



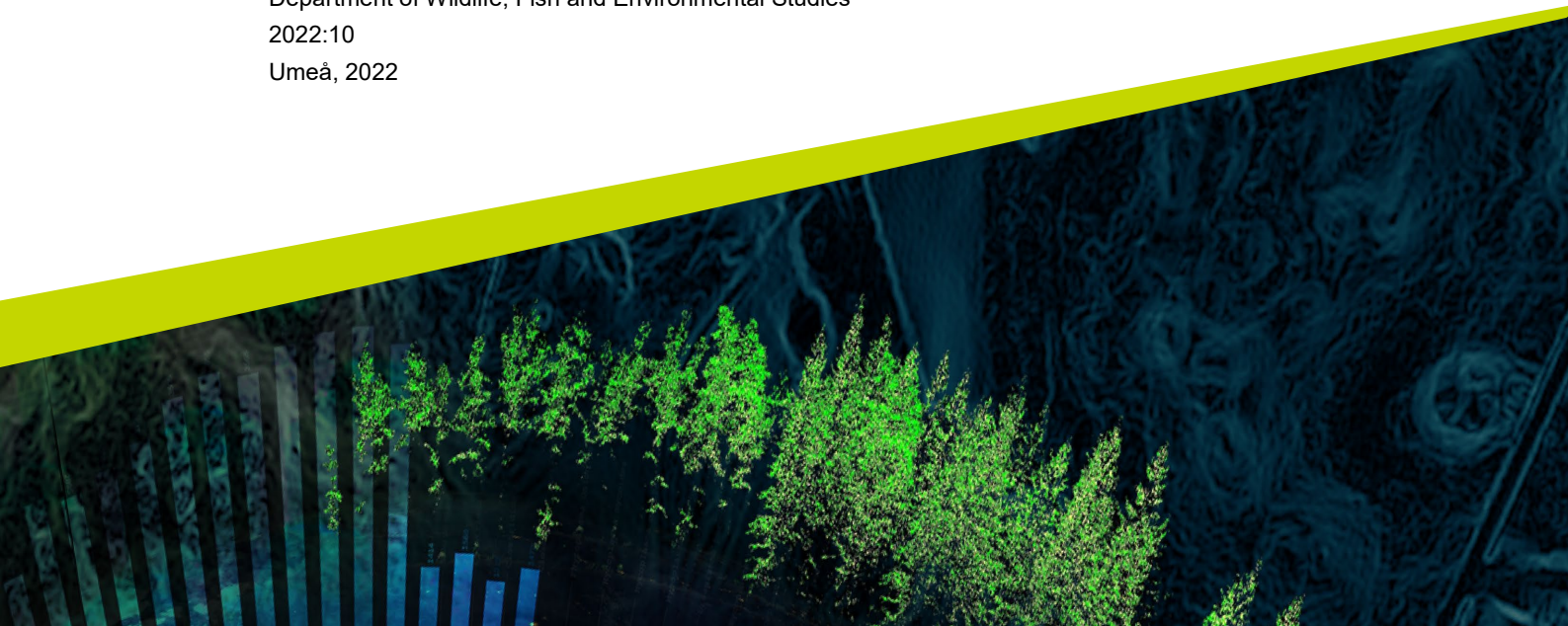
# **Could horse grazing be used to restore abandoned fields?**

– A comparison of the vegetation between horse pastures and abandoned fields, and an inventory of the effects of grazing- history and intensity

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Jantien Vogel

Master's thesis • 30 credits  
Swedish University of Agricultural Sciences, SLU  
Department of Wildlife, Fish and Environmental Studies  
2022:10  
Umeå, 2022





# Could horse grazing be used to restore abandoned fields? - A comparison of the vegetation between horse pastures and abandoned fields, and an inventory of the effects of grazing-history and intensity

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## Abstract

Semi-natural fields, created by traditional land-use systems like low-intensity cattle grazing, have high ecological value due to the occurrence of numerous plant species, and their associated faunal communities. In Sweden, this habitat is threatened by both land-abandonment and agricultural intensification. Reintroduction of low intensity grazing by large herbivores at abandoned sites might enable restoration of this habitat. The aim of this study is to investigate the potential of horses to benefit a grazing associated, diverse plant community. I surveyed forbs within 20 horse pastures and 20 abandoned fields, to evaluate how horse grazing affects the vegetation. Within the horse pastures, the effect of grazing- history and intensity was analysed.

The forb community composition differed clearly between horse pastures and abandoned fields. Forb species richness tended to be higher in horse pastures, which were dominated by ruderal, grazing associated species, whereas forb communities on abandoned fields mainly consisted of competitive forb species. Eight semi-natural pasture species were found, primarily within horse pastures. Forb species at horse pastures had a lower canopy height and lower seed mass, which are two known grazing associated traits. Contrary to expectations, specific leaf area (SLA) was higher at abandoned fields, despite the fact that high SLA is associated with grazing tolerance. Horse pastures had a higher number of plants that are pollinated by pollinators from different taxa (generalists), the number of bee-pollinated and wind-pollinated species did not differ.

Grazing history affected species richness, which was lower in newly grazed pastures (< 6 years) compared to pastures that had been grazed for over 15 years. Furthermore, more generalist-pollinated species were present in these older (>15) pastures, compared to the pastures that were grazed for less than 6 years. There were no effects of grazing intensity.

This study shows that horses are able to create more diverse, grazing associated plant communities compared to abandoned sites, and that species richness increases after the first 5 years of grazing. However, it has to be noted that both habitats sustain very different plant communities, on which different species might be reliant. Furthermore, few semi-natural pasture species were found within horse pastures, which might be due to lack of source populations. Nevertheless, horse grazing could have the potential to restore abandoned fields. More research is needed on how to benefit targeted species, e.g. by varying the time slot of grazing and mowing, and by investigating the availability of source populations.

*Keywords: Abandoned field, grazing, horse pasture, functional traits, species richness, vegetation*

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# 1. Introduction

During the Pleistocene, many plant species evolved grazing associated adaptations as a result of the herbivore-structured environment (Sandom *et al.*, 2014). Despite the loss of the majority of the wild grazers of this time (Barnosky *et al.*, 2004), grazing associated plant species have remained in the landscape due to pre-historic agriculture, and were more recently supported by traditional land-use systems (Eriksson, 2021). Low-intensity cattle grazing is a common form of traditional land-use and the semi-natural fields which resulted from this system were among the most biodiverse habitats in Europe (Wilson *et al.*, 2012). Such semi-natural fields covered a large part of Sweden during the 19<sup>th</sup> and 20<sup>th</sup> century (Plieninger, Höchtl and Spek, 2006) and approximately 600 different plant- and tree species are associated with this habitat (Svensson, 1998). The large majority of semi-natural grasslands in Europe have disappeared due to either agricultural intensification or the abandonment of farmland (Strijker, 2005). Compared to the year 1900, less than 10% of the acreage of semi-natural fields remains (Eriksson and Cousins, 2014). Of the 434 red-listed vascular plant species in Sweden, 157 are at least partially dependent on traditional agricultural landscapes (Eide *et al.*, 2020), and are expected to decline or go extinct if these habitats disappear (Eriksson, 2021).

In Sweden, large scale land abandonment is ongoing due to a decline of inhabitants and farmers in rural areas, and the diminishing number of grazing cattle in the agricultural sector (Plieninger, Höchtl and Spek, 2006; Benayas *et al.*, 2007). Since 1990, the amount of Swedish farmers was reduced by approximately 30%, and the number of dairy cows have dropped with the same percentage over the last 20 years (SCB, 2019). Currently, approximately 75% of the Swedish agricultural land is at moderate to high risk of abandonment (Schuh *et al.*, 2020). The effects of land abandonment on the diversity and composition of the vegetation have been studied quite intensively, and the large majority of the European studies conclude that land abandonment results in a decrease of overall biodiversity (Queiroz *et al.*, 2014). Therefore, the European Union tries to prevent land abandonment by subsidizing field maintenance (Renwick *et al.*, 2013). Despite this, land abandonment is expected to increase in the coming years (Schuh *et al.*, 2020).

Recreating or restoring semi-natural fields is crucial, because many associated plant species, as well as species from other taxa, are expected to go extinct in Sweden if this habitat type will disappear (Eriksson, 2021). The introduction of

large grazers is a potential measure to increase diversity at formerly abandoned sites, and to simultaneously recreate semi-natural grasslands through low-intensity grazing (van Wieren, 1995; Garrido *et al.*, 2019). Garrido *et al.* (2019) showed how horses were able to promote plant diversity and plant composition at formerly abandoned pastures in Sweden. The use of horses as grazers at abandoned sites might suit Sweden in particular, because horses have increased by approximately 25% from 2004-2016 to approximately 355.500 individuals (SCB, 2005, 2017), and now exceed the number of dairy cows in the country (SCB, 2019). Another advantage is that horses are generally not kept for food production, and therefore do not need fertilized pastures to enhance meat or milk production. Absence of fertilization, is one major factor that causes semi-natural grasslands to be very rich in species, as high nutrient levels cause dominance of a few species (Hansson and Fogelfors, 2000).

The ability of grazing to generate a diverse, grazing-associated vegetation at abandoned sites is dependent on many factors, including the site condition at the start of restoration (Cramer, Hobbs and Standish, 2008). Field history affects successional pathways (Myser and Pickett, 1990), which might subsequently affect restoration effects. For example, high fertilizer input in the past can prevent successful biodiversity promotion for many years, because the remaining high nutrient levels cause a few fast-growing species to become dominant (Gough and Marrs, 1990). Therefore, the number of years a field has been managed non-intensively might impact the composition of the vegetation and thus restoration efforts. Additionally, the intensity of grazing has been found to impact the species richness and composition of the plant community (Herrero-Jáuregui and Oesterheld, 2018). Plant species richness reaches an optimum under moderate grazing, although this optimum can differ between sites, due to variation in site productivity (Olf and Ritchie, 1998; Pulungan *et al.*, 2019; Gao and Carmel, 2020). Furthermore, additional management practices, like mowing are often applied in grasslands, which can also affect vegetation composition- and richness (Hansson and Fogelfors, 2000; Tälle *et al.*, 2016).

