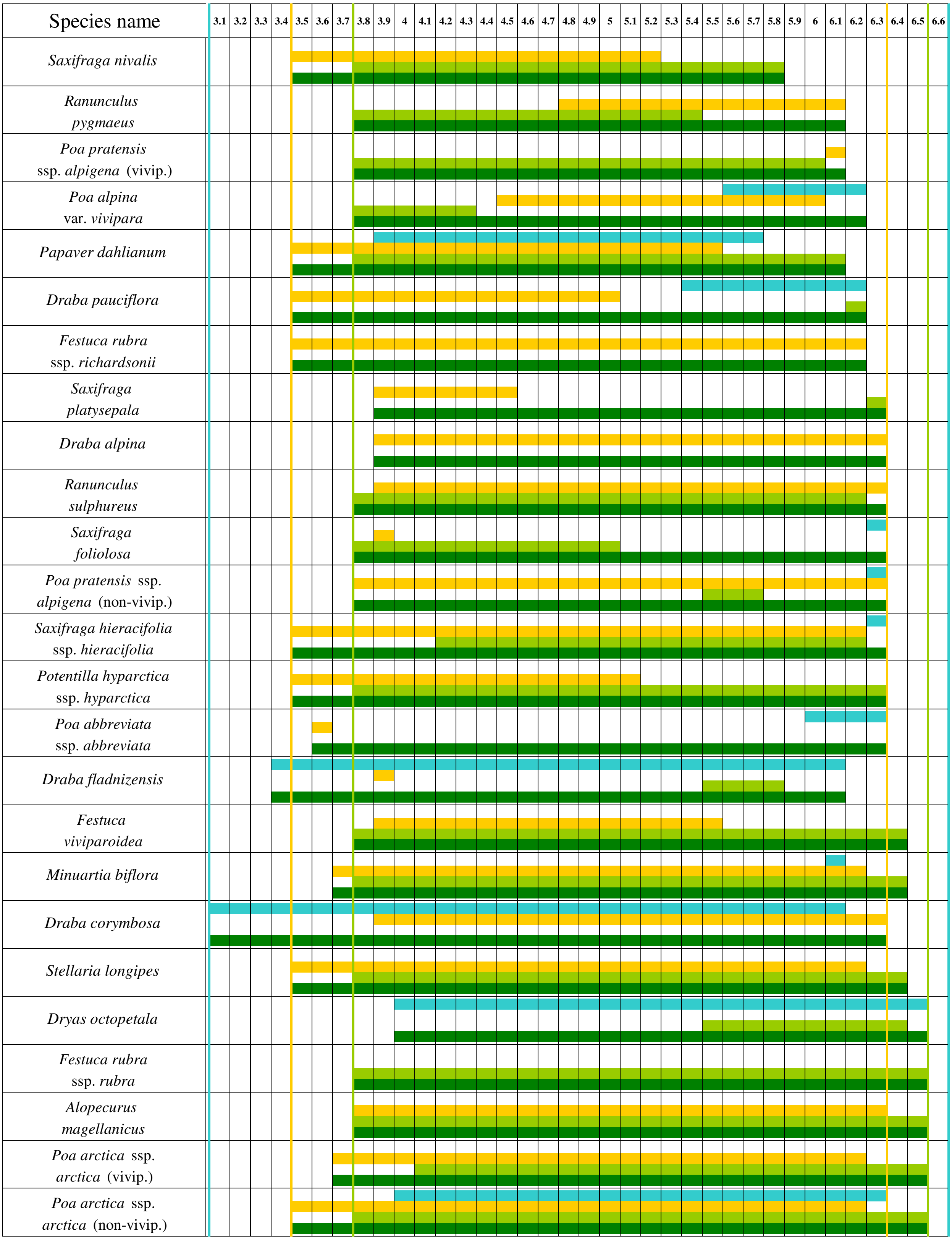
2) Species observed at medium temperatures:



