Hooves on the heath, scales on the sand

The effects of heathland management and grazing on reptile populations of the Doldersummerveld

Thesis Research Report

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A report completed as part of the requirements of the B.Sc. Animal Management (Major: Wildlife Management) thesis project, for the University of Applied Sciences Van Hall Larenstein, in collaboration with Stichting Het Drentse Landschap.

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Preface

This report is the result of my thesis research project for my Major in Wildlife Management within the Bachelor program of Animal Management at the University of Applied Sciences Van Hall Larenstein, Leeuwarden, the Netherlands. This graduation research took place between April and October 2014.

Many thanks go out to my supervisors Jelmer van Belle and Marcel Rekers, whose support, insight and expertise proved invaluable from the start of this project right to the very end.

Also, I would like to thank Edo van Uchelen for his share of thoughts in coming up with this subject, his expertise and the fantastic work he has done over the years regarding reptiles and amphibians in the Netherlands

I would like to extend my deep appreciation and thanks to Bertil Zoer of Stichting Het Drentse Landschap for giving me the necessary field permits but also for the huge amount of information he sent me regarding the Doldersummerveld which made this project possible.

Last but definitely not least, I would like to thank Henry Kuipers, who was always willing to share his incredible expertise in statistics and did not mind doing so even during his lunch breaks or long after working hours.

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Summary

Heathland, with its frail character, has always been one of the most essential habitats for almost all indigenous reptile species in the Netherlands. Situated in the Drents-Friese Wold National Park, the Doldersummerveld ranks as one of the best developed heathland areas of Western Europe and counts as one of the most bio diverse areas within the province of Drenthe. Managed by the non-profit foundation, Stichting Het Drentse Landschap, the area has seen a variety of management measures including some fairly recent practices such as sod cutting, mowing and grazing by large herbivores (i.e. Highland cattle and Schoonebeeker sheep). Heathland, being a successional stage on its own, would evolve into woodland when left unmanaged. The management measures applied to the Doldersummerveld are primarily conducted in order to avoid encroachment by purple moor grass (*Molinia caerulea*). However, combined with common heather (*Calluna vulgaris*), this vegetation is essential to most reptile species that inhabit these heathlands while the management measures that are applied here could also have detrimental effects on reptile populations when applied too intensively or on an extensive scale. The combination of said management measures might also be contradictory to the envisioned goal as a highly nitrogenous (N) and phosphorized (P) soil due to a high volume of faecal matter by grazers (particularly on sod cut areas) could favour the regrowth of purple moor grass over common heather. In order to test the effects of sod cutting, mowing and grazing on reptile populations, the 12 largest and most recently sod cut and mowed areas were selected as plots throughout the area (6 of each) for monitoring the Grass snake (*Natrix natrix*), European adder (*Vipera berus*) and Viviparous lizard (*Zootoca vivipara*) using line transects while each managed area was appointed a, vegetation wise, control plot. In order to assess the grazing intensity and vegetation composition of the plots, (random) quadrants were set out where a variation of the Braun-Blanquet method was performed combined with a faecal count. Between the 17th of June and the 21st of August 2014, 177 individuals of the target reptile species were found while sampling the various transects (7 grass snakes, 37 European adders and 133 viviparous lizards). The results from the Generalized Linear Mixed Models analysis (GLMM) indicated a significant difference between the cores of both sod cut and mowed plots compared to their respective control plots (by a factor of 0,115 in the case of sod cutting and 0,165 in the case of mowing), suggesting a decimation of the present reptile population in said areas where sod cutting or mowing was applied. Grazing did not show to have significant effects on reptile populations or heather vegetation (i.e. *Calluna vulgaris* and *Erica tetralix*), although this could just be due to the chosen method or the eventual low sample size and lack of variety among the faecal density scale. Sod cutting should only be applied when one wants to establish a new area that contains both *Calluna* and *Erica* vegetation, and only on a small enough scale and a large enough timeframe on (homogenous) nutrient rich heathland. When only *Calluna* is desired, fencing a nutrient rich area to avoid grazing should be sufficient. Nutrient poor heathland needs neither mowing or sod cutting when grazing is applied moderately in order to avoid succession. Placing fences around sod cut and mowed areas for the first few years after said management measure is conducted, to retain grazing animals from entering these areas, is recommended.

Table of contents

1. Introduction

1.1 Reptiles & Heathland

The Netherlands are home to three species of snakes and four species of lizards, which make up the entire indigenous reptilian fauna of this small country (RAVON, [no date]). Heathland, with its tenuous character, is essential for the smooth snake (*Coronella austriaca)*, sand lizard (*Lacerta agilis)*, European adder (*Vipera berus)* and viviparous lizard (*Zootoca vivipara)* (Table 1), while the slow worm (*Anguis fragilis)* and grass snake (*Natrix natrix)* are also frequently observed here (Stumpel & van der Werf, 2011). This biotope, in general, provides them with enough shelter to avoid predation and allow for adequate places to bask in the sun. (RAVON, [no date]) The vegetation structure of (moist) heathland allows for a more stable temperature pattern with less rapid fluctuations in temperature compared to the open ground (Delany, 1953). The micro-climate within the vegetation can also maintain a high humidity when the outside air gets less humid (Delany, 1953), which benefits the reptiles that crawl within these heath bushes. (van Uchelen, 2006)

Habitat type / Species	Forest	Scrub	Heath land	Bog and wet heath	Coastal sand dune	Old sea wall	Marsh and ditch	Old stone wall
Anguis fragilis	■ ■ ■	■ ■ ■	■ ■	■				
Vipera berus	■ ■	■ ■	■ ■ ■	■ ■ ■				
Coronella austriaca	■	■ ■	■ ■ ■	■ ■				
Zootoca vivipara	■	■ ■	■ ■ ■	■ ■ ■	■	■		
Lacerta agilis	■	■ ■	■ ■ ■		■ ■ ■			
Natrix natrix	■	■	■ ■	■ ■		■ ■	■ ■ ■	
Podarcis muralis								■ ■ ■

Table 1. Main habitat types of reptiles in the Netherlands. The number of squares indicates the importance of this type of habitat for the specific reptile species. (Stumpel, 2004, p.111)

With five out of six heathland-based indigenous reptile species having been assessed as near-threatened (*Zootoca vivipara*) to endangered (*Coronella austriaca*) red-list species (*Lacerta agilis*, *Natrix natrix* and *Vipera berus* are listed as vulnerable) on a national scale (van Delft et al., 2007), it is vital to maintain a sufficient amount of heathland areas and to implement a proper management scheme to avoid encroachment by *Molinia* and *Deschampsia* vegetation while also preventing succession by *Calluna* and *Erica* vegetation as monotonous areas with heath vegetation of equal age tend to be avoided by reptiles (van Uchelen, 2006).

1.2 The Doldersummerveld

As shown in Table 1, reptiles in the Netherlands and heterogeneous heathland are evermore interconnected with each other. One prime example of such heathland is the Doldersummerveld which is part of one of the largest national parks in the Netherlands: the Drents-Friese Wold. Connected to the Wapserveld, this extensive (wet) heathland area ranks as one of the best developed heathland areas in Western Europe (NP-Drents Friese Wold, [no date]). With an extensive alternation between dry and wet heath, the Doldersummerveld is known as one of the most bio diverse areas within the province of Drenthe (Stichting Het Drentse Landschap(1), 2012). This stems from the fact that the field knows no less than 111 species of breeding birds, of which 20 are classified as endangered to critically endangered (Stichting Het Drentse Landschap(1), 2012).

The area provides a sanctuary to many extremely rare species of plants such as *Gentiana pneumonanthe* (accompanied by the even rarer *Phengaris alcon* butterfly (De Vlinderstichting, 2010)), *Pedicularis sylvatica* and *Dactylorhiza maculate* (Stichting Het Drentse Landschap (1), 2012).

At least four species of reptiles are frequently observed within the Doldersummerveld (*Anguis fragilis*, *Natrix natrix*, *Vipera berus* and *Zootoca vivipara*) (RAVON, 2012). Sporadic encounters of *Coronella austriaca* are also reported every now and then, while some rumours circulate that *Lacerta agilis* is also making a march towards the area, this however remains just a rumour thus far.

The Doldersummerveld is being managed by Stichting Het Drentse Landschap, a non-profit foundation devoted to the conservation and development of nature and the preservation of cultural heritage within the Dutch province of Drenthe. Approximately 8.400ha of land is being managed by the organization, including the Doldersummerveld (Fig. 1) (Stichting Het Drentse Landschap(2), 2012).

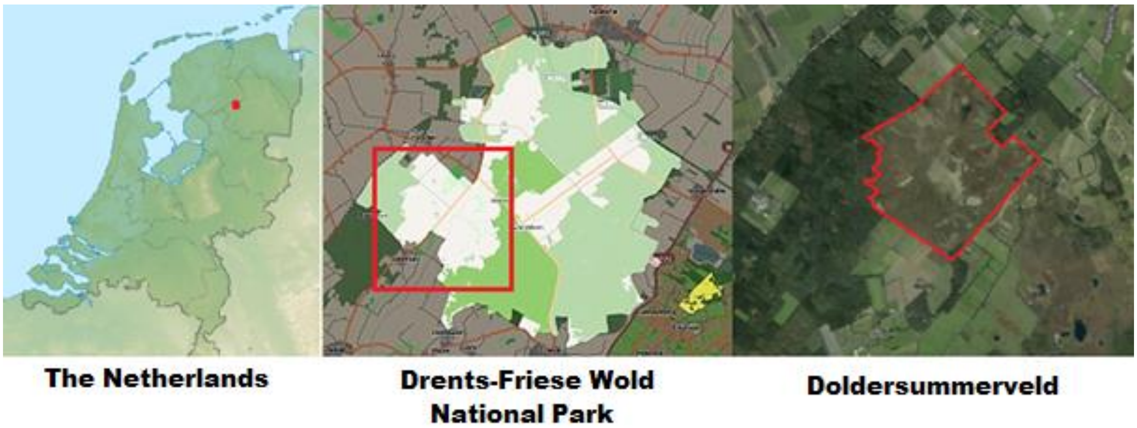

Fig. 1 The location of the Drents-Friese Wold National Park.

In order to avoid encroachment of *Molinia* vegetation and to keep the field relatively open and heterogeneous, Stichting Het Drentse Landschap has been making use of (mainly Highland-) cattle and Schoonebeeker sheep ever since a fire burned down the entire field in 1980 (the sheep had already been grazing the field for a few years before the fire). The Doldersummerveld is now home to a flock of 360 Schoonebeeker sheep, which graze the area for about 50% of the year. Half of their time on the Doldersummerveld is spent as a flock, while the other half is spent roaming individually or in small groups. They are housed at the adjoining Huenderhoeve, where a shepherd guides them to a designated area in the morning to graze and also guides them back around dusk.

A herd of 35 Highland cattle also roams the Doldersummerveld, of which around 5-10 individuals graze the area the whole year-round. During cold winters however, these are placed on neighbouring pastures when food is scarce. Together with the flock of Schoonebeeker sheep, they can graze 229ha on the Doldersummerveld. In 2011, a part of the Wapserveld (49ha) was added to their potential grazing area, possibly reducing grazing pressure on the Doldersummerveld. Between 1982 and 2001, a guideline was applied of a maximum of 1 sheep per 2ha (van Dijk & Heinemeijer, 2013). Nowadays however, this former guideline is widely exceeded.

Grazing is also applied to other heathland areas that are being managed by Stichting Het Drentse Landschap. The Dwingelderveld (3700ha) for instance, is home to over 250 Drenthe heath sheep (Schaapskudde Ruinen, 2014), and other grazers such as Simmentaler and blonde d'Aquitaine cattle. Together with Limousin cattle, Stichting Het Drentse Landschap uses a wide variety of grazers to manage their 8400ha of land. (Stichting Het Drentse Landschap(3), 2012)

Some areas of the Doldersummerveld have also been sod cut or mowed in order to stimulate the growth of more *Calluna* and *Erica* vegetation, but also to promote the growth of rarer plants such as *Narthecium ossifragum*, *Rhynchospora alba* and *Drosera intermedia*. Figure 2 shows the vegetation shift that the Doldersummerveld has witnessed in between 1982 to 2012. A more detailed history of the management history of the Doldersummerveld is found in Appendix II.

