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Red-listed vascular Plant Species in Sub-Alpine and Alpine Landscapes: How does Land-use affect their Distribution?

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Abstract

A major threat to red-listed vascular plant species in semi-natural habitats is land use change. In this study the effect of land use on the distribution of red-listed vascular plant species was investigated in a protected upland area: Budalen Landscape Conservation Area in mid-Norway (ca. 600-900 m a.s.l.). The selected species were *Gymnadenia conopsea* (Near threatened, NT), *Gentianella campestris* (NT), *Primula scandinavica* (NT), *Botrychium lunaria* (NT) and *Dactylorhiza incarnata* (NT). It is expected that low intensity land use benefit red-listed species in these semi-natural habitats and thus that land use variables such as former haymaking, woodcutting and distance to summer farms will affect the overall distribution of the species in the landscape. Also, land use (or rather abandonment of such) is expected to have an indirect effect on distribution by encroachment of birch (*Betula pubescens*). The area was examined by placing 27 transects on the southwest facing slope of the valley (from ca. 600-1200 m a.s.l.). Along the transects, birch and every detected red-listed species population were sampled. Birch height and stem diameter were recorded to quantify encroachment, and the population size and structure of the red listed species was recorded. Land use, altitude and vegetation data were extracted from ArcGIS to relate to the distribution of red-listed species. In this study it was found that when modelling distribution with red-listed species as a group, altitude, distance to nearest summer farm and former haymaking came out as the most important explanatory variables. Because of low abundance of the other species, only *Gentianella campestris* and *Gymnadenia conopsea* could be modelled separately. For *Gymnadenia conopsea* altitude, haymaking and vegetation type had significant effects on the distribution. The distribution of *Gentianella campestris* was significantly affected by altitude, distance to nearest summer farm and vegetation type. A population estimate of the species indicated that *G. conopsea* (15 157 individuals) and *G. campestris* (35 384 individuals) are abundant in the birch meadow grassland. There was also a high degree of birch recruitment regardless of altitude, and the proportion of recruits (birch < 20 years of age) in the local population was negatively correlated with the presence of red-listed species. All red-listed species in this study had land use variables as significant factors explaining their distribution. This indicates that changes in land use are very important in determining the distribution of red-listed species connected to semi-natural landscapes.

Keywords: Red-listed species, land use, encroachment, management.

Introduction

Humans have been influencing mountainous landscapes for at least the past two millennia (Tasser & Tappeiner, 2002; Eriksson et al., 2002), creating what we now call semi-natural cultural habitats. Strong traditions of resource exploitation (e.g. traditional agriculture and grazing of livestock) exist in these mountainous systems, throughout Scandinavia (Austrheim & Eriksson, 2001). The traditional agricultural system consisted of permanent farms in the valley, and summer farms in the mountains. This type of land use has declined in Scandinavia since the late 19th century, and many areas are now abandoned (Eriksson et al., 2002).

The mountainous regions of Norway also played an important part in subsistence agriculture in the pre-industrial society. The onset and intensity of utilization of natural resources in alpine and sub-alpine areas in Norway varies greatly between locations, but grazing of livestock is considered to have been continuous since the last glaciation (however with varying intensity) (Olsson et al., 2000, Austrheim & Eriksson, 2001). The first summer farms in Norway are dated to 1690 BP, but generally the development of summer farming systems are thought to have begun sometime during the 16th century (Olsson et al., 2000). Traditional agricultural practices include haymaking, woodcutting (mostly for fuel) and grazing (Austrheim et al., 1999), and are a form of mixed agriculture, with seasonal movements of livestock between the permanent farms in the lowland and the mountain summer farms (Olsson et al., 2000). Like in the rest of Scandinavia, the traditional land use in mountains has declined also in Norway.

Species diversity and distribution in the mountains are affected by abiotic factors, such as topography, snow cover, soil moisture and freezing, solifluction and soil nutrient composition, as well as biotic factors (e.g. competition, facilitation or grazing) (Austrheim et al., 2010; Marini et al., 2007; Vittoz et al., 2008;Austrheim & Eriksson, 2001). A study by Choler et al. (2001) indicated that facilitation in alpine communities allowed species from lower elevations to move upward. Regional dynamics of plants, and especially connectivity between sources and sinks, is also important for the distribution of species (van Andel & Aronson, 2006; Jones, 2011). Additionally, land use influences the vegetation dynamics and regional distribution of species in mountains (Tasser & Tappeiner, 2002).

Alpine ecosystems are considered to be important reservoirs for biodiversity (Britton et al., 2009), and semi-natural grasslands are among the habitats with highest diversity of vascular plant species in Europe (Myklestad & Sætersdal, 2004). Mountainous areas are also considered to be species rich because of the vast range of different conditions and microclimates naturally present here, especially in the transit zone between closed forest and open alpine habitats (along the forest line)(Körner & Ohsawa, 2005). Land use has contributed to biodiversity by creating patchy distributions of habitats, and a range of different disturbance regimes, in an area that otherwise would have been dominated by forest (sub-alpine) and dwarf shrubs (alpine)(Tasser & Tappeiner, 2002).

Habitat fragmentation (e.g. due to building of cabins and roads) and degradation are two of the major threats to biodiversity in sub-alpine and alpine landscapes (Austrheim et al., 2010). Abandonment of traditional land use most often leads to semi-natural habitat degradation through encroachment of birch (Eriksson et al., 2002; Austrheim et al., 1999). Austrheim et al., (2010) conclude that the main threats for red-listed species in these areas are changes in land use (40% of species affected), and climate change (affected close to 40 % of species).

An important management initiative for the conservation of biodiversity has been to establish conservation areas. Historically, conservation consisted of protecting areas by limiting human access in hope that species would recover on their own (e.g. national parks and reserves). In time we have learned that nature is not that simple, and that maintaining traditional land use and a certain level of disturbance might be beneficial for species richness in an area (Eriksson et al, 2002). In Norway, 4,4% of the area is protected as landscape conservation areas (LCA´s)(Direktoratet for naturforvaltning, 2007). In contrast to historical protected areas (like national parks), these areas have mainly been areas containing landscapes created and affected by land use processes (semi-natural cultural habitats), and the main aim has been to conserve cultural heritage and biological diversity, often by allowing and encouraging a degree of human disturbance (DYLAN, 2011; Direktoratet for naturforvaltning, 2012).

The historical protection method of excluding all human influence would most likely be unproductive in semi-natural areas, as these are areas that have been influenced by human activities for a long time, and studies have shown that these areas begin transforming (reforestation in most cases) immediately after abandonment ((Eriksson et al., 2002; Austrheim et al., 1999; Tasser & Tappeiner, 2002). Indeed, a report from Riksrevisjonen (Office of the Auditor General, 2006) stated that 30% of all protected areas in Norway are considered threatened due to encroachment caused by changes in land use.

350 vascular plant species in Norway are associated with semi-natural habitats (Kielland-Lund, 1992), and in 2006 174 of these where put on the Norwegian Red List for species (Kålås et al., 2006).). The Norwegian Red List for species states the probability each species has of being eradicated from Norway. The evaluations are based on methods developed by the International Union for Conservation of Nature (IUCN) that enjoys wide acceptance in both national and international science communities. First and foremost the Red List is an important tool in the conservation and management of biodiversity (Kålås et al., 2006).

Management actions to maintain vulnerable habitats and species are dependent on basic knowledge on the abundance and distribution of species. To effectively manage populations of plant species, knowledge of both the underlying anthropogenic and environmental factors responsible for species richness and structuring of these communities is needed (Hofgaard, 1997; Klimek et al., 2007).

Recently there has been a shift from monitoring single species to considering larger scale dynamics among conservationists (Jones, 2011). Non-random sampling, or placing of transects is commonly used when study species are rare or have limited distribution, to increase chances of detection (Jones, 2011).

Monitoring species presence-absence may not in itself be an appropriate tool to detect subtle changes in community composition. Rather, monitoring of demographic stages of target species may give a more accurate scenario on the future development of vulnerable species, e.g. if recruitment processes are maintained (Bühler & Schmid, 2001). Information about such subtle changes will be important feedback to the success of management regimes.

The intention of performing the present study was to (1) broaden the knowledge of what factors influence the distribution of red-listed vascular plant species connected to semi-natural cultural habitats in the sub-alpine and alpine region of a protected area (Budalen). (2) To examine the birch demography of the area. Budalen is a landscape conservation area (LCA) below the tree line, and a national park above. The area has a history of traditional land use (mountain summer farming) since the late-18th century, but haymaking was practiced from the 15-16th century (Solem et al., 2011). The vegetation in the area examined is mostly birch meadow forest dominated by graminoids and herbs with patchy occurrences of mire habitats (Solem et al., 2011). The red-listed species associated with this semi-natural habitat are mostly small to intermediate sized herbs, expected to have their main distribution in unfertilized open areas.

I hypothesize that (1) types and intensity of land use will be significant explanatory variables, explaining the distribution of the selected species in these semi-natural cultural habitats. Specifically I expect that the presence of red-listed species is negatively associated with birch recruitment. I also hypothesize (2) that birch will recruit heavily in semi-natural habitats (sub-alpine and alpine) that have been abandoned recently, and that young and small individuals will be more common than mature individuals. Additionally, the management implications of the results of this study will be discussed.

