UNIVERSITY OF GOTHENBURG

DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCES

HOW DOES GRAZING AND BURNING AFFECT THE OCCURRENCE AND DEVELOPMENT OF VASCULAR PLANTS?

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Abstract

Grazing and burning are disturbances that can be used for management of landscapes that are in need of restoration. When applying these disturbances, you can create a more diverse flora and fauna and control the grazing pressure from domestic cattle. In this study five different plants were used to study the effects that burning and grazing can have on vascular plants, and to get an idea of what the best way is to treat savanna-like grassland landscapes. The plants used in this study was *Primula veris, Leucanthemum vulgare, Draba verna, Centaurea jacea* and *Succisa pratensis*. These plants were sown by hand during 2016 and 2017 and have been exposed to different treatments that included burning and grazing. They all flower during spring and summer. In the spring of 2022, half of the areas that have been exposed to grazing since the project start in 2015 were fenced. The analyses of the data showed that there were more species, plants, stalks with flowers and buds, highest flower in cm and less shading and in the fenced and non-fenced burned and grazed areas, as compared to the control areas. These results can contribute to a better understanding of how burning and grazing can be used more efficiently for restoration purposes and to reach your goals in a faster and easier way by minimizing the workload.

Keywords: burning, grazing, plot, restoration, plant, flower

Abstrakt (SE)

Bete och bränning är störningar som kan användas under restaurering och skötsel av landskap. När du tillämpar dessa störningar kan du skapa en mer varierad flora och fauna och även kontrollera betestrycket från tamboskap. I denna studie användes fem olika växter för att studera effekterna av bränning och bete på kärlväxter, och för att få en uppfattning om hur det bästa sättet är att sköta savannliknande gräsmarkslandskap. De arter som användes i denna studien var *Primula veris, Leucanthemum vulgare, Draba verna, Centaurea jacea* och *Succisa pratensis*. De såddes för hand under 2016 och 2017 och har utsatts för olika behandlingar som har bestått av bränning och bete. Växterna blommar under våren och sommaren. Under våren 2022 blev hälften av de områden som varit utsatta för bete sedan projektstarten 2015 inhägnade. Analyserna av data insamlad från fält visade att flera faktorer hade en signifikant skillnad med mer arter, plantor, stjälkar med blommor och knoppar, högsta blomman och mindre skuggning i de stängslade och icke stängslade brända och betade ytorna jämfört med kontroll ytorna. Dessa resultat kan bidra till en bättre förståelse för hur bränning och bete kan användas mer effektivt i restaureringssyften och för att nå dina mål på ett snabbare och enklare sätt genom att minimera arbetsbelastningen.

Introduction

Species richness is declining in Swedish landscapes, due to changes in land use (Lindborg et al., 2005). The landscapes are damaged directly or indirectly by human activities. Species-rich and grazed semi-natural grasslands are among the most threatened habitats in Scandinavia and are thus in focus for conservation in Sweden (Lindborg et al., 2005). According to Cousins et al., 2015, ninety-six percent of semi-natural grassland area from their study area, located in Sweden, have turned into forest during the 20th century (Cousins et al., 2015).

Natural disturbances such as fire and grazing are used to restore grasslands around the world (Fuhlendorf et al., 2009; Vogel et al., 2007). Finding alternative managements for landscapes to maintain the composition of the plant species and the structure of the vegetation that developed under traditional management is one of the goals for many conservationists (Köhler et al., 2004). Fire and grazing have been shown to influence vegetation composition by removing above-ground biomass (Archibald et al., 2005), and are considered independent forces that can alter landscapes (Archibald & Hempson, 2016; Fuhlendorf & Engle, 2004). Fire is part of the natural dynamics in a lot of landscapes. By burning, you can help seeds germinate faster, create areas of low competition, preserve pyrophytes (species dependent on fire) and a strong, unique selection pressure (Nilsson, 2005). You will also create a mosaic of different vegetation patches that can contribute to an increase in species diversity (Fuhlendorf & Engle, 2004; Nilsson, 2005). The areas that have recently been burned and heavily grazed are the most diverse in terms of structure and composition (Fuhlendorf & Engle, 2004). Fire may be either a negative or a positive disturbance, partly depending on its size and if it is under control (Granström, n. d.). In contrast to a wildfire, a controlled fire is a tool to preserve the species and structures that are dependent on fire without causing damage (Nilsson, 2005). The treatment must be recurrent, because if there is no burning for 2-3 years the vegetation returns to its pre-fire state (Fuhlendorf & Engle, 2004).

The composition of the vegetation after a fire will be determined by the intensity of the fire, by the depth that it penetrated into the soil and if it left viable roots or seeds (Nilsson, 2005). Species that show a certain response to land use changes that cause disturbances can be used as indicator species. If you are able to identify these species, you can estimate the success of restoration measures (Lindborg et al., 2005). Three of the vascular plants that was used for this study are Cowslip (*Primula veris*), Devil's bit scabious (*Succisa pratensis)* and Ox-eye daisy (*Leucanthemum vulgare*). They are considered to be good indicators of general diversity (Rosqvist, 2003). The other two species that are included in this study is Spring whitlow- mustard (*Draba verna)* and Knapwort harshweed (*Centaurea jacea*). Grazing and burning can affect the dispersal of the plant and therefore also biodiversity in landscapes where these plants grow if flowers and fruits are destroyed. The ability to flower and produce seeds despite burning and grazing is important to grassland species if they shall thrive. Otherwise, they have to spread by vegetative reproduction (e.g. roots) or not spread at all.

The ecological interaction of fire and grazing is sometimes called pyric herbivory, which means that that grazing depends on fire and influences future patterns of fire (Fuhlendorf et al., 2009) and although they are fundamentally different, grazing being a biological process and fire a physical one, these two disturbances can control vegetation and also be controlled by it. Other similarities are that they are both amenable to human manipulation (Archibald & Hempson, 2016) and according to Archibald et al., 2005, these two factors are connected by the so called “magnet effect”. The “magnet effect” means that animals will choose to graze the areas that has recently been burnt. Most grazers or browsers prefer to eat from the burnt areas since they contain new and fresh vegetation (Archibald et al., 2005). Grazing animals spend more than 70% of their grazing time in the burned areas (Fuhlendorf & Engle, 2004). This behavior creates landscapes with different kinds of vegetation, which is important for biodiversity (Archibald et al., 2005; Bakker et al., 2015), when herbivores are allowed to graze freely from the burned and unburned parts of the landscape (Archibald et al., 2005). One difference between fire and grazing is that fires consume a range of fuel types and are not selective in the way that grazing is. This gives a profound impact on the ecosystems that is affected by both disturbances (Bond & Keeley, 2005).

Burning and grazing can with their common “magnet effect” be very useful during restorations. Restoration is an intentional activity where you want to initiate or speed up the recovery of an ecosystem with respect to its health, integrity, and sustainability. The goal is to get the ecosystem back to its historic condition, but an ecosystem that is considered for restoration will not necessarily be recovered to its former state. Burning and grazing are both natural disturbances that can be useful during restorations (SER, 2004) and their effect on the vegetation have been the main focus in this study.