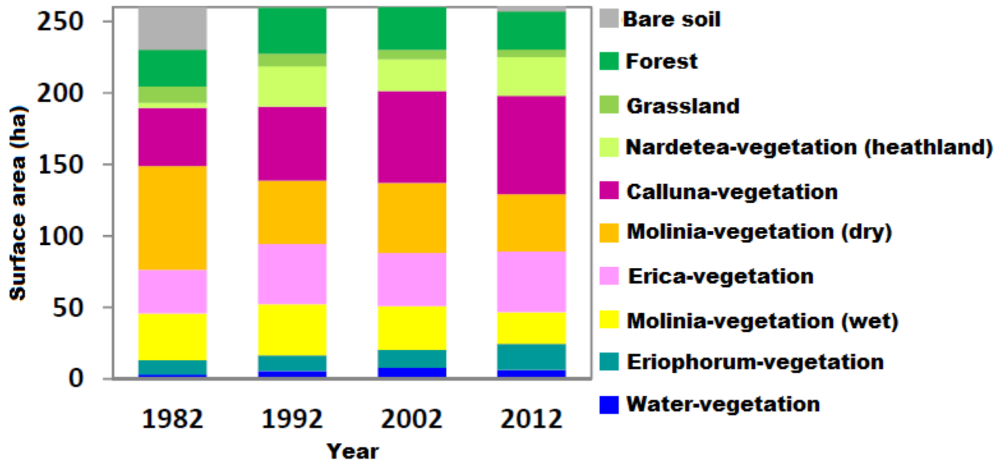

Fig. 2 Vegetation composition of the Doldersummerveld in four years. (van Dijk & Heinemeijer 2013, p. 63)

The graph shows a decline in *Molinia* vegetation (particularly dry *Molinia*), which has made way for heathland vegetation such as *Calluna*- and, to a lesser extent, *Erica* vegetation. A more detailed display of this vegetation shift, and the relative management measures that were applied to achieve this vegetation shift are shown in appendix I and appendix II.

1.3 Problem description

The Doldersummerveld is an important area with regard to the Dutch reptilian fauna. This is even more accentuated by the given that the province of Drenthe is designated as (very) important to the country's *Coronella austriaca*, *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* populations. These species are furthermore listed as (fairly/very) common in the province of Drenthe, except for *Coronella austriaca* which is listed as rare (van Uchelen, 2010). The wide range of (at times rather intensive) management measures that take place on the Doldersummerveld are however not primarily directed towards the conservation of these reptile populations, but more towards averting the encroachment of *Molinia* vegetation as was described in the previous subchapter.

Due to their lifestyle, many reptile species are very sensitive to large scaled and intensive management measures (van Uchelen, 2006). This makes it important to take the requirements of a suitable reptile-habitat into consideration when planning management measures, and to monitor the status of these reptile populations when these management measures have been carried out (Edgar et al., 2010).

Not every reptile species in the Netherlands reproduces each year (Nilson, 1980; Luiselli, 1997), which makes it difficult for said species to recover from a sudden substantial decline in population size (van Uchelen, 2010). Even though heathland is essential to the prolonged survival of these reptile species in the Netherlands, this heathland however, has to meet certain standards in order to accommodate these species. One key example of this is a mosaic of different types of microhabitats that contain a combination of *Calluna*- and *Molinia* vegetation (Stumpel & van der Werf, 2011) and are rich in structure, which alternate one another and where eventually the open sand gives way to forest as each reptile species is more or less tied to a certain intermediate stage in the succession (generally the later stages of succession) of open to closed vegetation types (Offer et al., 2003; van Dijk and Heinemeijer, 2013).

Previous studies (Blanke & Podloucky, 2009; Lenders, 2011, cited in Stumpel & van der Werf, 2011) have already suggested that (intensive) grazing has a negative effect on reptiles in general. Grazing mostly influences the mosaic pattern of the landscape, but not sufficiently the vertical structure of the vegetation (Newton et al., 2009) on which most reptiles depend (Stumpel, 2004). Particularly *Vipera berus* tends to avoid grazed areas (Strijbosch, 2002; Stumpel, 2004; van Uchelen, 2006, cited in Stumpel & van der Werf, 2011). However, without grazing, most heathland would eventually succumb to the succession of woodland (Strijbosch, 2002).

This is due to heathland being a successional stage on its own, namely between pioneer vegetation and forest (Webb, 2008). Heathland in its turn knows four successional stages which are marked by the shape and size of the vegetation, particularly the *Calluna* vegetation (Fig. 3), which has a lifecycle of around 40 years under natural conditions without management or grazing (Webb, 2008; Watt, 1955).

Fig. 3 Diagrammatic profile sketch of the four successional stages of *Calluna* vegetation.
(L-R: Pioneer, Building, Mature, Degenerate (Webb, 2008)) (Watt, 1955)

When management measures are constantly being applied to an area of heathland, stands of heather with different ages may develop and succession into woodland is prevented, which in turn is favourable for reptiles (Webb, 2008; Offer et al., 2003). In the past, this resetting of succession was done by large herbivores that grazed the heathland which, inadvertently, secured the prolonged survival of its reptilian inhabitants (Offer et al., 2003). These reptiles survived through the dynamic dispersal of meta-populations which colonized new heathlands that developed over time (Offer et al., 2003).

This form of grazing is beneficial to reptiles for most heathland habitats (possibly with the exception of degenerate dry heath). These benefits however, can only be realized after the grazers are withdrawn from the area, or otherwise reduced in numbers (Offer et al., 2003).

Stichting Het Drentse Landschap combines the grazing by Schoonebeeker sheep and cattle with other management measures such as small scale sod cutting and mowing (van Dijk and Heinemeijer, 2013). These localized practices are generally short-termed but the intensity of the disturbance is far greater compared to an extensive grazing regime, which usually covers a much larger area and timeframe and exerts a more steady pressure on the direction of succession which also brings about a different result (Offer et al., 2003).

As was described earlier in subchapter 1.2, the mowing and sod cutting of parts of the Doldersummerveld is mainly set out in order to stimulate the growth of *Calluna* and *Erica* vegetation and to increase the heterogeneity of the field while also contributing to the reduction of encroachment by *Molinia* vegetation (van Dijk & Heinemeijer, 2013). This combination of management measures however, could have a contradicting effect one another.

When areas of *Molinia* vegetation are mowed or sod cut, it is possible for *Calluna* and *Erica* vegetation to colonize the newly created vacant area. However, when this form of management is combined with grazing, and the intensity of this grazing is high, the nitrogen- and phosphorus-concentration in the top layer of the soil could rise due to the large deposits of feces by the grazing herbivores (Franzluebbers & Stuedemann, 2009). A possible change in the chemical composition of the soil could cause *Molinia* vegetation to settle faster compared to *Calluna* vegetation due to its root structure being higher up in the soil (Friedrich et al., 2011). Once the *Molinia* vegetation has reached a certain point in its development, the competing *Calluna* vegetation is no longer able to interfere with the *Molinia* (Friedrich et al., 2011), which ultimately makes the whole management effort (and the disturbances that come with it) futile.

1.4 Goals

The goal of this research is gain insight in the effects of management measures such as mowing, sod cutting and grazing by Schoonebeeker sheep (Fig. 4) and Highland cattle (Fig. 5) on the populations of *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* populations within the Doldersummerveld.

The aim is to ultimately provide recommendations for effective heathland management which incorporates the conservation of heathland-dwelling reptile species.

**Fig. 4 The flock of Schoonebeeker sheep of the Doldersummerveld.
Photo by: Jonno Stelder**

**Fig. 5 The herd of Highland cattle of the Doldersummerveld.
Photo by: Jonno Stelder**

1.5 Research questions

In order to achieve the goal formulated in the previous subchapter, the following research questions need to be answered:

Main research question:

- What are the effects of management measures and grazing of the Doldersummerveld heathland on the present *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* populations?

Sub-questions:

- What are the population numbers of *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* on heathland that have been exposed to management measures (sod cutting or mowing), and what are the population numbers on heathland that has not been subjected to such management measures?

- What is the relation between management measures/grazing and vegetation composition?

- What is the relation between *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* population numbers and grazing on heathland?

- What is the relation between *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* population numbers and grazing by the different species of grazers that inhabit the Doldersummerveld?

2. Methods & materials

2.1 Research design

In order to uncover the effects of management measures and grazing of heath on reptile populations, areas within the Doldersummerveld that have been exposed to sod cutting or mowing have been compared to areas of the same vegetation composition, but who were not exposed to such management measures while also taking the grazing intensity of said areas into account.

2.1.1 Plots

Stichting Het Drentse Landschap has provided a report on the Doldersummerveld that contains a detailed management history of the past decades. This report by van Dijk & Heinemeijer (2013), contains maps of each management measure the Doldersummerveld has witnessed from ~1980's to the present day, including detailed maps of the vegetation throughout the entire area and the shift it has witnessed these past decades. From the maps that contained the sod cutting and mowing history of the field, the six largest (~0.5-2.1ha), and most recently (2008-2011) sod cut or mowed areas from both maps were selected. In these areas, the effects of these management measures were still most noticeable. These maps were placed over satellite images of the area in Google Earth Pro using the Image Overlay option. Combined with the provided map that included the vegetation composition of the field, another corresponding area that encompassed a comparable vegetation type was manually drawn for each of the chosen sod cut or mowed areas. These corresponding areas were also of the same approximate sizes (and shapes) as their related areas. In order to avoid possible differences in density due to natural barriers, all tandem areas were in close proximity of each other. Figure 6 shows a map of the Doldersummerveld with all of the 24 selected plots and their corresponding plot codes.

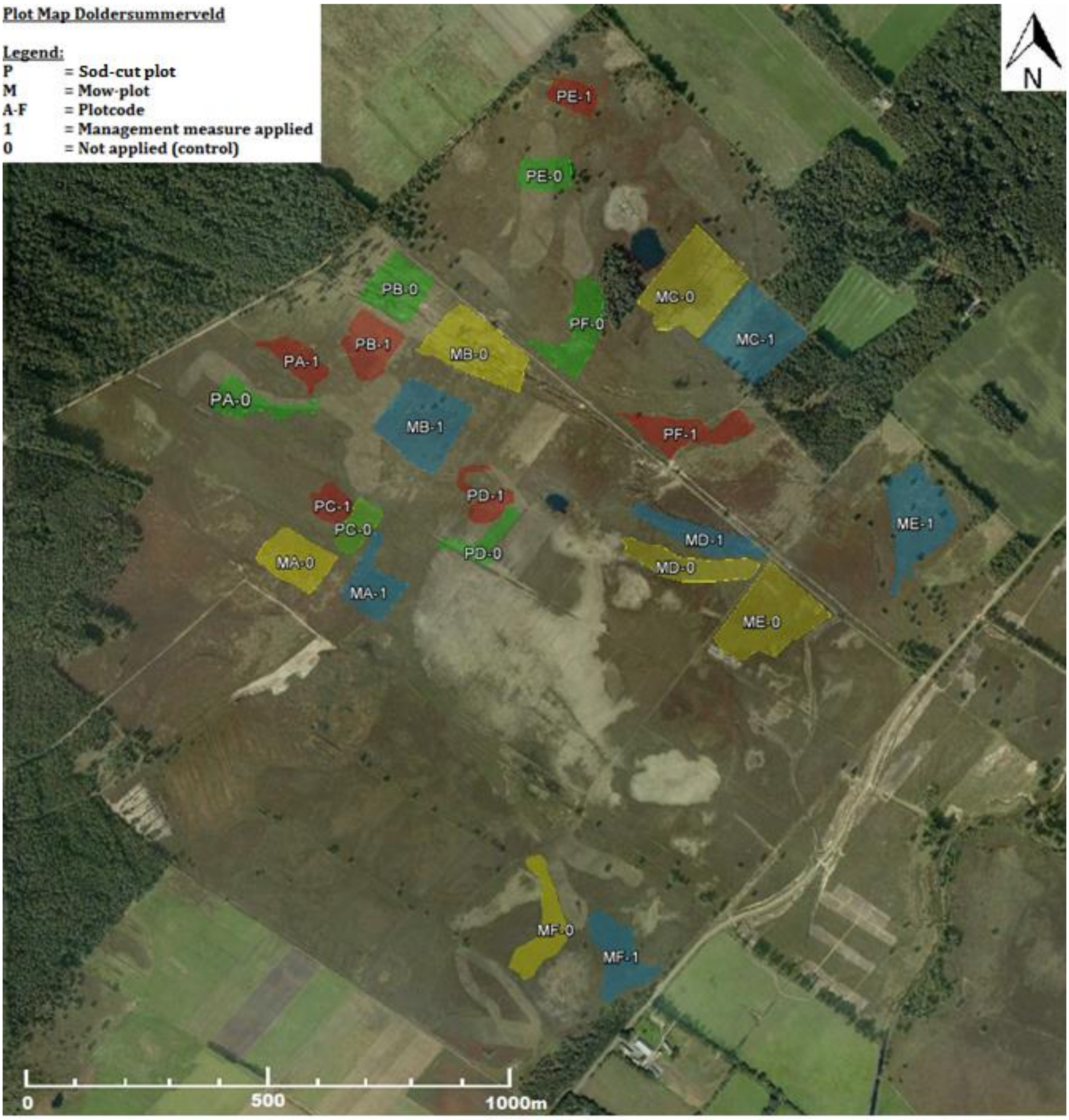

Fig. 6 Map of the Doldersummerveld showing all of the 24 selected plots and their corresponding plot codes.