Methods:

Study area:

Data collection took place in Budalen (Midtre-Gauldal municipality, Sør-Trøndelag County)(Figure 1), more specifically at 10° 33 - 10° 41 E and 62° 42 - 62° 48 N. The bedrock in Budalen consists of granite and amphibolic quartz that is rich in lime, but partially covered by peat and quaternary deposits (Austrheim et al., 1999). The vegetation is a mosaic of wood-pastures with grass and herb rich fields, blanket bogs, fens and open grasslands. The climate is slightly oceanic and the mean annual precipitation is 760 mm. Mean annual temperature is 2.5°C and the growing season is 140-160 days long (Austrheim et al., 1999).

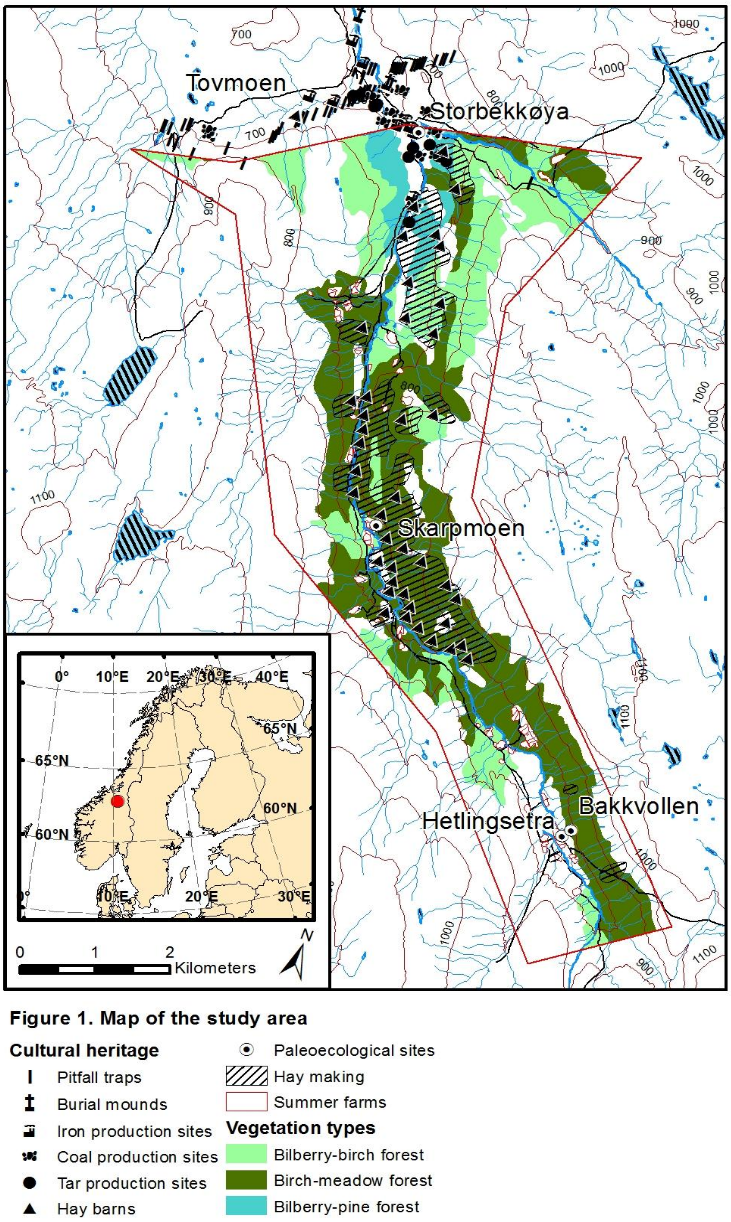

Figure 1: Map of the Budalen Landscape Conservation Area, with the most important types of land use and vegetation depicted. Study area in this study is the area south of Skarpmoen.

Land-use history:

Land-use history is well known for the study area due to previous studies in early 1990s (Espelund & Stenvik Olsson et al. 1995; Austrheim et al. 1999; Olsson et al. 2000) and during the years 2009-2011 (Solem et al. 2011). The first known land use began 2000 years BC, with iron extraction. This demanded wood for burning, and the wood was harvested from the nearby forest. The iron extraction took place in the Northern parts of the valley and was common until the 14th century. Mountain summer farming began in the late 18th century, but haymaking was practiced from the 15-16th century. Haymaking was most common in the northern and middle parts of the valley, with only patchy occurrences further south. The fields were harvested every second or third year, and were additionally sometimes grazed by livestock. Haymaking was common until the 1950s. Mountain summer farming was also most common in the northern and middle parts of the valley. Summer farming included grazing livestock for dairy and self-sustainability, harvesting of wood for timber and burning and finally working the fields (both on the permanent farm sites and in the outcrops in relation to haymaking). Grazing pressure has been relatively stable throughout the centuries, but has been increasing during the 20th century. The grazing density decreased in the mid-20th century, when former haymaking areas were made available for grazing. Also, the composition of grazing animals present has changed, from an abundance of cows, to an abundance of sheep (for more detailed information see Rekdal (2001)). Mountain summer farming was common until the mid-20th century, but there are still some active summer farms left in Budalen. The general trend regarding land use in Budalen is that intensity and continuity decreases with increasing distance from permanent settlements (for more detailed information on land use history in Budalen I refer to Solem et al., 2011).

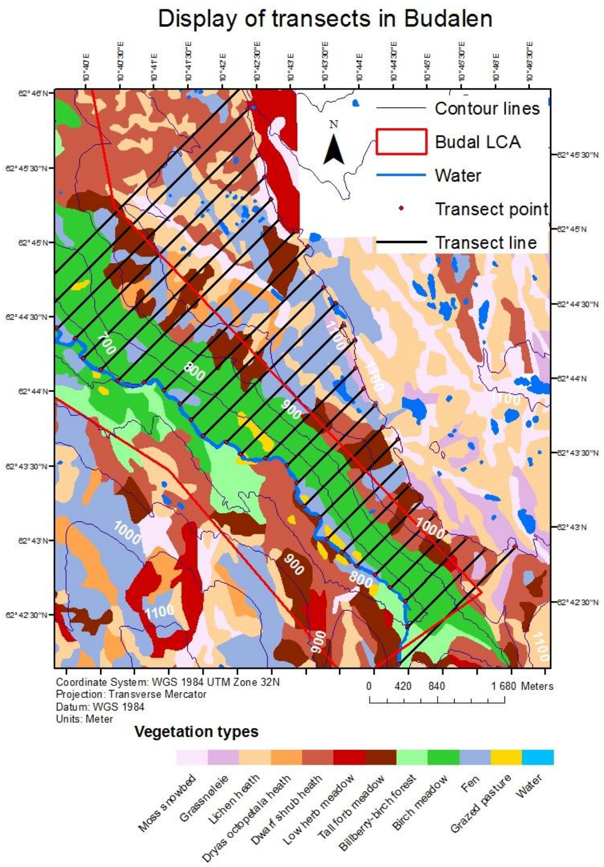

Figure 2: Display of transects in Budalen, made in ArcGIS. The river was the starting point of all transects. Vegetation types are also displayed.

Birch demography:

The transect lines for birch sampling were made in ArcGIS (Figure 2). All 27 lines were placed on the south-west facing slope of Budalen, from the river at about 600 m a. s. l and up to 1100 m a.s.l., each line 250m apart and each on a bearing of 45 degrees.

In the field a GPS was used to locate the start of any given transect. Upon locating the start-point, the GPS would be reprogrammed to show the endpoint of the same transect. The transect would then be walked, using the course function on the GPS to stay on as straight a line as possible.

Below the tree line the transect width was set to 0,5 m. A 0,5 m long stick was used as a helping tool, as it would be held out in front of the recorder as transects were walked. Every birch that was rooted within the length of the stick was recorded (Appendix 1). First a GPS waypoint would be taken. Secondly, the birch height (folding rule) and stem-base diameter measured (calliper), and finally the habitat would be noted. With birch higher than 2 m, their height was estimated to nearest meter. Above the tree line the transect width was extended to 4 m to increase the number of sampled trees. Additionally, every 20th birch encountered was cut at the stem base and stem disc sampled for later aging.

Birch aging:

The cut birches were prepared for aging through ring counting by making a cut as smooth and as level as possible through the stem base with a scalpel. The resulting surface was subsequently treated with zinc salve. The larger specimens were smoothed down with sand paper before zinc was applied. All the specimens were examined under a microscope (LEICA MZ 16 A), where age of the specimens was determined by counting the number of annual growth rings.