Plant functional traits can facilitate insights in how environmental factors shape plant communities (McGill *et al.*, 2006). Functional traits were defined by Violle *et al.*, (2007) as “any morphological, physiological or phenological feature, measurable at the individual level, which impacts fitness indirectly via its effects on growth, reproduction and survival”. This viewpoint on plant communities has gained popularity during the past years (Russell *et al.*, 2014), and many studies have focused on identifying grazing-associated traits (McIntyre *et al.*, 1999). Some general patterns emerged from these efforts, of which Specific Leaf Area (hereafter SLA), the ratio of leaf area to leaf dry mass, is one. High SLA is beneficial for species with a short life span due to fast return of investment (Poorter, 1994), where long-lived species gain more benefit from the greater leaf life-span associated with



low SLA (Reich, Walters and Ellsworth, 1992; Westoby, 1998). Furthermore, high SLA is known to increase grazing tolerance, due to the increased ability to regrowth after grazing (Laliberté *et al.*, 2012). Another trait associated with grazing is canopy height. Being tall enables species in undisturbed habitats to compete for light (J. P. Grime, 1977), while low canopy height facilitates grazer avoidance (Zheng *et al.*, 2015). Furthermore, seed-mass has been found to be affected by grazing. Species at frequently disturbed habitats (i.e. grazed fields) generate a high number of seeds (Golodets, Sternberg and Kigel, 2009; Peco *et al.*, 2012), which increases the chance of successful dispersion, whereas species in a more competitive environment produce larger seeds which enable seed survival in hazardous environments, like low light or high competition (Westoby, Leishman and Lord, 1996).

Grazing has been found to affect the presence of other taxa, by altering vegetation composition and consequently the presence of species that are associated with these species (Wang and Tang, 2019). Quantifying each occurring plant's biodiversity potential i.e., the amount of non-plant species that utilize or rely on each particular species, can provide insights in how vegetational changes affect the overall species richness of a site (Tyler *et al.*, 2021). Because plants provide nectar and pollen to their pollinators, they have a large impact on the survival of this species group in particular (Fowler, Rotheray and Goulson, 2016; Mallinger, Gibbs and Gratton, 2016). Plants can differ a lot in nectar and/or pollen content, which causes the composition of the vegetation to affect the suitability of the habitat for pollinators (Söderström *et al.*, 2001). As pollinators are essential to ecosystem functioning (Klein *et al.*, 2007), the effects of restoration efforts on their food resources should be taken into account. Furthermore, certain pollinators, f.e. wild bees and honeybees (*Apis mellifera*), are currently declining (Biesmeijer *et al.*, 2006), which stresses the need for restoration efforts to benefit these species.

In this study I explored whether grazing by horses is a potential measure to restore biodiversity at abandoned fields in Northern Sweden. I compared plant-species richness and composition in horse grazed pastures and abandoned fields, in order to identify how grazing affects vegetation structure and what the consequences are to habitat suitability of pollinators. At grazed sites, I evaluated the effects of grazing intensity, and grazing history (the number of years a pastures was grazed by horses) on vegetation composition, species richness and pollinator habitat quality.

I expected horse pastures to have a higher plant species richness than abandoned fields, and I hypothesized that horse grazing would result in a distinct vegetation, with a high abundance and species richness of grazing-associated plant species (van Wieren, 1995; Garrido *et al.*, 2019). Based on the results of Garrido *et al.*, (2019), I predicted there to be more bee-pollinated plant species within horse pastures compared to abandoned fields. Furthermore, I hypothesize that grazing intensity

and grazing history will alter plant composition. For grazing intensity, I expect an optimum of plant species richness at intermediate intensity (Pulungan *et al.*, 2019; Gao and Carmel, 2020). I expect plant species richness to increase over time since grazing started (grazing history) (Pykälä, 2003, 2005; Lindborg and Eriksson, 2004), until a maximum species richness has been reached.

## 2. Methods

### 2.1. Data collection

A vegetation survey of a total of 20 summer-grazed horse pastures and 20 abandoned fields was conducted in the Eastern part of Västerbotten county in Northern Sweden (Figure 1). I included horse pastures that were grazed for at least 2 years. In order to try to get a similar distribution of horse pastures and abandoned fields in the study area I asked the owner of the horse pastures for a location of a nearby abandoned pasture. Additionally, abandoned fields were found by driving around the study area. In the latter case, local people were asked to verify whether the field had been abandoned for at least 5 years. I selected abandoned fields which had low tree cover (<10%), to ensure an upper age limit.

Within each field, I recorded the presence of the occurring forb (from now on coined as vegetation for simplicity) species in 20 square meter plots. The plots were spread out evenly on the field after randomly choosing a starting plot and then placing the rest of the plots in a systematic grid pattern. The distance between plots were adapted to field size so that plots were spread out over the whole field. No plot were placed closer than 2 meters to the field edge.

The owners of the horse pastures were interviewed to collect data about the characteristics of the pastures. The following information was obtained from the pasture owners: (1) The number of years a pastures was grazed by horses (range 2-50 years, from now on referred to as grazing history). (2) The number of horses and/or ponies per pasture. If this number varied among years, the average over the time of grazing was taken. Pastures where fluctuations were bigger than plus or minus one horse, were excluded from the analysis of grazing intensity. (3) The average number of grazed weeks per year. (4) The frequency of mowing, which was categorized into 3 groups; absence of mowing, yearly mowing, and mowing less frequently than yearly. (5) Pesticide and fertilizer use since grazing started.

Additionally, the size of each pasture (range 0.29 – 4.35 ha) was calculated by using Google Maps and Landmäteriet. Furthermore, a differentiation in food intake between horses and ponies was made, as size differences affect food intake, and therefore subsequently grazing intensity. The following formula was used to

calculate food intake:  $MJ = 0.5 \times V^{0.75}$  (Jansson, 2011). MJ = energy needed in Mega Joule per day, and V = the mass of the horse in Kg. An average weight of 300 kilograms for ponies and 550 kilograms for horses was assumed (Górniak *et al.*, 2020). Based on this information, a grazing intensity index was calculated, with the following formula:  $GI = PS / (H * FI * TG)$ . GI = grazing index (ha/intensity), PS = pasture size (ha), H = number of horses and/or ponies, FI = food intake (differentiation between horses and ponies, based on previous formula), and TG = time of grazing (weeks per year). Low numbers represented high grazing intensities and vice versa.

Due to the absence of pesticide use and the few occurrences of fertilizer use (Appendix, table 1), these variables were not taken into account. Only one of the horse pastures was ploughed within the period the field was grazed. For this field, I assumed the year in which the ploughing occurred the start of the number of years the pasture had been grazed. Specific site information can be found in the Appendix 1.

Soil types of the fields were identified by maps from Sveriges Geologiska Undersökning (<https://apps.sgu.se/kartvisare/kartvisare-jordarter-25-100.html>).

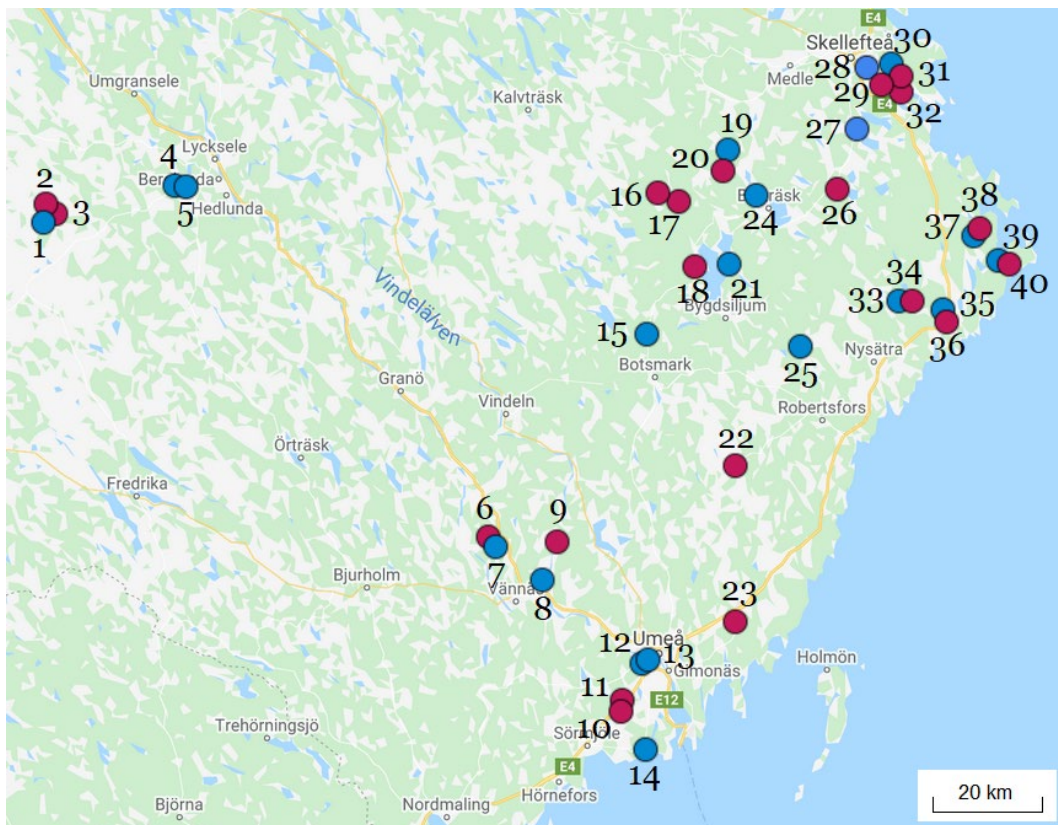


Figure 1: Map of the study area. The red dots correspond with the locations of the abandoned fields, whereas the blue dots represent the locations of the horse pastures that were included in this study. Each location is numbered, field specific details can be found in the Appendix (table 1). This map was created with Google Maps.

## 2.2. Plant traits

### 2.2.1. Ecological strategy

Based on multiple functional traits, J. P. Grime (1977) developed the CSR triangle, an ecology strategy scheme, which associates functional trait values with variation in stress and disturbance levels. Competitive (C) plants invest in traits related to efficient use of resources, like elevated leaf canopy, to optimize efficiency in environments where both stress and disturbance are low. Stress-tolerators (S), which are well-adapted to high stress and low disturbance, have a small stature and low potential relative growth rate. Ruderals (R), which are often annuals or short-lived perennials, invest in seed production rather than vegetative growth, which favors these species under high disturbance and low stress (J. P. Grime, 1977).

This scheme is relevant for grazing research, as grazing is considered to be a form of disturbance (J.P. Grime, 1977). Because the model is based on multiple traits, a species can have components of multiple strategies.