2.1.2 Transects

In order to estimate the relative population numbers of *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* within these 24 selected plots, without letting the size of the plot influence the results, line transects were set out throughout each plot. This way the actual surveyed area of each plot is the same and the relative search-effort put into each plot can be aligned.

Each transect covered a length of approximately 1000m (Fig. 7), of which a 1:2 ratio between the border of a plot of a plot and the core of a plot was attained (i.e. ~333m at the border and ~666m within the core of the plot), due to the given that most reptiles prefer the combination of different types of vegetation, such as *Calluna* and *Molinia* (Stumpel & van der Werf, 2011) This combination or transition between different types of vegetation is most likely to be found at the border of said plots (primarily the plots that have been subjected to a form of management).

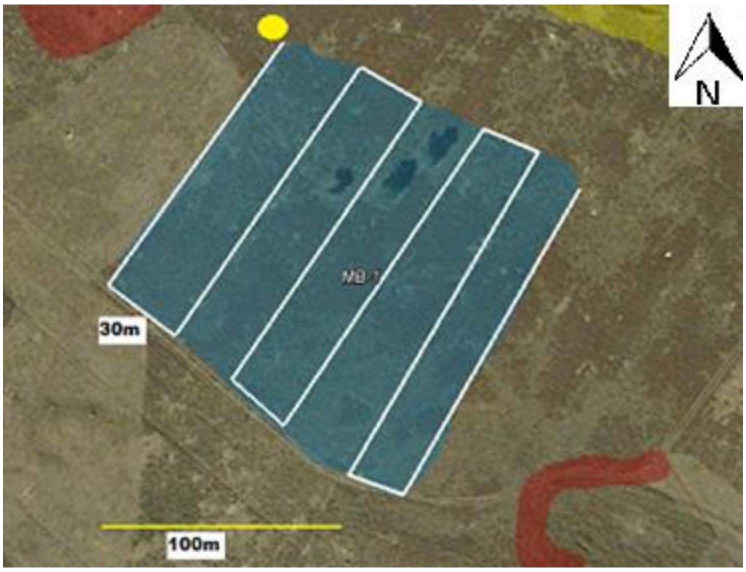

Fig. 7 Example of a transect, in this case plot MB-1 with the white line representing the 1000m transect.

2.1.3 Vegetation & grazing intensity

In order to assess the relation between management measures, grazing and vegetation composition, and the effect these factors have on the population numbers of *Natrix natrix*, *Vipera berus* and *Zootoca vivipara* populations, quadrants were set out within the selected areas throughout the Doldersummerveld.

Using Google Earth Pro combined with an image overlay of a grid, eight quadrants of 5x5m were randomly selected for each of the 24 plots. The first four quadrants were set out on each cardinal direction along the border of a plot (i.e. border-quadrants). The remaining four were set out by labeling each grid square with a number after which a random number generator was used in order to randomly select these core-quadrants (Fig. 8).

Each quadrant was surveyed once during the data collection period, where the composition of the vegetation (i.e. coverage and height-profile) was written down and the grazing intensity was measured in the form of a faecal count.

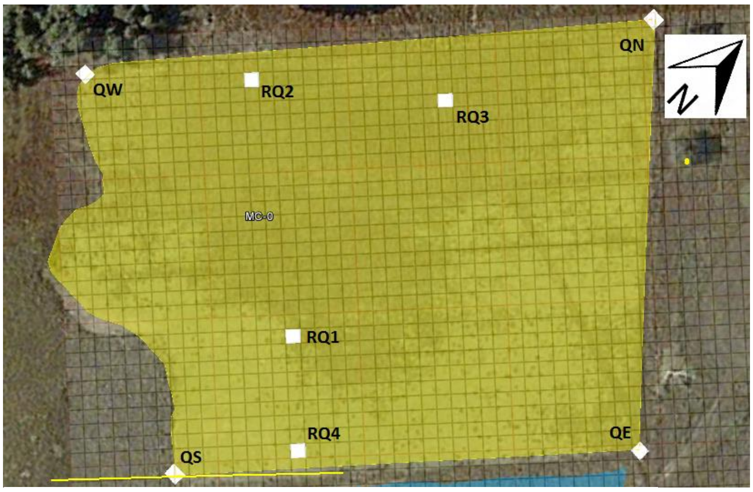

Fig. 8 Plot MC-0 with its quadrants.

2.2 Data collection

2.2.1 Transects & timetable

The data collection period was carried out from the 17th of June 2014 to the 21st of August 2014. Due to the given that many reptile species exhibit a bimodal activity pattern during the summer months, where their locomotive activity is lowered during the hottest hours of the day in order to avoid overheating (Foà and Bertolucci 2001) and thus becoming less likely to detect (especially in the case of cryptic species), a method to avoid this dip in activity was established.

All the plot- and transect-details were put into a GPS (Garmin GPSMAP 64) to allow for the exact allocation of all the transect lines. Each transect was surveyed at a pace of ~1kph, where a strip-width of ~2.5m was attained to both sides of the transect line (so each transect lasted ~1 hour). In general, the transect line was closely followed, however, when a certain point within strip width of the transect was considered a favourable spot for reptiles (e.g. a shrub of *Calluna* vegetation or a piece of dead wood), the observer shortly diverged from the transect line in order to examine this specific spot more closely.

Due to the limited amount of time available for data collection, each of the 24 transects was surveyed four times at different times in a day. According to the National Amphibian and Reptile Recording Scheme (U.K.), this is the ideal number of visits for a survey of this nature. Incorporating the bimodal activity pattern described above, each transect was surveyed twice in the morning (at 9:45 and 11:00), and twice in the (late) afternoon (at 14:00 and 15:15).

In summary, each of the 24 plots contained ~1000m transects that were surveyed four times during one hour transects. With a strip width of ~2.5m to both sides, 0.5ha of each plot was surveyed for reptiles attaining a four hour search-effort.

At the beginning of each transect, the date, plot code, the name of the observer, time of day and weather conditions (i.e. temperature, wind speed, humidity and sky conditions) were recorded. Each transect sample also received a number ID for easier analysis later on.

Whenever a reptile was observed during a transect, the species, the time of the observation, stage in life (i.e. juvenile or adult), weather conditions during observation and the vegetation the reptile was found in was recorded. For each observation, a GPS-point was made and an individual ID number was given to the observation,

At the end of the transect, the time and weather conditions were once more recorded. Any remarks to a certain observation or transect sample were also written down. An example of the field form used while sampling the transects is found in Appendix IV.

2.2.2 Vegetation analysis & grazing intensity

Each of the 192 (24 x 8) quadrants were sampled once at some point during the data collection period. During this sampling, the date, plot code and quadrant code were written down, after which three pictures were taken from a random corner of the quadrant for documentation. The first one at knee height, the second at eye height and the last one diagonally from above with stretched arms (Fig. 9).

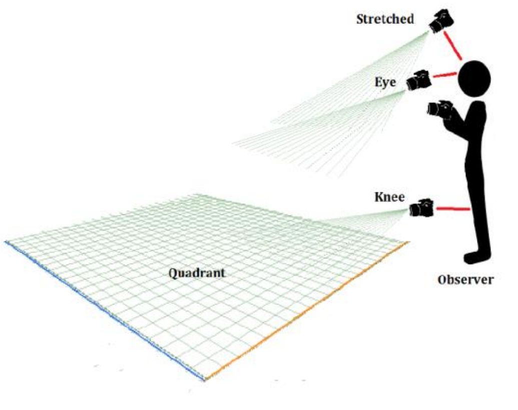

Fig. 9 The three camera angles used for the quadrant vegetation documentation.

From this point, the vegetation coverage of the quadrant was assessed using a method that was derived from the Braun-Blanquet vegetation cover-abundance method (Wikum and Shanholtzer, 1978). The percentage of coverage of each (dominant) plant (or percentage of bare soil) within the quadrant was recorded, after which the average height of the entire vegetation within a quadrant was recorded, as well as the height of the 'invisible layer'. The latter is defined by the height at which it would be possible to visually observe a reptile. Below this height, the vegetation is presumably too dense to visually observe any reptiles (Fig. 10). The data for this were recorded by sticking a pencil (or forearm) through the vegetation at the center of a quadrant, the length of the pencil (or forearm) which was no longer visible due to the vegetation was recorded as the 'invisible layer'.

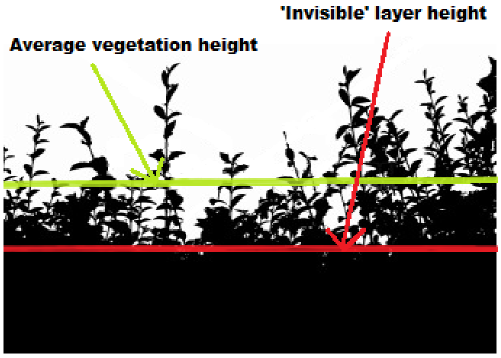

Fig. 10 Example of what is regarded as the average vegetation height and the 'invisible' layer height.

The grazing intensity was assessed by counting the number of faecal matter within the quadrant, subdivided into "Cattle", "Sheep" and "Other". The latter, in general, belonged to hare, deer and rabbits.

An example of the field form used for the vegetation analysis and grazing intensity is shown in Appendix IV.

2.3 Data analysis

After all the data were collected, it was put into IBM SPSS (v.22). One database was made for the transect data in regards to the questions concerning reptile population numbers and another database was created for the quadrant data in regards to the questions concerning vegetation composition and grazing.

2.3.1 The effects of management measures

In order to correct for any influenced results by situational variables (for instance wind speed or temperature differences between samples), a Generalized Linear Mixed Model (GLMM) was created.

By using this model, it was possible to discover significant relations between mowing, sod cutting and grazing of the Doldersummerveld heathland on the present reptile populations by comparing the number of reptiles found within the mowed/sod cut plots, and seeing if they are significantly different to their respective control plots (while also detecting and correcting for possible influences from other variables).

Because the target variable, namely the number of observations, represents a count of occurrences with high variance, the negative binomial regression option was chosen in order to create the model with the best fit.

Due to the distinction that is made between the core of a plot and the border of the same specific plot, four pairwise comparisons arise. Namely the cores of each tandem plot, as well as the borders of each tandem plot, both for mowed plots and sod cut plots (and their respective control plots).

As the management measure of each plot (e.g. mowed/sod cut or no management/control) is the independent variable, this variable was the fixed factor for the GLMM analysis. With six other variables that could be taken into the final model (i.e. grazing intensity, temperature, wind speed, humidity, vegetation height and the 'invisible' vegetation height), 64 different possible combinations were tested for each set (i.e. managed core versus unmanaged core and managed border versus unmanaged border for both mowing and sod cutting). Meaning that a total of 256 different models were analyzed in order to determine the model with the best possible fit for each pairwise comparison.