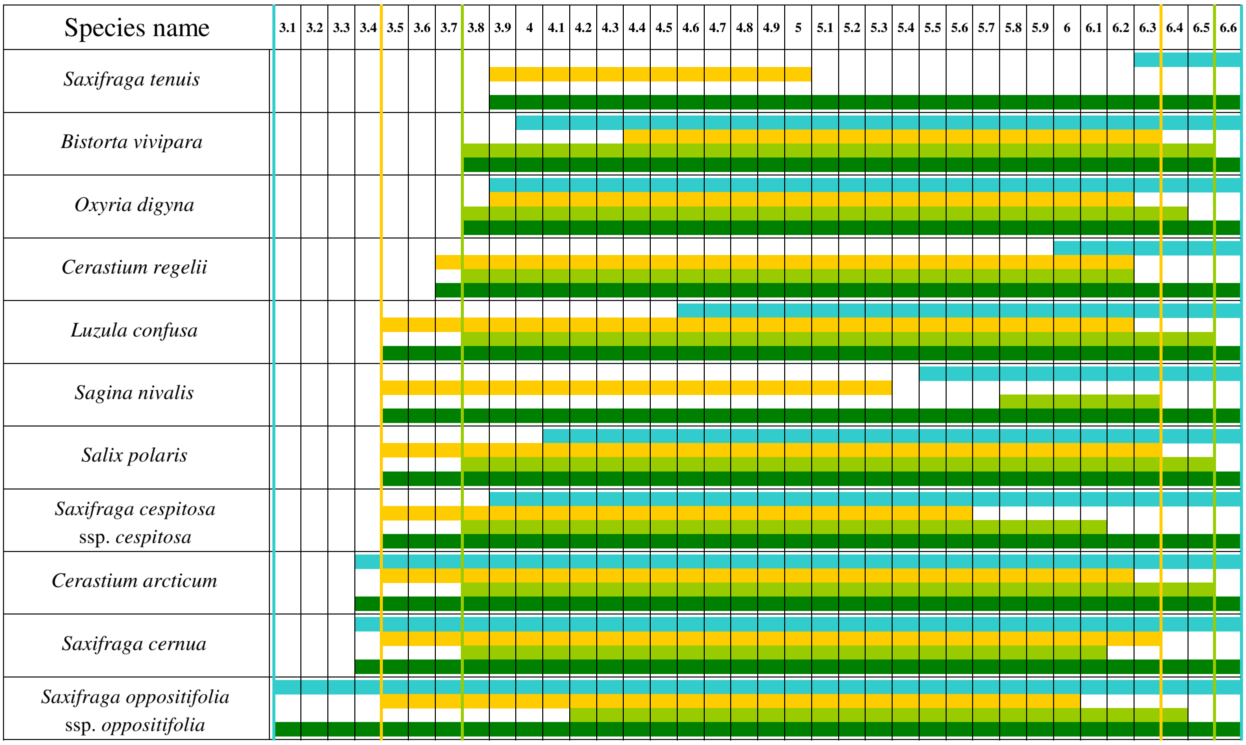
3) Species observed at high temperatures:



4) Species observed along broad temperature ranges (part I):



4) Species observed along broad temperature ranges (part II):



Appendix VII

Summarised are the results of backward elimination and forward selection for each tested model for each species. Residual deviances and p-values are given per species for each tested model. Null deviances and residual deviances for the full models are presented below each other on the top of the columns for the species (0 and 5). Not significant results of the backward elimination are given in white, significant results of the backward elimination are given in yellow and bold. Forward selection was used to test the remaining models for significant differences. The results are given in green. The majority of the species was analysed for differences between two transects. Species that were analysed regarding the differences among three transects are presented in orange.

	Alo. mag.		***Bis. viv.***		***Cer. arc.***		***Cer. reg.***		***Dra. cor.***		***Dra. sub.***	
Model	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**
0		99.758		154.943		108.695		98.42		94.745		74.578
5		80.882		89.318		94.61		74.801		89.988		67.345
1	**0.004**	**91.63**	0.002	142.853	0.586	108.399	0.006	90.953	0.57	94.423	0.523	74.17
2	0.083	88.622	4.22E-10	103.844	0.095	105.61	0.63	90.721	0.962	94.421	0.429	73.544
3	0.06	85.084	0.42	103.193	0.625	105.372	0.049	86.833	0.894	94.403	**0.044**	**69.496**
4	0.349	84.206	0.813	102.78	**0.002**	**95.388**	0.442	86.243	0.056	90.74	0.143	67.352
5	0.068	80.882	**0.001**	**89.318**	0.378	94.61	**0.001**	**74.801**	0.386	89.988	0.935	67.345

	Fes. viv.		***Luz. con.***		***Oxy. dig.***		***Ped. hir.***		***Poa alp. ssp. viv.***		***Poa arc. ssp. arc.* (non-viv.)**	
Model	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**
0		97.074		150.915		99.813		85.081		64.881		99.758
5		66.179		76.407		75.657		46.075		37.93		80.728
1	2.27E-04	83.48	2.35E-11	101.968	0.031	95.17	0.004	76.822	0.596	64.6	0.06	96.227
2	0.002	73.871	0.022	96.696	0.16	93.196	0.002	66.883	0.204	62.985	0.929	96.219
3	**0.048**	**69.977**	0.558	96.352	0.003	84.314	0.013	60.768	0.71	62.847	0.283	95.068
4	0.445	69.395	**3.80E-04**	**80.599**	**0.005**	**76.255**	**1.37E-04**	**46.229**	**6.84E-07**	**38.188**	**1.54E-04**	**80.74**
5	0.073	66.179	0.123	76.407	0.439	75.657	0.695	46.075	0.612	37.93	0.915	80.728

	Pot. hyp. ssp. hyp.		***Ran. sul.***		***Sag. niv.***		***Sax. cer.***		***Sax. niv.***		***Ste. lon.***	
Model	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**	**P-value**	**Res. dev.**
0		94.184		99.758		94.745		152.36		98.42		88.632
5		68.526		67.435		63.417		82.882		54.999		62.113
1	9.05E-05	78.858	1.21E-04	84.975	0.666	94.559	8.48E-11	105.98	0.035	93.97	0.807	88.572
2	0.514	78.432	0.062	81.5	0.151	92.497	0.071	102.73	1.65E-04	79.781	0.286	87.433
3	0.382	77.666	0.038	77.197	0.452	91.932	0.701	102.58	0.003	70.999	4.08E-05	70.6
4	**0.003**	**68.528**	0.038	72.897	**9.64E-08**	**63.486**	0.005	92.105	**8.41E-05**	**55.536**	**0.004**	**62.185**
5	0.962	68.526	**0.019**	**67.435**	0.793	63.417	**0.01**	**82.882**	0.464	54.999	0.789	62.113