Current study and aim

The fieldwork for this study was conducted in the “Ecopark” that is a part of the animal park called Nordens Ark in Bohuslän, Sweden. The “Ecopark” consists of pastures that was restored from being production forest. This project concerning the effects of burning and grazing started in 2015. Burning was practiced from 2015 to 2020. Grazing also started 2015 and is still ongoing. The staff at Nordens Ark burned the areas that was used for this study, which were grazed by cows. During June 2022, we fenced half of the project areas in the “Ecopark” that have been grazed from 2015 until present. The aim of this study is to find out if these treatments of grazing, burning or a combination of both treatments improve these plants’ spread and survival.

Method

Background

The collection of data for this study have been carried out in pastures that was previously used as production forests. They are located in the Ecopark at Nordens Ark in Sweden. The ongoing projects that take place in the Ecopark have been active since 2015. The project I am taking part in concerns the vascular plants that was sown in the pastures in 2016 and 2017. During 2020 inventory was made by Mats Niklasson (scientific leader at Nordens Ark) to document the spread, flowering, other vegetation cover and shading of these plants. I performed the same type of inventory during the late spring and summer of 2022 and used the data collected for this study.

The ”big- and flower plots”

The “big plots”

In the field, I collected data from various so-called "big plots" containing “flower plots”. The “big plots” are fenced and non-fenced areas in 4 different pastures (see Amsten et al., 2021 for more detail). There are a total of 24 plots, 6 in each pasture. These plots are spread out, 2-100 meters apart. Each big plot is 14x14 m and is divided into four squares of 7x7 m (fig. 1 & 2) with two "flower plots" in each square. These four squares are:

- Control square - no grazing or burning - fenced
- Burnt square - burning but no grazing - fenced
- Grazed square - grazing but no burning - not fenced
- Burnt and grazed square - burning and grazing - not fenced

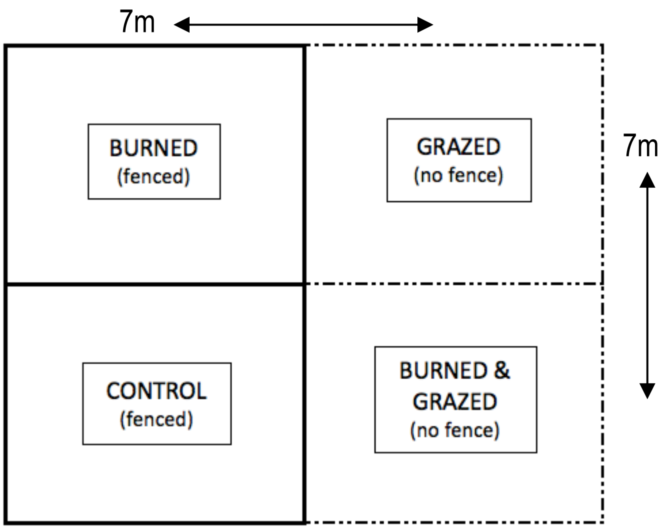


Figure 1. Grazing and burning experiments in grassland. The four squares in a plot. Each square is 7x7m and a plot is a total of 196 square meters in area. Each square has been treated differently; burned, grazed, controlled, and burned and grazed. Two of the squares are fenced, burned and control, and two are not fenced, grazed, and burned and grazed. The solid lines are fence and the dashed lines is no fence. The closed squares are always situated in the same way as in this figure. The unfenced can sometimes be situated in other ways (due to inaccessible terrain), but always in contact with the fenced squares.

Figure 2. Grazing and burning experiments in natural grassland. A "plot". This is the fenced part. The non-fenced part is located in different locations around the fenced area.

The "flower plots"

The "flower plots" consists of 12 small squares (15x15cm) that contains 5 squares that have been sown with 5 different plant species (fig. 3). Each square in the "big plots" contains two "flower plots", one that was sown 2016 and one 2017 (fig. 4). During the late spring of 2022 we fenced the "flower plots" that have been grazed since 2015. This was done to see the how the years of grazing have affected the sown plants when you let them not be grazed for a season.

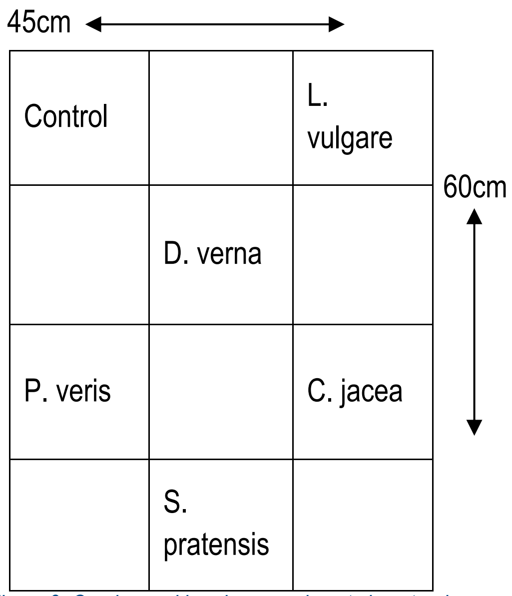


Figure 3. Grazing and burning experiments in natural grassland. The template for the 5 different species of plants which were sown in the "flower plots". The control square contains no seeds.

Figure 4. Grazing and burning experiments in natural grassland. One of the now fenced burned and grazed squares (was not fenced before). The two small poles indicate where the plot from 2016 and 2017 are located.

The vascular plants

Primula veris is a long-lived perennial herb that blooms from April to May (Lehtilä et al., 2006; Brys & Jacquemyn, 2009) and is mainly pollinated by bumblebees (Holzschu et al., 2011). It is a species which can grow in a large range of habitats i.e. it is native to meadows, grasslands, pastures and various forest successions, from quite open woodlands to closed canopies (Lehtilä et al., 2006) in most of Europe. It can form large and conspicuous populations with high densities, if the conditions are satisfactory. Human activity is one of the major biotic factors that promote the survival or loss of P. veris. When shrubs and canopy that could otherwise shade the plants are removed by grazing and mowing, populations will grow (Brys & Jacquemyn, 2009).

Leucanthemum vulgare is a short-lived perennial forb native to Europe that blooms from May to August (Janzon, 2021; Suttle, 2003), and is considered invasive in other places, such as in the USA (Ahmad et al., 2019; Suttle, 2003). It is commonly found in drier grasslands, meadows, pastures and road edges (Howarth & Williams, 1968; Janzon, 2021). It used to have a viable and strong population in Sweden, but since the open landscapes where they thrived have decreased in extent because of changed land use, the species are not as common as they used to be (Janzon, 2021).

Centaurea jacea is a perennial herb native to Europe that blooms from July to August and is typically found in meadows and grasslands (Albrecht, 2009; Bucharova, 2016). They have a good supply of nectar. Multiple studies say that they are among the most popular plant for multiple insects for nectar collection (Kolkman, 2021; Ouvrard et al., 2018).

Succisa pratensis is a herbaceous, long-lived perennial plant that blooms from August to September (Vergeer et al., 2003). In Sweden, it is most commonly found in dry to wet semi-natural grasslands. It is a typical representative of rare grassland species in agricultural landscapes in southern Sweden

(Munzbergova, 2005). *S. pratensis* is vulnerable to habitat deterioration (Vergeer et al., 2003) and intensive grazing regimes (Buhler, 2001), but according to Munzbergova, 2005, *S. pratensis* can also benefit from grazing, if it is under control and not to intense.

Draba verna is a small annual plant from Europe that blooms from April to May and have naturalized in various parts of the USA. It is usually found in disturbed habitats such as fields and roadsides and has a low ability to compete against other plants for survival. The seeds of the *D. verna* germinate very little or not at all in constant darkness, but they will germinate if given a short exposure to light (Baskin & Baskin, 1970).