After analyzing the 256 different models, the model with the lowest AICc index value (Akaike Information Criterion) for each pairwise comparison was chosen as the final model. By taking the statistical goodness of fit into account, as well as the number of parameters that have to be estimated in order to achieve this particular degree of fit, the AIC index imposes a penalty for increasing the number of parameters, meaning that the model with the lowest index value is the one with the best fit (i.e. the one with the fewest parameters that still provides an adequate fit to the data). (Everitt, 1998) The AICc value is the corrected AIC value for finite sample sizes.

When the AICc values for all the fitted models is known, the Akaike Weight is calculated (Burnham & Anderson, 1998) and later the evidence ratio (probability) of the five lowest ranking models is displayed in a table. This evidence ratio (Fig. 11) shows the likelihood for each certain model relative to the other considered models (going upwards from 1 to infinity where 1 is the value for the best fitted model).

$$w_i = \frac{exp(-0.5 * \Delta_i)}{\sum_{r=1}^{R} exp(-0.5 * \Delta_r)}$$

Fig. 11 The formula used in order to calculate the evidence ratio or 'Weight of evidence'. Where w_i is the Akaike weight for the best approximating model in the set and the denominator is the sum of the relative likelihoods for all candidate models. (Burnham & Anderson, 2002)

2.3.2 The cores & borders of managed plots

The same type of analysis could be used to test whether the number of observations between the cores and borders of all plots is significant. But due to the low number of samples available for this analysis and the absence of variation among most covariates (i.e. temperature, wind speed and humidity) since the samples were taken on the same transects, it was both undesirable and unfeasible to run a GLMM test for this comparison. Instead, a nonparametric related samples test (Wilcoxon) was used to test for significant differences between the number of observations found at the cores or borders of all plots.

2.3.3 The effects of grazing on vegetation composition

Finally, in order to test whether grazing intensity (or just faecal density) could have a significant impact on the future vegetation composition (and therefore possibly an indirect significant effect on reptiles populations) as to a high faecal density favoring the regrowth of *Molinia* vegetation over *Calluna* vegetation, a Spearman's rank correlation coefficient test is used to find correlations between grazing intensity/faecal density and the most relevant vegetation for the target reptile species (*Molinia*, *Calluna*, *Erica* or *Poaceae* vegetation).

3. Results

3.1 General results

During the course of the fieldwork in the Doldersummerveld, a total of 177 of the targeted reptile species were found during the 96 samples taken from the 24 different transects (Table 2). Of these 177 observations, 133 were *Zootoca vivipara*, 37 were *Vipera berus* and 7 of them were *Natrix natrix*.

Species:	Mowing		Control (mowing)		Sod cutting		Control (sod cutting)		All
	Core	Border	Core	Border	Core	Border	Core	Border	Total
Natrix natrix	0	2	0	1	0	1	3	0	7
Vipera berus	2	6	4	3	2	3	10	7	37
Zootoca vivipara	11	14	32	15	3	15	31	12	133
Total:	13	22	36	19	5	19	44	19	177
	35		55		24		63		

Table 2. The total number of observations for each set of plots for all target species.

Table 2 shows that most observations in the mowed plots were at the border of said plots (22 out of 35). The same can be said for sod cut plots where 19 of the 24 total observations were at the border of these plots (note that the transect length at the borders is only half of the transect length at the cores). Also, for both management measures, less reptiles were found at the managed plots in comparison to their relative control plots (35 to 55 for mowing and 24 to 63 or sod cutting). A table showing the numbers of reptiles found at both the cores and borders of each individual plot can be found in Appendix X.

3.2 Reptile observations, weather conditions & the time of day

When looking at the total number of reptiles found during the four different transect times, no significant differences were found when doing so for all three species individually. However, when combined, a trend is found where the number of observations decreases over the course of the day (Fig. 12).

During this study, a variation in the daily weather circumstances was experienced. The average daily humidity levels ranged from 40% up to 76%. Average daily wind speeds varied from barely any wind at all (1,4 m/s) at which almost any reptile movement could be heard, to strong winds (7,5 m/s) where it was close to impossible to hear any reptiles nor to distinguish them from the rustling vegetation that surrounded them. Temperatures also varied, where the coldest average daily temperature was measured at 17,1°C and the hottest average daily temperature was found at 32,2 °C. Also, large variations in the number of reptiles were found among different sampling days, ranging from 0 observations up to 25 observations on a single day. (Fig. 13)

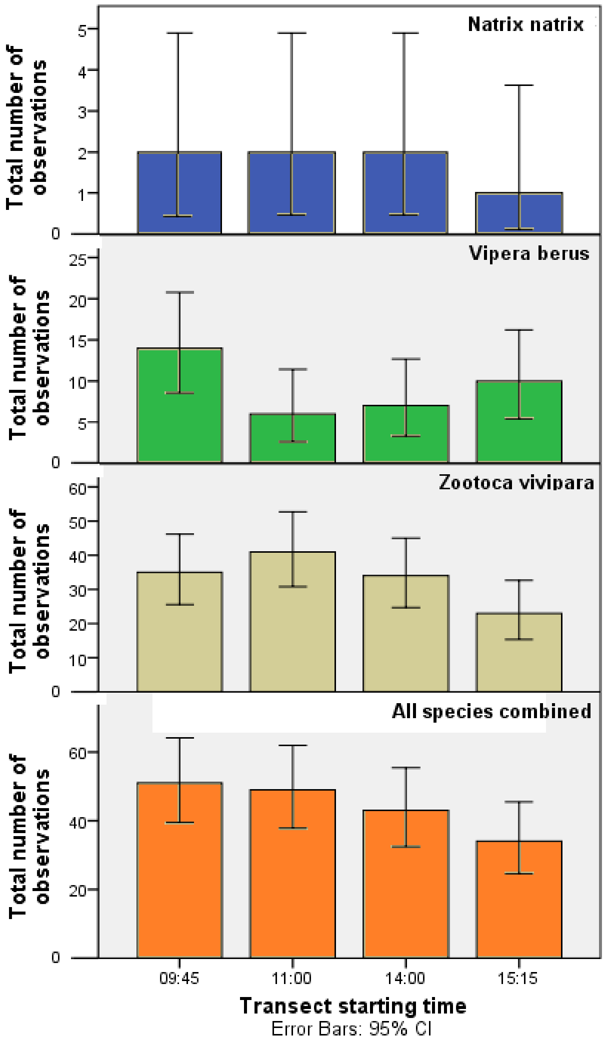

Fig. 12 The total number of observations per species and with all the species combined for all four transect times.

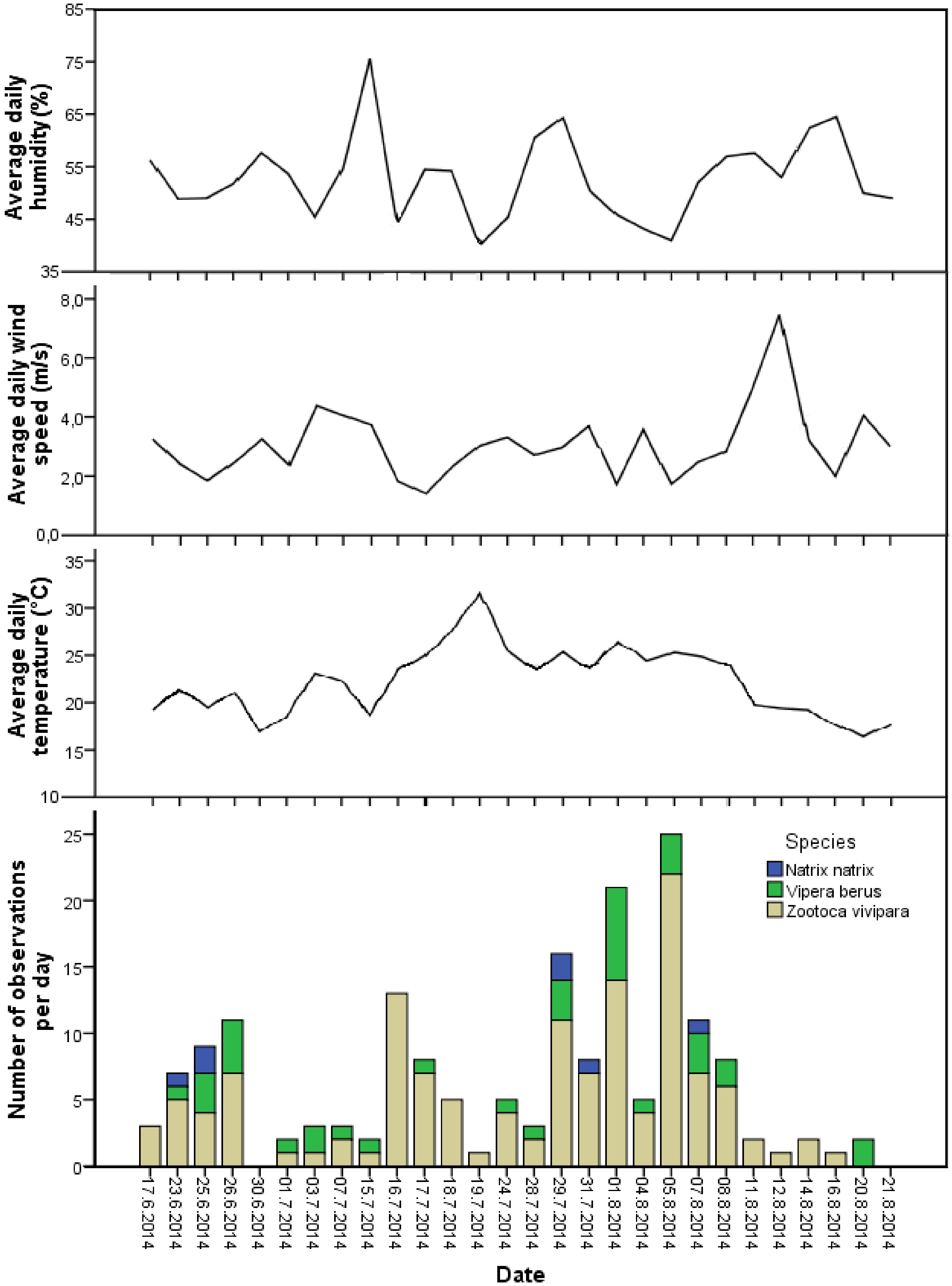

Fig. 13 An overview of the number of reptiles found each sampling day (subdivided per species) combined with the average daily weather conditions (temperature, wind speed and humidity).

3.3 Grazing intensity & vegetation composition

When looking at the vegetation at which these reptiles were found (Table 3), *Poaceae* (i.e. other grasses besides *Molinia*) is the vegetation at which most reptiles were found for all species (110 observations in total). However, when looking at the supply and demand of the various vegetation types in relation to reptile observations (Fig. 14), the percentage of observations at *Poaceae* (36-39%) differs from the coverage percentage of this vegetation type (38%). The only outliers are found with *Vipera berus* and *Molinia* vegetation with 33% of all Vipera berus observations versus a *Molinia* coverage percentage of 17%, and *Zootoca vivipara* with *Calluna* vegetation where 36% of all *Zootoca vivipara* observations were made in a *Calluna* vegetation type that covered 22% of the Doldersummerveld (leaving *Natrix natrix* out of account due to a low sample size).