Despite the popularity of Grimes CSR model, Westoby (1998) argued that its basis on reference concepts and the absence of a strategy under high stress- and high disturbance affected the applicability of the model. Westoby (1998) proposed a focus on three functional traits: 1) specific leaf area (SLA); i.e. the ratio of leaf area to leaf dry mass ( $\text{mm}^2/\text{mg}$ ), 2) canopy height at maturity (cm), and 3) seed mass (mg). SLA reflects the growth response to variation in stress (C-S axis), and canopy height and seed mass indicate variation in response to disturbance (R-axis). The model is based on log values of these traits, because the traits are known to be approximately lognormally distributed, and because the relationships between species are best characterized by the difference in log compared to the absolute difference (Westoby, 1998). In this study, I used both models to investigate the level of grazing-associated traits among forbs in horse pastures and abandoned fields.

CSR scores were primarily obtained from the Biolflor database (Kühn, Durka and Klotz, 2004). The classification of *Rubus arcticus* was obtained from (Ecke and Rydin, 2000). SLA, canopy height and seed mass were derived from the LEDA trait database (Kleyer *et al.*, 2008). There were no records of *R. arcticus* in this database, and therefore the canopy height of this species was obtained from “Den Nordiska Floran (The Nordic Flora)” (Mossberg and Stenberg, 1992). For SLA, the value of *Rubus saxatilis* was taken from the LEDA traitbase (Kleyer *et al.*, 2008), due the relatedness of the species. I measured the dry weight of *R. arcticus* by taking the average oven dried weight of 212 *R. arcticus* seeds. The seeds were oven dried for 24 hours at 80 degrees Celcius (Nedeva and Nikolava, 1999).

### 2.2.2. Biodiversity potential

To assess differences between the non-plant species associated with the vegetation in horse pastures and abandoned fields, I used the biodiversity potential score created by Tyler *et al.* (2021). The score is described as follows: “The number of other organisms that depend on, or utilize, the species as food source, substrate, shelter or mutualistic partner”. Because precise estimations for each species could not always be obtained, Tyler *et al.* (2021) developed the following eight-degree scaling system: 1 = <6 associated species, 2 = 6–12, 3 = 13–24, 4 = 25–50, 5 = 51–100, 6 = 101–200, 7 = 201–400, 8 = >400 (Tyler *et al.*, 2021).

### 2.2.3. Pollinator habitat quality

The nectar production of each plant species was derived from the Tyler *et al.*, (2021). They created a seven-degree scale, while taking the number of flowers and the duration of the flowering season into consideration. The degrees are defined as follows: 1 = no nectar production (0 g sugar/m<sup>2</sup>/year) and no collectable pollen, 2 = nectar production insignificant (< 0.2 g), or absent but with low but significant amounts of collectable pollen, 3 = nectar production small (0.2–5 g), or lower but with copious collectable pollen 4 = nectar production modest (5–20 g), 5 = rather large (20–50 g), 6 = large (50–200 g), 7 = very large (> 200 g).

Plant-pollinator associations were obtained from the Bioflor database (Kühn, Durka and Klotz, 2004). We differentiated between bee-pollinated, wind-pollinated and generalist-pollinated plants (Garrido *et al.*, 2019) (Appendix, table 2). There was no data for the species *R. arcticus* in this database. Based on Burns (2018), in which multiple pollinators of this species were described, *R. arcticus* was classified as a generalist.

## 2.3. Statistical analyses

All analysis were conducted in R version 4.0.4 (R Core Team, 2021). Firstly, a comparison between the two field types was carried out. A generalized linear mixed model (GLMM) with Poisson distribution (log-link), with field type as a factor and location as a random nested factor, was used to compare species richness (Bolker *et al.*, 2009). The ‘lme4’ package (Bates *et al.*, 2015) was used to perform this analysis, and each of the following GLMM’s in this study. Differences in plant composition were analyzed based on frequency data; the presence of each species was added for each of the 20 replicates per site. Non-metric multidimensional scaling (NMDS) was used to visualize the differences in composition between horse pastures and abandoned fields. The difference in composition was statistically tested with a permutational Analysis of Variance (PerMANOVA). Both the NMDS and PerMANOVA were conducted with the ‘vegan’ package (Oksanen *et al.*,

2020). A species indicator analysis indicated which species are typically associated with the different field types. The ‘indicspecies’ package (De Cáceres and Legendre, 2009) was used to perform this analysis.

CSR values, LHS (log-transformed) values, biodiversity potential score and nectar score were calculated for each plot by taking the average value or score for each of the species that occurred in the plot. Differences between these trait values were tested individually through GLMM’s with Gaussian distribution and a nested random structure (replicate within field). The number of species per plant-pollinator association was tested with the same model, but a Poisson distribution was assumed for the number of generalist-pollinated species per plot, and a non-binomial distribution for the number of wind-pollinated species per plot.

The effect of grazing intensity, grazing history, frequency of mowing and dominating soil type on the vegetation were analyzed as follows. Grazing history was modelled based on four age categories, 1-5 years, 6-10 years, 11-15 years, and over 15 years grazed. The grazing intensity index was grouped as follows, low ( $> 0.5$ ), intermediate ( $0.25-0.50$ ), and high ( $<0.25$ ).

The effect of each of the variables on species richness was modelled by a GLMM with a Poisson (log-link) distribution, with site nested as a random factor. For plant composition, variable impact was visualized with an NMDS and statistically tested with a perMANOVA.

The effect of the grazing variables on mean CSR values, LHS (log-transformed) values, biodiversity potential score and nectar score were tested through GLMM’s with Gaussian distribution. Again, the number of generalist-pollinated species was modelled with a Poisson distribution, and wind-pollinated species with a non-binomial distribution. For each of the GLMM’s, p-values were obtained through the ‘emmeans’ package (Russell *et al.*, 2022).

The impact of grazing-history and intensity are shown in separate models, because adding grazing intensity did not improve the AICc value of each grazing-history model.

## 3. Results

Mowing and dominating soil type did not affect any of the response variables, and both of these variables were not represented in sufficient numbers to be added as an interaction with the other variables. Therefore, they were excluded from the results.

### 3.1. Encountered species

During this study, I encountered 72 forb species out of a total of 4233 observations. *Vicia cracca* was most abundant (333 observations), followed by *Ranunculus repens* (317 observations), and *Achillea millefolium* (296 observations). These species comprised 22 percent of the total dataset. Other abundant species, that were observed over 200 times were, *Anthriscus sylvestris*, *Ranunculus acris*, *Trifolium repens*, *Rumex acetosa*, *Leontodon autumnalis*, and *Epilobium angustifolium*. *Trifolium repens* and *R. repens* were most common in horse pastures, *V. cracca* and *A. sylvestris* were the most recorded species within abandoned fields.

No red-listed species were observed in either of the field types. A total of 8 species that typically occur in semi-natural pastures (Pihlgren, 2010) were recorded; *Alchemilla sp* (35 observations), *Campanula rotundifolia* (4 observations), *Cirsium helenioides* (33 observations), *Euphrasia stricta* (62 observations), *Leucanthemum vulgare* (1 observation), *Melampyrum pratense* (2 observations), *Melampyrum sylvaticum* (31 observations), and *Veronica officinalis* (3 observations). *C. rotundifolia* and *L. vulgare* were exclusively found in horse pastures, where the majority of *Alchemilla* (33/35), *E. stricta* (59/62) and *V. officinalis* (2/3) were found as well. *M. pratense* was found once in each field type. *C. helenioides* was found most often within abandoned fields (31/33), as was *M. sylvaticum* (30/31).



## 3.2. Comparison vegetation abandoned fields and horse pastures

### 3.2.1. Species Richness

A total of 65 species were found in horse pastures, and 52 species were found in abandoned fields. There was a trend of higher species richness in horse pastures compared to abandoned fields ( $p = 0.06$ ). Horse pastures contained approximately one more species per plot on average (figure 2, table 3).

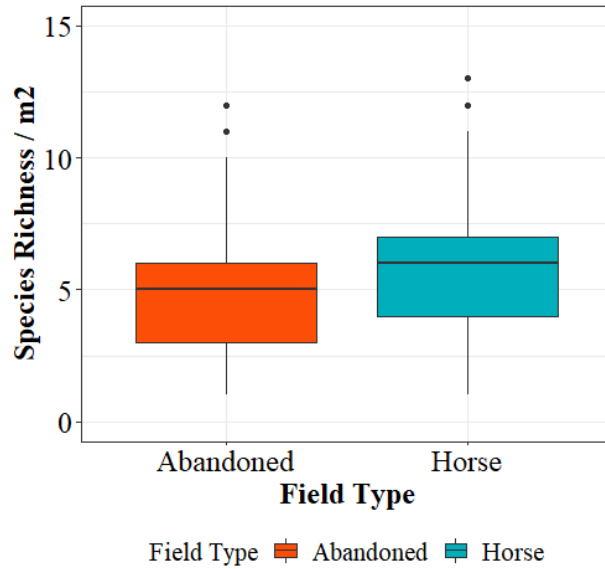


Figure 2: Plant species richness of abandoned fields and horse pastures.  $N=400$  for both treatments (20 fields with 20 replicates each).

### 3.2.2. Composition of the vegetation

The composition of the vegetation differed significantly between field types ( $p=0.001$ ). The difference is clearly illustrated by the NMDS plot, which shows that there is no overlap between forb communities in horse grazed fields compared with abandoned fields (figure 3). Of this difference, 28% was explained by field type. Eleven species were associated with horse pastures, while the occurrence of 10 species correlates with abandoned fields (table 2). The traits of these species will be discussed further on in this report.

Table 1: Results from PerMANOVA testing the difference in forb community composition between horse pastures and abandoned fields. The analysis is based on Bray-Curtis dissimilarities using frequency data of plant species.

| Factor     | Df | Sum SQ | Pseudo-F | R <sup>2</sup> | P-value |
|------------|----|--------|----------|----------------|---------|
| Field Type | 1  | 2.66   | 14.47    | 0.28           | 0.001   |
| Residuals  | 38 | 6.99   |          | 0.72           |         |
| Total      | 39 | 9.65   |          | 1.00           |         |

Df= degrees of freedom; Sum SQ = sum of squares; Pseudo-F = F value by permutation. The P-value is based on 999 permutations.