Collection of data

In every “flower plot” I checked if I could see any rosettes, leaves, or flowers belonging to the sown plants. I counted how many plants they were of each species, and if they had been grazed or had any flowers or buds. I counted each rosette as one plant. The shading coverage from e.g. bushes and trees where written down in the percentage of coverage on the “flower plots”.

All the field data was put in an Excel file and later analyzed in the statistics program SPSS to determine if there were any significant differences in the data.

Analysis

I used the statistics program SPSS to analyze my results. My data were not normally distributed according to the Kolmogorov-Smirnov test. I still chose to use ANOVA, which is a parametric test, since it is allowed when the N-value is large enough, according to the central limit theorem. Also, there was no significant heteroskedasticity for any factor (appendix 2, tab. 4 & 5), I analyzed my data by using ANOVA and Tukey’s post hoc test, to find out if there were significant differences between

- plots sown in the years 2016 and 2017
- the four treatments, i.e. fenced or non-fenced, burnt and grazed (BG) and grazed (G), burned (B) and control (C)
- the plant species
- fenced and non-fenced “flower plots”

This was done with regard to the number of species, flowers and buds, stalks with flowers and buds, highest flower, eaten flowers and the shade coverage of the “flower plot”.
Fenced and non-fenced BG and G plots was grouped together when comparing them to Control and Burned to see if there was a difference from the plots that have been fenced for about 7 years (built 2015) compared to the ones that have only been fenced for a few months (built spring of 2022).

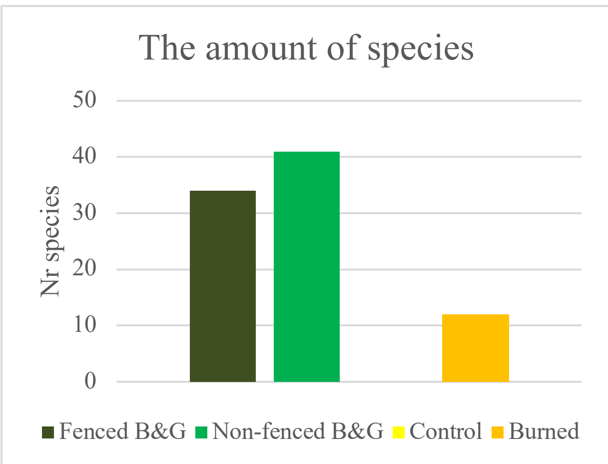
Result

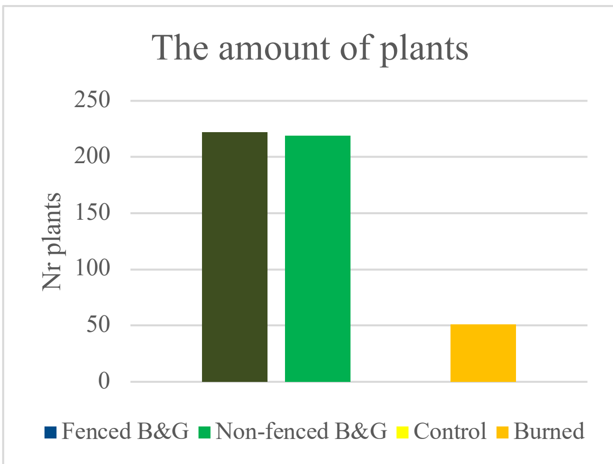
A significant difference was found for the “flower plots” in all four treatments; fenced BG & G, non-fenced BG & G, Control and Burned when it came to the factors of the number of species and plants, stalks with flowers and buds, highest flower, eaten flowers and the shade coverage of the plant (tab. 1. & appendix 2 tab. 6).

*Table 1. Grazing and burning experiments in natural grassland. Analysis of comparing different factors in the “flower plots” between the 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned) by using ANOVA. There is a significant difference (p< .042) between the 4 treatments for the number of species, plants, stalk with flowers, the highest plant with a flower, number of eaten flowers, and the percentage of shading. *Nr species- how many of the 5 species in each “flower plot” / cm – height in centimeters / % - percentage of the amount of shading from other vegetation.*

Factors	F	df	p-value
Nr species* (N tot = 87)	12.591	3	<.001
Nr plants (N tot = 492)	5.555	3	.001
Nr stalks with flowers (N tot = 105)	2.794	3	.042
Height highest flower (N tot = 621cm*)	3.371	3	.020
Eaten flowers (N tot = 32)	3.732	3	.012
Shading (N tot = 6460%*)	50.616	3	<.001

Tukey’s post hoc test (appendix 2 tab .8) showed that the number of species, plants, stalks with flowers and highest flower in cm was bigger in the fenced and non-fenced BG & G than in the control and burned area (p< .022). Shading from other vegetation in percentage was highest in the control plots (p< .001) and the most amount of eaten flowers was in the non-fenced BG & G plots (p< .010). All the factors had N=0 in the control plots except for the shading (N=3690) (fig. 5-10).