Distribution of red-listed species:

Red-listed species were recorded whenever they were observed from the transect (i.e. the transect was not width-limited). Additionally red-listed species were searched for when walking back down from the end of each transect, making sure to be nowhere nearer than 30m to the adjacent transects. The individual first discovered became the center of a circular plot, 2 m in radius(Appendix 2). This was done because we wanted a detection probability analysis, and an estimate of the total size of the population of each red-listed species we found in Budalen. This meant that we had to be careful to record the individual actually first seen from the transect. A 2m radius was set to narrow down the area to be thoroughly searched. Two nails connected by a 2 m long thin rope were used to set up the plot. The rope and outer nail was then subsequently moved around the circle as the plot was examined. A plot was first given a waypoint with the GPS. A specialized form was then filled out, were information about species, habitat, elevation, demography, land use and encroachment was filled in. The species` demography was divided into two stages; vegetative and flowering. Additionally, to get a better overview of the demography for the long-lived species the vegetative stage was divided into three classes; small (1-2 leaves with total leaf area < 2cm^2), medium (1-3 leaves with total leaf area 2-6 cm^2) and large (2-3 leaves with total leaf area > 6 cm^2)(Øien & Moen, 2002).

Gymnadenia conopsea (status: NT, red-listed in 2006) is a long-lived perennial species, characterized by a high fruit set and a low probability of flowering in subsequent years (Øien & Moen, 2002; Sletvold & Ågren, unpublished). There is a high cost of flowering, and an individual is not able to flower until at least three years old (Øien & Moen, 2002). Flowering occurs from the middle of July to the beginning of August. It is primarily found in more open areas and prefers wet ground (e.g. fens, wet grassland and herb-rich woodlands), and on base-rich soils (Øien & Moen, 2002).

Gentianella campestris (status: NT, red-listed in 2006) is a short-lived species (Milberg, 1994). It has a strictly biennial life cycle, forming a rosette the first summer, with subsequent flowering and death the following summer (Lennartsson & Oostermeijer, 2001). Flowering takes place either early in July (aestival type) or in August (autumnal type). A flowering plant reaches 5-20 cm in height, and produces 5-15 lilac flowers (Lennartsson & Oostermeijer, 2001; Huhta et al., 2000). The species is highly self-fertilizing, but can also be pollinated by bumblebees. *G. campestris* is mainly found in managed semi-natural grasslands, and usually survives poorly when management stops (Milberg, 1994; Lennartsson & Oostermeijer, 2001). Few natural habitats are known (Lennartsson & Oostermeijer, 2001).

Primula scandinavica (status: NT, red-listed in 2006 and 2010) is endemic to Scandinavia, and is primarily found in mountainous grasslands (Thompson et al, 2005; Artsdatabanken, 2006). The leaves form a rosette, and all the flowers sit on a single stem (Lid & Lid, 2005). The species is perennial and prefers open habitat on base-rich soil (Mazer & Hultgard, 1993). Flowers between June-July.

Botrychium (B. lunaria, B. boreale and *B. multifidum)* are perennial herb species. *B. lunaria* (status: NT, red-listed in 2006 and 2010) resides in alpine grasslands (Austrheim & Olsson, 1999), but all the *Botrychium* species generally are most diverse at high altitudes and elevations. They favour growing in disturbed meadows and woods, and reach 3-15 cm in height (Lid & Lid, 2005). *B. lunaria* is the most common of the three in Budalen. The other two have only been located on one site each. It flowers between June-August.

Dactylorhiza incarnata (status: NT, red-listed in 2006) generally produce 15 pink flowers on a single flower head. It flowers from June-July and its flowers open sequentially, during the course of three weeks. Bumblebees are the main pollinators (Mattila & Kuitunen, 2000), and it usually prefers moist soils such as fens or marshes (Dijk & Eck, 1995).
These species were all chosen because they have been found in Budalen before.

Data analysis:
GIS can be a very valuable tool when performing landscape change analyses, because it can integrate data on both the cultural and natural environmental drivers for change in an area. ArcGIS 10 (ESRI, 2012) was used to extract already mapped information to the points sampled in the field. This would be information such as areas of haymaking, woodcutting, elevation, vegetation and distance to a summer farm. The woodcutting and haymaking GIS layers were made based on information gathered from interviewing people familiar with the history of these types of land use in Budalen. The locations of summer farms were recorded by Olsson et al. (1995). The digital vegetation map is developed by Skog og Landskap, using photos and to some extent field surveys. Also, GIS was used to calculate the proportion of the birch sampled along the transects under a certain age (10, 20, 30 years) within an area of 25x25m, along the transects. Additionally, ArcGIS was used to display the data and the results of models in R and samples recorded in the field. The R models were displayed in ArcGIS by back-transforming the output model estimates and using the tool "Raster calculator" to enter the equation in. All variables were in raster (1/0) format at this point.

Distance sampling is another commonly used and accepted tool when it comes to estimating density of a species with imperfect detection (Thomas et al., 2010). Here, the program DISTANCE Version 6.0 (Distance Home Page, 2011) was used to estimate detection probability and population size of the red-listed species in the area. Models were set up and run according to Thomas et al. (2010).

The detection probability was used as an offset in the statistical analyses in R (version R 2.12.1 GUI 1.35 Leopard build 32-bit (5665)). Binomial-family generalized linear models (GLM) were used to find the minimum adequate models in regards to presence probability of red-listed species as a group (RLS), and also on the species level (*G. campestris* and *G. conopsea*). RLS, *G. conopsea* and *G. campestris* were used as the respective response variables.

The minimum adequate models were selected by first including all relevant variables in the model, then doing a stepwise selection based on AIC to remove variables from the model. Subsequently relevant interaction terms were added to the model, one by one, and likelihood ratio tests were used to compare models (Chi squared anova). R was also used to display or extract simple statistics and tables of the data.

Additionally, R was used to find a regression model to extrapolate the estimated birch age for every birch recorded from the age of the birch specimens sampled. The minimum adequate model was found with a GLM-analysis (poisson family) and by using birch age as the response variable, and altitude, birch height and birch diameter as explanatory variables.

Results

Red-listed species

A total of 117 populations of red-listed species were recorded in the field. Of the five species originally searched for, only two had sufficient observations to further analyse their distribution (Figure 3).

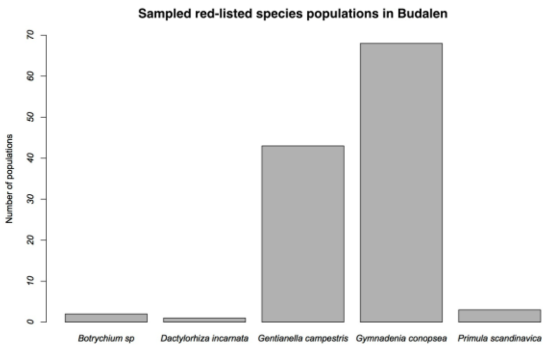

Figure 3: The number of sampled populations during fieldwork in Budalen. In total, 117 populations were recorded.

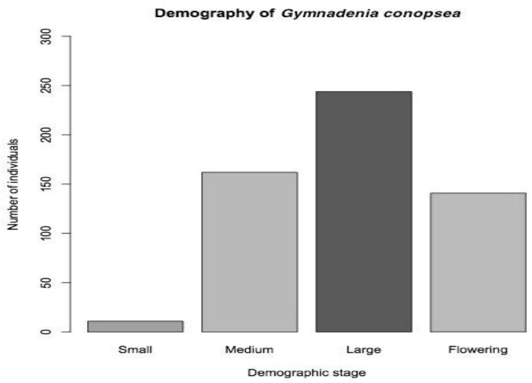

Figure 4: Number of individuals in each demographic stage for *G. conopsea*.

Demographic stages were recorded for both species, but were finally only used for *G. conopsea* (Figure 4), because in the end *G. campestris* proved too difficult to discover in the rosette stage.

Because of the fact that the red-listed species populations are considered hard to discover, on the basis that they are rare and that their visibility will vary in different habitats, the detection probability was calculated for both species (*G. campestris* and *G. conopsea*) (Table 1).

Table 1.Output from DISTANCE-analyses. Calculated on the basis of 20 populations of G. campestris and 32 populations of G. conopsea, for which we had obtained distance from transect data (this was only recorded going up the transects). Most observations were made by detecting a flowering individual.