Vegetation type:	*Poaceae* (Other grasses)	*Molinia caerulea*	*Calluna vulgaris*	*Erica tetralix*
Natrix natrix	5	4	2	2
Vipera berus	25	21	15	3
Zootoca vivipara	80	32	76	20
Total:	110	57	93	25

Table 3. Total number of observations made at the four most dominant vegetation types for all target reptile species. (Note that an observation can be made at a combination of several vegetation types)

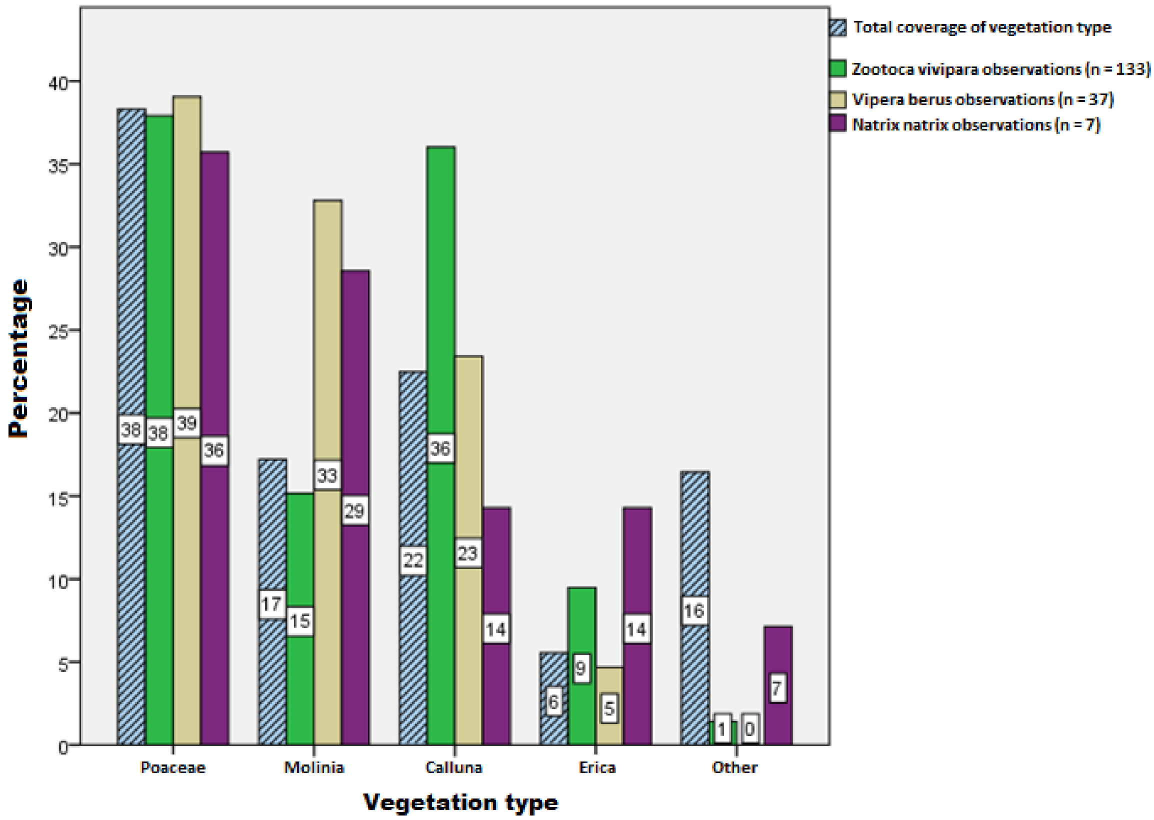

Fig. 14 Graph showing the percentage of the total coverage for each vegetation type from all the quadrants, combined with the percentage of the total number of observations for each target reptile species found at this vegetation type.

The tables resulting from the final Spearman's rank correlation coefficient test, where grazing intensity/ faecal density for each separate grazing species is correlated with the cover abundance of different vegetation types in order to test for significant influence are shown in Table 4 for mowing and Table 5 for sod cutting.

Grazing intensity/ faecal density on mowed plots shows a significant negative correlation (p = ,028) in regards to *Molinia* vegetation, particularly by sheep (p = ,003) (Fig. 15). Also a significant negative correlation between grazing intensity/faecal density by other grazers than cattle or sheep (i.e. hare, deer or rabbits) and *Erica* vegetation was found (p = ,019).

For sod cut plots, grazing intensity/faecal density shows a significant negative correlation (p = ,029) with *Molinia* vegetation cover (Fig. 16). The same goes for *Poaceae* vegetation (p =,013), particularly by sheep (p = ,037) and other grazers besides cattle (p = ,000). This can also be said for *Erica* vegetation (p = ,002), especially by cattle (p = ,024) and other grazers excluding sheep (p = ,010).

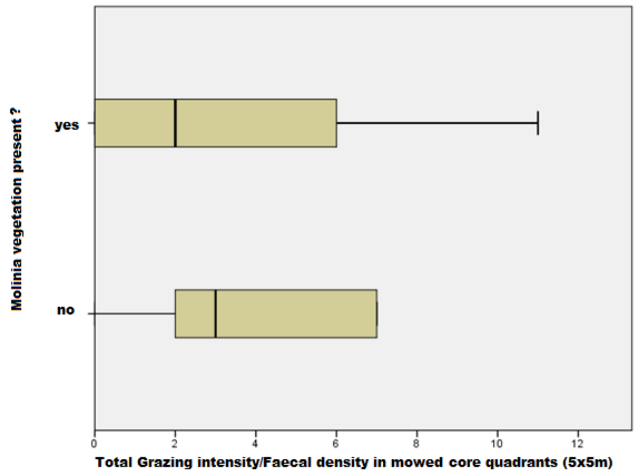

Fig. 15 Boxplot showing the influence of grazing intensity/faecal density on *Molinia* presence in mowed plots.

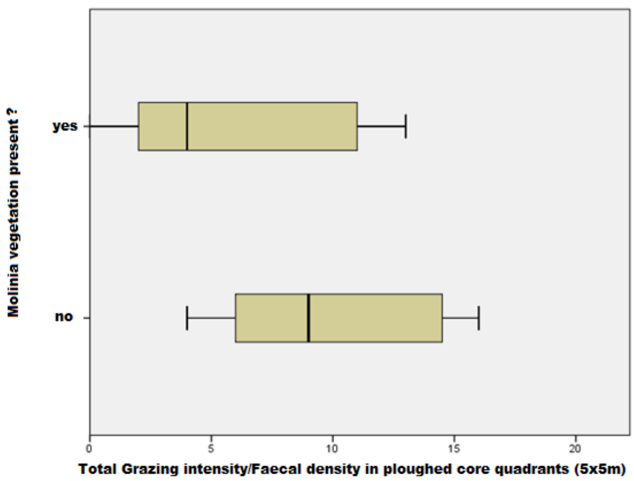

Fig. 16 Boxplot showing the influence of grazing intensity/faecal density on *Molinia* presence in sod cut plots.

Spearman's rho Correlations (Cores Mowed Plots)		Cattle	Sheep	Other	Total
Poaceae	Correlation Coefficient	-,117	,231	,041	,084
	Sig. (2-tailed)	,585	,278	,851	,696
	N	24	24	24	24
Molinia	Correlation Coefficient	-,188	-,578	-,276	-,450
	Sig. (2-tailed)	,379	,003	,191	,028
	N	24	24	24	24
Calluna	Correlation Coefficient	,232	-,286	-,084	-,131
	Sig. (2-tailed)	,276	,176	,697	,542
	N	24	24	24	24
Erica	Correlation Coefficient	-,269	-,140	-,474	-,368
	Sig. (2-tailed)	,203	,514	,019	,077
	N	24	24	24	24

Table 4. Spearman's rho test results for mowed plots. Significant correlations are highlighted in grey.

Spearman's rho Correlations (Cores Sod cut Plots)		Cattle	Sheep	Other	Total
Poaceae	Correlation Coefficient	,268	,428	,664	,499
	Sig. (2-tailed)	,206	,037	,000	,013
	N	24	24	24	24
Molinia	Correlation Coefficient	-,288	-,279	-,197	-,446
	Sig. (2-tailed)	,172	,187	,355	,029
	N	24	24	24	24
Calluna	Correlation Coefficient	,016	-,264	,023	-,024
	Sig. (2-tailed)	,942	,212	,914	,912
	N	24	24	24	24
Erica	Correlation Coefficient	-,459	-,144	-,513	-,595
	Sig. (2-tailed)	,024	,503	,010	,002
	N	24	24	24	24

Table 5. Spearman's rho test results for sod cut plots. Significant correlations are highlighted in grey.

3.4 The cores and borders of managed plots

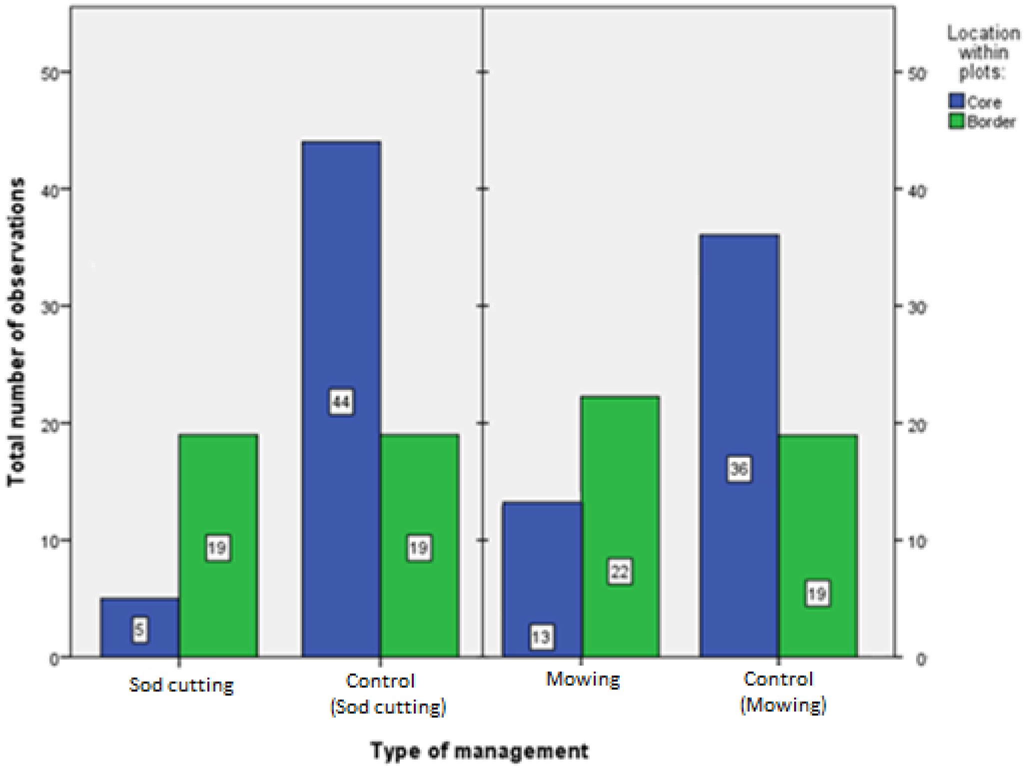

Fig. 17 The total number of observations inside the cores or at the borders of each set of plots.

The Wilcoxon test indicated that the number of reptiles observed at the borders in relation to the cores of both sod cut plots (p = ,027) as well as mowed plots (p = ,042) differed significantly (Fig. 17). This could not be said for the control plots for both sod cutting (p = ,686) and mowing (p = ,752), which is not unexpected as these control plots do not contain clear borders (as no distinctive management measure is applied here), unlike the actual managed plots.

Note that the number of observations at the borders was doubled for the Wilcoxon test (not for Figure 17) due to the transect lengths at the borders being only half of that at the cores. Also the detection probability at the borders of managed plots is most likely lower compared to the cores due to the higher and more dense vegetation (Fig. 18).

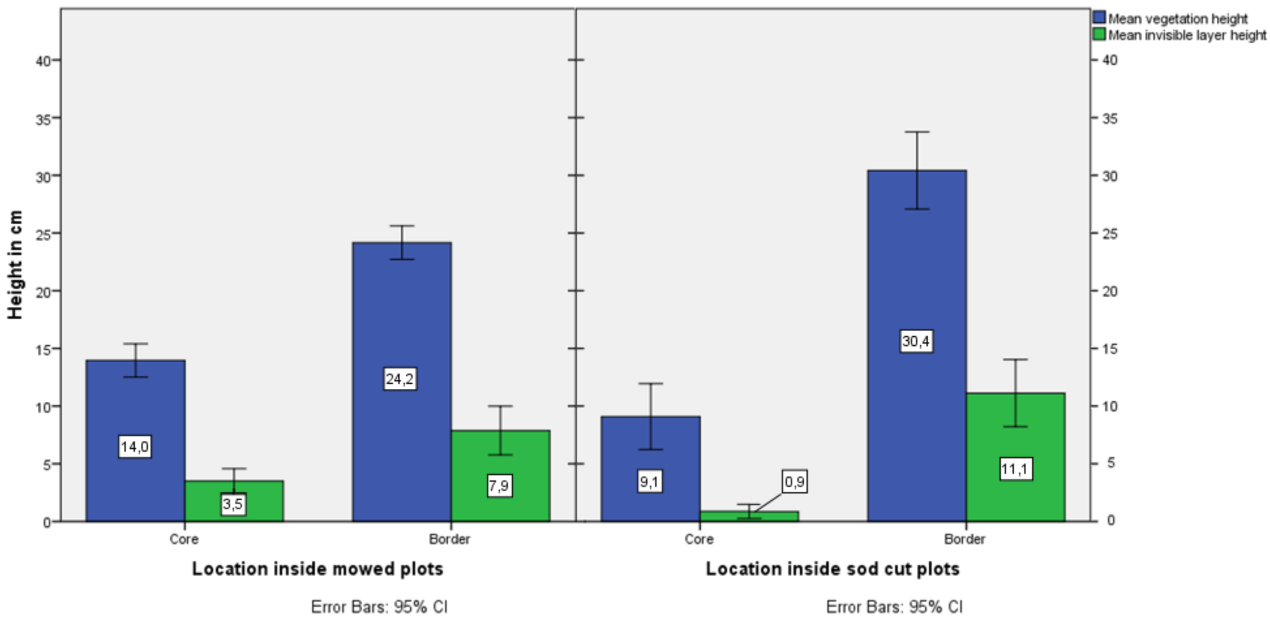

Fig. 18 The average height profile of the cores and borders of mowed and sod cut plots.