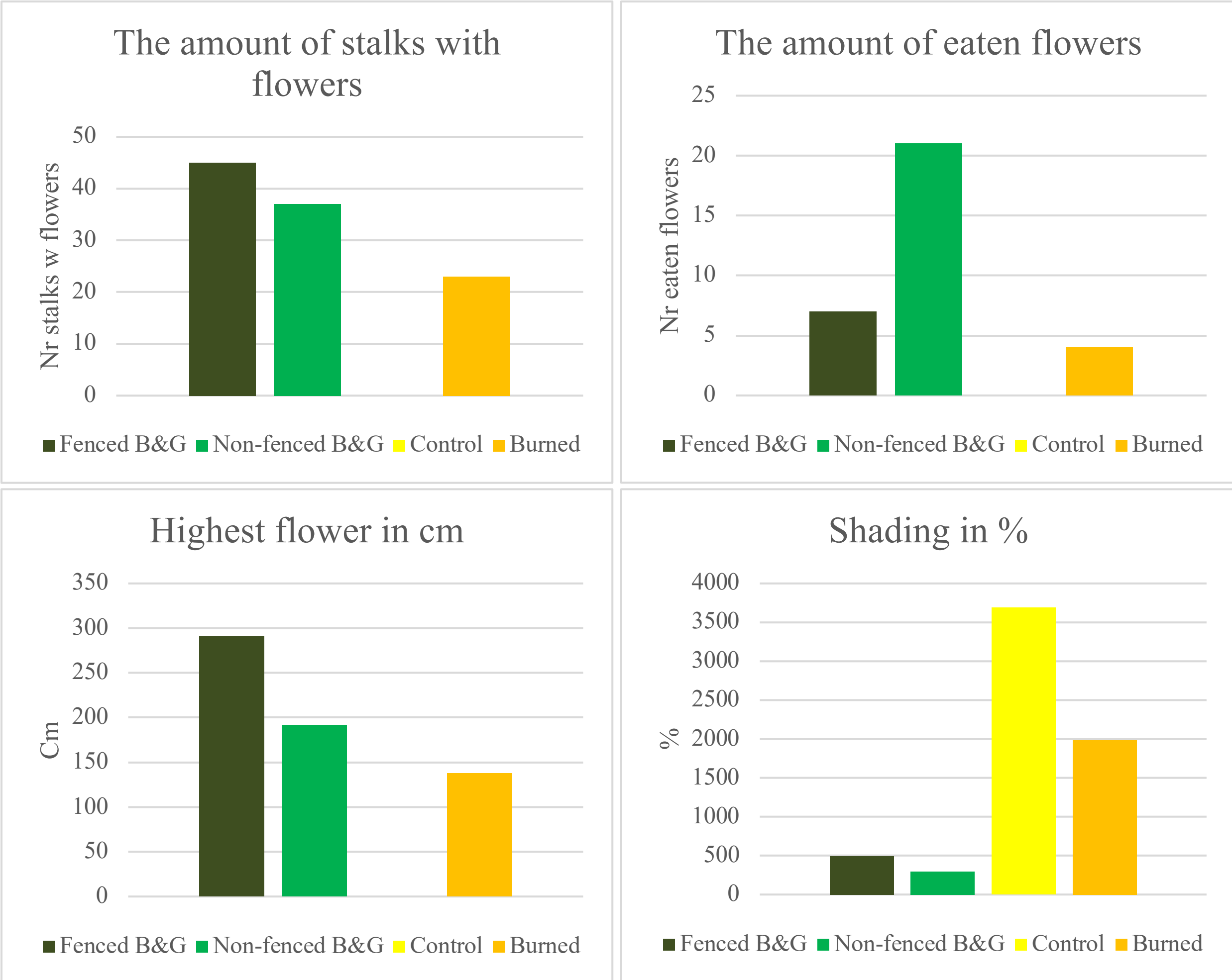


Figure 5-10. Grazing and burning experiments in natural grassland. The number of species and plants, stalks with flowers and buds, highest flower, eaten flowers and the shade coverage of the plant in the 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned). The control treatment was N=0 in all factors except for the shading.

The 4 treatments showed no significant difference for the species *Draba verna* (N=0) and *Primula veris*. For the species *Leucanthemum vulgare, Centaurea jacea* and *Succisa pratensis* there was a significant difference (p< 0.05) in the amount of species in the treatments (tab. 2 & appendix 2 tab. 7).

Table 2. Grazing and burning experiments in natural grassland. Analysis of comparing the amount of each plant species in the "flower plots" between the 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned) by using ANOVA. There is a significant difference (p< .05) between the 4 treatments for the number plants of Leucanthemum vulgare, Centaurea jacea and Succisa pratensis. There was no significant difference (p>.05) for Draba verna and Primula veris.

Species	F	df	p-value
Draba verna (N tot = 0)	-	3	-
Primula veris (N tot = 4)	1.000	3	.394
Leucanthemum vulgare (N tot = 188)	2.657	3	.050
Centaurea jacea (N tot = 149)	5.710	3	<.001
Succisa pratensis (N tot = 154)	5.544	3	.001

Tukey's post hoc test (appendix 2 tab .9) showed that there was no significant difference for *Draba verna, Primula veris* and *Leucanthemum vulgare.* As for *Centaurea jacea* and *Succisa pratensis,* the biggest amount of plants were recorded in the non-fenced BG & G plots ($p < .029$). All species had N=0 in all the control plots (fig. 11-14).

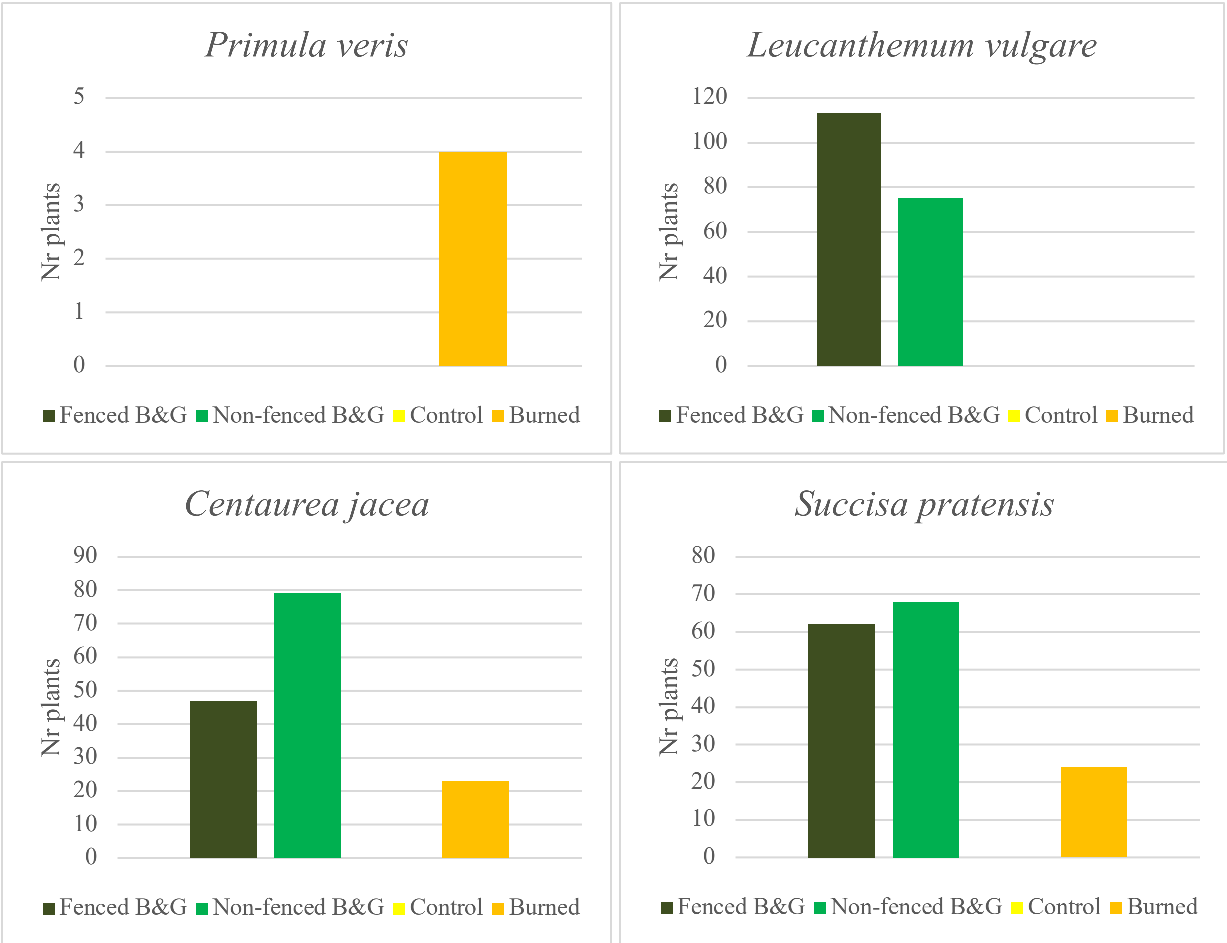


Figure 11-14. Grazing and burning experiments in natural grassland. The number of plants of Primula veris, Leucanthemum vulgare, Centaurea jacea and Succisa pratensis in the 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned). The control treatment was N=0 for all species

No significant difference was found when comparing the "flower plots" built 2016 and 2017 with the "flower plots" when comparing both the species and all the factors ($p > 0.05$).

Discussion

The amount of shading from other vegetation differed significantly between the fenced and non-fenced BG and G plots from both years and to the burned and control plots. Most shading occurred in the control plots, and the least in the non-fenced BG and G plots. There were more species, plants, stalks with flowers and buds and highest flower in the fenced and non-fenced BG & G plots. The amount of flowers that had been eaten and the number of plants of *Centaurea jacea* and *Succisa pratensis* was highest in the non-fenced BG & G plots. *Leucanthemum vulgare, Draba verna* and *Primula veris* showed no significant difference in all 4 treatments; fenced BG & G, non-fenced BG & G, C and B.