Species	Detection probability (%)	Estimated range on detection (m)	Average number of individuals per population	Estimated density in study area (individuals/km^2)	Estimated total number of individuals
Gymnadenia conopsea	0.211 (SE: 0.022)	6.3	6,6	1073,5	15 157
Gentianella campestris	0.108 (SE: 0.022)	3.2	12,9	2506	35 384

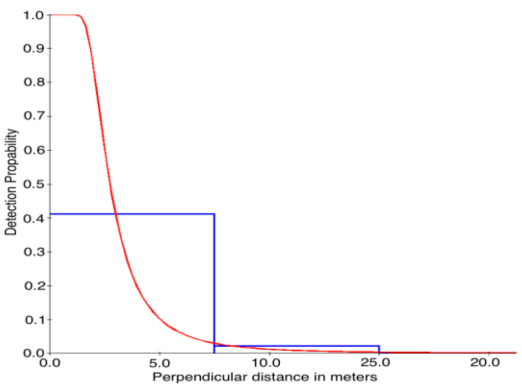

Figure 5: Detection probability of *G. campestris.*

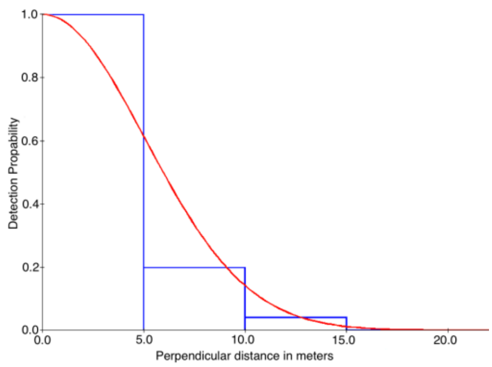

Figure 6: Detection probability of *G. conopsea*

The DISTANCE software calculated the detection probability to be 0,11 and 0,21 for *G. campestris* and *G. conopsea* respectively. This depicts the probability of finding the species, with increasing distance to the transect (Figure 5 and 6). Additionally, one can estimate the number of populations in the total area, based on the estimated density of populations there (Table 1). Here, *Gymnadenia conopsea* has an estimated 15 157 population in the total area examined (total area: 14,12 km^2), whilst *Gentianella campestris* has an estimated 35 384 populations. The detection probability graph for *G. campestris* falls very rapidly to zero (Figure 5). In fact, the model claims that if an individual is further away than 3 meters from the transect, it will most likely be missed by the observer. The same is the case for *G. conopsea* (Figure 6). The graph drops relatively quickly, but here, the distance to the transect is increased to 6 meters, before an individual is likely to be missed by the observer.

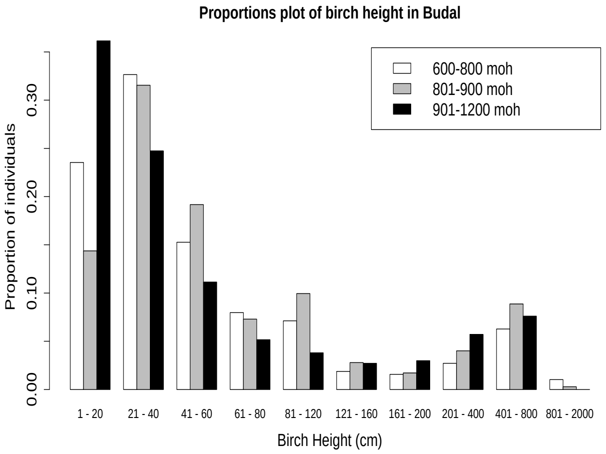

Figure 7: Proportions plot of birch height. The bars sum to 1 within the altitudinal intervals. These particular intervals were chosen because we expect 800-900m to be the most important altitude range, and 900 m.a.s.l. was a very natural break, because of the forest line.

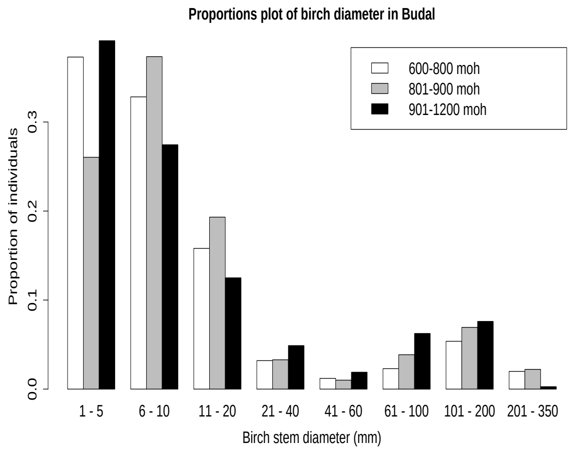

Figure 8: Proportions plot of birch diameter. The bars sum to 1 within the altitudinal intervals. These particular intervals were chosen because we expect 800-900m to be the most important altitude range, and 900 m.a.s.l. was a very natural break, because of the forest line.

Birch:

In total, 3482 birch were examined along the transects. Birches between 1-20 mm in diameter and 1-40 cm in height (Figure 7) were very common all along the altitudinal gradient, even above the present tree line (ca. 900 m a.s.l.). From Figure 8 it seems to be a lack of individuals with stem diameter between 20-60 mm, but then the number rises again for birch with stem diameter 60-200 mm. This is most likely an effect of the widths of the diameter and height intervals on the x-axis, but a decline in individuals is clear. Mature birches were outnumbered by recruiting birch, but have a more equal distribution across altitudinal intervals (except there are none of the very largest birch above 900m a.s.l.).

The 168 destructively harvested birches were used to make a regression between the assigned birch age on the harvested individuals and birch height, diameter and altitude. The birch-age regression model was later used to extrapolate ages to the remaining sampled birch (Figure 9). Figure 9 show that there has been a lot of recent recruitment at all altitudes, but especially at low altitudes. And again it seems there is a missing generation, of 20-50 year olds, before the number of individuals increases again for birch older than 50 years. The minimum adequate model included birch diameter and altitude as explanatory variables (Table 2). The estimated ages were which again used to model the proportion of the sampled population, younger than 20 years, along the transects (ArcGIS was used to place 25x25m rectangles on the transects, and the proportion of birch was calculated within these). This variable (Birch recruits) was used as a measure of encroachment, when modelling the red-listed species distribution in R (Tables 3, 4 and 5).

The model with red-listed species (Table 3) as response variable showed significant effects of all the variables included in the model. Specifically, intermediate altitudes, increasing distance to summer farms and former haymaking increased the chances of finding a red-listed species. The vegetation type factors also indicate that the species are significantly more likely to be found in the reference factor level; birch meadow. Increasing proportion of birch recruits was negative for the chances of finding a red-listed species. The interaction terms are explained further down.

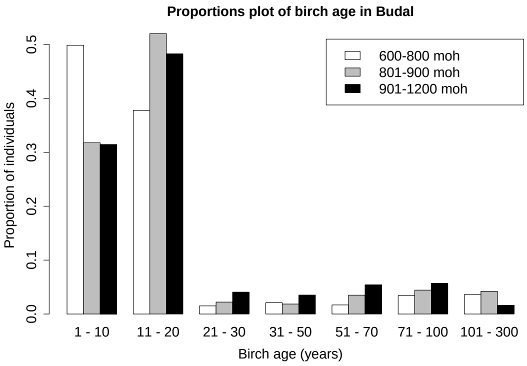

Figure 9: Proportions plot of birch age. The bars sum to 1 within the altitudinal intervals. These particular intervals were chosen because we expect 800-900m a.s.l. to be the most important altitude range, and 900 m.a.s.l. was a very natural break, because of the forest line.

Table 2: Minimum adequate birch-age regression model. With parameter estimates, standard error and p-value.

Call:	**Birch age ~Birch diameter + Altitude, family=poisson**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	1.099	3.329	0.74
Birch diameter	0.583	0.038	< 0.001 ***
Altitude	0.007	0.004	0.08 .
AIC	939.4		

Table 3: Minimum adequate model for the distribution of red-listed species, with birch recruits included as a variable. With parameter estimates, standard error and p-value. For the vegetation type factor, birch meadow is used as reference factor level.

Call:	**Red-listed species~Altitude+Altitude²+Distance to summer farm+Haymaking+Vegetation type+Altitude*Distance to summer farm+Distance to summer farm*Birch recruits, family=binomial**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	-7.866e+01	1.552e+01	< 0.001 ***
Altitude	1.631e-01	3.722e-02	< 0.001 ***
Altitude²	-8.377e-05	2.240e-05	< 0.001 ***
Distance to nearest summer farm	1.171e-02	5.209e-03	0.03 *
Haymaking	1.444e+00	2.756e-01	< 0.001 ***
Vegetation type: (vs. Birch meadow)			
Grazed pasture	-5.675e-01	1.053e+00	0.59
Bilberry-birch forest	-1.399e+01	7.095e+02	0.98
Fen	-1.046e+00	3.108e-01	< 0.001 ***
Heath	-1.962e+00	5.325e-01	< 0.001 ***
Dwarf shrub heath	-1.005e+00	3.826e-01	0.008 **
Snowbed	-1.446e+00	1.038e+00	0.16
Birch recruits	-2.328e+00	7.069e-01	< 0.001 ***
Altitude:Distance to summer farm	-1.531e-05	5.940e-06	0.001 **
Birch recruits:Distance to summer farms	2.151e-03	1.008e-03	0.03 *
AIC	691.56		

Intermediate altitudes, former haymaking areas and birch meadow also had significant positive effects on the distribution of *G. conopsea* (Table 4). Increasing birch recruits had a negative effect. For *G. campestris* (Table 5), intermediate altitudes had a positive effect, whilst increasing distance to summer farms and increasing proportions of birch recruits had a negative effect. All three models showed a significant effect of birch recruits, and when comparing these models (pairwise based on response variable) to the models without the birch recruit variable (models made for ArcGIS extrapolation of the predicted distribution), we find that they are all significantly different, and the models including birch recruits were the best models.

Table 4: Minimum adequate model for the distribution of *G. conopsea*, with birch recruits included as a variable. With parameter estimates, standard error and p-value. For the vegetation type factor, birch meadow is used as reference factor level.