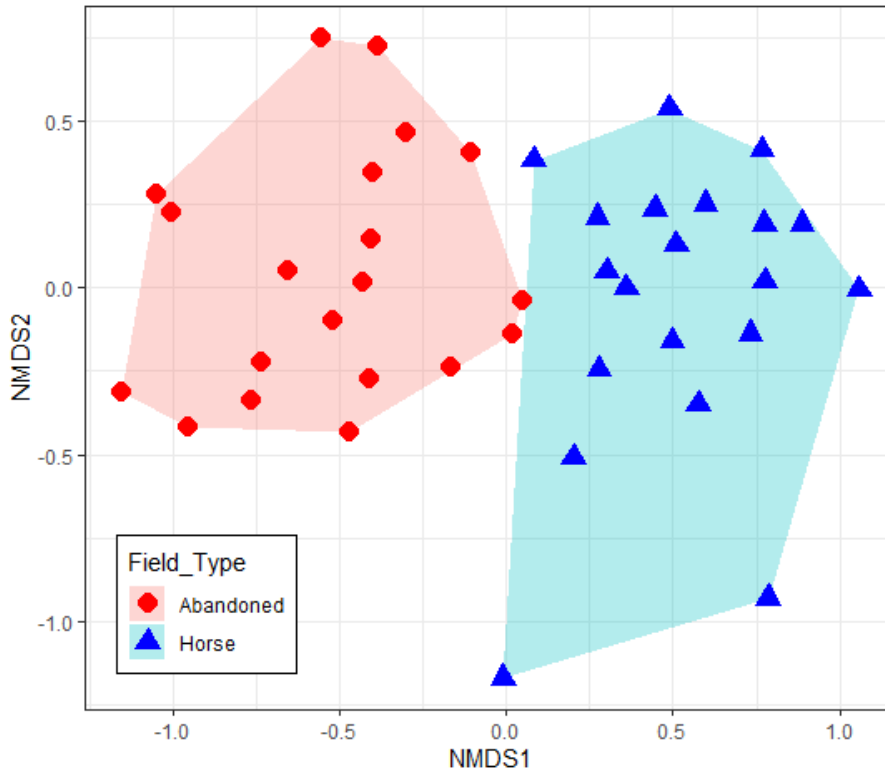


Figure 3: Nonmetric Multidimensional Scaling (NMDS) ordination of vegetation community structure in horse pastures and abandoned fields.  $N = 20$  for both field types.

Table 2. Indicator species for each field type.

| Horse Pastures              |         | Abandoned Fields               |         |
|-----------------------------|---------|--------------------------------|---------|
| Species                     | P-value | Species                        | P-value |
| <i>Alchemilla sp.</i>       | 0.029   | <i>Anthriscus sylvestris</i>   | 0.003   |
| <i>Euphrasia stricta</i>    | 0.003   | <i>Cirsium helenioides</i>     | 0.005   |
| <i>Leontodon autumnalis</i> | <0.001  | <i>Epilobium angustifolium</i> | <0.001  |
| <i>Plantago major</i>       | <0.001  | <i>Galeopsis tetrahit</i>      | <0.001  |
| <i>Polygonum aviculare</i>  | 0.021   | <i>Galium mollugo</i>          | 0.048   |
| <i>Ranunculus repens</i>    | <0.001  | <i>Melampyrum sylvaticum</i>   | 0.013   |
| <i>Rumex acetosella</i>     | 0.039   | <i>Rubus arcticus</i>          | 0.012   |
| <i>Taraxacum officinale</i> | <0.001  | <i>Urtica dioica</i>           | 0.006   |
| <i>Trifolium pratense</i>   | 0.001   | <i>Valeriana sambucifolia</i>  | 0.020   |

|                            |        |                     |       |
|----------------------------|--------|---------------------|-------|
| <i>Trifolium repens</i>    | <0.001 | <i>Vicia cracca</i> | 0.014 |
| <i>Veronica serpyfolia</i> | 0.004  |                     |       |

### 3.2.3. Functional traits

#### CSR – Competitors, Stress-tolerators and Ruderals

The proportion of each of the CSR strategies was analyzed by a GLMM where the response variable was the mean C/S/R score (0-1) for all plants that occurred at the plot. The vegetation at abandoned sites was more competitive than at horse pastures ( $p < 0.001$ ), the estimate for C was 0.23 higher for abandoned plots. A contrary pattern was found for ruderal traits; the R score at abandoned fields was lower than it was for horse pastures ( $p < 0.001$ ). The R score was estimated to be 0.20 higher at horse pasture plots. There was no difference in stress-tolerance between the two field types ( $p = 0.21$ ). The full model output can be found in table 3.

The indicator species of each of the field types showed that species which

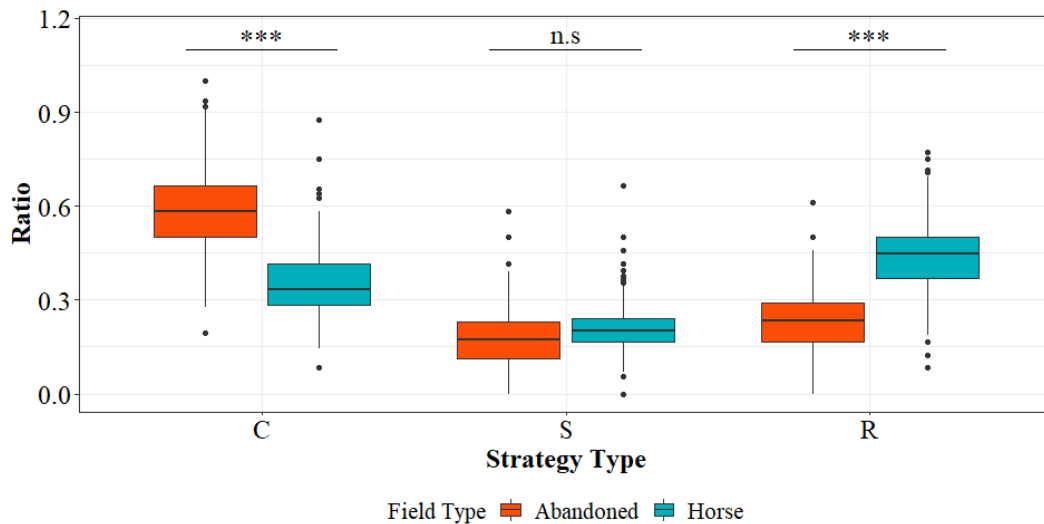


Figure 4: Comparison of CSR-strategy. C = Competitors, S = Stress-tolerators, R = Ruderals. The ratio of each strategy was averaged for each occurring species per plot.  $N=400$  for abandoned fields, and  $N = 399$  for horse pastures (20 replicates on 20 fields, no forbs recorded in one of the replicates). Stars refer to significance levels; \* =  $p < 0.05$ , \*\*  $p < 0.01$ , and \*\*\*  $p < 0.001$ .

typically occur in horse pasture species have an average R score of 0.64, and that the C and S score are much lower. Species that typically occurred at abandoned fields had a very high average C-score, 0.70, and much lower S and R scores (Appendix, table 3). In summary, the indicator species showed the same pattern as the whole population, but the pattern was slightly stronger.

#### LHS – The Leaf-Height-Seed scheme

Species at abandoned sites had a higher SLA compared to the vegetation at horse pastures ( $p=0.02$ ) while canopy height ( $p < 0.001$ ) and seed mass ( $p < 0.001$ ) were higher in abandoned fields (table 3).

The same pattern was found when taking the average scores of the indicator species. Nevertheless, some indicator species diverted from this pattern, (Appendix, table 4).

### 3.2.4. Biodiversity potential

There was no difference in average biodiversity potential per plot between horse pastures and abandoned fields (table 3). The indicator species showed a similar trend, as the average biodiversity potential of the horse pasture indicator species was 4.3, compared with an average score of 4.2 for the indicator species of abandoned fields (Appendix, table 5).

### 3.2.5. Pollinator habitat quality

There was no difference in average nectar score per plot between horse pastures and abandoned fields (table 3). For the indicator species, the average score for both field types differed quite a bit. The indicators of horse pastures had an average score of 3.5, compared to a score of 4.3 of the indicator species of abandoned fields (Appendix, table 6).

In horse pastures there were more wind-pollinated species ( $p = 0.05$ ) and generalist-pollinated species ( $p = 0.04$ ). Nevertheless, the number of wind pollinated species was very low in both field types, and was estimated to be only 0.20 higher in horse pastures (table 3). For both field types, most indicator species were associated with multiple species (generalists). Horse pastures had 2 wind-pollinated, and 2 bee-pollinated indicators. There were 3 bee-pollinated indicators and 1 wind-pollinated indicator for abandoned fields (Appendix, table 7).

Table 3: Summarized results of all GLMM's that were used to compare the vegetation of abandoned fields and horse pastures.

| Model                         | Treatment | B              | SE           | z/t-value     | p-value        |
|-------------------------------|-----------|----------------|--------------|---------------|----------------|
| <i>Species Richness</i>       | Abandoned | <b>1.51</b>    | <b>0.08</b>  | <b>19.91</b>  | <b>0.06*</b>   |
|                               | Horse     | + <b>0.20</b>  | <b>0.11</b>  | <b>1.87</b>   |                |
| <i>C</i>                      | Abandoned | <b>0.59</b>    | <b>0.02</b>  | <b>31.62</b>  | < <b>0.001</b> |
|                               | Horse     | - <b>0.24</b>  | <b>0.03</b>  | - <b>8.88</b> |                |
| <i>S</i>                      | Abandoned | 0.18           | 0.01         | 14.54         | 0.21           |
|                               | Horse     | + 0.02         | 0.02         | 1.26          |                |
| <i>R</i>                      | Abandoned | <b>0.23</b>    | <b>0.02</b>  | <b>15.86</b>  | < <b>0.001</b> |
|                               | Horse     | + <b>0.21</b>  | <b>0.02</b>  | <b>10.53</b>  |                |
| <i>SLA</i>                    | Abandoned | <b>1.42</b>    | <b>0.004</b> | <b>332.39</b> | <b>0.02</b>    |
|                               | Horse     | - <b>0.014</b> | <b>0.006</b> | - <b>2.25</b> |                |
| <i>Canopy height</i>          | Abandoned | <b>1.67</b>    | <b>0.018</b> | <b>90.94</b>  | < <b>0.001</b> |
|                               | Horse     | - <b>0.23</b>  | <b>0.026</b> | - <b>8.78</b> |                |
| <i>Seed Mass</i>              | Abandoned | <b>0.13</b>    | <b>0.04</b>  | <b>3.10</b>   | < <b>0.001</b> |
|                               | Horse     | - <b>0.23</b>  | <b>0.06</b>  | - <b>3.84</b> |                |
| <i>Biodiversity potential</i> | Abandoned | 4.52           | 0.06         | 73.71         | 0.13           |
|                               | Horse     | + 0.13         | 0.09         | 1.51          |                |
| <i>Nectar Score</i>           | Abandoned | 4.07           | 0.09         | 45.84         | 0.42           |
|                               | Horse     | - 0.10         | 0.13         | - 0.80        |                |
| <i>Generalist pollinated</i>  | Abandoned | <b>3.03</b>    | <b>0.25</b>  | <b>12.04</b>  | <b>0.04</b>    |
|                               | Horse     | + <b>0.75</b>  | <b>0.35</b>  | <b>1.91</b>   |                |
| <i>Wind pollinated</i>        | Abandoned | 0.68           | 0.07         | 7.61          | 0.10           |
|                               | Horse     | - 0.29         | 0.10         | 2.00          |                |
| <i>Bee pollinated</i>         | Abandoned | 1.11           | 0.13         | 8.74          | 0.57           |
|                               | Horse     | + 0.10         | 0.18         | 0.57          |                |