Conservationists are mostly trained to analyze and focus on the plants, climate, and soil interactions and to not take into consideration how predation can affect the vegetation structure and diversity. Consumers (herbivores) and resources (e.g. soil, climate) are usually the main reasons behind the composition of the vegetation. Therefore, it is important to find out which one is the main driver for the structure of the landscape to be able to know how to affect and change it properly. Ecosystems that are mostly consumer-controlled should show considerable changes if the consumers are removed (Bond, 2005), but this does not relate to all ecosystems. Every landscape does not consist of the same vegetation or have the same conditions. Tallgrass prairies is one type of landscapes that are often insensitive to changes in fire and grazing intensity. The composition and diversity of the plant community in the prairies do not show a great difference between management strategies. They are more affected by the change in climate and soil, and patch burning will probably not make a great difference on plant diversity (McGlinn and Palmer, 2019). Climate can set limits to plant growth when the vegetation is dependent on temperature and moisture (Bond, 2005).

When planning a restoration project you need to have clearly stated goals from the beginning set from the conditions of the area you are trying to restore. To be able to conserve and restore biodiversity it is important that conservationist gain enough insight into the processes that is maintaining the variations in vegetation structure (Olff et al., 1999). The goals can be ideals that you try to reach, and you can use different objectives that are concrete solutions for the issues the project is facing (SER, 2004). To reach your conservation goals the one way is to remove all disturbances. Although this approach work with some landscapes or smaller refugees it can result in an important loss of heterogeneity, which is a key factor for biodiversity (Fuhlendorf & Engle 2004). Pyric herbivory is a process that has been used for maintaining the vegetation structure, and similar methods to study the fire-grazing effect have been used in other studies, such as Vogel et al., 2007, where the study area was divided into units based on the restoration practices (burned, grazed or burned and grazed) and while my study and others that have been executed in the same way it can show long-term ecological processes, the results may be difficult to interpret. Using a common species in my study, e.g. *Primula veris*, can be of great help during fieldwork, because it will be more easy to detect and monitor (Lindborg et al., 2005).

Grazing

The appropriate choice of grazing animals, cattle and/or wild herbivores that will graze in a field or pasture can be made according to their feeding habits. If the herbivores in a field are dominated by specialists which each selectively feed on certain plant species, this will give another effect on the diversity on the vegetation when compared to if it was dominated by generalists that compete for the same food resource. Having a mix of generalists and specialists will therefore give a greater net resource utilization of the vegetation (Bardgett & Wardle, 2003). Tree coverage or shading from bushes (i.e. raspberry, blackberries) can also be a factor that plays a big role in generating diversity. Some plant species are sensitive to shading and need a lot of light to be able to grow. Herbivores can control the vegetation and depending on if they are grazers or browsers, they can either increase or decrease the amount of shading that comes from tarees and bushes. According to Archibald & Hempson, 2016, grazers (e.g. cows) will increase the tree cover and browsers (e.g. deer) will decrease the coverage. This is because of their dietary preferences; cows mostly consume low growing vegetation e.g. grass, while deer’s prefer both higher vegetation e.g. tress and lower (Archibald & Hempson, 2016). This can be the general idea of how herbivores work, but according to my study where cows (grazers) were the main herbivores, the shading coverage would still have a significant decrease. Wild browsers were present in the area, but the main consumers were domestic cattle. The non-fenced BG & G plots had the least amount of shade coverage, while control had the highest. When starting a restoration project it is important to have an idea of what kind of result you want. Planning to let wildlife be the only consumers or introduce domestic cattle to the landscape is a choice which depends on what your goal with the restoration is. Should everything be grazed or do you still want to keep some of the plants that are unpalatable to some herbivores, and do you want high or low shade coverage? By using domestic cattle as surrogates for wild herbivores for pyric herbivory and agricultural production you can still enhance biodiversity without wildlife according to Fuhlendorf & Engle 2004 and Fuhlendorf et al. 2006.

Fire

Fire is unique and has a fundamental importance as a structure-shaping factor in the landscape and can only be partially replaced by other restoration methods (Nilsson, 2005). We could still keep the fire's influence by prescribing burning in order to restore land that have been degraded due to the lack of disturbances (Bernes et., 2015). When using fire as a management method it is important to have prior knowledge of how fire can behave in order to be able to use it in a safe and sustainable way (Davies et al. 2009). Due to the presence of herbs and grass, the moisturize levels in the vegetation is higher during summer than during spring, when the grasslands often are dry. Hence, the risk that fires should spread is lowest during summer (Granström, n. d.). Climate change could increase the number and the size of fires (Niklasson & Granström, 2000). It is necessary to know the behavior of the fire to prevent it from spreading or to ignite the soil (Davies et al. 2009). Plants also need a way to be able to recolonize a burnt area, there are four common strategies; root- and stub shoots, by seeds that have been resting in the ground and get activated by the fire, regrowth from the ground in buried rhizome and by seeds spreading to the burnt ground (Nilsson, 2005).

Fire and grazing

Fire have barely been considered as an alternate consumer of vegetation in the ecological literature even though it consumes large amounts of plant material and thrives on the features that makes plants inedible to herbivores, i.e., when they are high in lignine and cellulose and low in nitrogen. Indigestible plants therefore fuel the fires during burning and the fire consumes vegetation irrespective of quality, whereas grazing animal are more selective (Bond, 2005). It is important to consider the difference between fire and herbivory when a restoration project is planned. A fire's intensity, size and type varies depending on the conditions of the landscape and the same goes for the behavior of the herbivores in terms of forage (Archibald & Hempson, 2016).

When disturbances are created, the feedback can be divided in to two categories, positive or negative feedback. Positive feedback is when grazers eat from recently burned areas, and negative feedback occurs when the probability of fire is reduced on recently grazed areas. When grazers and fire interact, interaction creates different levels of disturbance intensity across the landscape. (Fuhlendorf & Engle 2004). The previous knowledge about fire and grazing have been acquired through experimental studies where the treatments are applied to small and homogenous experimental units. This can give an unnatural view of how fire and grazing works (Fuhlendorf et al., 2009). Understanding heterogeneity is critical for conservation to be successful and bigger studies can be a great start (Fuhlendorf & Engle 2004).