3.5 The effects of management measures

While looking for significant differences between managed and unmanaged plots, the GLMM analysis showed that the numbers of reptiles found at the cores of both mowed and sod cut plots were significantly different to those found at the cores of their respective control plots. With an AICc value of 28,911 for sod cutting (Akaike Weight = 0,26), the model that included both the management measure as well as the (mean) wind speed showed a significant difference in the number of reptiles found in the cores of sod cut plots in relation to the cores of their respective control plots (p = ,002 with) by a factor of 0,115. Even though the wind speed was incorporated in the model, it was not of a significant influence.

The model for the cores of mowed plots and the cores of their respective control plots showed an AICc value of 26,933 (Akaike Weight = 0,32) when taking the management measure, as well as the (mean) temperature and the (mean) wind speed into the model. This model showed that the (mean) temperature during the different samples taken had a significant effect (p = ,012) on the number of reptiles observed. Significantly fewer reptiles were found within the cores of mowed plots compared to the cores of their respective control plots (p = ,003) by a factor of 0,165.

Contrary to the cores, the numbers of reptiles found at the borders of both mowed and sod cut plots were not significantly different to those found at the borders of their respective control plots (p = 1,000 for sod cutting and p = 0,386 for mowing). The model with the best fit for sod cutting only included the management measure into the final model, while both the management measure and (mean) temperature were included in the final model for mowing. AICc values for these corrected models were 21,971 (Akaike Weight = 0,23) in the case of sod cutting and 27,144 (Akaike Weight = 0,20) in the case of mowing.

Note that all these models did not show a significant effect of the numbers of faecal pellets of both individual grazing species and all grazing species combined on reptile population numbers. The tables showing the 5 best fitting models for each pairwise comparison are shown in Appendix III.

4. Discussion

4.1 Reptiles, management measures & grazing on similar heathland areas

Most studies concerning reptiles and heathland, tend to focus primarily on the effects of grazing on reptile populations. Especially *Zootoca vivipara* is often chosen as the target species, due its commonness and high potential of being the first reptile species to colonise new heathland patches (Jofré & Reading, 2012). Many of these reports found that intensively grazed areas contain significantly fewer *Zootoca vivipara* compared to extensively grazed areas, and that ungrazed areas contain the highest densities of *Zootoca vivipara.* A study by Holzhauer & Onnes (2012) on the Hatertse Vennen in the Netherlands found much higher *Zootoca vivipara* densities on ungrazed heathland (54 lizards/ha on wet heath, 70 lizards/ha on dry heath) compared to grazed heathland (4 lizards/ha on wet heath, 18 lizards/ha on dry heath). Wallis de Vries *et al.* (2013), who conducted a study on the Strabrechtse heide and the Spinsterberg in the Netherlands, found that *Zootoca vivipara* densities on extensively grazed areas were only half of those at ungrazed areas. Intensively grazed areas in this study showed such low densities on intensively grazed areas that the *Zootoca vivipara* populations here were denoted as unviable. They concluded that a situation where grazing is absent is most favourable for *Zootoca vivipara,* as long as succession to woodland is avoided. Population trends of *Zootoca vivipara* on heathlands in the Dutch province of Noord-Brabant also show a stable image on ungrazed areas, while populations on grazed areas (sum of both intensively grazed and extensively grazed) are declining.

4.2 Faecal count as a measure of grazing intensity

Interestingly enough, only the study by Wallis de Vries *et al.* (2013) was found to have used the same method (i.e. faecal count) for grazing intensity as was used in this study. In addition, they also noted the presence of trails created by cattle and, when possible, the abundance of feeding marks found on the vegetation. However, in the end, they used this data to create an ordinal scale for grazing intensity (from ungrazed to intensively grazed) rather than a numeric scale. All other similar studies found also used an ordinal scale for grazing intensity, but in most cases, acquired this scale through communications with the forester rather than precise measurements. Most of these studies used multiple research sites where it was clear how much a particular area was grazed in recent years. In the Doldersummerveld however, this distinction is much more difficult to make since it is only a single area where the grazers can roam free (particularly the Highland cattle).

The study by Wallis de Vries *et al.* (2013) was almost exclusively focused on grazing. Contrary to this study, it did not contain research sites where management measures such as sod cutting and mowing were applied. This made a faecal count a suitable method as a means of measuring grazing intensity. In this study however, sod cut plots, in many cases, did not contain any vegetation at all (Figure 19). This made the large quantities of faeces found within the cores of these plots conspicuous. It became clear that a faecal count as a measuring method of grazing intensity, while satisfactory in other studies (Wallis de Vries et al. 2013; Moen et al., 2009), might not have been the most suitable method for the envisioned goal in this particular study.

Fig. 19 The lack of vegetation inside a sod cut plot (PC-1). Photo by: Jonno Stelder

Fig. 20 Highland cattle resting on a recently mowed area. Photo by: Jonno Stelder

From the observer's (physical) viewpoint, particularly the Highland cattle seemed to spend most of their time within the confines of either sod cut or mowed areas (Fig. 20), which would explain the large quantities of faeces found here. In a study conducted by Lake (2002) on the role of grazing in lowland heathland conservation, cattle showed a tendency for increased dunging around their resting areas, which in its turn could mean a transfer of nutrients between foraging and resting sites. The Highland cattle herd that roams the Doldersummerveld was not monitored throughout the entire day and it is unclear where or how they spend their time at night or at twilight hours. However, other studies indicate that cattle will predominantly graze at night or at crepuscular hours during the hot summer months (Krysl, 1993; Linnane et al., 2000), which means that a faecal count could still be a suitable way of measuring grazing intensity in the control plots. Another question that arises from this observation is, of course, if they would defecate in the same areas where they forage in the absence of sod cut or mowed areas. However, while this method might not be a suitable way of measuring grazing intensity (in this situation), it can still be used as a measure of faecal density (i.e. nutrient transfer), which was principally the essence of the subquestion on the relation between management measures, combined with grazing on the vegetation composition.

4.3 Effects of grazing on vegetation

The results found in Figure 14 indicated a preference for *Calluna* vegetation (*Zootoca vivipara*) and *Molinia* vegetation (*Vipera berus*). These findings coincide with the study by Stumpel & van der Werf (2011), who additionally found a preference for the combination of these two vegetation types. An experimental study in Denmark by Buttenschon & Buttonschon (1982) showed that sheep continuously feed on *Calluna vulgaris* throughout the year, while cattle only do so in July and August when this vegetation is in bloom. This while the study by Lake (2002) in southern England showed that cattle actively select areas of high cover by fine grasses and *Calluna* vegetation, where they positively selected young *Calluna* plants. Another study in southern England by Bullock & Pakeman (1997) showed that grazing significantly reduced dwarf shrub layer height and litter depth, while also increasing the amount of bare ground cover at one of their research sites. This percentage of bare ground cover was also higher at intensively grazed areas compared to extensively grazed areas. Translating this to reptiles would mean that grazing reduces the amount of suitable refuges, while the coverage of habitat that is unfit for use increases.

While grazing is mostly applied on heathland to avoid *Molinia* encroachment and succession into woodland, multiple studies indicate that this actually accelerates succession due to the added nitrogen from dung deposition by grazers (Bokdam, 2002; Mitchell et al., 2000; Strijbosch, 2002). Furthermore, the removal of the litter layer also stimulates plant growth as this litter layer normally withholds nitrogen (Hay & Kicklighter, 2001) from reaching the soil, thus accelerating succession. In turn, grazing by cattle does not prevent the encroachment of silver birch and pine, which share the same ecological niche with *Calluna*, yet are unpalatable to this type of grazer (Bokdam & Gleichman, 2000; Bokham, 2002).

Even though the final model in this study showed that grazing does not have a significant direct effect on the number of reptiles observed within the sampled areas, it could however still have a significant indirect effect on reptiles over time, especially as to the sod cut plots where the chemical composition of the soil could be altered due to the nutrient transfer caused by the large quantities of faeces being deposited here.

This, in turn, could favour the growth of *Molinia* vegetation over *Calluna* vegetation (Friedrich et al., 2011) and could thusly affect the reptile populations in the long run. However, due to the small sample size and the lack of equal distribution of different gradients along the faecal density scale it was not possible to find such a correlation. A study over time with a larger sample size is needed in order to confirm or disprove this theory. It should also be noted that the faecal densities found at said plots might have been different previously and have not yet had the time to alter the chemical composition of the soil, and with it the vegetation composition.

4.4 Vegetation responses to management on different soil nutrient availability levels

The interaction between vegetation such as *Calluna*, *Erica* and *Molinia* and their response to management measures differs on different nutrient levels of the soil. An experimental study by Aerts *et al.* (1990) on the Deelense Veld where they monitored competition among vegetation on heathland along a gradient of nutrient availability, indicated that both *Calluna* and *Erica* outcompete *Molinia* when nutrient availability levels are low. However, at high nutrient availability levels, *Calluna* and *Erica* each respond differently in regards to competition by *Molinia*. At high nutrient availability levels, *Erica* is outcompeted by *Molinia* due to *Molinia* having a higher potential growth rate and taller structure. On the other hand, at these nutrient availability levels, *Calluna* can still outcompete *Molinia*. This is due to *Calluna* exhibiting more evergreen traits, while *Molinia* tends to be more deciduous (i.e. *Calluna* carries leaves throughout the year while *Molinia* loses its foliage in winter) . This means that *Calluna* will close its canopy earlier in the season (while also having a high leaf biomass and a rather high positioning of these leaves), ultimately outcompeting *Molinia* (mainly due to light interception) even though *Molinia* has a higher growth rate potential and higher maximum foliage height.

According to Aerts *et al.* (1990)*, Molinia* can only attain dominancy on dry heathland at high levels of nutrient availability when the *Calluna* canopy is opened (enabling more light absorption by *Molinia*), implying that encroachment by *Molinia* can be prevented by decreasing nutrient availability. Hartley & Mitchell (2005), who manipulated the availability of nutrients and grazing intensity in the Scottish uplands, showed that *Calluna* significantly benefitted (i.e. increased coverage) when grazers were excluded. They also found that *Calluna* coverage declined in situations where grazing was applied, particularly when this was combined with added nitrogen. In the absence of grazing, the addition of nutrients did not result in significant declines of *Calluna* coverage. This would mean that the high densities of faecal matter, as was found in this study, could alter the nutrient availability of the soil causing an increase in *Calluna* coverage. However, on the other hand, this increase in *Calluna* would most likely be brought to a halt when the *Calluna* has reached a height where it becomes a target for grazers, which in its turn would advance the growth of *Molinia*.

4.5 Other reptile studies on the Doldersummerveld

Unfortunately, most studies on heathland conducted in this region, tend to focus on the adjoining Wapserveld rather than the Doldersummerveld (especially the ones regarding reptiles). Therefore, not a lot of information could be found concerning reptile population numbers of this particular area. This is rather peculiar when looking at the quality of the Doldersummerveld heathland in terms of biodiversity en heterogeneity (although the Wapserveld is also well-known for these traits).