Call:	***G. conopsea*~Altitude+Altitude²+Haymaking+Vegetation type+Birch recruits, family=binomial**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	-1.395e+02	2.129e+01	< 0.001 ***
Altitude	3.135e-01	4.833e-02	< 0.001 ***
Altitude²	-1.785e-04	2.738e-05	< 0.001 ***
Haymaking	1.835e+00	3.111e-01	< 0.001 ***
Vegetation type: (vs. Birch meadow)			
Grazed pasture	-1.617e+01	2.280e+03	0.99
Bilberry-birch forest	-1.570e+01	1.842e+03	0.99
Fen	-1.138e+00	4.180e-01	0.006 **
Heath	-1.353e+00	5.448e-01	0.01 *
Dwarf shrub heath	-5.175e-01	4.669e-01	0.27
Snowbed	-1.537e+01	9.067e+02	0.99
Birch recruits	-8.515e-01	3.391e-01	0.01 *
AIC	457.5		

Table 5: Minimum adequate model for the distribution of *G. campestris*, with birch recruits included as a variable. With parameter estimates, standard error and p-value. For the vegetation type factor, birch meadow is used as reference factor level.

Call:	***G. campestris*~Altitude+Altitude²+Distance to nearest summer farm+Vegetation type+Birch recruits, family=binomial**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	-7.911e+01	2.041e+01	< 0.001 ***
Altitude	1.697e-01	4.602e-02	< 0.001 ***
Altitude²	-9.142e-05	2.593e-05	< 0.001 ***
Distance to nearest summer farm	-2.691e-03	6.940e-04	< 0.001 ***
Vegetation type: (vs. Birch meadow)			
Grazed pasture	-2.317e-01	1.063e+00	0.827
Bilberry-birch forest	-1.602e+01	3.322e+03	0.996
Fen	-8.916e-01	4.994e-01	0.0741 .
Heath	-1.641e+01	7.940e+02	0.984
Dwarf shrub heath	-1.081e+00	6.234e-01	0.083 .
Snowbed	-1.620e+01	1.536e+03	0.992
Birch recruits	-9.379e-01	4.414e-01	0.0336 *
AIC	354.72		

The detection probabilities estimated for the species were further used as offset variables in the models used to map the distribution of species in ArcGIS. This was done in three turns, first for all the red-listed species as one unified group (Table 6), then for each of the two abundant red-listed species separately (Table 7 and 8).

Table 6 has all red-listed species sampled as response variable. Altitude has a significant effect on the distribution, and from the parameter estimates it is clear that the probability of finding a red-listed species is higher in an elevation belt, not too low, but not too high above sea level. Distance to summer farm was also a significant explanatory variable. The closer to a summer farm the lower the probability of finding a red-listed species. Finally, areas with previous haymaking activity had higher probability of containing a red-listed species.

This model (Table 3) was the only one with enough statistical power to include interaction terms. Altitude and distance to summer farm were both significant factors, and an altitude:distance to summer farm interaction received significant support in this study. The interaction had a significantly negative effect on the distribution, meaning that the higher you get in altitude and the further away you come from a summer farm, the lower the probability of finding a red-listed species. The other interaction examined was distance to summer farm and vegetation type. This interaction was significant, but only at one level; Distance:(Snowbed vs. birch meadow). At this level, the interaction was significantly positive, indicating that being far from a summer farm in addition to being in the vegetation type snowbed, increases the probability of finding a red-listed species, compared to vegetation type birch meadow.

Table 6: Minimum adequate model of RLS distribution in Budalen. With parameter estimates, standard error and p-value. For the vegetation type factor, birch meadow is used as reference factor level.

Call:	**Red-listed species ~Altitude+ Altitude^2+Distance to nearest summerfarm+Haymaking+Vegetation type+Distance to nearest summer farm*Altitude+ Distance to nearest summer farm*Vegetation type, family = binomial**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	-7.133e+01	1.547e+01	< 0,001 ***
Altitude	1.386e-01	3.689e-02	< 0.001 ***
Altitude^2	-6.605e-05	2.221e-05	0.003 **
Distance to nearest summer farm	1.955e-02	5.599e-03	< 0.001 ***
Haymaking	1.384e+00	2.734e-01	< 0.001 ***
Vegetation type: (vs. Birch meadow)			
Grazed pasture	1.163e+00	1.473e+00	0.43
Bilberry- birch forest	-2.156e+01	7.287e+03	0.99
Fen	-7.420e-01	9.441e-01	0.43
Heath	-1.999e+00	1.638e+00	0.22
Dwarf shrub heath	-1.163e+00	1.175e+00	0.32
Snowbed	-1.305e+01	4.210e+00	0.002 **
Altitude:Distance to nearest summer farm	-2.388e-05	6.518e-06	< 0.001 **
Distance to nearest summer farm:Vegetation type (vs. Birch meadow)			
Grazed pasture	-1.044e-02	2.304e-02	0.65
Bilberry-birch forest	6.082e-03	5.257e+00	0.99
Fen	-3.681e-04	1.346e-03	0.78
Heath	1.337e-04	2.302e-03	0.95
Dwarf shrub heath	3.045e-04	1.476e-03	0.84
Snowbed	9.632e-03	2.546e-03	< 0.001 ***
AIC	704.92		

G. conopsea is the response variable in the model in table 7. Again we see that altitude is a significant explanatory variable, but again it suggest an elevation belt not too low and not too high above sea level. Previous haymaking is also significant with the probability of finding *G. conopsea* increasing in these areas.

Table 7: Minimum adequate model of distribution of *G. conopsea* in Budalen. With parameter estimates, standard deviation and p-value. For the vegetation type factor, birch meadow is used as reference factor level.

Call:	***G. conopsea*~ Altitude+ Altitude²+ Haymaking+ Vegetation type, family=binomial, offset=offsetBRSP**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	-1.365e+02	2.115e+01	< 0,001 ***
Altitude	3.044e-01	4.795e-02	< 0,001 ***
Altitude²	-1.726e-04	2.712e-05	< 0,001 ***
Haymaking	1.804e+00	3.069e-01	< 0,001 ***
Vegetation type: (vs. Birch meadow)			
Grazed pasture	-1.627e+01	2.275e+03	0.99
Bilberry-birch forest	-1.562e+01	1.879e+03	0.99
Fen	-1.121e+00	4.147e-01	0.007 **
Heath	-1.449e+00	5.426e-01	0.007 **
Dwarf shrub heath	-5.734e-01	4.627e-01	0.22
Snowbed	-1.555e+01	9.031e+02	0.99
AIC	462.32		

In table 8, *G. campestris* is the response variable of the model. Also here the species is more likely to be found in an elevation belt. Distance to nearest summer farm is also a significant explanatory variable, with the probability of finding the species decreasing with increasing distance to a summer farm.

Table 8: Minimum adequate model of the distribution of *G. campestris* in Budalen. With parameter estimates, standard deviation and p-values. For the vegetation type factor, birch meadow is used as reference factor level.

Call:	***G. campestris* ~Altitude+ I(Altitude^2)+ Distance to nearest summerfarm+ Vegetation type, family=binomial, offset=offsetBAKS**		
Variables	**Estimates**	**SE**	**P-value**
Intercept	-7.695e+01	2.018e+01	< 0.001 ***
Altitude	1.627e-01	4.541e-02	< 0.001 ***
Altitude²	-8.682e-05	2.555e-05	< 0.001 ***
Distance to nearest summer farm	-2.641e-03	6.986e-04	< 0.001 ***
Vegetation type: (vs. Birch meadow)			
Grazed pasture	-2.642e-01	1.056e+00	0.80
Bilberry-birch forest	-1.606e+01	3.350e+03	0.99
Fen	-8.689e-01	4.975e-01	0.08 .
Heath	-1.644e+01	8.003e+02	0.98
Dwarf shrub heath	-1.055e+00	6.216e-01	0.09 .
Snowbed	-1.631e+01	1.539e+03	0.99
AIC	357.77		

Finally, these models were used to create three maps in ArcGIS, which represent the probability of finding at least one individual of a red-listed species, or one individual of *G. campestris* or *G. conopsea* respectively in the area of Budalen (Figures 10, 11 and 12). The predicted distribution of all the red-listed species as a group is shown in figure 10. The probability of finding an individual is clearly higher at intermediate altitudes, and in areas of former haymaking. Also, the distance to the summer farms is clearly important, and again, intermediate distances seem to give higher probability of finding a red-listed species.