The fire-grazing method (i.e. pyric herbivory) is proven to be useful for grassland management (Fuhlendorf & Engle, 2004) but you need to take in to consideration that this methods extent and impact varies greatly depending on the ecosystem (Archibald & Hempson, 2016) since climate or soil could also have an influence on the vegetation (Köhler et al., 2004). Bare ground can be much more prominent on sites that are only burned, compared to the ones that include grazing (Vogel et al., 2007). By using both fire and grazing you can alter landscapes by changing grazers foraging patterns (Archibald et al., 2005). This can be done by using small and controlled patches of fire on the grassland which can create patch-selective grazing by herbivores (Fuhlendorf & Engle, 2004). Grazers can also affect fire intensity by reducing the fuel loads and preventing shrub encroachment (Roques et al., 2001) and therefore alter the fire's spread in a landscape (Archibald et al., 2005). Thus, a combination of fire and grazing promotes a shifting mosaic across the landscape. This mosaic is the basis of the biodiversity that is needed. Fire and grazing can have negative, positive or no effect on the native species so to be able to restore diverse communities it requires a varied landscape sculpted by different disturbances (such as fire and grazing) (Fuhlendorf & Engle, 2004). Pyric herbivory may also contribute to greater diet stability for the grazers. By burning different areas, you will provide high-quality and high-nitrogen forage (Fuhlendorf & Engle 2004). But if the burned patches are small and the grazing pressure is heavy, the growing vegetation will most likely be consumed and this will create poor species variety among the plants. Large, burned areas with low grazing pressure, will create grazing lawns within the burned patch, since the vegetation will then outgrow the animal's ability to forage the entire burned area. This is important to take into consideration as conservation areas and preserves are small areas in a fragmented landscape. These kinds of situations may require other kind of strategies as these areas will most likely respond in a different way compared to larger landscapes (Fuhlendorf et al., 2009). The Ecopark, where my inventory was performed, consists of large pastures with a low to medium grazing pressure since there was cattle in the pastures every other week. The burned patches that was also grazed had high amount of species and plants. Therefore it seems that there was a good amount of pressure from both burning and grazing that resulted in more diversity and more plants.

Plant species

According to Olff et al., 1999, the key processes that needs to be understood in grazed landscapes are what strategies plants have as to cope with herbivores and their selectivity, and how much light the plants require (Olff et al., 1999). When grazing cattle are allowed to roam the pastures freely, plants are usually in a better condition and are bigger than when the cattle graze continuously. This is because the grazing pressure will be lower, compared to if they were contained in a network of small paddocks and rotated around these. In the bigger pastures with lower grassing pressure, the plants are allowed to grow larger since the grass surrounding the plants will be in a better condition, higher and more tasteful, and therefore, the herbivores will choose to consume them over the plants (Goodenough & Sharp, 2016). The pastures that were used in this study are big areas where the cattle were moved every other week, so grazing is absent from these pastures during certain periods of time. This will give a low grazing pressure that should be positive for the plants according to Goodenough & Sharp, 2016 and this theory fits the results that my study showed; there were more flowers, plant species, stalks with flowers, higher plant (with flower) and less shading in the fenced and non-fenced plots compared to the Burned (B) and Control (C) areas that was not exposed to grazing.

Burning and grazing showed no significant effect on the amount of *Draba verna* and *Primula veris*, but this can have been affected by the fact that no *D. verna* and only four *P. veris* was found during the fieldwork. *D.*

verna and *P. veris* have an early blooming season (April-May) and can therefore already have been grazed before the fencing and inventory was performed. *Centaurea jacea* and *Succisa pratensis* differed in abundance between the four treatments (BG, G, C and B). The species was represented by the highest amount of rosettes in Burned and Grazed areas (N= 444) (fenced and no-fenced BG & G), and lowest in the Control plots (N= 0). They are also the species in this study that have a later and longer blooming season (May-September) compared to *D. verna* and *P. veris*, so they have an advantage of being able to be found more easily during the inventory ,and was also protected by the fencing before their blooming started.

When plants produce fewer flowers or rosettes than before, it is a good, first indication that there might be a declining survival of the species. A loss of plants can be a delayed response to dominant disadvantageous conditions (Endels et al., 2004). According to Endels et al., 2004, shading from canopy can be one of those conditions that affect the flowers development negatively. Studies on *Primula veris* have shown that by applying grazing early in the growing season, plants will be prevented from developing flowers for the current season and future ones. *P. veris* usually flowers during April to May and if the flowering stalks gets eaten or are damaged they cannot compensate this by producing compensatory flowers or fruits. This will lead to a lower production of seeds and therefore fewer new individuals. Since the fencing of the “flower plots” was constructed after their blooming season they could already have been grazed by the cattle before they were protected. The inventory was also performed during July to August so finding *P. veris* in the field would have been very unlikely. However according to Brys et al., 2004, if grazing is applied in early July (the later part of the growing season), the size of the population increases. The growth rate of *P. veris* populations is mostly affected by the probability that the adult plants will start flowering. By not managing the areas where these plants grow, there will be a lower chance for adult plants to develop flowering potential. *P. veris* will struggle to survive if they are not treated with managed disturbances (Brys et al., 2004). According to Brys & Jacquemyn, 2009, studies have shown that *P. veris* does not perform well under shade and from competition by other plants. This can be controlled by using grazing cattle, but if the grazing gets too intense and occurs during the growing season the chance of reproductive tissue and the plants being able to flower will decrease (Brys & Jacquemyn, 2009). For an efficient conservation management, you therefore need to have a good idea of the amount of pressure you can put on the plants when it comes to e.g. grazing and burning (Lehtilä et al., 2006). Population size can also be an important factor to consider as *Succisa pratensis* can react differently to stress depending of the size of their population. Small, inbred populations do not react the same way compared to large populations with lower levels of inbreeding when exposed to unfavorable habitat conditions. The populations in this study are likely counted as small and inbred. To be able to create long-lasting and successful restorations of all populations, a combination of management methods for restoration are required, also to prevent genetic erosion (Vergeer et al., 2003).

The result from the fieldwork shows that the “flower plots” built 2016 and 2017 did not differ significantly when comparing the two years for all the factors for all treatments. When looking at the newly fenced BG & G plots and the non-fenced ones, there was a difference between the two kinds when it came to the amount of flowers that where eaten. There were three times as much eaten flowers in the non-fenced BG & G plots compared to the fenced ones. This shows that the new fencing that was built in the spring did give an effect; a difference to unfenced areas. The fence was able to withstand cows from grazing in most of these fenced “flower plots”. The rest of the factors had no significant effect. Notably, the number of plants and stalks with flowers were therefore the same even though half of them where fenced.

Conclusion

As said before, fire and grazing work well together. Ecologists would benefit from using these methods together more often. High cellulose and lignin content make plants inedible for herbivores but work as a great fuel for fire while edible plants can make fires decrease (Bond, 2005). According to Bond, 2005, the interaction between fire and herbivory have been given remarkably little attention to be able to use as shapers of vegetation and landscapes. He claims that an experiment like this is useful to show the importance of these consumers, i.e. fire and grazing, and how they can be used. According to Amsten et al., 2021, fire and grazing are important plant consumers that are in control of temperate environments such as Bohuslän, where the study was performed. They state that these kind of disturbances are absent as natural processes in large parts of Europe. The results of the present study show, that without grazing or burning, woody biomass would take over the area and shade the ground underneath. Hence, control by these consumers must be considered during restoration or management.

The aim of this study was to investigate the effects of management on the vegetation and different plant species. However, the interactions that happens between burning and grazing are often hard to study because they occur on such large scales. Therefore, you will only get a simplified understanding of these methods and the interactions between them when you perform this kind of study. Even if the results are simplified, I think that they can be very useful when influencing landscapes. They can guide you in the right direction, so that you can reach the goal you have with your restoration and also tell what method that will not give a good result, thereby minimizing the workload. For the pastures that that have been exposed to different treatments in the Ecopark at Nordens Ark, I conclude that using burning and grazing by burning patches during spring each year and having grazing cattle every other week, will give the most diversity and quantity for most flowering plants.

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Appendix 1: Popular science summary

How does grazing and burning affect the occurrence and development of vascular plants?

Felicia Ivarsson

Grazing and burning are two natural disturbances that can be used as methods for restoring landscapes that have been damaged, either by man or by nature. In this study I have put my focus on how these two disturbances effect 5 different flower species. Does these flowers flourish from these disturbances or is it better to just let them be?