Only one other survey on reptile population numbers of the Doldersummerveld was found. Two volunteers have been performing line transects in the Doldersummerveld region since 1997, where they record all reptile species they encounter. In recent years they have also implemented a plate-method, which is a very suitable method when studying slow worms (*Anguis fragilis*) (Walpot, 2013). When looking at the results from their Doldersummerveld line transect through the period of 2004 – 2013 (Appendix VI), most of their observations were *Vipera berus* (47,1%, 644 observations), while *Zootoca vivipara* only takes up 28,8% (393) of all observations. *Natrix natrix* was observed 285 times (20,9%), 43 *Anguis fragilis* were observed (3,2%) and also 1 smooth snake (*Coronella austriaca*) was found.

While the percentage of *Natrix natrix* observations here was quite high compared to this study (3,9%), this difference is not very surprising as their transect location, the (south-) western part of the Doldersummerveld, includes a bog area while the heathland part is also predominantly wet. The difference in observation percentages of *Zootoca vivipara* (28,8% compared to 74,7%) and *Vipera berus* (47,1% compared to 20,8%) however, is more intriguing. This is because plot MA-0 and PA-0 lie directly next to this research location and contained much more *Zootoca vivipara* (19 and 8, resp.) than *Vipera berus* (0 and 4, resp.) (see Appendix VII), while both plots (especially MA-0) shared the same vegetation type (for a large part) with this research location.

4.6. Border observations

Where it is assumable that observations made within the cores of the various sampled plots, the observed reptile actually makes use of said area, this is not necessarily the case for observations made along the borders of plots. In the case of sod cut or mowed plots, it could be that the reptiles observed along the border here may not make use of the actual area which has been sod cut or mowed, but rather live among the areas surrounding the managed area and actively avoid the part which has actually been sod cut or mowed. It should also be noted that, in the case of control plots, there is not necessarily something that can be regarded as a border because these areas were selected beforehand primarily based on the vegetation type at the core. This all would make all statements derived from the comparison between observations at the borders of sod cut or mowed plots with the border observations at their respective control plots meaningless in terms of reptiles preferring the transition between different vegetation types (or open and closed vegetation).

4.7. Reptiles of the Doldersummerveld

Over the course of the data collection period, it stood out that the reptiles of the Doldersummerveld are very timid compared to other visited areas within the Netherlands. Out of all 177 observations, only one was reasonably documented on camera (Fig. 21) and only very few were documented on camera at all. This drew the attention because in many other areas throughout the Netherlands where reptiles occur, it is not uncommon to see, for instance, a *Vipera berus* or *Natrix natrix* basking in clear sight that does not scurry off at the first hint of human presence. This in contrary to the Doldersummerveld where you almost exclusively see their tails as they seek cover amongst the vegetation. Reason for this could be the, in many cases, very dense and sometimes high vegetation the Doldersummerveld comprises. It could also be a trait for these particular reptile populations, which might hold an interesting new study topic.

Fig. 21 The only reptile (*Natrix natrix*) that was reasonably documented on camera during the course of this study. Photo by: Jonno Stelder

4.8. Study over time

The research design of this study consisted of a data collection period of two months due to a limited amount of time available. Because of this, each sod cut or mowed plot was assigned a control plot of which the vegetation composition was assumed comparable to the situation of the sod cut and mowed plots before said management measure was conducted. Even though the results from the GLMM analysis were staggering, a long term study over time could prove to be valuable as this would allow for a more precise survey into the exact changes in population numbers of the surveyed reptile species within the sod cut or mowed areas. This would also make it possible to compare the original situation before the management measure is conducted to the desired future situation.

4.9. Snake observations

During the course of this study, only 7 Natrix natrix and 37 *Vipera berus* were found. This relatively small number of observations (compared to 133 *Zootoca vivipara*) was too small to allow for a proper analysis of population numbers in regards to management measures or grazing. Buckland *et al*. (1993, p. 302) suggests a minimum *n* of 60-80 for proper analysis in line transect sampling. Reason for the low number of *Natrix natrix* could be that the most southwestern part of the Doldersummerveld contains a more suitable microclimate (i.e. wetter) for this particular species (see the large area of *Eriophorum* vegetation in Appendix I). This area however, is currently being used as a study site for another survey on reptiles, of which the concerning researchers requested to avoid on account of possible disturbance.

5. Conclusion

Population numbers of managed heathland compared to unmanaged heathland

The final models from the GLMM analysis showed a significant difference between the number of reptiles found within the cores of both sod cut and mowed plots compared to the cores of their respective control plots. Provided that the current situations of the control plots are comparable to the situations of the mowed/sod cut plots right before said management measure was conducted, one can conclude that both mowing and sod cutting have a highly detrimental effect on the populations of the target reptile species. With a population reduction by a factor of 0,165 for mowing and 0,115 for sod cutting, one could say said reptile populations are decimated. The nonparametric related samples test (Wilcoxon) found significant differences between the number of reptiles observed at the cores and borders of both sod cut and mowed plots, which is no surprise regarding the sod cut plots as many of these did not have any vegetation at all at the cores. For the mowed plots, these results indicate a preference for a higher, and more dense vegetation composition with access to a more open vegetation type for basking and other activities. Assuming that the border of said mowed plots is not also the border of the home range for the reptiles found here. These significant differences are also probably larger, taking the difference in detection probability at the borders compared to the cores into account.

Relation between management measures/grazing and vegetation composition

The low number of samples and the lack of equal distribution of different gradients along the faecal density scale led to distorted Spearman's rank correlation coefficient test results. Even though the results indicated that a high faecal density has a significant negative effect on *Molinia* vegetation (and *Erica* vegetation in the case of sod cut plots), but no significant effects on *Calluna* vegetation, the limitations mentioned above made the test results too frail in order to draw solid conclusions from. Other studies however did give rise to more solid conclusions, indicating that both sheep and cattle actively select *Calluna* vegetation to forage. At the same time the dwarf shrub layer height and litter depth is reduced while bare ground cover increases, while in turn accelerating succession. Also, plant responses to management measures in terms of competition are different at various soil nutrient availability levels.

Relation between reptile population numbers and grazing on heathland

The GLMM models indicated that grazing, combined with management measures such as sod cutting or mowing, has no significant additional (negative) effect on reptile populations. In contrast, many other studies indicated that grazing does have a significant negative influence on *Zootoca vivipara* numbers. Due to the small sample size and the lack of equal distribution along the grazing intensity/faecal density scale in this study, the results are inconclusive. could be responsible for these results. Also, it became apparent that a faecal count was not a suitable method in this situation.

Relation between reptile populations numbers and different species of grazers

The GLMM analysis indicated that grazing (as a whole) had no direct significant influence on reptile population numbers. The same applies to individual species of grazers. In terms of indirect effects, grazing by different species of grazers could give rise to different future outcomes as regards to vegetation.

The effects of management measures and grazing of heathland on reptile populations

This study found sod cutting and mowing to have highly negative effects on reptile population numbers, whereas multiple other studies indicate that grazing also has a significant negative effect on reptiles (particularly *Zootoca vivipara*). Therefore, the combination of these practices is not expected to hold any positive outcomes in terms of reptile population numbers.

Since *Zootoca vivipara* is regarded as the first colonizing reptile species on new heathland areas, the low numbers of this particular species found at the cores of both sod cut and mowed plots (3 and 11 observations in total respectively) do not bode well in regards to other reptile species such as *Vipera berus* and *Natrix natrix*. The future perspective of these newly created areas shows no promise of being beneficial to reptiles. On account of grazing and/or the large quantities of faecal depositis, impeding the settlement of *Calluna* vegetation, while favouring the growth of *Molinia*, silver birch or pine (potentially creating a homogenous *Molinia* area or an area which heads more towards woodland rather than heathland).

6. Recommendations

Given the fact that the target reptile species of this study are sensitive to large scaled and intensive management measures, and may have difficulties recovering from sudden substantial declines in population size, it is recommended to incorporate the needs of these species more firmly into future management plans.

Without any form of management, heathland would ultimately succumb to succession and turn into woodland, benefitting neither the envisioned goal nor reptiles. However, none of the current management tools (i.e. sod cutting, mowing or grazing) are harmless towards reptiles, yet a decision has to be made. In order to incorporate reptiles into current management goals, it is best to choose the lesser of two evils in terms of management measures.

When looking at nutrient poor heathland, neither mowing or sod cutting has an additional benefit as to avoiding encroachment by *Molinia* (although mowing might prove useful initially to clear out homogenous *Molinia* areas). Presumably the best management from the perspective of reptiles would be to apply moderate grazing pressure. Due to the poor nature of the soil, *Calluna* and *Erica* will outcompete *Molinia* as was originally intended. Any potentially emerging woodland tree species (e.g. silver birch and pine) can be removed manually over the course of years.

On nutrient rich heathland, two different approaches can be pursued depending on the envisioned outcome:

When the aim is to create an area that is rich in *Calluna* cover, it would be best (from the perspective of reptiles) to simply avoid grazing in the specific area (e.g. fencing). Where ideally the *Molinia* will be outcompeted by *Calluna* due to its closed canopy.

If the aim is to create an area that is rich in both *Calluna* and *Erica* cover, the best option would be to apply sod cutting (moderately) on homogenous areas followed by fencing. This would remove the nutrients from the soil so that *Molinia* will be outcompeted by both *Calluna* and *Erica*. Even though detrimental to reptiles at first, the eventual outcome would most likely comply more with the envisioned management goal (and also in terms of reptile requirements). Contrary to grazing, the disruption caused by said management measure is one time only, after which the area can be left alone (and possibly recolonized by reptiles) for the coming decades.

When looking at the diet and foraging behaviour of the species of grazers that currently inhabit the Doldersummerveld (i.e. Highland cattle and Schoonebeeker sheep), the use of different species of grazers (e.g. horses) might be more beneficial to use as a means of avoiding encroachment and succession, and in turn could be less harmful to reptiles. However, further research is needed to test whether this is both the case and is feasible.

A future, long term study that monitors reptile populations (and vegetation composition) during the course of succession after either sod cutting or mowing has been conducted to a specific area (starting right before said management is conducted) may prove to be invaluable for future heathland management.

Currently, the fate of the reptiles that inhabit an area that has been mowed or sod cut is still uncertain in terms of them surviving (i.e. migrating) or dying. An experimental study that would monitor whether said reptiles migrate to surrounding areas or are simply killed during the process could change the perspectives on drastic management measures such as sod cutting and mowing.