The estimate for abandoned fields are given for each model, and the positive (+) or negative (-) deviation of this estimate for horse pastures. Significant models, and models that show a clear trend\* ( $p < 0.10$ ) are in **bold**. B = model estimate, SE indicates the Standard error of each model.

### 3.3. Grazing intensity and grazing history within horse pastures

#### 3.3.1. Species richness

The effect of grazing-history and grazing-intensity on species richness was modelled. Species richness was higher in fields that had been grazed over 15 years compared to sites that had been grazed for 1-5 years. Fields that had been grazed for 6-10 years and 11-15 years showed a trend of higher species richness compared to 1-5 year old fields (table 4). Grazing intensity did not affect species richness ( $p=0.97$ ). Full model results can be found in the summary table (table 8).

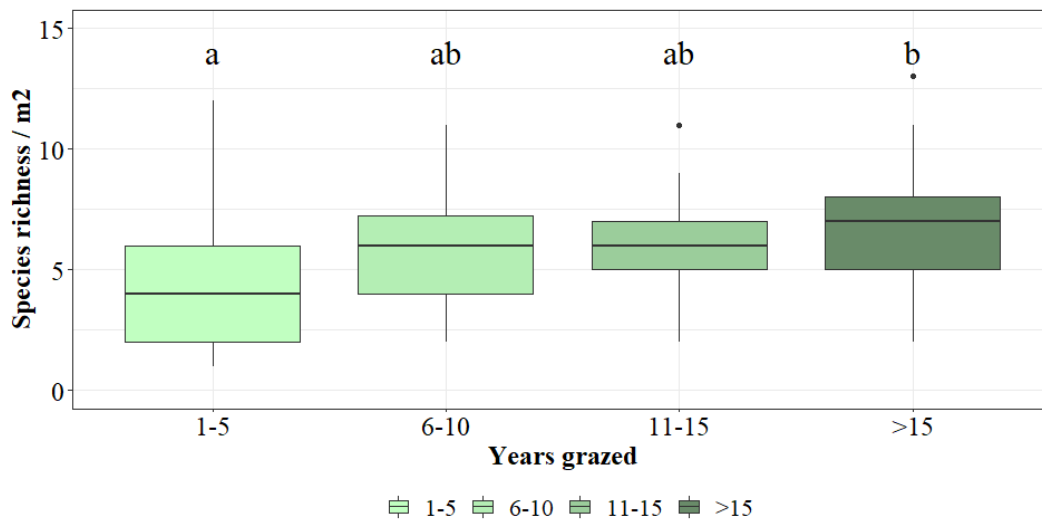


Figure 5: Comparison of species richness between different groups of grazing history.  $N = 100$  for each category (5 horse pastures with 20 replicates each). Different letters indicate significant differences.

Table 4: Statistical results of the effect of grazing history categories on species richness.

| Comparison   | $\beta$ | SE   | z-ratio | p-value |
|--------------|---------|------|---------|---------|
| 1-5 – 6-10   | -0.41   | 0.18 | -2.35   | 0.09    |
| 1-5 – 11-15  | -0.45   | 0.18 | -2.54   | 0.05    |
| 1-5 – >15    | -0.52   | 0.18 | 2.96    | 0.02    |
| 6-10 – 11-15 | -0.03   | 0.17 | 0.19    | 1.00    |
| 6-10 – >15   | -0.11   | 0.17 | 0.61    | 0.93    |
| 11-15 – >15  | -0.07   | 0.17 | 0.43    | 0.97    |

This table shows the comparisons between the 4 grazing history categories. The GLMM was fitted with a Poisson distribution,  $\beta$  = model estimate for nectar score, SE = standard error,  $N=100$  for each category (5 pastures with 20 replicates each).

### 3.3.2. Composition of the vegetation

Grazing history ( $p = 0.15$ ) and grazing intensity ( $p = 0.70$ ) did not affect the composition of the vegetation significantly (Appendix, table 7 and 8).

The NMDS of the grazing history categories showed a lot of overlap among the categories (figure 6). Furthermore, plant community composition varied a lot within certain categories, especially for 1-5 years of grazing.

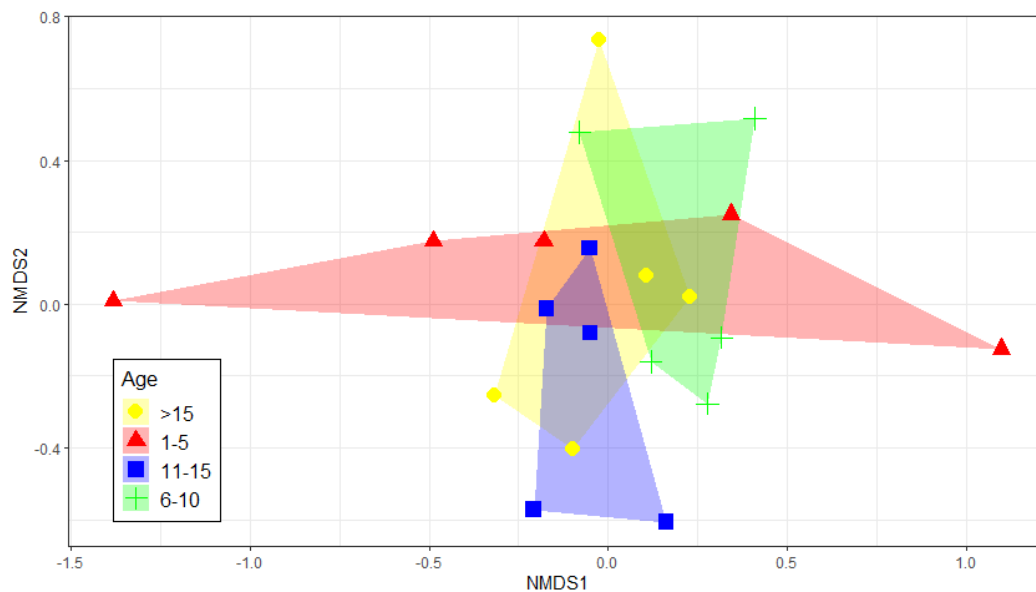


Figure 6: NMDS of the vegetation composition of the grazing history categories. Each point represents one pasture, and is based on the frequency of the presence of plant species in each of the 20 plots per pasture.  $N = 5$  for each category.

The NMDS of grazing intensity and plant composition shows that there is a lot of overlap between, and variation within the categories, which affirms the insignificance of the perMANOVA (figure 7).

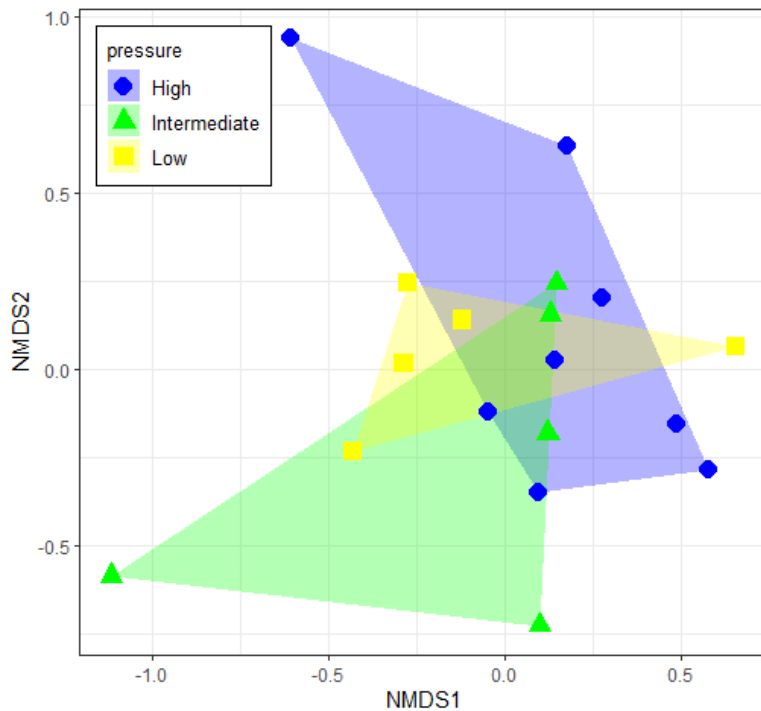


Figure 7: NMDS of the vegetation composition of the grazing intensity categories. Each point represents one pasture, and is based on the frequency of the presence of plant species in each of the 20 plots per pasture.  $N = 5$  for low and intermediate grazing intensity, and  $N = 8$  for high grazing intensity.

### 3.3.3. Functional traits

Both the CSR strategy components and the LHS components were not significantly affected by grazing history and grazing intensity (table 8). There was a trend of lower SLA during the first 5 years of horse grazing ( $p = 0.07$ ), where the biggest difference ( $p = 0.08$ ) was found between the newly grazed sites ( $< 6$  years) and pastures that had been grazed over 15 years.

### 3.3.4. Biodiversity potential

Grazing- history and intensity did not affect the average biodiversity potential score per plot (table 8).