Grazing and burning are two different methods that can be used to influence the landscape in a positive way - increasing biodiversity. They often affect the composition of the vegetation and how well species can recolonize in the landscape. When restoring landscapes (conservation), which involves assisting ecosystems so that they can recover to their original appearance and composition, grazing and burning can be a great help.

You can see the cooperation between burning and grazing when the fire spreads in the landscape and the herbivores choose to graze the areas that have recently been burned. This creates landscapes with different kinds of vegetation, which is important for biodiversity, and arise from herbivores being allowed to graze freely from the burned and unburned parts of the landscape.

Cowslip (Primula veris)

Spring whitlow-mustard (Draba verna)

Knapwort harshweed (*Centaurea jacea)*

Devil's bit scabious (*Succisa pratensis)*

Ox-eye daisy (Leucanthemum vulgare)

Vascular plants

The vascular plants used for my study is Cowslip, Spring whitlow-mustard, Knapwort harshweed, Devil's bit scabious and Ox-eye daisy. These plants will flower, which is important. Otherwise, there will be no dispersal through seeds, and the only option is vegetative reproduction (e.g. roots) or no spread at all.

Burning can affect these plants by either making it easier for them to spread and grow, or it will inhibit it. Grazing and browsing animals can eat the plants down to the ground or just eat the flowers. Therefore we must know the actual outcome of these actions.

This study is a part of an ongoing doctoral project at Nordens Ark (started 2015) and is conducted together with multiple partners, e.g. SLU. The fieldwork is done in the Ecopark of Nordens Ark. The

Ecopark consists of pastures that was restored from being production forest. We burn the areas that is used for the study and the animals that are grazing the areas are cows and other wildlife.

Something you have to consider in this study is that the interactions that happens between burning and grazing are often hard to study because they occur on such large scales. Therefore, you will only get a simplified understanding of these methods and the interactions between them when you perform this kind of study. Even if the results are simplified, I think that they can be very useful when influencing landscapes. They can guide you in the right direction, so that you can reach the goal you have with your restoration and also tell if a method won’t give a better result and thereby minimizing the workload.

Appendix 2: Tables

Homogeneous subsets

Table 4. Grazing and burning experiments in natural grassland. Results from the analysis of the homogeneous subsets for Centaurea jacea, Succisa pratensisin, Primula veris and Leucanthemum vulgare for all 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned). No analysis was made for Draba verna since N=0.

Centaurea

Tukey HSD[a]

		Subset for alpha = 0.05	
treatment	N	1	2
3	48	.00	
4	48	.48	
1	48	.98	.98
2	48		1.65
Sig.		.091	.381

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

Succisa

Tukey HSD[a]

		Subset for alpha = 0.05	
treatment	N	1	2
3	48	.00	
4	48	.50	.50
1	48		1.29
2	48		1.42
Sig.		.602	.108

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

Primula

Tukey HSD[a]

		Subset for alpha = 0.05
treatment	N	1
1	48	.00
2	48	.00
3	48	.00
4	48	.08
Sig.		.492

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

Leuc.

Tukey HSD[a]

		Subset for alpha = 0.05
treatment	N	1
3	48	.00
4	48	.00
2	48	1.56
1	48	2.35
Sig.		.100

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

Homogeneous subsets

Table 5. Grazing and burning experiments in natural grassland. Results from the analysis of the homogeneous subsets for the number of species, stalk with flowers, plants (nr flowers), the highest plant with a flower, the percentage of shading, and the number of eaten flowers in all 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned).

nr species

Tukey HSD[a]

treatment	N	Subset for alpha = 0.05: 1	2
3	48	.00	
4	48	.25	
1	48		.71
2	48		.85
Sig.		.392	.793

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

nr stalk w flowers

Tukey HSD[a]

treatment	N	Subset for alpha = 0.05: 1	2
3	48	.00	
4	48	.48	.48
2	48	.77	.77
1	48		.94
Sig.		.122	.552

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

nr flowers

Tukey HSD[a]

treatment	N	Subset for alpha = 0.05: 1	2
3	48	.00	
4	48	1.06	1.06
2	48		4.56
1	48		4.63
Sig.		.880	.065

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

height highest flower

Tukey HSD[a]

treatment	N	Subset for alpha = 0.05: 1	2
3	48	.00	
4	48	2.88	2.88
2	48	4.00	4.00
1	48		6.06
Sig.		.172	.360

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

forest (%)

Tukey HSD[a]

treatment	N	Subset for alpha = 0.05: 1	2	3
2	48	6.15		
1	48	10.31		
4	48		41.25	
3	48			76.88
Sig.		.919	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

nr eaten flowers (stumps)

Tukey HSD[a]

treatment	N	Subset for alpha = 0.05: 1	2
3	48	.00	
4	48	.08	.08
1	48	.15	.15
2	48		.44
Sig.		.722	.057

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 48.000.

ANOVA

Table 6. Grazing and burning experiments in natural grassland. Results from the ANOVA for the number of species, plants (nr flowers), stalk with flowers, the highest plant with a flower, number of eaten flowers, and the percentage of shading in all 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned).

		Sum of Squares	df	Mean Square	F	Sig.
nr species	Between Groups	22.682	3	7.561	12.591	<.001
	Within Groups	112.896	188	.601		
	Total	135.578	191			
nr flowers	Between Groups	819.375	3	273.125	5.555	.001
	Within Groups	9243.875	188	49.170		
	Total	10063.250	191			
nr stalk w flowers	Between Groups	24.307	3	8.102	2.794	.042
	Within Groups	545.271	188	2.900		
	Total	569.578	191			
height highest flower	Between Groups	920.391	3	306.797	3.371	.020
	Within Groups	17108.063	188	91.000		
	Total	18028.453	191			
nr eaten flowers (stumps)	Between Groups	5.208	3	1.736	3.732	.012
	Within Groups	87.458	188	.465		
	Total	92.667	191			
forest (%)	Between Groups	154909.375	3	51636.458	50.616	<.001
	Within Groups	191788.542	188	1020.152		
	Total	346697.917	191			

ANOVA

Table 7. Grazing and burning experiments in natural grassland. Results from the ANOVA for Primula veris, Leucanthemum vulgare, Centaurea jacea and Succisa pratensisin all 4 treatments (fenced BG & G, non-fenced BG & G, Control and Burned).

		Sum of Squares	df	Mean Square	F	Sig.
Draba	Between Groups	.000	3	.000	.	.
	Within Groups	.000	188	.000		
	Total	.000	191			
Primula	Between Groups	.250	3	.083	1.000	.394
	Within Groups	15.667	188	.083		
	Total	15.917	191			
Leuc.	Between Groups	199.125	3	66.375	2.657	.050
	Within Groups	4696.792	188	24.983		
	Total	4895.917	191			
Centaurea	Between Groups	71.432	3	23.811	5.710	<.001
	Within Groups	783.937	188	4.170		
	Total	855.370	191			
Succisa	Between Groups	64.896	3	21.632	5.544	.001
	Within Groups	733.583	188	3.902		
	Total	798.479	191			

Tukey's post hoc

Table 8. Grazing and burning experiments in natural grassland. Tukey's post hoc results for number of species, plants (nr flowers), stalk with flowers, the highest plant with a flower, number of eaten flowers, and the percentage of shading in all 4 treatments (1- fenced BG & G, 2- non-fenced BG & G, 3- Control and 4- Burned).