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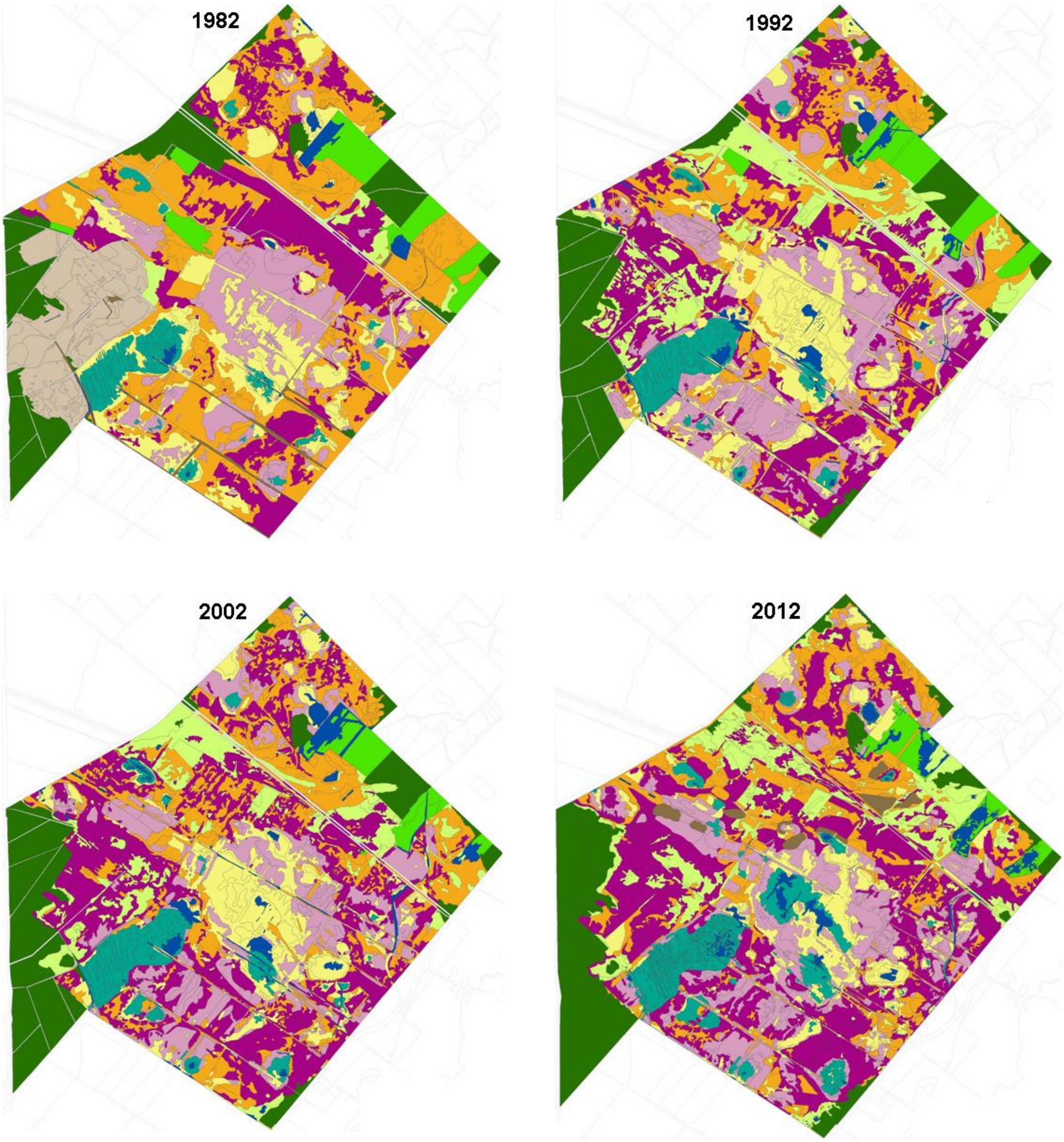
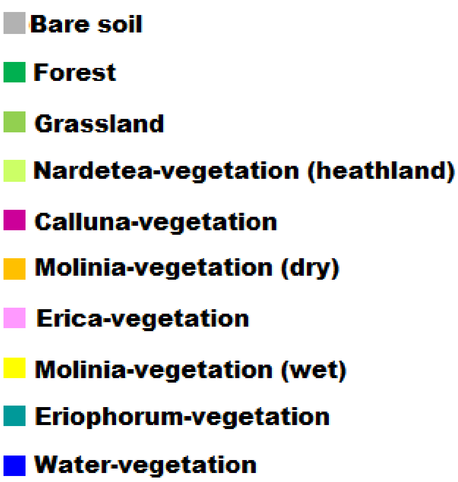
Appendices

Appendix I: Maps of the Doldersummerveld showing the vegetation shift in between 1982 and 2012.





Appendix II: Table showing the management history of the Doldersummerveld from 1967 to 2013.

	Plaggen ha	Maaien ha	Branden ha	Bos kappen ha	Opslag kappen ha	Sloten dempen m	Water op land ha	Begrazing ha	Aantal runderen	Opmerking runderen	Aantal schapen	Aantal paarden	Opmerking schapen, paarden
1967			59,4				29						
1968			9,3		13,0		24						
1969				3,9	30,0	100	29						
1970				5,0	50,0		29						
1971				13,5			24						
1972			95,1		35,0		15						
1973				0,3			8						
1974				1,4			7						
1975							29	9			100		alleen op graslandjes
1976			47,4	1,3			2	9			100		alleen op graslandjes
1977							3	9			100		alleen op graslandjes
1978	2,1		70,8			4320	12	9			100		alleen op graslandjes
1979		16,1					24	74	0		100		alleen op graslandjes
1980			19,4		4,5		15	74	80	jongvee	100	20	alleen op graslandjes, paarden op heide
1981		14,0	165,0	40,1		3363	54	169	80	jongvee	100	20	alleen op graslandjes, paarden op heide
1982	2,2	9,0					29	169	60	jongvee	40	22	
1983	0,3					690	71	189	60	jongvee	60	16	
1984		4,8				520	54	189	90	60 jongvee, 30 ossen	80		
1985	1,5	3,1		0,5	1,8		44	189	90	60 jongvee, 30 ossen	104		
1986	1,6			5,4			54	189	110	80 limousines, 30 ossen	100		
1987	3,0						54	189	110	80 limousines, 30 ossen	90		
1988	0,7	3,3					71	189	110	80 limousines, 30 ossen	90		
1989		8,7			0,3	450	54	189	60	limousines	90		
1990	4,8	1,3					24	189	60	limousines	90		
1991		5,7					24	229	60	limousines	90		
1992		19,0					10	229	30	jongvee	80		
1993	0,1	13,5					29	229	30	jongvee	80		
1994							71	229	30	jongvee	75		
1995							94	229	30	jongvee	70		
1996	0,3	3,1					5	229	30	jongvee	70		
1997							7	229	30	jongvee	70		
1998		10,6					29	229	30	jongvee	70		
1999	1,5	7,1					94	229	15	hooglanders, deels jaarrond	80		
2000				1,5	2,0		54	229	15	hooglanders, deels jaarrond	85		
2001							54	229	15	hooglanders, deels jaarrond	136		
2002							71	229	15	hooglanders, deels jaarrond	151		grotendeels overstap op kudde
2003	0,2	10,9				1320	29	229	33	hooglanders, deels jaarrond	229		
2004	1,5	4,2			3,0		34	229	30	hooglanders, deels jaarrond	245		
2005							44	229	30	hooglanders, deels jaarrond	255		
2006		0,2		2,1			8	229	34	hooglanders, deels jaarrond	255		
2007							44	229	45	hooglanders, deels jaarrond	297		
2008		5,6			0,7		34	229	45	hooglanders, deels jaarrond	270		
2009	1,4						29	229	40	hooglanders, deels jaarrond	299		
2010	2,5	23,9			0,5	320	34	229	35	hooglanders, deels jaarrond	305		
2011	2,7	2,0	4,0	1,0			12	229	35	hooglanders, deels jaarrond	350		Huenderwg overgraasbaar
2012							54	229	35	hooglanders, deels jaarrond	365		
2013		9,8					44	229	35	hooglanders, deels jaarrond	360		
totaal	26,5	175,8	470,4	75,8	140,8	11083							

Appendix III: Tables showing the five best fitting models of the GLMM analysis for all four pairwise comparisons according to the AICc value, Akaike weight and evidence ratio with their results for significant effects and exponential coefficients.

Model Mowing Border	Number of parameters	AICc value	Akaike weight	Evidence ratio	Significant effects	Exp (Coefficient)
Management + temperature	2	27,144	0,20	1,00	None	Not significant
Management + wind + temperature	3	27,800	0,14	1,39	None	Not significant
Management + grazing + temperature	3	29,417	0,6	3,12	None	Not significant
Management	1	29,522	0,6	3,28	None	Not significant
Management + wind	2	29,654	0,6	3,51	None	Not significant

Model Mowing Core	Number of parameters	AICc value	Akaike weight	Evidence ratio	Significant effects	Exp (Coefficient)
Management + temperature + wind	3	26,933	0,32	1,00	Management (p = ,003) Temperature (p = ,012)	Management = 0,165 Temperature = 1,813
Management + grazing + temperature + wind	4	29,605	0,08	3,80	Management (p = ,004) Temperature (p = ,016)	Management = 0,162 Temperature = 1,805
Management + temperature + wind + invisible layer height	4	30,844	0,05	7,07	Management (p = ,006) Temperature (p = ,016)	Management =0,175 Temperature = 1,847
Management + temperature + wind + humidity	4	31,084	0,04	7,97	Management (p = ,009)	Management = 0,174
Management + humidity	2	32,060	0,03	12,98	Management (p = ,006) Humidity (p = ,008)	Management = 0,309 Humidity = 0,911

Model Sod cutting Border	Number of parameters	AICc value	Akaike weight	Evidence ratio	Significant effects	Exp (Coefficient)
Management	1	21,971	0,23	1,00	None	Not significant
Management + wind	2	22,336	0,19	1,20	None	Not significant
Management + temperature	2	24,046	0,08	2,82	None	Not significant
Management + temperature + wind	3	24,410	0,07	3,39	None	Not significant
Management + grazing	2	24,475	0,06	3,50	None	Not significant

Model Sod cutting Core	Number of parameters	AICc value	Akaike weight	Evidence ratio	Significant effects	Exp (Coefficient)
Management + wind	2	28,911	0,26	1,00	Management (p = ,002)	0,115
Management	1	29,462	0,19	1,32	Management (p = ,001)	0,114
Management + grazing	2	30,560	0,11	2,28	Management (p = ,020)	0,207
Management + grazing + wind	3	30,650	0,11	2,39	Management (p = ,021)	0,203
Management + temperature + wind	3	30,650	0,11	2,39	Management (p = ,003)	0,116

Appendix IV: Example of the field forms used during this study. The first one was used for all the transects, the second was used for quadrant sampling (vegetation composition and grazing intensity).

Transect field form						
Plot ID: Date: Transect time period:			Observer:			
Time at start transect: Time at end transect:			Weather conditions at start transect: Temperature: °C Humidity: % Wind speed: m/s Weather conditions at end transect: Temperature: °C Humidity: % Wind speed: m/s			
#	Species	Time	Adult/Juvenile	Weather	Vegetation	GPS #

Plot ID: Date:	Q- north	Q- east	Q- south	Q- west	Random Q1	Random Q2	Random Q3	Random Q4
<u>Grazing</u> Cattle:								
Sheep:								
Other:								
Total:								
<u>Vegetation:</u> % Open								
% Poaceae								
% Molinia								
% Calluna								
% Erica								
% ……..								
Average Height:								
Invisible Layer:								
Pictures: (knee/eye/stretched)								

Appendix V: Table showing the total number of observations for each individual plot, with the distinction between core and border observations.

Mowed plots			Control plots (Mowing)		
	Total number of observations			Total number of observations	
	Core	Border		Core	Border
MA-1	6	3	MA-0	15	5
MB-1	1	3	MB-0	8	5
MC-1	0	1	MC-0	1	1
MD-1	2	7	MD-0	4	3
ME-1	4	6	ME-0	4	5
MF-1	0	1	MF-0	4	0
Sod cut plots			**Control plots (Sod cutting)**		
	Total number of observations			Total number of observations	
	Core	Border		Core	Border
PA-1	0	3	PA-0	13	1
PB-1	2	3	PB-0	4	4
PC-1	0	1	PC-0	4	2
PD-1	0	5	PD-0	6	7
PE-1	3	3	PE-0	11	3
PF-1	0	4	PF-0	6	2

Appendix VI: Table showing the total number of observations per species and their corresponding percentages by Walpot on the RAVON monitoring route of the Doldersummerveld in between 2004-2013 and this study.

	Walpot		This study	
Species	Total number of observations	Percentage of all observations	Total number of observations	Percentage of all observations
Vipera berus	644	47,1 %	37	20,8 %
Coronella austriaca	1	0,07 %	0	0,00 %
Anguis fragilis	43	3,15 %	1	0,56 %
Zootoca vivipara	393	28,8 %	133	74,7 %
Natrix natrix	285	20,9 %	7	3,93 %

Appendix VII: Table showing the total number of observations per species for all plots.

	Species		
	Natrix natrix	*Vipera berus*	*Zootoca vivipara*
Plot Nr:	Number of observations	Number of observations	Number of observations
MA-0	1	0	19
MA-1	1	1	7
MB-0	0	3	10
MB-1	0	0	4
MC-0	0	0	2
MC-1	0	0	1
MD-0	0	2	5
MD-1	0	5	4
ME-0	0	2	7
ME-1	1	2	8
MF-0	0	0	4
MF-1	0	0	1
PA-0	2	4	8
PA-1	1	0	2
PB-0	1	2	5
PB-1	0	3	2
PC-0	0	1	5
PC-1	0	1	0
PD-0	0	4	9
PD-1	0	0	5
PE-0	0	5	9
PE-1	0	0	5
PF-0	0	1	7
PF-1	0	1	4