### 3.3.5. Pollinator habitat quality

The number of generalist-pollinated species was affected by grazing history ( $p=0.01$ ); there were fewer generalist-pollinated species per plot during the first 5 years of grazing compared to fields that have been grazed over 15 years ( $p = 0.001$ ). A trend of higher species richness compared to the first 5 years of grazing was also found for the other two grazing history categories (table 7). Grazing intensity and grazing history did not affect the average nectar score per plot (table 8).

Table 7: Statistical results of the effect of grazing history categories on species richness.

| <b>Comparison</b> | <b><math>\beta</math></b> | <b>SE</b> | <b>z-ratio</b> | <b>p-value</b> |
|-------------------|---------------------------|-----------|----------------|----------------|
| 1-5 – 6-10        | - 0.39                    | 0.16      | - 2.37         | 0.08           |
| 1-5 – 11-15       | - 0.34                    | 0.17      | - 2.02         | 0.18           |
| 1-5 – >15         | - 0.50                    | 0.16      | - 3.24         | 0.001          |
| 6-10 – 11-15      | 0.39                      | 0.17      | 0.34           | 0.99           |
| 6-10 – >15        | - 0.11                    | 0.16      | - 0.69         | 0.90           |
| 11-15 – >15       | - 0.17                    | 0.16      | - 1.05         | 0.72           |

*This table shows the comparisons between the 4 grazing history categories. The GLMM was fitted with a Poisson distribution,  $\beta$  = model estimate for nectar score, SE = standard error, N=100 for each category (5 pastures with 20 replicates each).*

Table 8: Summarized results of all GLMM's that were used to analyze the effects of grazing-history and intensity on the vegetation.

| <b>Model</b>                        | <b>Factor</b>  | <b>Chisq</b> | <b>Df</b> | <b>p-value</b> |
|-------------------------------------|----------------|--------------|-----------|----------------|
| <b><i>Species Richness</i></b>      | <b>History</b> | <b>10.50</b> | <b>3</b>  | <b>0.01</b>    |
|                                     | Intensity      | 0.06         | 2         | 0.97           |
| <i>C</i>                            | History        | 0.44         | 3         | 0.93           |
|                                     | Intensity      | 1.36         | 2         | 0.51           |
| <i>S</i>                            | History        | 0.86         | 3         | 0.84           |
|                                     | Intensity      | 0.49         | 2         | 0.78           |
| <i>R</i>                            | History        | 0.72         | 3         | 0.87           |
|                                     | Intensity      | 1.40         | 2         | 0.50           |
| <b><i>SLA</i></b>                   | <b>History</b> | <b>7.21</b>  | <b>3</b>  | <b>0.07*</b>   |
|                                     | Intensity      | 0.12         | 2         | 0.94           |
| <i>Canopy height</i>                | History        | 5.19         | 3         | 0.16           |
|                                     | Intensity      | 0.11         | 2         | 0.95           |
| <i>Seed Mass</i>                    | History        | 0.49         | 3         | 0.92           |
|                                     | Intensity      | 1.20         | 2         | 0.55           |
| <i>Biodiversity potential</i>       | History        | 2.23         | 3         | 0.53           |
|                                     | Intensity      | 0.29         | 2         | 0.86           |
| <i>Nectar Score</i>                 | History        | 1.30         | 3         | 0.73           |
|                                     | Intensity      | 0.51         | 2         | 0.77           |
| <b><i>Generalist pollinated</i></b> | <b>History</b> | <b>11.17</b> | <b>3</b>  | <b>0.01</b>    |
|                                     | Intensity      | 0.70         | 2         | 0.70           |
| <i>Wind pollinated</i>              | History        | 6.13         | 3         | 0.11           |
|                                     | Intensity      | 0.58         | 2         | 0.75           |
| <i>Bee pollinated</i>               | History        | 1.92         | 3         | 0.59           |
|                                     | Intensity      | 1.63         | 2         | 0.44           |

Significant models, and models that show a clear trend\* ( $p < 0.10$ ) are in **bold**.

## 4. Discussion

### Species richness

Contrary to my hypothesis, there was no significant difference found in species richness between the horse pastures and abandoned fields in this study. Nevertheless, the results did show a trend of higher species richness for horse pastures, as species richness was estimated to be 13 percent higher within horse pastures compared to abandoned fields. This trend is in line with the findings of Garrido *et al* (2019) and other grazing experiments with large herbivores in Northern Europe (Pykälä, 2003, 2005). Excluding the newly grazed sites (< 6 years) would have given a higher species richness of horse pastures, as these fields were found to be less species rich.

Apart from the inclusion of sites that had been grazed for few years, the relatively small difference in species richness could also be due to the type of grazing animal. During the time in which traditional land-use was dominant, cows were primarily used to graze fields rather than horses. Cows and horses differ in diet (López *et al.*, 2019); contrary to cows, horses are more selective in the plant species they graze (Archer, 1973; Celaya *et al.*, 2011). This selective grazing could cause dominance of the species that are not being grazed.

Grazing history was the only grazing parameter affecting species richness in horse pastures. Fields where grazing was introduced recently (< 6 years), were significantly lower in plant diversity compared to fields that had been grazed for over 15 years, and there was a trend of higher species richness in the fields that were grazed 6-10 and 11-15 years compared to the fields with the shortest grazing history. This result shows that it takes a few years for horse grazing to improve species richness, which is in accordance with my hypothesis (Pykälä, 2003, 2005; Lindborg and Eriksson, 2004). Additionally, this time-lag in the effect of grazing on plant composition has also been found to work the other way around, as fields tend to become less diverse in plant composition with ongoing time of abandonment (Lindborg and Eriksson, 2004). Therefore, analysing the effect of time of abandonment on plant- species richness and composition would be very interesting.

The absence of effects of grazing intensity was unexpected, because several studies show that grazing intensity does affect plant species richness (Pykälä, 2005; Herrero-Jáuregui and Oesterheld, 2018; Gao and Carmel, 2020). A plausible reason for the absence of effects could be that pasture owners do not want their pastures to

be under- or overgrazed, and therefore prevent this by adapting stocking densities, shifting between pastures and/or by supplementary feeding. Consequently, low and (especially) high grazing intensities were probably excluded from this study, which could very well have caused the absence of the expected pattern. Additionally, I did not collect information on supplementary feeding, which could have affected the grazing behaviour of the horses. Furthermore, grazing intensity partially depends on pasture productivity (Olf and Ritchie, 1998; Gao and Carmel, 2020), which was not taken into account in this study. In future studies, pastures with lower and higher grazing intensities should be included within the study, and the productivity of the soil should be taken into account (Bauer and Black, 1994).

### Species composition

There was a distinct difference in species composition between the two treatments, which is in accordance with my hypothesis and previous studies, in which the effects of large-herbivore grazing on plant composition have been described (van Wieren, 1995; Pykälä, 2003).

Within both field types, no red-listed species were observed (Tyler *et al.*, 2021), but 8 species that are typically associated with semi-natural pastures were found. Two of these species (*C. rotundifolia* and *E. stricta*) are specifically associated with semi-natural pastures while the remaining 6 species can also be found in other habitats such as lawns (Pihlgren, 2010). *C. rotundifolia* was exclusively found in horse pastures as well as more than 95% of the occurrences of *E. stricta*. This pattern suggests that horse pastures have the potential to support forb species associated with semi-natural pastures.

Nevertheless, many species that are known to be associated with semi-natural fields were not found during the vegetation survey (Pihlgren, 2010). This might have been caused by the timing of grazing and mowing. Traditionally, semi-natural fields were mown quite late in summer (early-July to mid-August), whereafter autumn grazing (if applied) occurred. (Lennartsson and Oostermeijer, 2001; Dahlström *et al.*, 2008). Nowadays, grazing occurs throughout the growing season, which might affect the reproduction of species from multiple taxa (Dahlström *et al.*, 2008). By damaging plants early in their reproductive cycle continuous grazing causes a decrease in seed production compared to traditional management. This, in turn, negatively affects reproductive success (Lennartsson and Oostermeijer, 2001; Wissman, 2006). Adding fields where mowing and/or grazing is applied later in the season could therefore affect the number of observations of red-listed and semi-natural species.

Additionally, the absence of source populations of semi-natural and red-listed species could be causing the low number of observations of these plants (Pywell *et al.*, 2002; Winsa *et al.*, 2015). In future studies, the vicinity of semi-natural fields should be taken into account. It could also be useful to experiment with the sowing

of these species in within horse pastures, to see whether these species would survive and reproduce among these conditions.

There were no significant differences in species composition between the different groups of grazing- history and intensity. For grazing intensity, this could be due to the aforementioned reasons that might have impacted the accuracy of this variable in representing the actual grazing intensity. The absence of difference between grazing history categories indicates that grazing associated plants arise early after the start of grazing, which was also indicated by the absence of differences in functional traits between these groups, and that (many of) these plants remain present as grazing continues.

### Functional traits

Horse pastures were dominated by disturbance-tolerating ruderal species, whereas abandoned fields were primarily covered with competitors, which thrive in undisturbed habitat. These results reflect how differences in disturbance affects species composition, which is in accordance with my expectations, based on other experimental studies (Prévosto *et al.*, 2011; Rupprecht, Gilhaus and Hölzel, 2016; Garrido *et al.*, 2019; Rysiak *et al.*, 2021).

SLA, canopy height and seed mass were higher in abandoned fields than within horse pastures. Larger canopy height in abandoned fields was expected, because a higher canopy is advantageous in habitats with competition for light (J. P. Grime, 1977). Additionally, having a low canopy height is a known strategy of grazer avoidance (Zheng *et al.*, 2015). Higher seed mass in abandoned fields was also in accordance with the expectations and other studies (Golodets, Sternberg and Kigel, 2009; Peco *et al.*, 2012), because high seed mass enhances seedling survival, which is beneficial in competitive environments. However, the results of the SLA component of the scheme was rather unexpected. SLA is generally assumed to be higher in grazed areas, because high SLA facilitates grazing tolerance through enabling quick regrowth after grazing damage (Laliberté *et al.*, 2012). Nevertheless, SLA has been reported to be uncorrelated with grazing in another study (Díaz, Noy-Meir and Cabido, 2001), and might therefore not always be a good reflector of grazing. Nonetheless, I was unable to find other studies where SLA was lower in grazed areas. An explanation for this pattern could be that, because there are various strategies for coping with grazing (Núñez-Farfán and Valverde, 2020), the occurring species had a lower SLA due to an investment in other grazing- tolerance or avoidance traits. I.e., *R. repens*, an abundant indicator species of the horse pastures, avoids grazing through chemical defense rather than investing in grazer-tolerance via high SLA.

Neither grazing- history nor grazing intensity affected the grazing-associated functional traits. This could indicate that species that do not tolerate grazing disappear within grazed fields relatively quickly, even if the grazing intensity is

relatively low. Nevertheless, there was a trend of lower SLA during the first 5 years of grazing, especially compared to fields that had been grazed longer than 15 years. Therefore, removing newly grazed fields could possibly result in a smaller difference in SLA between horse pastures and abandoned fields.

### Biodiversity potential

There was no difference in average biodiversity potential score between field types, which means that the plant species that occurred within the plots of both field types were associated with roughly the same amount of species of other taxa. Furthermore, the biodiversity potential score was unaffected by grazing- history and intensity.

These results indicate, that although abandoned fields and horse pasture have very different plant communities, the occurring species do provide habitat to approximately the same number of species from other taxa. Nevertheless, based on this result, I cannot say that the vegetation of horse pastures is more valuable than the vegetation of abandoned fields, or vice versa, because which other species that is associated with each plant is not accounted for in this scoring system. I.e., it could be that one field type sustains more vulnerable or threatened species, or that there is a lot of overlap between the species that utilize both habitats. Additionally, it is possible that the field types are complementary, and both sustain different species. In the latter case, it would be beneficial to maintain both field types. The latter explanation is more probably, as both field have different plant communities.

The creator of the biodiversity potential score states that the data used to determine the score was not very precise for part of the species (Tyler *et al.*, 2021), and therefore actual monitoring of the presence of non-plant species, by pitfall trapping or pollinator monitoring, would increase accuracy. Additionally, using species cover to calculate the score per plot would have given a much more exact estimate of the average score per square meter, instead of taking the average score of the occurring species. Therefore, I emphasize that I worked with this score to explore if the plant species within each plot showed big differences in biodiversity potential, rather than to actually estimate the amount of associated species per plot.

### Pollinator habitat quality

The average nectar score per plot did not differ between treatments and grazing-history and intensity. There is little known about how grazing affects nectar availability, although Vanbergen *et al.*, (2014) reported nectar resources to be higher at grazed sites versus ungrazed sites. Absence of differences between the two treatments could be due to the fact that I did not collect species cover data, which reduces the accuracy of the nectar availability per plot.

There were more generalist-pollinated species in horse pastures, which, could have a positive impact on the pollinator abundance/species richness (Potts *et al.*,

2009). These results were unexpected, as the bee-pollinated species were higher in the horse pastures compared to an ungrazed area in the study of Garrido (2019).

Generalist-pollinated plants were more abundant in fields that were grazed for 15 years compared to fields that had been grazed for a maximum of 5 years. Therefore, grazed habitat might increase in value to pollinators with time. Again, there were no effects of grazing intensity, which might be caused by aforementioned reasons.

## 5. Conclusion

This study show that grazing by horses affects vegetation composition, and generates a more ruderal plant community with short, small-seeded plants. Although abandoned fields were generally a bit lower in plant species richness, they did not deviate from horse pastures in biodiversity potential score or nectar availability. Consequently, although different in plant composition, both field types might provide habitat to a similar number of other species.

Neither grazing history nor grazing intensity affected the forb community composition within horse pastures suggesting that horse owners adapt the grazing to keep the horses healthy and avoid overgrazing.

In future research, the scarcity of semi-natural pasture species should be investigated, by studying the availability of source populations, and by experimenting with grazing later in the growing season. Additionally, monitoring other species groups will provide a more precise estimate of the effect of horse grazing.



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## Appendix

Table 1: Details for each of the 20 horse pastures and 20 abandoned fields.

| <b>Horse Pastures</b> | Size (Ha) | F        | Mowing   | GH (Years) | GP   | <b>Abandoned Fields</b> | Size (Ha) | TA** (Years) |
|-----------------------|-----------|----------|----------|------------|------|-------------------------|-----------|--------------|
| <b>1</b>              | 0.31      | -        | 2 Yearly | 8          | 0.02 | <b>2</b>                | 0.07      | >5           |
| <b>4</b>              | 0.72      | Yes      | Yearly   | 8          | 0.02 | <b>3</b>                | 0.12      | >5           |
| <b>5</b>              | 2.81      | -        | -        | 25         | 0.01 | <b>6</b>                | -         | 45           |
| <b>7</b>              | 0.54      | -        | -        | 7          | 0.04 | <b>9</b>                | 0.46      | >5           |
| <b>8</b>              | 4.35      | -        | -        | 2          | 0.11 | <b>10</b>               | 0.37      | >5           |
| <b>12</b>             | 0.44      | -        | 2 Yearly | 20         | 0.02 | <b>11</b>               | 0.78      | 10-15        |
| <b>13</b>             | 1.28      | -        | Yearly   | 12         | 0.01 | <b>16</b>               | 0.80      | >20          |
| <b>14</b>             | 3.41      | -        | Yearly   | 50         | 0.02 | <b>17</b>               | 1.08      | 50           |
| <b>15</b>             | 2.81      | -        | 2 Yearly | 3          | 0.14 | <b>18</b>               | 0.60      | >5           |
| <b>19</b>             | 0.29      | -        | Yearly   | 15         | 0.01 | <b>20</b>               | 1.2       | 45           |
| <b>21</b>             | 2.81      | -        | Yearly   | 25         | 0.04 | <b>22</b>               | 2.39      | >5           |
| <b>24</b>             | 0.46      | -        | -        | 10         | 0.00 | <b>23</b>               | 1.00      | 30           |
| <b>25</b>             | 2.02      | Yes<br>* | 2 Yearly | 15         | -    | <b>26</b>               | 0.87      | >5           |
| <b>27</b>             | 1.74      | -        | -        | 5          | 0.02 | <b>29</b>               | 0.33      | >5           |
| <b>28</b>             | 0.41      | -        | 2 Yearly | 18         | 0.01 | <b>31</b>               | 0.18      | >5           |

|           |      |   |        |    |      |           |      |    |
|-----------|------|---|--------|----|------|-----------|------|----|
| <b>30</b> | 1.20 | - | -      | 15 | 0.07 | <b>32</b> | 0.18 | 30 |
|           |      |   |        |    | 5    |           |      |    |
| <b>33</b> | 1.30 | - | -      | 15 | 0.05 | <b>34</b> | 0.27 | 40 |
|           |      |   |        |    | 4    |           |      |    |
| <b>35</b> | -    | - | -      | 10 | -    | <b>36</b> | 0.60 | 20 |
| <b>37</b> | 0.37 | - | -      | 5  | 0.01 | <b>38</b> | 0.17 | >5 |
|           |      |   |        |    | 6    |           |      |    |
| <b>39</b> | 2.95 | - | Yearly | 5  | 0.05 | <b>40</b> | 0.32 | 10 |
|           |      |   |        |    | 5    |           |      |    |

Each of the numbers correspond with the numbers on the map of figure 1. *F* = Fertilizer use, *GH* = Grazing History, *GP* = Grazing intensity, and *TA* = Time of Abandonment. \* At field 25, only a small part of the field was fertilized. \*\* The time of abandonment is >5 when there was no close estimation of time of abandonment, but the locals did know it had been abandoned for at least five years.

Table 2: Overview of the flower classes and their corresponding plant-pollinator-associations.

| <b>FC</b> | <b>Description</b>   | <b>PA</b>  |
|-----------|--|------------|
| A         | Flowers with open nectar; Typical pollinators: beetles, flies, syrphids, wasps, medium tongued bees                | Generalist |
| AB        | Flowers with partly hidden nectar; Typical pollinators: syrphids, bees   | Generalist |
| B         | Flowers with totally hidden nectar; Typical pollinators: bees, bumblebees, wasps, bombylides, syrphids             | Generalist |
| B'        | Flower associations with totally hidden nectar; Typical pollinators: bees, bumblebees, wasps, bombylides, syrphids | Generalist |
| BD        | Transition type flowers with totally hidden nectar - fly flowers; Typical pollinators: flies                       | Generalist |
| BH        | Transition type flowers with totally hidden nectar - bee flowers;<br>Typical pollinators: hymenopteres             | Generalist |
| D         | Fly flowers; Typical pollinators: flies  | Generalist |
| Ds        | Syrphid flowers; Typical pollinators: syrphids   | Generalist |
| Ft        | Butterfly flowers; Typical pollinators: butterflies  | Generalist |
| H         | Hymenoptere flowers; Typical pollinators: hymenopteres   | Bee        |
| Hb        | Bee flowers; Typical pollinators: bees   | Bee        |
| Hh        | Bumblebee flowers; Typical pollinators: bumblebees   | Bee        |

|      |   |            |
|------|---|------------|
| HhFt | Transition type bumblebee flowers - butterfly flowers;<br>Typical pollinators: bumblebees, butterflies            | Bee        |
| Po   | Pollen flowers; Typical pollinators: short tongued bees,<br>syrphids, flies, beetles                              | Generalist |
| W    | Wind flowers; Typical pollinators: -  | Wind       |
| Wb   | Wind flowers occasionally visited by insect; Typical<br>pollinators: Short tongued bees, syrphids, flies, beetles | Wind       |

FC = Flower Class based on Mueller (Kühn, Durka and Klotz, 2004), and PA = Pollinator Association (Garrido et al., 2019)

Table 3: Overview of the CSR values of the indicator species.

| Horse Pastures              |             |             |             | Abandoned Fields               |             |             |             |
|-----------------------------|-------------|-------------|-------------|--------------------------------|-------------|-------------|-------------|
| Species                     | C           | S           | R           | Species                        | C           | S           | R           |
| <i>Alchemilla sp.</i>       | x           | x           | x           | <i>Anthriscus sylvestris</i>   | 0.75        | 0.00        | 0.25        |
| <i>Euphrasia stricta</i>    | 0.00        | 0.00        | 1.00        | <i>Cirsium helenioides</i>     | 0.42        | 0.42        | 0.17        |
| <i>Leontodon autumnalis</i> | 0.17        | 0.17        | 0.67        | <i>Epilobium angustifolium</i> | 1.00        | 0.00        | 0.00        |
| <i>Plantago major</i>       | 0.17        | 0.17        | 0.67        | <i>Galeopsis tetrahit</i>      | 0.50        | 0.00        | 0.50        |
| <i>Polygonum aviculare</i>  | 0.00        | 0.00        | 1.00        | <i>Galium mollugo</i>          | 0.67        | 0.17        | 0.17        |
| <i>Ranunculus repens</i>    | 0.50        | 0.00        | 0.50        | <i>Melampyrum sylvaticum</i>   | 0.50        | 0.00        | 0.50        |
| <i>Rumex acetosella</i>     | 0.17        | 0.42        | 0.42        | <i>Rubus arcticus</i>          | 0.50        | 0.50        | 0.00        |
| <i>Taraxacum officinale</i> | 0.17        | 0.17        | 0.67        | <i>Urtica dioica</i>           | 1.00        | 0.00        | 0.00        |
| <i>Trifolium pratense</i>   | 0.33        | 0.33        | 0.33        | <i>Valeriana sambucifolia</i>  | 1.00        | 0.00        | 0.00        |
| <i>Trifolium repens</i>     | 0.42        | 0.17        | 0.42        | <i>Vicia cracca</i>            | 0.67        | 0.17        | 0.17        |
| <i>Veronica serpyfolia</i>  | 0.17        | 0.17        | 0.67        |                                |             |             |             |
| <b>Average</b>              | <b>0.21</b> | <b>0.16</b> | <b>0.64</b> |                                | <b>0.70</b> | <b>0.13</b> | <b>0.18</b> |

C = Competitors, S = Stress-tolerators, and R = Ruderals. Because *Alchemilla* was not determined to species level, values are absent.