Dependent Variable	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
nr species	1	2	-.146	.158	.793	-.56	.26
		3	.708*	.158	<.001	.30	1.12
		4	.458*	.158	.022	.05	.87
	2	1	.146	.158	.793	-.26	.56
		3	.854*	.158	<.001	.44	1.26
		4	.604*	.158	.001	.19	1.01
	3	1	-.708*	.158	<.001	-1.12	-.30
		2	-.854*	.158	<.001	-1.26	-.44
		4	-.250	.158	.392	-.66	.16
	4	1	-.458*	.158	.022	-.87	-.05
		2	-.604*	.158	.001	-1.01	-.19
		3	.250	.158	.392	-.16	.66
nr flowers	1	2	.063	1.431	1.000	-3.65	3.77
		3	4.625*	1.431	.008	.91	8.34
		4	3.563	1.431	.065	-.15	7.27
	2	1	-.062	1.431	1.000	-3.77	3.65
		3	4.563*	1.431	.009	.85	8.27
		4	3.500	1.431	.072	-.21	7.21
	3	1	-4.625*	1.431	.008	-8.34	-.91
		2	-4.562*	1.431	.009	-8.27	-.85
		4	-1.062	1.431	.880	-4.77	2.65
	4	1	-3.562	1.431	.065	-7.27	.15
		2	-3.500	1.431	.072	-7.21	.21
		3	1.063	1.431	.880	-2.65	4.77
nr stalk w flowers	1	2	.167	.348	.964	-.73	1.07
		3	.938*	.348	.038	.04	1.84
		4	.458	.348	.552	-.44	1.36
	2	1	-.167	.348	.964	-1.07	.73
		3	.771	.348	.122	-.13	1.67
		4	.292	.348	.836	-.61	1.19
	3	1	-.937*	.348	.038	-1.84	-.04
		2	-.771	.348	.122	-1.67	.13
		4	-.479	.348	.514	-1.38	.42
	4	1	-.458	.348	.552	-1.36	.44
		2	-.292	.348	.836	-1.19	.61
		3	.479	.348	.514	-.42	1.38
height highest flower	1	2	2.063	1.947	.715	-2.99	7.11
		3	6.063*	1.947	.011	1.01	11.11
		4	3.188	1.947	.360	-1.86	8.24
	2	1	-2.062	1.947	.715	-7.11	2.99
		3	4.000	1.947	.172	-1.05	9.05
		4	1.125	1.947	.939	-3.92	6.17
	3	1	-6.062*	1.947	.011	-11.11	-1.01
		2	-4.000	1.947	.172	-9.05	1.05
		4	-2.875	1.947	.454	-7.92	2.17
	4	1	-3.187	1.947	.360	-8.24	1.86
		2	-1.125	1.947	.939	-6.17	3.92
		3	2.875	1.947	.454	-2.17	7.92

Dependent Variable	(I) treatment	(J) treatment	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
nr eaten flowers (stumps)	1	2	-.292	.139	.159	-.65	.07
		3	.146	.139	.722	-.22	.51
		4	.063	.139	.970	-.30	.42
	2	1	.292	.139	.159	-.07	.65
		3	.438*	.139	.010	.08	.80
		4	.354	.139	.057	-.01	.72
	3	1	-.146	.139	.722	-.51	.22
		2	-.437*	.139	.010	-.80	-.08
		4	-.083	.139	.932	-.44	.28
	4	1	-.063	.139	.970	-.42	.30
		2	-.354	.139	.057	-.72	.01
		3	.083	.139	.932	-.28	.44
forest (%)	1	2	4.167	6.520	.919	-12.73	21.07
		3	-66.562*	6.520	<.001	-83.46	-49.66
		4	-30.937*	6.520	<.001	-47.84	-14.04
	2	1	-4.167	6.520	.919	-21.07	12.73
		3	-70.729*	6.520	<.001	-87.63	-53.83
		4	-35.104*	6.520	<.001	-52.00	-18.20
	3	1	66.563*	6.520	<.001	49.66	83.46
		2	70.729*	6.520	<.001	53.83	87.63
		4	35.625*	6.520	<.001	18.72	52.53
	4	1	30.938*	6.520	<.001	14.04	47.84
		2	35.104*	6.520	<.001	18.20	52.00
		3	-35.625*	6.520	<.001	-52.53	-18.72

Tukey's post hoc

Table 9. Grazing and burning experiments in natural grassland. Tukey's post hoc results for Primula veris, Leucanthemum vulgare, Centaurea jacea and Succisa pratensis in all 4 treatments (1- fenced BG & G, 2- non-fenced BG & G, 3- Control and 4- Burned). No post hoc was made for Draba verna since N=0.

Dependent Variable	(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Primula	1	2	.000	.059	1.000	-.15	.15
		3	.000	.059	1.000	-.15	.15
		4	-.083	.059	.492	-.24	.07
	2	1	.000	.059	1.000	-.15	.15
		3	.000	.059	1.000	-.15	.15
		4	-.083	.059	.492	-.24	.07
	3	1	.000	.059	1.000	-.15	.15
		2	.000	.059	1.000	-.15	.15
		4	-.083	.059	.492	-.24	.07
	4	1	.083	.059	.492	-.07	.24
		2	.083	.059	.492	-.07	.24
		3	.083	.059	.492	-.07	.24
Leuc.	1	2	.792	1.020	.865	-1.85	3.44
		3	2.354	1.020	.100	-.29	5.00
		4	2.354	1.020	.100	-.29	5.00
	2	1	-.792	1.020	.865	-3.44	1.85
		3	1.563	1.020	.421	-1.08	4.21
		4	1.563	1.020	.421	-1.08	4.21
	3	1	-2.354	1.020	.100	-5.00	.29
		2	-1.562	1.020	.421	-4.21	1.08
		4	.000	1.020	1.000	-2.64	2.64
	4	1	-2.354	1.020	.100	-5.00	.29
		2	-1.562	1.020	.421	-4.21	1.08
		3	.000	1.020	1.000	-2.64	2.64
Centaurea	1	2	-.667	.417	.381	-1.75	.41
		3	.979	.417	.091	-.10	2.06
		4	.500	.417	.628	-.58	1.58
	2	1	.667	.417	.381	-.41	1.75
		3	1.646*	.417	<.001	.57	2.73
		4	1.167*	.417	.029	.09	2.25
	3	1	-.979	.417	.091	-2.06	.10
		2	-1.646*	.417	<.001	-2.73	-.57
		4	-.479	.417	.659	-1.56	.60
	4	1	-.500	.417	.628	-1.58	.58
		2	-1.167*	.417	.029	-2.25	-.09
		3	.479	.417	.659	-.60	1.56
Succisa	1	2	-.125	.403	.990	-1.17	.92
		3	1.292*	.403	.009	.25	2.34
		4	.792	.403	.206	-.25	1.84
	2	1	.125	.403	.990	-.92	1.17
		3	1.417*	.403	.003	.37	2.46
		4	.917	.403	.108	-.13	1.96
	3	1	-1.292*	.403	.009	-2.34	-.25
		2	-1.417*	.403	.003	-2.46	-.37
		4	-.500	.403	.602	-1.55	.55
	4	1	-.792	.403	.206	-1.84	.25
		2	-.917	.403	.108	-1.96	.13
		3	.500	.403	.602	-.55	1.55