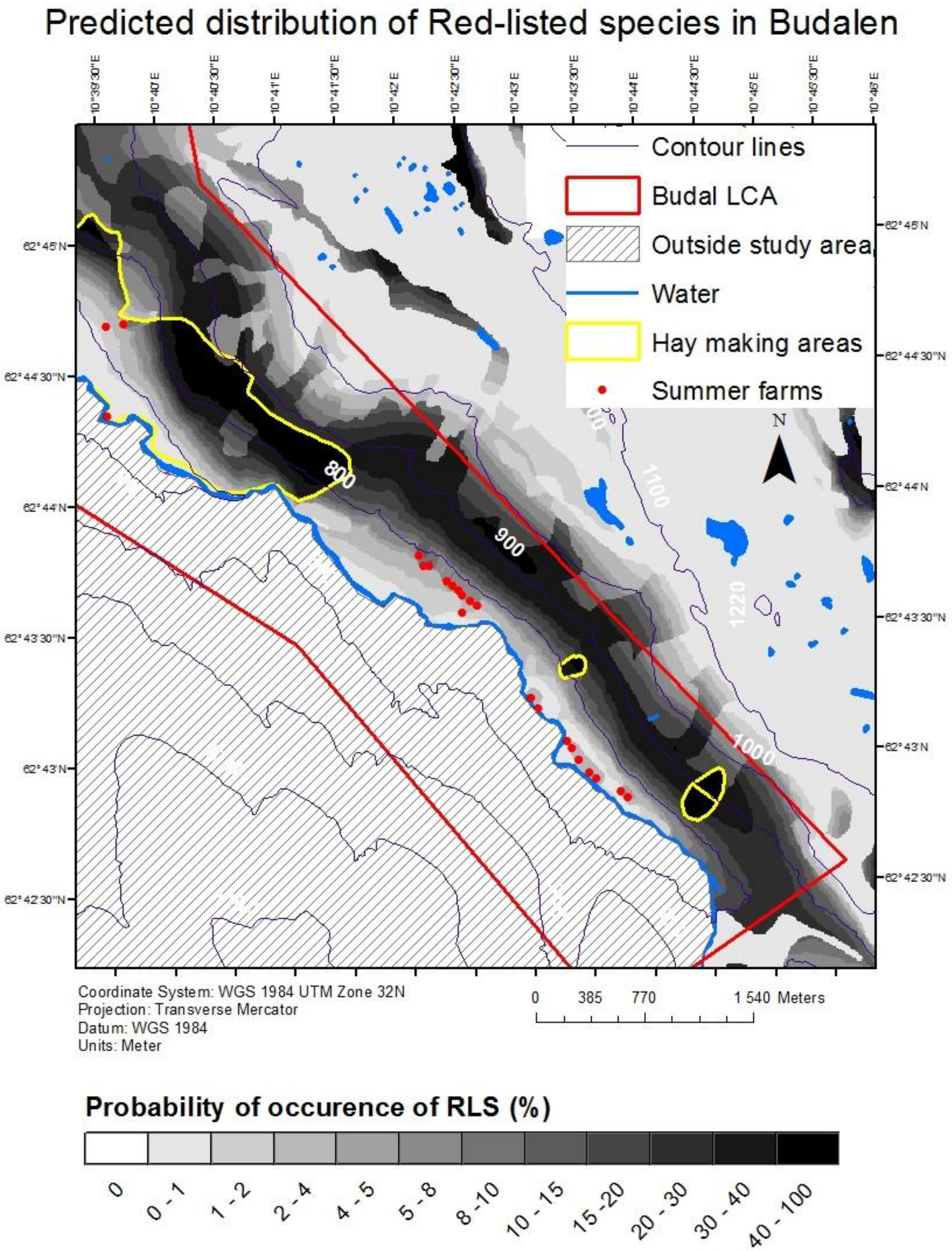

Figure 10: The predicted distribution of red-listed species across Budalen. The hatched area to the left is outside the range of this study. This map most importantly displays summer farms (red dots), former haymaking areas (yellow outlined polygons), the river all the transects started from, and the predicted distribution of the species. The darker the colour, the more likely of it being an individual of a red-listed species present there. Also displayed is the Budalen LCA border and contour lines.

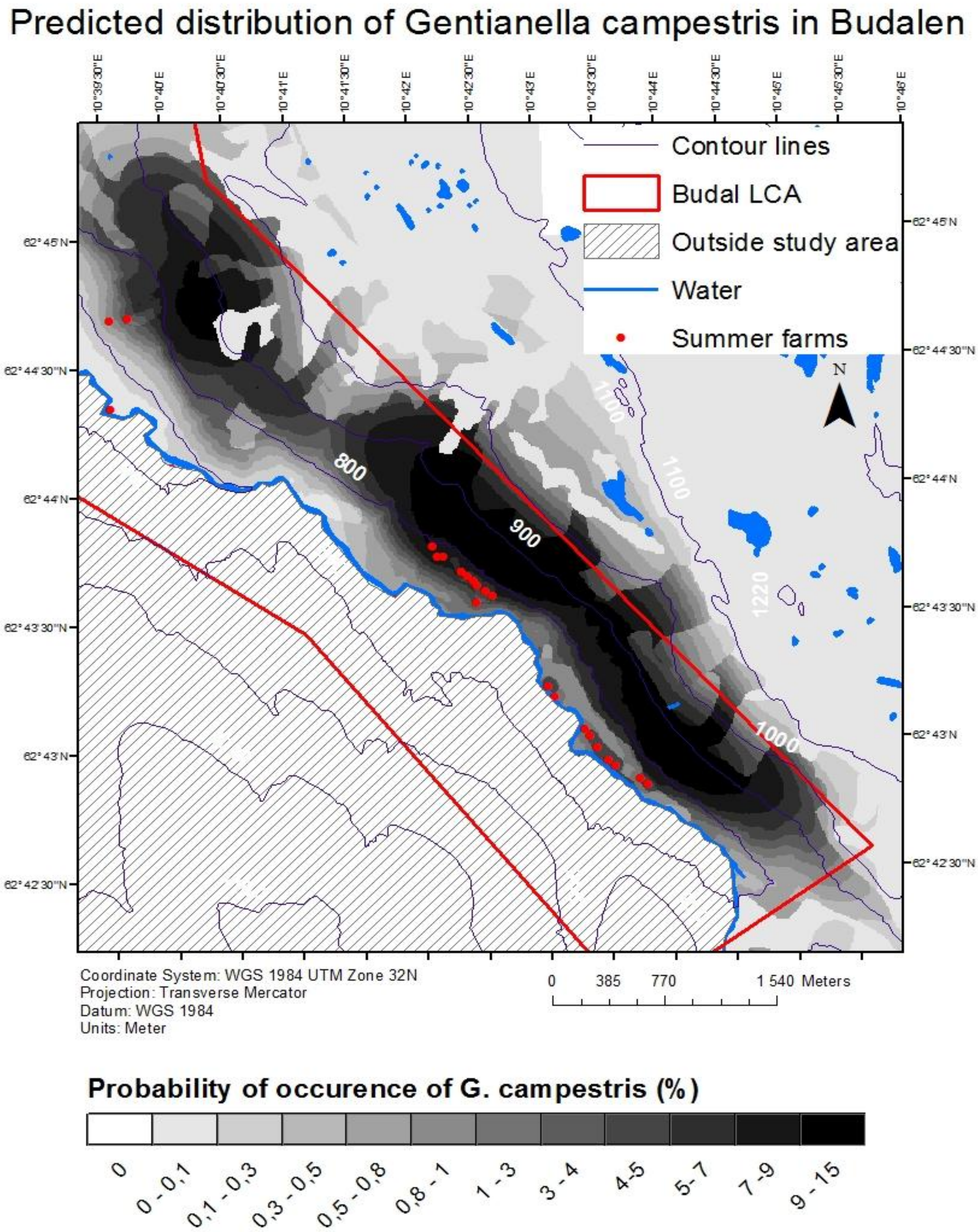

Figure 11: The predicted distribution of *G. campestris* across Budalen. The hatched area to the left is outside the range of this study. Also displayed are the summer farms (red dots), the river and the probability of occurrence of *G. campestris*. Again, the darker the colour the higher the probability of occurrence is.

The predicted distribution of *G. campestris* seems to be located between 800-1000 m.a.s.l. (Figure 11). Also, the distance to summer farms were a significant factor here, and the summer farms have therefore been displayed in the map. It seems the areas above the summer farms (in altitudinal terms), are more likely to contain an individual of the species *G. campestris.*