Table 4: Overview of the grazing-associated trait values for each of the indicator species.

| <b>Horse Pastures</b>       |             |             |              | <b>Abandoned Fields</b>        |             |             |             |
|-----------------------------|-------------|-------------|--------------|--------------------------------|-------------|-------------|-------------|
| Species                     | SL          | CH          | SM           | Species                        | SL          | CH          | SM          |
|                             | A           |             |              |                                | A           |             |             |
| <i>Alchemilla sp.</i>       | 1.27        | 1.35        | -0.33        | <i>Anthriscus sylvestris</i>   | 1.49        | 1.87        | 0.63        |
| <i>Euphrasia stricta</i>    | 1.36        | 0.88        | -0.91        | <i>Cirsium helenioides</i>     | 1.42        | 1.74        | 0.25        |
| <i>Leontodon autumnalis</i> | 1.41        | 0.82        | -0.10        | <i>Epilobium angustifolium</i> | 1.35        | 1.70        | -1.26       |
| <i>Plantago major</i>       | 1.35        | 1.57        | -0.57        | <i>Galeopsis tetrahit</i>      | 1.49        | 1.68        | 0.63        |
| <i>Polygonum aviculare</i>  | 1.46        | 2.06        | 0.26         | <i>Galium mollugo</i>          | 1.43        | 1.70        | -0.14       |
| <i>Ranunculus repens</i>    | 1.39        | 1.38        | 0.35         | <i>Melampyrum sylvaticum</i>   | 1.61        | 1.46        | 0.81        |
| <i>Rumex acetosella</i>     | 1.38        | 1.18        | -0.02        | <i>Rubus arcticus</i>          | 1.37        | 1.18        | 0.21        |
| <i>Taraxacum officinale</i> | 1.46        | 1.22        | -0.27        | <i>Urtica dioica</i>           | 1.45        | 1.94        | -0.75       |
| <i>Trifolium pratense</i>   | 1.37        | 1.45        | 0.20         | <i>Valeriana sambucifolia</i>  | 1.70        | 1.98        | -0.12       |
| <i>Trifolium repens</i>     | 1.50        | 1.54        | -0.23        | <i>Vicia cracca</i>            | 1.41        | 1.94        | 1.21        |
| <i>Veronica serpyfolia</i>  | 1.36        | 1.15        | -1.31        |                                |             |             |             |
| <b>Average</b>              | <b>1.39</b> | <b>1.33</b> | <b>-0.27</b> |                                | <b>1.47</b> | <b>1.71</b> | <b>0.15</b> |

The values are logarithmic. SLA = Specific Leaf Area, CH = Canopy Height and SM = Seed Mass. For *Alchemilla sp.*, the average of the trait value of the occurring species within the *Alchemilla* genus was taken.

Table 5: The biodiversity potential values for each of the indicator species.

| <b>Horse Pastures</b>       |                        | <b>Abandoned Fields</b>        |                        |
|-----------------------------|------------------------|--------------------------------|------------------------|
| Species                     | Biodiversity potential | Species                        | Biodiversity potential |
| <i>Alchemilla sp.</i>       | 2                      | <i>Anthriscus sylvestris</i>   | 4                      |
| <i>Euphrasia stricta</i>    | 2                      | <i>Cirsium helenioides</i>     | 4                      |
| <i>Leontodon autumnalis</i> | 4                      | <i>Epilobium angustifolium</i> | 4                      |
| <i>Plantago major</i>       | 6                      | <i>Galeopsis tetrahit</i>      | 4                      |
| <i>Polygonum aviculare</i>  | 5                      | <i>Galium mollugo</i>          | 5                      |
| <i>Ranunculus repens</i>    | 4                      | <i>Melampyrum sylvaticum</i>   | 3                      |
| <i>Rumex acetosella</i>     | 6                      | <i>Rubus arcticus</i>          | 5                      |
| <i>Taraxacum officinale</i> | -                      | <i>Urtica dioica</i>           | 5                      |
| <i>Trifolium pratense</i>   | 6                      | <i>Valeriana sambucifolia</i>  | 3                      |
| <i>Trifolium repens</i>     | 5                      | <i>Vicia cracca</i>            | 5                      |
| <i>Veronica serpyfolia</i>  | 3                      |                                |                        |
| <b>Average</b>              | <b>4.3</b>             |                                | <b>4.2</b>             |

The score for *Alchemilla sp.* was based on the scores of each of the occurring species of this genus in Sweden. For all the species of the *Alchemilla* genus that occur in Sweden, the biodiversity potential score was 2. There was no score in the database for *T. officinale*.

Table 6: The nectar score for each of the indicator species.

| <b>Horse Pastures</b>       |              | <b>Abandoned Fields</b>        |              |
|-----------------------------|--------------|--------------------------------|--------------|
| Species                     | Nectar-score | Species                        | Nectar-score |
| <i>Alchemilla sp.</i>       | 3            | <i>Anthriscus sylvestris</i>   | 5            |
| <i>Euphrasia stricta</i>    | 4            | <i>Cirsium helenioides</i>     | 7            |
| <i>Leontodon autumnalis</i> | 5            | <i>Epilobium angustifolium</i> | 6            |
| <i>Plantago major</i>       | 1            | <i>Galeopsis tetrahit</i>      | 5            |
| <i>Polygonum aviculare</i>  | 3            | <i>Galium mollugo</i>          | 2            |
| <i>Ranunculus repens</i>    | 3            | <i>Melampyrum sylvaticum</i>   | 4            |
| <i>Rumex acetosella</i>     | 1            | <i>Rubus arcticus</i>          | 4            |
| <i>Taraxacum officinale</i> | NA           | <i>Urtica dioica</i>           | 1            |
| <i>Trifolium pratense</i>   | 6            | <i>Valeriana sambucifolia</i>  | 5            |
| <i>Trifolium repens</i>     | 6            | <i>Vicia cracca</i>            | 4            |
| <i>Veronica serpyfolia</i>  | 3            |                                |              |
| <b>Average</b>              | 3.5          |                                | 4.3          |

Table 7: The plant-pollinator associations for each of the indicator species.

| <b>Horse Pastures</b>       |                               | <b>Abandoned Fields</b>        |                               |
|-----------------------------|-------------------------------|--------------------------------|-------------------------------|
| Species                     | Plant-pollinator associations | Species                        | Plant-pollinator associations |
| <i>Alchemilla sp.</i>       | Generalist                    | <i>Anthriscus sylvestris</i>   | Generalist                    |
| <i>Euphrasia stricta</i>    | Generalist                    | <i>Cirsium helenioides</i>     | Generalist                    |
| <i>Leontodon autumnalis</i> | Generalist                    | <i>Epilobium angustifolium</i> | Generalist                    |
| <i>Plantago major</i>       | Wind                          | <i>Galeopsis tetrahit</i>      | Bee                           |
| <i>Polygonum aviculare</i>  | Generalist                    | <i>Galium mollugo</i>          | Generalist                    |
| <i>Ranunculus repens</i>    | Generalist                    | <i>Melampyrum sylvaticum</i>   | Bee                           |
| <i>Rumex acetosella</i>     | Wind                          | <i>Rubus arcticus</i>          | Generalist                    |

|                             |            |                               |            |
|-----------------------------|------------|-------------------------------|------------|
| <i>Taraxacum officinale</i> | Generalist | <i>Urtica dioica</i>          | Wind       |
| <i>Trifolium pratense</i>   | Bee        | <i>Valeriana sambucifolia</i> | Generalist |
| <i>Trifolium repens</i>     | Bee        | <i>Vicia cracca</i>           | Bee        |
| <i>Veronica serpyfolia</i>  | Generalist |                               |            |

All *Alchemilla* species are generalists (Kühn, Durka and Klotz, 2004).

Table 8: PerMANOVA results of a comparison between the grazing history categories.

| Factor          | Df | Sum SQ | Pseudo-F | R <sup>2</sup> | P-value |
|-----------------|----|--------|----------|----------------|---------|
| Grazing history | 3  | 0.57   | 1.27     | 0.19           | 0.15    |
| Residuals       | 16 | 2.40   |          | 0.81           |         |
| Total           | 19 | 2.97   |          | 1.00           |         |

Df= degrees of freedom; Sum SQ = sum of squares; Pseudo-F = F value by permutation. The P-value is based on 999 permutations.

Table 9: PerMANOVA results of a comparison between the grazing intensity categories

| Factor          | Df | Sum SQ | Pseudo-F | R <sup>2</sup> | P-value |
|-----------------|----|--------|----------|----------------|---------|
| Grazing history | 2  | 0.27   | 0.82     | 0.10           | 0.70    |
| Residuals       | 15 | 2.48   |          | 0.90           |         |
| Total           | 17 | 2.75   |          | 1.00           |         |

Df= degrees of freedom; Sum SQ = sum of squares; Pseudo-F = F value by permutation. The P-value is based on 999 permutations.