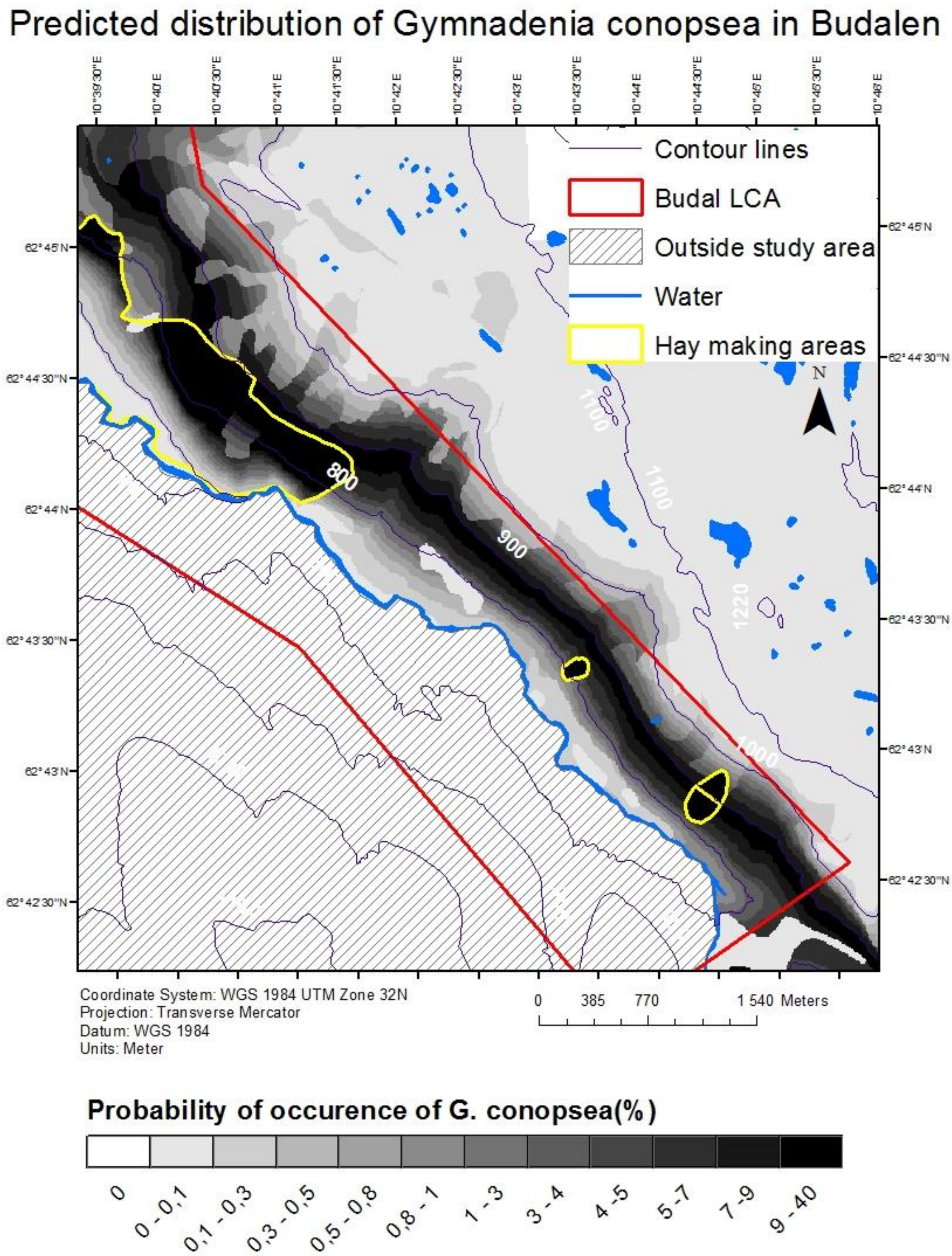

Figure 12: The predicted distribution of *G. conopsea* across Budalen. The hatched area to the left is outside the range of this study. Also displayed are the former haymaking areas (yellow outlined polygones), the river and the probability of occurrence of *G. conopsea*. Again, the darker the colour the higher the probability of occurrence is.

Concerning *G. conopsea*, the predicted distribution seems to be between 800-900 m.a.s.l. This is a narrower altitudinal distribution than *G. campestris*. Distance to nearest summer farm was not important for this species, so these features have not been included in the map. Hay making areas did come out with a significant impact in the minimum adequate models, and are hence displayed in the map (Figure 12).

Discussion

The main focus of this study was to identify the factors influencing the distribution of some red-listed vascular plant species in semi-natural habitats. In alpine landscapes little is known about the distributions and habitat requirements of Norwegian red-listed species, especially species connected to semi-natural habitats, and the need to attain this type of knowledge is pressing as land use change and climate change are two of the major impact factors on alpine species today (Austrheim et al., 2010). In this study, land use variables such as haymaking and distance to summer farms, in addition to altitude and proportion of birch recruits present, were some of the variables explaining the species distributions.

Populations of red-listed species:

An important result is that the red-listed species populations that were discovered contained a relatively high number of individuals. The mean cluster size for *G. conopsea* was 6,6 individuals, and for *G. campestris* it was 12,9 individuals. The estimated total number of individuals within the surveyed wooded meadow in Budalen was 15 157, and 35 384 for *G. conopsea* and *G. campestris* respectively. All the red-listed species examined here were in the category NT (Near threatened) on the Norwegian red-list for species in 2006 (Kålås et al., 2006). According to the guidelines of the International Union for Conservation of Nature (IUCN), a species should be placed in this category if it at present or in the near future is likely to fulfil the criteria needed to be classified in one of the other categories on the red-list (Critical, Endangered, Vulnerable)(Kålås et al., 2006). To be placed in the vulnerable (VU) category, a species population must have had a 50-70% population reduction (observed, estimated, inferred or suspected) during the past 10 years (Kålås et al., 2006). The fact that *G. conopsea* and *G. campestris* were both removed (along with *Dactylorhiza incarnata*) from the 2010 version of the Norwegian red-list for species (Kålås et al., 2010), should suggest that no such reduction has been suspected for these species. The data on estimated total number of individuals (for *G. conopsea* and *G. campestris*) in Budalen supports the decision of removing both these species from the red-list, but not *Dactylorhiza incarnata* (only one population was found). However, the state of the *D. incarnata* population may be better on a national basis, than what was reflected in Budalen.

Unfortunately, lack of data on *G. campestris* in its vegetative stage (small rosette) made it impossible to construct a demographic analysis of this species. The demographic analysis of *G. conopsea* (Figure 4) shows that most of the individuals were in the medium, large or flowering stage. A closer look at the demography of a species can give a better impression of what affects a species vitality rates (i.e. death, growth and recruitment)(Brys et al., 2004). The low number of individuals in the "small"-class could indicate a problem with recruitment in the *G. conopsea* population. Alternatively, the individuals in this class could have been missed, due to them being small and difficult to spot, or it could be a problem with the size classes. Individuals might be growing quickly from small to medium. If so, then this classification would say less about the amount of recruits in the population. Also, as stated by Olsson et al. (2000), short-lived species (such as *G. campestris*) will be expected to experience larger variances in number of individuals in the population. Because the fieldwork was done in a period when all the species were flowering, the detection data can be considered very reliable. However, the total number of individuals in the *G. campestris* population might only reflect a good year for the population. Additionally, onset of deflowering of *G. conopsea* during the final days of the fieldwork might have led to some individuals being missed.

Distribution of red-listed species:
In this study it was found that land use factors such as distance to nearest summer farm and haymaking in addition to altitude which is a natural factor, were significant explanatory variables, influencing the distribution of the red-listed species. This would indicate that human influence on the landscape to a large extent affects the distribution of these red-listed species in semi-natural cultural landscapes. The identification of anthropogenic factors as the major drivers of the distribution of red-listed species found in this study is supported by similar results in a range of other studies (Tassel & Tappeiner, 2002; Vittoz et al., 2008; Hofgaard, 1997; Polce et al., 2011). In the three distribution models made in this study, altitude had a significant effect in all of them. Specifically, the probability of finding a red-listed species peaked at intermediate altitudes in all the models. This suggests that there is a certain altitudinal belt where these red-listed species are more likely to occur. Other natural factors (not examined here) likely to influence the distribution of red-listed species are temperature (it is commonly believed that a rise in global temperature will cause the vegetation in the mountains to move upwards, e.g. Klanderud & Birks, 2003), moisture, snow cover (Hofgaard, 1997) and soil nutrient levels (Austrheim et al., 2010; Nagy et al., 2003). However, previous examinations of Budalen have shown that the southwest-facing slope is a relatively homogenous area, which might minimize the effect of abiotic factors on distribution, relative to the effect of land use (Solem et al., 2011).

Grazing by ungulates has, however proven to limit this type of upwards movement of vegetation, and most especially birch (Speed et al., 2010; Speed et al., 2012). The reasons for the lower probability of occurrence at the very lowest altitudes are probably more complicated, but are also most likely closely linked to human disturbance, grazing, or other biotic and abiotic factors, such as less favourable climate and probably dryer conditions on the fluvial sediments. There was also a significant effect of the interaction between altitude and distance to summer farms (Red-listed species model). A species can be found to thrive at a certain altitude, but still be dependent on a certain disturbance regime to persist there. Distance to summer farm can represent such a disturbance regime.

The models with red-listed species and *G. campestris* as response variables had distance to nearest summer farm as a significant factor explaining their distribution. The distance had a negative effect for *G. campestris* and a positive effect on red-listed species. Because the *G. campestris* model is a model with a single species as response variable, it is likely to be more precise than the model with red-listed species as the response variable, which after all is a cluster of all the sampled red-listed species populations in Budalen. Modelling assumes the variable red-listed species is a uniform group with equal requirements, which generally is not the case, as we can see from the model with *G. conopsea* as response variable, where distance to nearest summer farm was not a significant explanatory variable. However, such modelling can provide a general and cost-saving insight into the habitat requirements of the area´s red-listed species, which again can inform managers.

Former haymaking (ended in the late 1950s) was found to have a positive effect on the presence of red-listed species as a group and *G. conopsea* specifically, meaning that the models indicate a higher probability of finding the species (when modelled as a group) and *G. conopsea* in such areas. This is a very important result because haymaking is most definitely a human induced effect on the landscape. The fact that former haymaking areas can explain the distribution of *G. conopsea* could suggest that a low level of disturbance is positive for this species. Additionally, light availability is higher in haymaking areas, an environmental factor considered to be positive for short to intermediate sized herbs, like the once investigated here (Liira & Sepp, 2009). Haymaking may also reduce competitive effects for herbs, as indicated by the increase of *Thalictrum alpinum* and *Selaginella sellaginosum* in Budalen in the 15-16th century (onset of haymaking)(Solem et al., 2011). However, it is important to remember that populations of this species were also found outside former haymaking areas, leaving room for other factors to be influencing the distribution of this species.

All the models benefitted from adding vegetation type as an explanatory variable, but it was hardly significant in any of them. It can be argued that the resolution of the vegetation type variable is too low in the map, compared to reality, and that with a finer resolution the variable would most likely have had a greater influence in the model. To map vegetation precisely would be costly, because any landscape is generally consisting of a mosaic of different types of vegetation. The remaining variables in the models are more accurate (e.g. altitude) in regards to their location, probably because they are easier to map (a summer farm, haymaking, wood cutting) since they are uniform, but these again (except summer farms) are based on oral references from farmers in Budalen (Solem et al., 2011).

Birch encroachment

The forest line boundary marks the shift from sub-alpine forested habitats, to open alpine habitats. The abrupt change from forest to open areas also marks a distinct difference in species composition and environmental variables (Nagy et al., 2003). The tree line boundary is influenced by factors such as past and present climate and natural and human disturbance regimes (Hofgaard et al., 1997). Land use abandonment of semi-natural grasslands often leads to encroachment of birch, and a transition from open to forest habitat (Hofgaard, 1997; Eriksson et al., 2002). This indicates that birch encroachment can be considered a threat to red-listed species in semi-natural habitats (Pykälä et al., 2005). The main factors driving birch encroachment are changes (abandonment) in land use and seed dispersal (Gehrig-Fasel et al., 2007; Tasser et al., 2007). A warmer climate is expected to act together with abandonment, to speed up these successional processes (treeline advance) (Speed et al., 2010)

In this study, birch recruits were the most common stage of birch all along the altitudinal gradient investigated (even above the present tree line). This suggests that birch recruits are filling former openings, indicating that encroachment is currently taking place in Budalen LCA as well as treeline advance. Both the height and diameter distribution showed a decrease in numbers with increasing height and stem diameter, which could indicate that many recruits survive, but only up to a certain size (ca. 21 mm birch diameter and 61 cm birch height). This drop is likely explained by onset of stronger competition from other birch (light and other resources), or other challenges a faced by a taller birch (grazing, mechanical stress etc.). The cutting of single trees (in contrast to more large scale clear cutting) has been the harvesting strategy in this area until the 1970s according to the local management board (Statskog, G. Wagnild pers. info.). This would secure the availability of fuel-wood and also most likely prevent massive recruitment of birch.

In this study, it was also found that the proportion of birch recruits (birch < 20 years) in the local population had a significant negative effect on the presence of red-listed species in all three models. This indicates that the on-going birch recruitment in Budalen LCA is negatively affecting the distribution of red-listed species. As mentioned before, grazing has been shown to limit spread of birch both into the alpine zone, and in open sub-alpine habitats (Speed et al., 2010; Tasser et al., 2007; Gehrig-Fasel et al., 2007). Because maintenance of semi-natural areas is very important to halt forest succession (Austrheim et al., 1999), grazing has even been suggested as a tool for managers (Marriott et al., 2009), and might be a cheaper and more economical alternative to manually mowing abandoned areas. The challenge would be to find the right intensity of grazing, with a peak diversity of species as a main goal, knowing that there exists an ecological threshold in vegetation responses to grazing (Sasaki et al., 2008; Mysterud, 2006), and that some alpine areas are considered overgrazed (Austrheim & Eriksson, 2001).

Management implications:

Conservationists and managers of protected areas such as Budalen have a responsibility to ensure sustainable use and protection of natural resources. Since adoption of the law of biodiversity this has become ever more important (Lovdata, 2012). Managers also have a responsibility to protect red-listed species and habitats, in addition to a responsibility as information gatherers, e.g. conducting regular surveys to build a good basis for suggesting management regimes (Midtre Gauldal kommune, 2012). This task will be easier if the distributions of these species are known, and if the main factors affecting their distribution are known. This very study can contribute with knowledge about such distributions, specifically in Budalen, but it can also help clarify what variables might be important in affecting the distribution of red-listed species elsewhere. As suggested by Jones (2011), landscape-scale monitoring and data collection can be very useful when informing policy and management. Knowledge of where a species is likely to occur is important when making area plans. In Norway, for instance, many people want to build cabins directly below the tree line. This study indicates that this is the altitudinal band *G. conopsea* and *G. campestris* is most likely to be found in. Also to be noted is that haymaking areas were a significant factor explaining the distributions. This could indicate that regular, intermediate disturbance over time, is better for the red-listed species than cutting down large areas of forest at one time is. Another risk factor to consider with this type of woodcutting is the birch recruits. Clearly they are many, and do thrive in Budalen, so cutting down mature forest to create open areas for red-listed species, may prove to only create a spawning ground for birch recruits. Especially since colonization of many herbs species in alpine areas is considered a slow and irregular process (Austrheim & Eriksson, 2001), whilst birch recruitment is not (Speed et al., 2010). Observations of recently cleared areas made during fieldwork in Budalen supports this claim.

Land use and humans have from a historical perspective had less impact on the area of Budalen examined in this study, compared to the northern parts of the valley. Pollen analyses suggest that the area was covered with birch meadow forest, with patches of herbs and graminoids in the field layer even before humans began really exploiting the outfields of Budalen. Further analyses of image-material depict a decline in the proportion of forest, from the onset of summer farming (15-1600s), to the mid-1900s. There has also been an increase in birch density the last decades (Solem et al., 2011). Results and historical facts like these, may suggest that many of the species associated with semi-natural habitats are able to survive in a mature birch meadow forest, but human induced land use and grazing will increase the abundance of these species.

Conclusion:

For the investigated sub-alpine and alpine semi-natural landscape, one can conclude that (1) the types of land use examined here are influencing the distribution of the studied species. Specifically, former haymaking areas were most important for explaining the distribution of *Gymnadenia conopsea* (haymaking had a positive effect), whilst shorter distance to nearest summer farm significantly increased the probability of presence of *Gentianella campestris*. In the combined model (red-listed species) both these types of land use were significant, but then the distance to nearest summer farm had a positive effect on the species distribution, meaning that the probability of occurrence increased with increasing distance to nearest summer farm. Haymaking areas still had a positive effect. All models had a significant effect of altitude, and probability of occurrence was highest at intermediate altitudes. Importance of vegetation type varied from model to model, but including the variable always improved the models. It is difficult to say something specifically about the importance of different intensities of land use, because this was hard to quantify. The haymaking areas have not been used for haymaking since the 1950s, and are only disturbed by grazing herbivores. This can be considered as extensive land use intensity. Summer farms have most likely had more intense use in close proximity, and less and less intense further away. Concluding from these assumptions would mean that *G. conopsea* is more likely to occur in extensively used areas, whilst *G. campestris* can thrive with a bit more intense disturbance regime. Presence of birch recruits also had a significantly negative effect on distribution in all models. Additionally, I conclude that (2) birch was recruiting heavily, in all areas and altitudes of Budalen, suggesting on-going encroachment and reforestation of the valley. The results of this study can specifically be used as a reference on expected species distributions of red-listed species when designing management plans for the area. Also, the negative effect of birch recruits, and the amount of birch recruiting across Budalen would indicate a need to manage the birch population, if a rich alpine flora is to be maintained.

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Appendix 1. Sheet used to record birch

Birch Recording Sheet — Sheet number:

Date:

Transect Number: — Recorders:

GPS WP	Habitat	Transect width	Birch Height	Stem Diameter	Notes
#		m	cm	mm	

Appendix 2. Sheet used to record populations of red-listed species.

Attachment 3.

Fieldwork Budalen 2011. Recording of red listed vascular plants.

Species: **Meters off course:**

Recorder: **Date:**

Coordinate (UTM_{WGS84}V32): **Hoh:**

Nature type:____

Demography:

Brudespore **Vegetative: [ ]small count:______ [ ]Flowering count:______**

[ ]medium count:

[ ]large count:______

Bakkesøte/Fjellbakkeblom **[ ] Rosette count:______ [ ]Flowering count:______**

Landuse: [ ] Not in use [ ] Extensive [ ]Traditional [ ] Moderate intensive
[ ] Intensive [ ] Very intensive

Type of land use: [ ] Plowing [ ] Grazing [ ] Hay making [ ] Fertilizing [ ] Spraying with pesticides [ ] Burning [ ] Manual clearing [ ] Wood cutting

Encroachment: [ ] In use [ ] Abandonment phase [ ] Early re-growth succession [ ] Late re-growth succession

Woody plant cover:____
(0-50, 50-100, 100-150…)

Additional information: