Can Adapted Management Promote Plant and Butterfly Diversity in Powerline Corridors?

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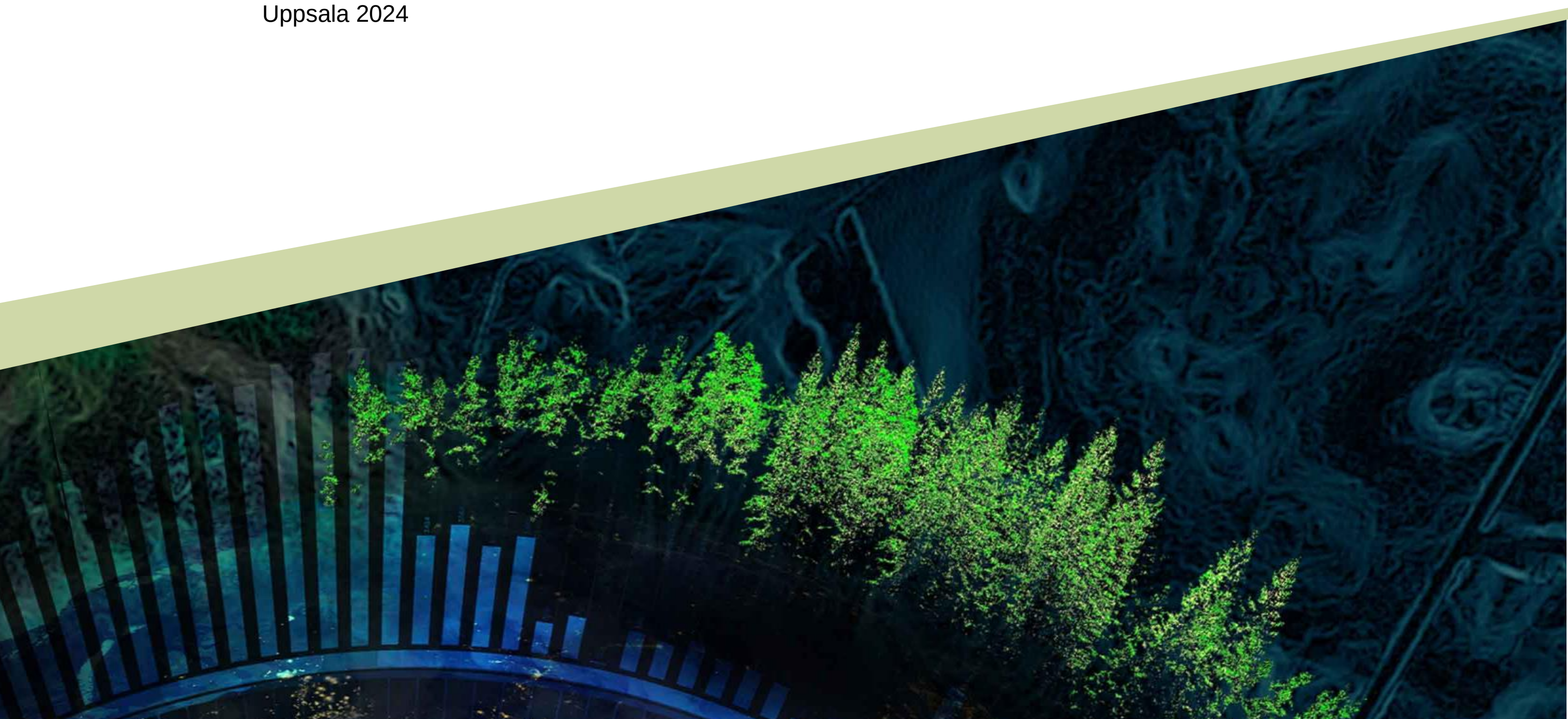

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Abstract

Over the past century, semi-natural grassland areas have been lost at alarming rates throughout Western Europe, leading to reduced populations and diversity of plants and butterflies, particularly grassland specialists. In this context, powerline corridors have emerged as alternative habitats, harbouring a relatively high level of plant and butterfly diversity, owing to regular clearings that promote disturbance-tolerant plants and create habitats suitable for many butterflies.

In Sweden, powerline corridors are typically cleared every eight years. In contrast to semi-natural pastures, butterfly diversity has been found to be negatively affected by increased vegetation height in these corridors. Recent studies suggest that more frequent clearing regimes can enhance both plant and butterfly species richness and abundance in powerline corridors, and that the removal of cleared residuals may further benefit plant and butterfly diversity.

This thesis investigates the impact of an altered management regime, consisting of more frequent clearings and removal of all cleared residuals, on general plant and butterfly diversity, as well as grassland-specific plant and butterfly diversity. A before-after control-impact study design was used, in which diversity metrics were compared between the altered and conventional management regimes over two years (2018 and 2024). The diversity metrics assessed were species richness, abundance/cover-abundance, and the Shannon diversity index.

No significant effects of the altered management regime were identified for any of the diversity metrics analysed. Some possible explanations include that more time is needed for the potential effects of the altered management to appear, and that butterfly diversity tends to be low during the first year after clearance, as is the case for the follow-up counts conducted in 2024.

Further research should evaluate the effects of the altered management regime after at least one, but ideally several, complete management cycles. Additionally, annual counts should increase the accuracy of future studies and analyses at the species level could provide useful grassland-specific plant and butterfly conservation implications.

Keywords: Plant, Butterfly, Powerline Corridor, Grassland, Diversity, Species Richness, Abundance, Ecology

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1. Introduction

1.1 Background

Neolithic settlers first arrived in Central Europe and Fennoscandia around 6000 – 8000 years ago (Squires et al., 2018). Since then, various agricultural practises have shaped the landscape in these areas; the use of pastures and hay meadows has led to the formation of semi-natural grasslands – unfertilised open-land ecosystems in which the management regime prevents the accumulation of woody vegetation while maintaining a diverse flora of herbaceous species (Squires et al., 2018). These semi-natural grasslands were once widely distributed throughout Europe. Nowadays, the biodiversity associated with these landscapes is threatened by modernised agricultural practices and altered land use (Habel et al., 2013). Most Western European countries have lost at least 95 percent of their former semi-natural grassland areas (Dahlström et al., 2008), and in Sweden only about 5-10% of traditionally managed grasslands remained at the end of the 20th century compared to the start of the century (Johansson et al., 2008; Cousins et al., 2015). In southern Finland, it has been found that recent termination of grazing in semi-natural grasslands cause significant declines in the species richness of vascular plant species (Luoto et al., 2003), and on a local scale, such declines have worsened with the duration since the termination of grazing (Luoto, 2000, as cited in Luoto et al., 2003).

Butterflies are particularly dependent on semi-natural grasslands, with 88 percent of European butterflies occurring in grasslands and 43 percent being grassland specialists (Squires et al., 2018). In Sweden and large parts of western Europe, butterfly species tied to semi-natural grasslands are in heavy decline due to the vast reduction in semi-natural grassland area and losses of traditional management practices (Dahlström et al., 2008; Nilsson, Franzén, and Pettersson, 2013). The loss of suitable habitats and the modernisation of agricultural practices have been proposed as the main threats to butterflies (Wagner, 2020; Warren et al., 2021), and a general pattern of butterfly decline is that losses are most severe for specialist species and usually include species previously common in the landscape (Wagner, 2020). Based on data from regional and national butterfly monitoring schemes in 16 European countries (including Sweden), overall grassland butterfly abundance has decreased by 39 percent since 1990 (Swaay et al., 2019). In Sweden, 32 percent of open-grassland plant species are listed as near threatened or worse (SLU Artdatabanken, 2020). In the 2010 European Red List of butterflies, 19 percent of European butterflies were listed as either threatened (9 percent) or near-threatened (10 percent), and 31 percent of all assessed butterfly species (90 percent of all butterfly species were assessed) had declining populations (Swaay et al., 2010). At least 45 percent of Swedish butterflies have faced negative population trends since the 1950s (Franzén and Johannesson, 2007).

1.2 Powerline corridors can provide alternative habitat

The large and rapid decline in semi-natural grassland areas has led to the search for alternative habitats for species dependent on such habitats, with different types of linear infrastructure suggested as suitable replacement habitats and refuges (Auestad et al., 2011; Berg et al., 2011; Lampinen et al., 2018; Horstmann et al., 2023).

Powerline corridors, which are cleared areas beneath overhead power lines for safe transmission of electricity (Figure 1), provide suitable habitats for grassland plant species (Lampinen et al., 2018). At the landscape scale, landscapes with powerline corridors, compared to landscapes without them, have been found to harbour, on average, six more plant species, indicating an increased extinction debt in landscapes with powerline corridors, making them suitable for plant conservation (Dániel-Ferreira et al., 2020). Powerline corridors have also been found to provide suitable plant habitats in the long term, with a positive relationship between the number of specialised plant species and the age of the powerline corridor (Horstmann et al., 2023). Additionally, the richness of butterflies in linear infrastructure habitats has been found to be largely dependent on plant species richness (Horstmann et al., 2023). The frequent clearance of powerline corridors promotes vascular plants, increases nectar availability, and creates warm and dry microhabitats, which is beneficial for many butterfly species (Lensu et al., 2011; Oki et al., 2021).

When comparing different types of open habitats in a south-central Swedish forest-farmland landscape, Berg et al. (2011) found that powerline corridors harboured a higher species richness and abundance of butterflies, as well as a higher abundance of red-listed butterflies, than semi-natural pastures, forest road verges, and forest clear-cuts. In another study, Berg et al. (2013) found that 12 of the 26 analysed butterfly species were more abundant in powerline corridors than in semi-natural pastures.

Powerline corridors can also provide suitable habitats for butterflies that are typically found in forests and mires. Oki et al. (2021) found that powerline corridors located within landscapes of conifer plantations provide important habitats for forest, ruderal, and grassland butterflies, and Lensu et al. (2011) found that the species richness and abundance of mire butterflies were the same in natural mires as in powerline corridors stretching across afforested drained mires. In contrast, the remaining areas of the same drained mires adjacent to the powerline corridors harboured a significantly lower species richness and abundance of mire butterflies (Lensu et al., 2011). Additionally, the presence of powerline corridors has been found to increase the species richness and abundance of butterflies in adjacent road verges and pastures up to approximately 500 m from the powerline corridor (Berg et al., 2016).

Despite the relatively high species richness and abundance of butterflies, novel grasslands, such as powerline corridors, usually lack some grassland specialist species that are more commonly found in traditionally managed semi-natural grasslands (Dániel-Ferreira et al., 2023). However, it is still argued that powerline corridors could be utilised for the conservation of grassland species, especially in areas where only a small fraction of traditionally managed grasslands remains, as powerline corridors can serve as important alternative habitats for grassland plants and butterflies (Dániel-Ferreira et al., 2023; Horstmann et al., 2023). Even small adjustments to the current management regimes of powerline corridors can increase plant diversity and thus pollinating services (Steinert et al., 2018), further strengthening the argument for using powerline corridors for conservation actions. Linear infrastructure can serve as the main habitat for several red-listed species (Svensson, Berg, and Ahrné, 2012). For example, Modin and Öckinger (2020) found that the endangered grassland specialist butterfly species *Lycaena helle* was largely dependent on powerline corridors within their study area in central Sweden.

1.3 How should powerline corridors be managed to promote biodiversity?

While conservation efforts for grassland-dependent species primarily target semi-natural grasslands, it is increasingly recognised that alternative habitats, such as powerline corridors, should also be considered because of their ability to harbour a high diversity and abundance of butterflies, and because they already cover large areas of the landscape and require frequent management (Berg et al., 2011, 2013, 2016). Powerline corridors have also been suggested as alternative habitats in plans aimed at conserving and increasing the area, quality, and connectivity of grasslands to benefit butterflies (Lampinen et al., 2018).

In Sweden, powerline corridors cover more than 220 000 ha, of which more than 14 000 ha are being managed more intensely, mainly in the inspection paths, whereas the remaining areas are cleared less frequently and are typically covered by young trees and/or shrubs (The Swedish Board of Agriculture, 2012). In contrast to semi-natural grasslands, which are typically mowed or grazed on an annual or biannual basis (Tälle, 2018), the management intensity of powerline corridors is relatively low. In Sweden, most powerline corridors are cleared of shrubs and young trees every eight years (Svenska Kraftnät, 2023). The cleared vegetation is usually left to decay in the corridor but is removed from the inspection paths to make them more accessible (Ecogain AB on behalf of Svenska Kraftnät, 2021).

How powerline corridors should be managed to benefit plants, butterflies, and other grassland-specific species has been a subject of recent research. Eldegard et al. (2017) suggests that frequent clearings of productive sites within powerline corridors could mitigate the loss of insect-pollinated plant species associated with former semi-natural grasslands. Although directly damaging to butterfly eggs and larvae, mowing or clearing of vegetation is crucial for hindering succession and afforestation in the long run (Bonari et al., 2017). For the benefit of butterflies, Berg et al. (2013, 2016) suggest that vegetation could be kept short by clearance of shrubs more frequently than the current standard of every eight years. While an increased vegetation height would normally benefit butterflies in semi-natural pastures, the opposite has been found for powerline corridors, where there is usually a shortage of areas covered by a short vegetation height due to the long clearing intervals (Berg et al., 2013). Furthermore, Oki et al. (2021) showed that grassland, ruderal, and forest butterfly species within powerline corridors are all negatively affected by vegetation height, indicating the importance of creating more open habitats within powerline corridors.

The removal of cleared shrubs and trees (which are usually left to decay in the corridor after clearance) has been found to increase the diversity of insect-pollinated plants, but to what extent depends on local abiotic and biotic conditions (Steinert et al., 2018). It has also been suggested that the removal of cleared residuals may benefit some butterfly species (Berg et al., 2013). Results from Komonen, Lensu, and Kotiaho (2013) indicate that the optimal clearing interval of powerline corridors with regard to butterfly species richness and abundance is roughly 2-4 years, although their results suggest that any shortening of the current 6-year clearing interval in their study area would be beneficial.

Theoretically, increasing the frequency of clearings and removing residual materials from powerline corridors is expected to benefit less competitive plant species, as it creates conditions more similar to those found in traditionally managed grasslands. This concept is in line with the Intermediate Disturbance Hypothesis, which suggests that moderate levels of disturbance promote diversity by preventing competitive exclusion and facilitating colonisation (Connell, 1978; Wilkinson, 1999). Additionally, Steinert et al. (2018) suggest that increased clearing intervals of powerline corridors increase the species and functional diversity of insect-pollinated plants, and Eldegard et al. (2017) also suggest that an increased clearing frequency could create a more valuable habitat for plants associated with semi-natural grasslands.

It has been suggested that an altered management regime consisting of an increased clearing frequency of powerline corridors and the removal of cleared residuals should benefit plant and butterfly diversity. The aim of this master’s thesis was to investigate whether such a management regime had any effects on the diversity of (1) plants and butterflies and (2) grassland-specific plants and butterflies.

2. Methods

2.1 Study sites

This study was conducted in powerline corridors in Northern and Eastern Uppland, Sweden. A total of 16 sites within the powerline corridors were chosen as study sites for butterfly monitoring, of which eight were used for the plant monitoring as well. The study sites were spread over two main areas: Odenslätt, consisting of six sites (60°N, 17°E), and Lydinge, consisting of ten sites (59°N, 18°E) (Figure 1). The study sites are located within a forest-farmland landscape, with the immediate surroundings consisting mainly of coniferous and mixed forests, dominated by Norwegian Spruce (Picea abies) and Scots Pine (Pinus sylvestris), but also of arable fields and pastures. This study is part of a long-term research project in collaboration with Svenska Kraftnät aimed at evaluating an alternative management regime applied in powerline corridors, focusing on promoting grassland flora and fauna.

2.2 Management regimes: conventional & experimental

In this study, the management regime typically used in Swedish powerline corridors is referred to as the conventional management regime. Under the conventional management regime, powerline corridors are typically cleared every eight years to prevent the vegetation from reaching too high, interfering with the electrical lines. The cleared vegetation is then left to decay on the ground after clearance. In most powerline corridors, there is an inspection path (usually 3 m wide) running along the powerline. The inspection path is cleared more frequently than the rest of the powerline corridor, typically every fourth year instead of eight, and the cleared vegetation is removed to allow transportation of ATVs along the inspection path. (Ecogain AB on behalf of Svenska Kraftnät, 2021)

The experimental management regime, further referred to as the altered management regime, consists of the same practices used in the conventional management regime, but with the addition of a 6 m wide and approximately 200 m long treatment section immediately adjacent to the inspection path (as illustrated in Figure 3 and 4). The alternative management regime used in these treatment sections mimics the management used in the inspection paths, meaning that it consists of a shortened clearance cycle of four years and the removal of all cleared residuals (including shrubs and young trees). Figure 1 shows a powerline corridor site used in this study.

Figure 1. *Photo of a site within one of the powerline corridors used in study. The inspection path is seen in the centre.*

2.3 Study design

A before-after control-impact (BACI) study design has been employed to study the effects of the alternative management regime (treatment) in powerline corridors. Plant and butterfly diversity responses to the treatment have been analysed in comparison to the conventional management regime (control) and between two points in time (before and after the altered management regime was introduced). The aim of the altered management regime was to promote grassland flora and fauna. In this study, both general and grassland-specific plant and butterfly diversity metrics were studied. For plants, counts from eight treatment areas were compared with counts from eight control areas, adjacent to the treatments, across two years (2018 and 2024). For butterflies, counts from eight treatment sites were compared to counts from eight control sites across the same two years. The study design used minimizes biases by accounting for natural fluctuations in response variables that could occur independently of the treatment, ensuring that any potential differences are due to the treatment rather than external factors (Christie et al., 2019).

In this experiment, the initial clearing, associated with the conventional management regime, occurred after the summer (butterfly peak season) of 2018, but prior to the end of the summer of 2019 at all sites. The additional clearing, linked to the altered management regime, was conducted during the summers of 2023 and 2024 depending on site.

2.4 Plants

For plants, a total of eight sites within powerline corridors have been surveyed. At each site, one treatment area has been located immediately adjacent to one side of the inspection path, and a control area has been located on the opposite side of the inspection path, also immediately adjacent to it (as illustrated in Figure 2 & 4). In each of these three groups (inspection path, treatment area, and control area), five 2 x 2 m plots have been surveyed for plants. The first three plots were placed 20 m from the start of the transect, one was placed in the centre of the inspection path, and the control and treatment plots were placed 4.5 m away from the centre plot in their respective directions and aligned adjacent to each other, as shown in Figure 2. The remaining 12 plots were placed 60, 100, 140, and 180 m from the starting point. The distances used between the plots were as accurate as the landscape allowed. When it was not suitable for plant surveying (e.g. rocky or wet surfaces, or too close to the forest edge), the plots were placed as close to the theoretical location as possible. A few transects were shorter than 200 m; in these cases, the distance between the plots was adjusted proportionally.

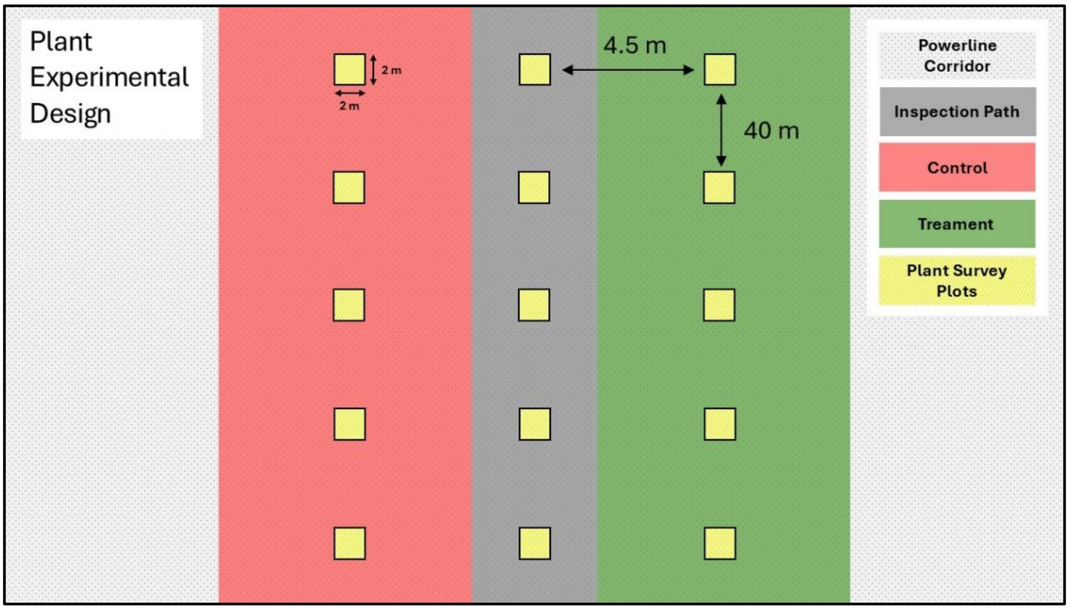

Figure 2. *The experimental study design for plants.*

In each plot, all plants were identified to the lowest possible taxonomic level (not lower than the species level) and recorded along with their cover-abundance. The cover-abundance score was recorded in accordance with a modified Braun-Blanquet scale (see Table 1). The modified scores were used for analyses of cover-abundance.

Baseline data were collected in 2018 before the modified management regime was introduced. An additional plant count was conducted in 2024. Plant counts were conducted between mid-June and late July in both years. The coordinates of each plot were recorded during the initial plant count in 2018; two diagonally opposite corners of each plot were also marked in the field using blue tent pegs. However, because of the difficulty in relocating the tent pegs and the exact plant survey plots in the field, many plots surveyed in 2024 had to be placed according to the coordinates and where they should have been located in relation to other plots. This means that the exact same plots were not always surveyed in 2018 and 2024. Therefore, the accuracy of the plots used in the analyses is somewhat limited.

Table 1. *Braun-Blanquet cover-abundance scale (van der Maarel 1979), with modified scores used in the calculations and analyses of plant- and grassland-specific plant cover-abundance.*

Braun-Blanquet scale	Modified Score	Description
r	0.1	Not many, 1-10 individuals
+	0.5	Sparsely or very sparsely present; cover very small (less than 5%)
1	1	Plentiful but of small cover (less than 5%)
2	2	Any number of individuals covering 5-25% of the area
3	3	Any number of individuals covering 25-50% of the area
4	4	Any number of individuals covering 50-75% of the area
5	5	Covering more than 75% of the area

2.5 Butterflies

In this thesis, the term butterfly is used to refer to both butterflies (*Rhopalocera*) and burnet moths (*Zygaenidae*). For butterflies, eight sections along the powerline corridors were selected as treatment sites. An additional eight sections along the same powerline corridors were selected as control sites. The idea was for the control sites to share similar characteristics to the treatment sites, although an initial difference in both species richness and abundance was found between the control and treatment sites (see Table 2 & 3). However, these baseline differences were accounted for using the BACI study design.

At each site, a 200 m transect located in the centre of the inspection path was surveyed (see Figures 3 & 4). The number of individuals of each butterfly species was recorded for each transect. The butterfly surveys were conducted according to the standard protocol (Pollard, 1977), with recordings of all butterflies within 2.5 m to the left and right, and 5 m in front of and above the surveyor, at a slow pace (excluding the time of notetaking or species identification). When it was not possible to identify a butterfly at a distance, it was caught in a butterfly net and released immediately after species identification. Butterflies that could not be identified were recorded as the species they were most likely to belong to, based on prior observations. For example, if a large orange butterfly flew by quickly and five previous sightings of *Speyeria aglaja* were recorded in the transect on the same day, with no other similar butterflies observed, the unidentified butterfly would be classified as *Speyeria aglaja*. To obtain sufficient samplings of most butterfly species throughout the season, butterfly surveys were conducted at three times during the butterfly peak season (once in mid-June, early July, and late July/early August) between 10:00 and 16:30. The sites were surveyed in different order during the separate visits, to avoid time-of-day related biases in butterfly behaviour. Surveys were conducted on sunny or mostly sunny days, with minimal or no precipitation, at a temperature of at least 17°C, wind speeds below 8 m/s, and only when the field layer was dry.

An initial butterfly count was conducted at each of the 16 sites in 2018, before the altered management regime was initiated. A second count was conducted in 2024 after the control sites had been cleared once and the treatment sites had been cleared twice.

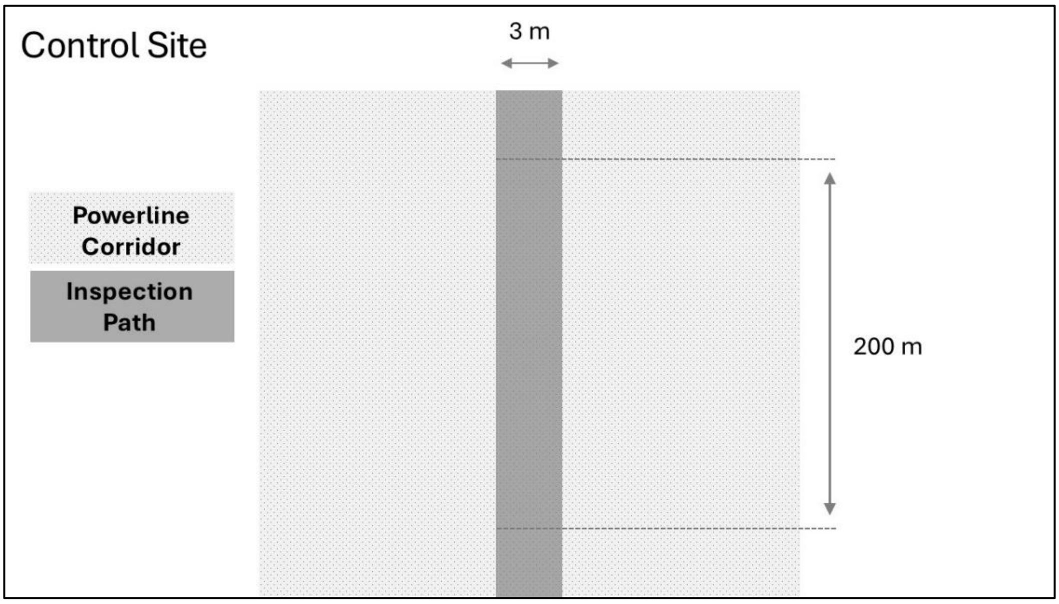

Figure 3. *Butterfly control site: The grey dotted area represents the powerline corridor being manged conventionally; the solid grey area represents the inspection path, which is cleared every fourth year and in which the cleared residuals are being removed.*

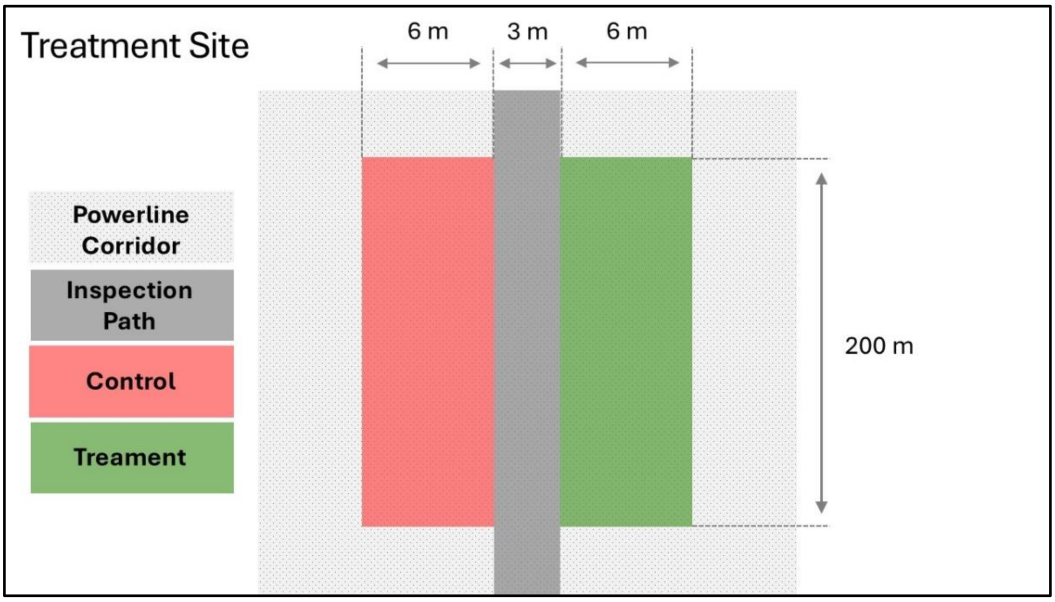

Figure 4. *Butterfly treatment site: the grey dotted area represents the powerline corridor being manged conventionally; the solid grey area represents the inspection path, which is cleared every fourth year and in which the cleared residuals are being removed; the green area represents the area of the altered management, where the clearing mimics the one used in the inspection path; the red area represents the control area for the plant surveying, in which the management regime is the same as in the powerline corridor (grey dotted area).*

2.6 Definition of grassland-specific plants and butterflies

Grassland-specific plants were selected and filtered using the grazing/mowing category of the classification of Swedish vascular plants made by Tyler et al. (2021). Within the classification, there are eight levels of grazing/mowing, ranging from intolerance to grazing/mowing to complete dependence on it. In this study, all species belonging to level five or above have been included as grassland-specific plants, meaning species that either (5) are favoured by some grazing/mowing, but also survive in unmanaged habitats, (6) are strongly favoured by regular grazing/mowing but also endures some years without management, (7) are strongly favoured by grazing/mowing and disappear within a few years if management ceases, or (8) demand repeated/continuous grazing/mowing. Grassland-specific butterflies were classified according to Öckinger et al. (2012) (classification made by M. Franzén, Linköping Univ., based on data from Eliasson, Ryrholm, and Gärdenfors, 2005).

2.7 Statistical analyses

For plants, the species richness and the Shannon diversity index per plot were used as response variables. For plants, the Shannon diversity index was calculated using species richness and the corresponding cover-abundance score derived from the modified Braun-Blanquet scale (see Table 1). The predictor variables used were year (2018 or 2024), management type (control or treatment), and the interaction between year and management type. The effects of the predictor variables were tested using linear mixed-effects models. To account for potential variations linked to the individual sites and plots surveyed, they were included as random-effects variables. The plots were modelled as nested within sites to allow the model to account for potential within-site variability, taking the hierarchical structure of the data into consideration, as this leads to more accurate estimates of the fixed effects. Therefore, the models used to analyse plant responses were therefore specified as follows:

$$Plant\ Response\ Variable \sim Year \times Management\ Type + (1 \mid Site/Plot)$$

For grassland-specific plants, the same response variables were used as for plants in general but with the addition of cover-abundance as well. This analysis was performed because the total cover-abundance of grassland-specific plant species is expected to affect butterfly diversity (Lensu et al., 2011; Oki et al., 2021). The statistical analyses for grassland-specific plants were performed in the same way as those for plants, with the addition of the analysis of grassland-specific plant cover-abundance.

An important difference in the grassland-specific plants analyses is that only taxa identified at the species level are included, as opposed to the general plant analyses, since the classification is limited to the species level and does classify plants at different taxonomical levels. For both plants and grassland-specific plants, only the treatment and control plots were analysed, that is, not the plots within the inspection paths (see Figure 2).

For butterflies, the counts from all three separate visits were summed for each year. The species richness, number of individuals (abundance), and Shannon diversity index per site were used as response variables in the butterfly analyses. The predictor variables used were the same as for the plant analyses, i.e. year (2018 or 2024), management type (control or treatment), and the interaction between year and management type. The effects of the predictor variables were tested using linear mixed-effects models, where site was included as a random effects variable to account for potential local-scale differences, thereby increasing the accuracy of the fixed effects estimates. The models used to analyse butterfly responses were therefore specified as follows:

$$Butterfly\ Response\ Variable \sim Year \times Management\ Type + (1 \mid Site)$$

For grassland-specific butterflies, the analyses were executed in the same manner as for butterflies. In the analyses of butterflies and grassland-specific butterflies, two separate pairs of species have been lumped and considered to belong to the same species since they were difficult to correctly identify in the field. These pairs consist of *Leptidea juvernica* and *Leptidea sinapis* (for both butterfly and grassland-specific butterfly analyses) and *Plebejus argus* and *Plebejus idas* (for buttefly analyses).

The data analyses and visualizations were all performed using R Statistical Software (R Core Team, 2023) and RStudio (Posit team, 2024). The dplyr package (Wickham et al., 2023) was used for data manipulation, such as filtering and summarising the datasets. The ggplot2 package (Wickham et al., 2016) was used to create visualisations of the datasets, and was used in combination with the patchwork package (Lin Pedersen, 2024) to allow merging of several plots into a single cohesive layout. The vegan package (Oksanen et al., 2024) was used for calculating diversity metrics. Additionally, the lme4 package (Bates et al., 2015) was used for fitting the linear mixed-effects models, and the lmerTest package (Kuznetsova et al., 2017) provided p-values for the fixed effects of the models.

3. Results

3.1 Plants

The total plant species richness increased across both treatment and control groups from 2018 to 2024, from 120 to 134. For the treatment group, the total species richness increased from 109 to 114, and for the control group, it increased from 84 to 108 (Table 2). From 2018 to 2024, the mean species richness per plot increased for both management types, from 11.1 (± 4.9) to 11.8 (± 4.8) in the treatment group and from 10.7 (± 4.6) to 11.1 (± 4.4) in the control group (Table 2). However, no significant differences in species richness were found between the two management types or years (Year: Estimate = 0.40, SE = 0.53, p = 0.456; Management type: Estimate = 0.38, SE = 0.83, p = 0.652; Interaction: Estimate = 0.35, SE = 0.75, p = 0.644; Table 3). A variation in species richness between plots (variance = 8.05, SD = 2.84) and sites (variance = 7.76, SD = 2.77) was found, explaining 73.5% of the total variation in species richness (Table 4).

The total plant cover-abundance (summed values from the modified scores; see Table 1) across all plots was 908 in 2018 and 761 in 2024. In the treatment group, the total cover-abundance was 472 in 2018 and 394 in 2024, whereas in the control group, it was 436 in 2018 and 367 in 2024 (Table 2). Although this metric has not been statistically analyses, it is presented as a reference for grassland-specific plant abundance.

For plants, the Shannon diversity index was significantly influenced by year (Estimate = 0.12, SE = 0.06, p = 0.035; Table 3) but not by management type (Estimate = 0.06, SE = 0.08, p = 0.462; Table 3) or the interaction between year and management type (Estimate = -0.01, SE = 0.08, p = 0.876; Table 3). For treatment plots, the mean Shannon diversity index increased from 1.81 (± 0.42) in 2018 to 1.92 (± 0.44) in 2024, and for control plots, it increased from 1.75 (± 0.41) in 2018 to 1.88 (± 0.41) in 2024 (Table 2). A plot-level variance of 0.06 (SD = 0.24) and a site-level variation of 0.05 (SD = 0.25) was found, explaining a total of 62.6% of the variation in Shannon diversity (Table 4).

3.2 Grassland-specific plants

Total grassland-specific plant species richness increased across both treatment and control groups from 2018 to 2024, from 35 to 48. For the treatment group, the total species richness increased from 30 to 43, and for the control group, it increased from 22 to 36 (Table 2). From 2018 to 2024, the mean species richness per plot increased for both management types, from 2.4 (± 2.3) to 3.3 (± 2.9) in the treatment group and from 2.1 (± 2.0) to 2.8 (± 3.2) in the control group (Table 2). A significant difference in species richness was found between years (Estimate = 0.75, SE = 0.31, p = 0.019; Table 3), but not between the two management types (Estimate = 0.35, SE = 0.47, p = 0.454; Table 3), nor by the interaction of year and management type (Estimate = 0.15, SE = 0.44, p = 0.735; Table 3). A variation in species richness between plots (variance = 2.39, SD = 1.55) and sites (variance = 2.33, SD = 1.53) was found, explaining a total of 70.7% of the variation in species richness (Table 4).

The total grassland-specific plant cover-abundance across all plots was 351 in 2018 and 231 in 2024. In the treatment group, the total abundance was 201 in 2018 and 118 in 2024. In the control group, it was 150 in 2018, and 113 in 2024 (Table 2). In the treatment group, grassland-specific plants made up 42.6% of the total cover-abundance in 2018, and in 2024 it had decreased to 29.9%. In the control group, grassland-specific plants made up 34.4% of the total plant cover-abundance, and in 2024 it had decreased to 30.8%. Grassland-specific plant cover-abundance was significantly higher in the treatment sites compared to the control sites (Management type: Estimate = 1.28, SE = 0.52, p = 0.015; Table 3), but neither year (Estimate = -0.92, SE = 0.52, p = 0.080; Table 3) nor the interaction of year and management type (Estimate = -1.16, SE = 0.74, p = 0.118; Table 3) had any significant effect on the cover-abundance. The mean cover-abundance per treatment plot was 5.0 (± 2.2) in 2018 and 3.0 (± 2.4) in 2024. For the control group, the mean cover-abundance per plot was 3.8 (± 2.7) in 2018 and 2.8 (± 2.0) in 2024 (Table 2). No plot-level variation was found, but a site-level variation of 0.03 (SD = 0.17) was detected, explaining 0.5% of the variation in grassland-specific plant cover-abundance (Table 4).

For grassland-specific plants, none of the predictor values had any significant effect on the Shannon diversity index (Management type: Estimate = 0.10, SE = 0.10, p = 0.314; Year; Estimate = 0.07, SE = 0.09, p = 0.451; Interaction: Estimate = -0.10, SE = 0.13, p = 0.431; Table 3). For treatment plots, the mean Shannon diversity index decreased from 0.87 (± 0.44) in 2018 to 0.84 (± 0.87) in 2024, and for control plots, it increased from 0.77 (± 0.51) in 2018 to 0.48 (± 0.82) in 2024 (Table 2). A plot-level variance of 0.03 (SD = 0.18) and a site-level variation of 0.06 (SD = 0.25) was found, explaining a total of 37.9% of the variation in Shannon diversity (Table 4).

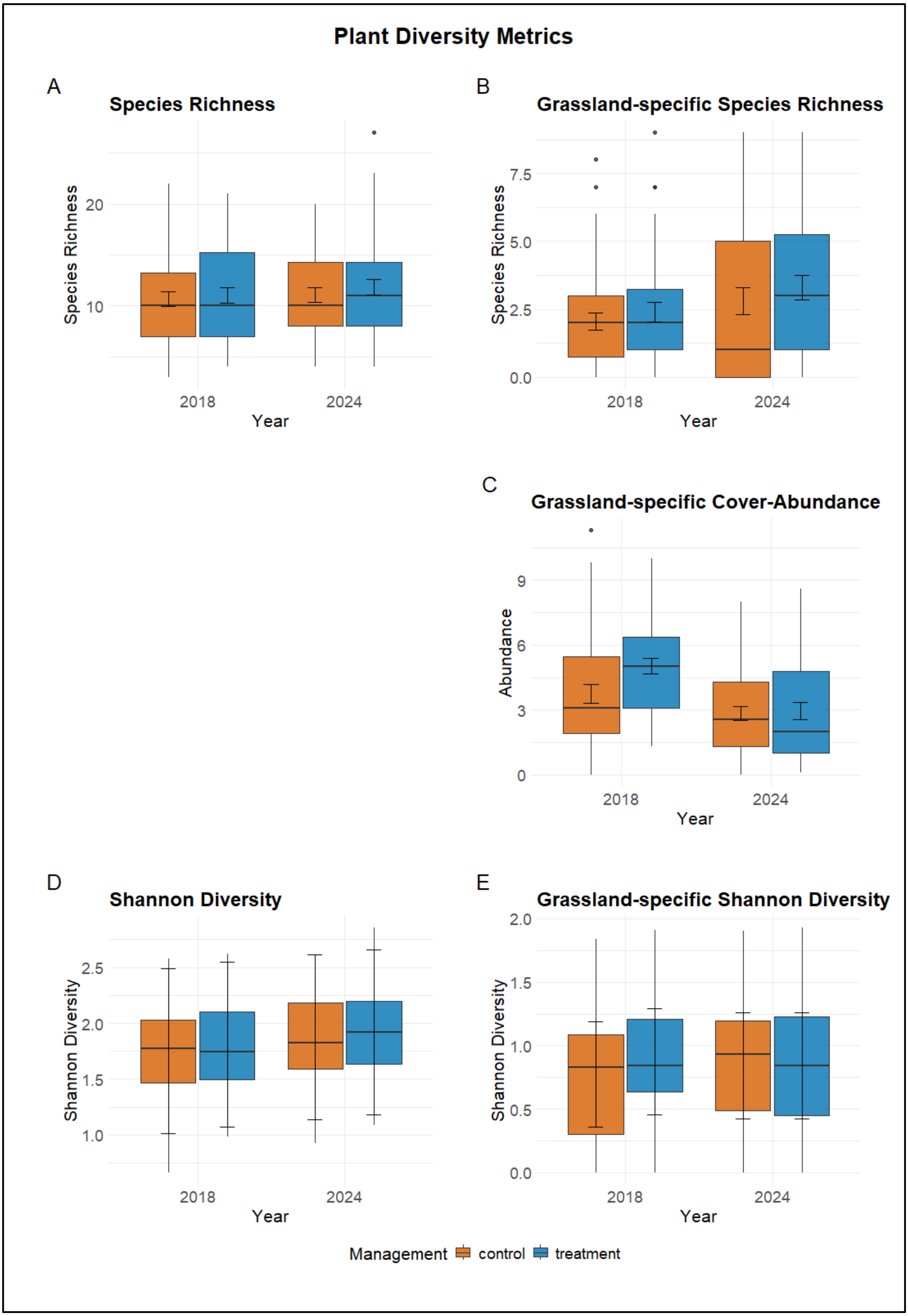

Figure 5. Boxplot of plant diversity metrics. Error bars display SE.

3.3 Butterflies

A total of 33 butterfly species were recorded in 2018 and 31 in 2024 across all treatment and control sites. For the different management types, the total species richness decreased from 31 species in 2018 to 26 species in 2024 for the treatment group and from 24 species in 2018 to 23 species in 2024 for the control group (Table 2). In both years, the treatment group had a higher mean species richness per site than the control group (Estimate = 4.13, SE = 1.36, p = 0.005; Table 3). Year did not have a significant effect on the species richness of butterflies (Estimate = 1.13, SE = 0.96, p = 0.384; Table 3). For the treatment group, the mean species richness per site went from 13.4 (± 2.5) in 2018 to 12.1 (± 2.8) in 2024, and for the control group, it went from 9.3 (± 3.8) in 2018 to 10.4 (± 2.3) in 2024 (Table 2). The change in species richness from 2018 to 2024 did not differ between the treatment and control groups (Interaction: Estimate = -2.38, SE = 1.78, p = 0.200; Table 3). A site level variance of 1.06 (SD = 1.03) was found, explaining about 14.3% of the total variation in butterfly species richness (Table 4).

The total butterfly abundance (number of individuals recorded) increased from 586 individuals in 2018 to 590 individuals in 2024. The total abundance decreased in the treatment group while it increased in the control group from 2018 to 2024. For the treatment group, the abundance decreased from 366 in 2018 to 358 in 2024, and for the control group, it increased from 220 to 232 (Table 2). While the mean abundance did not differ significantly between years (Estimate = 1.50, SE = 6.97, p = 0.832; Table 3), the treatment sites had a significantly higher mean abundance than the control sites in both years (Estimate = 18.25, SE = 7.19, p = 0.016; Table 3). The mean abundance per treatment site remained the same across the years (45.8 ± 15.9 in 2018 and 45.8 ± 12.3 in 2024). For the control group, the mean abundance per sites increased from 27.5 (± 20.5) in 2018 to 29.0 (± 11.0) in 2024 (Table 2). The interaction between year and management type was not significant (Estimate = -2.50, SE = 9.86, p = 0.803; Table 3). A site-level variance of 12.22 (SD = 3.50) was found, explaining 5.9% of the total variation in butterfly abundance (Table 4).

When both butterfly species richness and relative abundance were considered in the Shannon diversity index, neither year (Estimate = 0.02, SE = 0.16, p = 0.925; Table 3), management type (Estimate = 0.15, SE = 0.16, p = 0.369; Table 3), nor the interaction between the two (Estimate = -0.32, SE = 0.23, p = 0.171; Table 3) had a significant effect. In the treatment group, the mean Shannon diversity index per site decreased from 2.21 (± 0.26) to 2.06 (± 0.39), and across the control sites, the mean Shannon diversity index per site increased from 1.90 (± 0.45) to 2.08 (± 0.24) from 2018 to 2024 (Table 2). No site-level variance was detected, while the residual variance was 0.10 (SD = 0.32) (Table 4).

3.4 Grassland-specific butterflies

A total of 14 grassland-specific butterfly species were recorded in 2018 and 15 in 2024 across the treatment and control groups. For the different management types, the species richness remained the same across the years for both treatment and control groups (13 species in the treatment group and 10 species in the control group; Table 2). Year did not have a significant effect on mean grassland-specific butterfly species richness (Estimate = 0.88, SE = 0.75, p = 0.253; Table 3). From 2018 and 2024, the mean grassland-specific butterfly species richness increased for both management types, from 5.5 ±1.6 to 5.6 ±1.2 in the treatment sites, and from 3.3 ±1.8 to 4.1 ±1.8 in the control sites (Table 2). The treatment group had a higher mean species richness per site than the control group (Estimate = 2.25, SE = 0.75, p = 0.005; Table 3). The change in species richness from 2018 to 2024 did not statistically differ between the treatment and control groups (Interaction: Estimate = -0.75, SE = 1.06, p = 0.485; Table 3). No site level variance was found (Table 4). The Residual variance was 2.26 (SD = 1.50).

The total grassland-specific butterfly abundance increased from 246 individuals in 2018 to 262 individuals in 2024. From 2018 to 2024, the abundance decreased slightly in the treatment group (from 175 to 174 individuals), while it increased in the control group (from 71 to 88) (Table 2). While the mean abundance did not differ significantly between years (Estimate = 2.13, SE = 2.96, p = 0.483; Table 3), the treatment group had a significantly higher mean abundance per site than the control group (Estimate = 13.00, SE = 3.51, p = 0.001; Table 3). From 2018 to 2024, the mean abundance per treatment site decreased slightly, from 21.9 (± 6.7) to 21.8 (± 10.4), while in control sites, it increased from 8.9 (± 5.8) in 2018 to 11.0 (± 6.3) in 2024 (Table 2). The interaction between year and management type was not significant (Estimate = -2.25, SE = 4.19, p = 0.598; Table 3). A site-level variance of 14.11 (SD = 3.76) was found, explaining 28.7% of the total variation in grassland-specific butterfly abundance (Table 4).

When both grassland-specific butterfly species richness and relative abundance were considered in the Shannon diversity index, neither year (Estimate = -0.10, SE = 0.17, p = 0.560; Table 3), management type (Estimate = -0.12, SE = 0.17, p = 0.942; Table 3), nor the interaction between the two (Estimate = -0.16, SE = 0.23, p = 0.511; Table 3) had a significant effect. For the treatment group, the mean Shannon diversity index per site increased from 1.41 (± 0.69) in 2018 to 1.49 (± 0.28) in 2024, and for the control group, it increased from 0.89 (± 0.60) to 1.39 (± 0.29) (Table 2). No site-level variance was detected, while the residual variance was 0.11 (SD = 0.33) (Table 4).

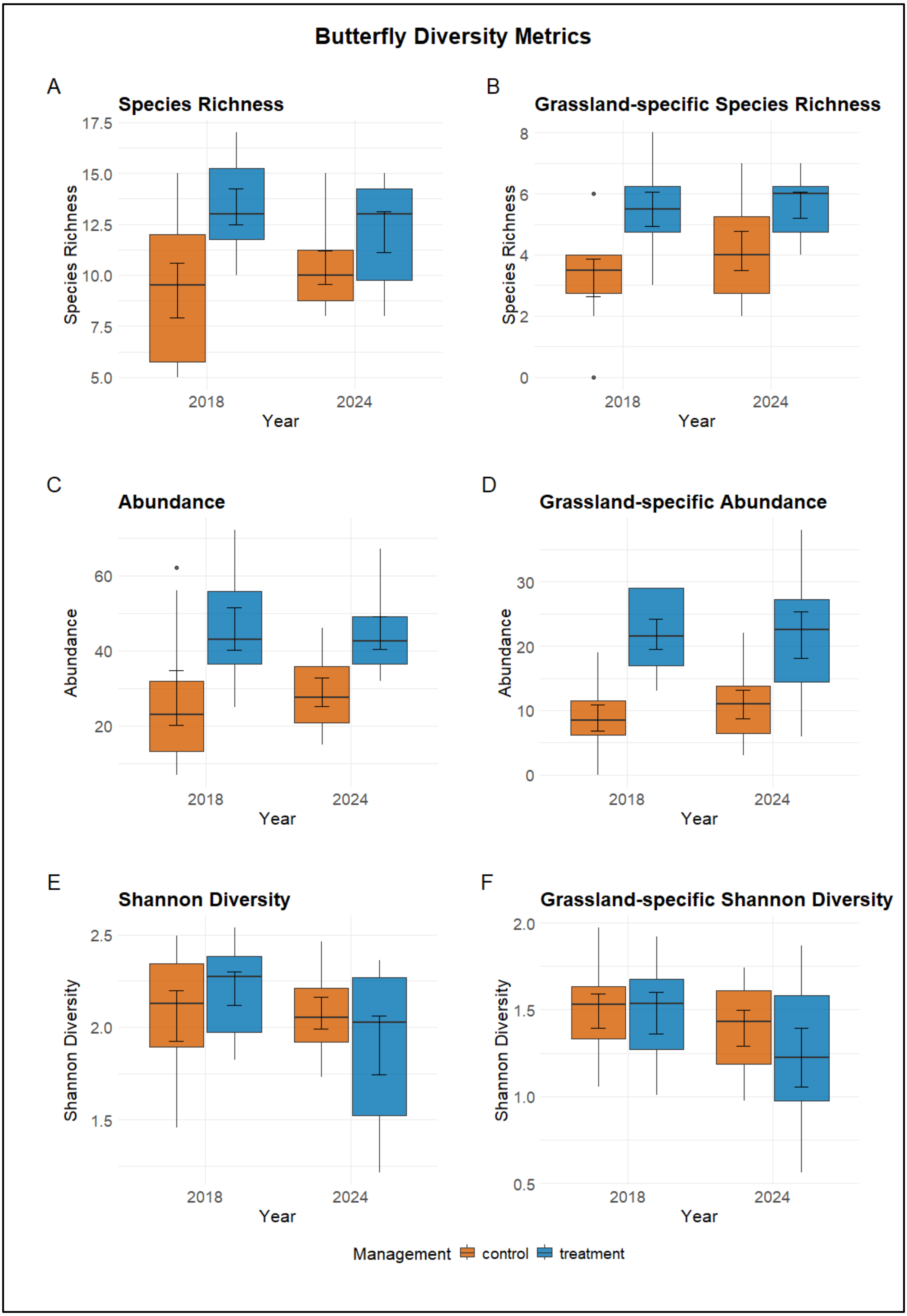

Figure 6. *Boxplot of butterfly diversity metrics. Error bars display SE.*

Table 2. *Diversity numbers from the field counts of plants, grassland-specific plants, butterflies, and grassland-specific butterflies. The columns Overall, Treatment Group and Control Group is the total number for all sites and/or plots in the category, whereas the columns Treatment (Mean ± SD) and Control (Mean ± SD) is the mean per plot for plants and mean per site for butterflies.*

Variable	Year	Overall	Treatment Group	Control Group	Treatment (Mean ± SD)	Control (Mean ± SD)
Plant Species Richness	2018	120	109	84	11.1 ± 4.9	10.7 ± 4.6
	2024	134	114	108	11.8 ± 4.8	11.1 ± 4.4
Plant Cover-Abundance	2018	908	472	436		
	2024	761	394	367		
Plant Shannon Diversity Index	2018				1.81 ± 0.42	1.75 ± 0.41
	2024				1.92 ± 0.44	1.88 ± 0.41
Grassland-specific Plant Species Richness	2018	35	30	22	2.4 ± 2.3	2.1 ± 2.0
	2024	48	43	36	3.3 ± 2.9	2.8 ± 3.2
Grassland-specific Plant Cover-Abundance	2018	351	201	150	5.0 ± 2.2	3.8 ± 2.7
	2024	231	118	113	3.0 ± 2.4	2.8 ± 2.0
Grassland-specific Plant Shannon Diversity Index	2018				0.87 ± 0.44	0.77 ± 0.51
	2024				0.84 ± 0.87	0.84 ± 0.82
Butterfly Species Richness	2018	33	31	24	13.4 ± 2.5	9.3 ± 3.8
	2024	31	26	23	12.1 ± 2.8	10.4 ± 2.3
Butterfly Abundance	2018	586	366	220	45.8 ± 15.9	27.5 ± 20.5
	2024	590	358	232	45.8 ± 12.3	29.0 ± 11.0
Butterfly Shannon Diversity Index	2018				2.21 ± 0.26	1.90 ± 0.45
	2024				2.06 ± 0.39	2.08 ± 0.24
Grassland-specific Butterfly Species Richness	2018	14	13	10	5.5 ± 1.6	3.3 ± 1.8
	2024	15	13	10	5.6 ± 1.2	4.1 ± 1.8
Grassland-specific Butterfly Abundance	2018	246	175	71	21.9 ± 6.7	8.9 ± 5.8
	2024	262	174	88	21.8 ± 10.4	11.0 ± 6.3
Grassland-specific Butterfly Shannon Index	2018				1.41 ± 0.69	0.89 ± 0.60
	2024				1.49 ± 0.28	1.39 ± 0.29

Table 3. *Predictor variable results from the statistical analyses. Significant results marked in bold text in the p-value column. The term Year x Treatment refers to the interaction between year and management type.*

Variable	Predictor Variable	Estimate	SE	p-value
Plant Species Richness	Treatment	0.38	1.04	0.718
	Year	0.40	0.53	0.456
	Year x Treatment	0.35	0.75	0.644
Plant Shannon Diversity Index	Treatment	0.06	0.09	0.536
	Year	0.12	0.06	**0.035**
	Year x Treatment	-0.01	0.08	0.876
Grassland-specific Plant Species Richness	Treatment	0.35	0.47	0.454
	Year	0.75	0.31	**0.019**
	Year x Treatment	0.15	0.44	0.735
Grassland-specific Plant Cover-Abundance	Treatment	1.28	0.52	**0.015**
	Year	-0.92	0.52	0.080
	Year x Treatment	-1.16	0.74	0.118
Grassland-specific Plant Shannon Diversity Index	Treatment	0.10	0.10	0.314
	Year	0.07	0.09	0.451
	Year x Treatment	-0.10	0.13	0.431
Butterfly Species Richness	Treatment	4.13	1.36	**0.005**
	Year	1.13	0.96	0.384
	Year x Treatment	-2.38	1.78	0.200
Butterfly Abundance	Treatment	18.25	7.19	**0.016**
	Year	1.50	6.97	0.832
	Year x Treatment	-2.50	9.86	0.803
Butterfly Shannon Diversity Index	Treatment	0.15	0.16	0.369
	Year	0.02	0.16	0.925
	Year x Treatment	-0.32	0.23	0.171
Grassland-specific Butterfly Species Richness	Treatment	2.25	0.75	**0.005**
	Year	0.88	0.75	0.253
	Year x Treatment	-0.75	1.06	0.485
Grassland-specific Butterfly Abundance	Treatment	13.00	3.51	**0.001**
	Year	2.13	2.96	0.483
	Year x Treatment	-2.25	4.19	0.598
Grassland-specific Butterfly Shannon Diversity Index	Treatment	-0.12	0.17	0.942
	Year	-0.10	0.17	0.560
	Year x Treatment	-0.16	0.23	0.511

Table 4. *Variance in response variables explained by the random effects variables. The "Percentage of Total Variation" column is the ratio of the summed variance of the random effects variables divided by the total variance from the random effects and residual variance, i.e. (Site Variance + Plot Variance) / (Site Variance + Plot Variance + Residual Variance).*

Category	Response Variable	Random Effects variables	Site Variance (SD)	Plot Variance (SD)	Residual Variance	Percentage of Total Variation
Plants	Species Richness	Site & Plot	7.76 (2.79)	8.05 (2.84)	5.69 (2.39)	73.5
	Shannon Diversity Index	Site & Plot	0.05 (0.26)	0.06 (0.24)	0.06 (0.25)	62.6
Grassland-specific Plants	Species Richness	Site & Plot	2.33 (1.53)	2.39 (1.55)	1.96 (1.40)	70.7
	Abundance	Site & Plot	0.03 (0.17)	0.00 (0.00)	0.00 (2.33)	0.5
	Shannon Diversity Index	Site & Plot	0.06 (0.25)	0.03 (0.18)	0.16 (0.40)	37.9
Butterflies	Species Richness	Site	1.06 (1.03)		6.32 (2.15)	14.3
	Abundance	Site	12.22 (3.50)		194.25 (13.94)	5.9
	Shannon Diversity Index	Site	0.00 (0.00)		0.10 (0.32)	0.0
Grassland-specific Butterflies	Species Richness	Site	0.00 (0.00)		2.26 (1.50)	0.0
	Abundance	Site	14.11 (3.76)		35.05 (5.92)	28.7
	Shannon Diversity Index	Site	0.00 (0.00)		0.10 (0.33)	0.0

4. Discussion

The aim of this master’s thesis was to investigate whether an altered management regime consisting of an increased clearing frequency of powerline corridors and removal of cleared residuals had any effects on several diversity metrics of (1) plants and butterflies in general and (2) grassland-specific plants and butterflies. The effects of the altered management regime have been assessed by analyses of field counts of butterflies and plants in control and treatment sites. A baseline count was conducted in 2018, before the altered management was introduced, and a second follow-up count was conducted in 2024. The results indicate that the altered management regime has not yet significantly affected the butterfly and plant diversity metrics. These findings imply that the investigated responses may require more time to display or that the altered management regime may not be sufficient to significantly affect the studied response variables in these habitats.

The altered management regime did not have any significant effect on any of the plant- or grassland-specific plant diversity metrics (species richness, cover-abundance, and Shannon diversity). Interestingly, the mean grassland-specific plant species richness increased significantly from 2018 to 2024 for both management groups, but the mean cover-abundance seemed to decrease during the same period (Table 3). However, annual fluctuations are common in grassland plant communities because of differences in environmental factors between years, affecting which species are being promoted (Adler et al., 2006; Cleland et al., 2013; Fischer et al., 2020), which may explain why some of the diversity metrics differed between years for both plant and grassland-specific plants. Another, more specific explanation for why the grassland-specific plant species richness have increased despite a potential decrease in cover-abundance may be that a decrease in cover-abundance may have enabled more grassland-specific species to compete. This explanation follows from what is predicted by the Intermediate Disturbance Hypothesis (Connell, 1978; Wilkinson, 1999), since less shading by other plants should promote more species. However, this potential effect should not be attributed to the altered management regime since there was no difference between the two management groups but is nonetheless something to consider in the process of plant conservation planning.

Neither the butterfly nor grassland-specific butterfly diversity metrics (species richness, abundance, and Shannon diversity) were affected by the altered management regime (interaction of year and management), indicating that it does not influence butterfly diversity. This is in stark contrast with Komonen, Lensu, and Kotiaho (2013), who found that an increased clearing frequency of powerline corridors to between 2-4 years (compared to 6 years) benefits butterfly diversity.

The results are also contrary to Berg et al. (2013, 2016), who imply that management cycles should be shortened and that cleared residuals should be removed for the benefit of butterfly diversity within powerline corridors.

However, it is worth noting that Komonen, Lensu, and Kotiaho (2013) also found there to be a dip in the abundance of butterflies within the first year after clearings of powerline corridors, and attribute this to the fact that populations need this time to regrow and for immigration to take place into the populations. In this experiment, the first clearing occurred after the summer (butterfly peak season) of 2018, but before the end of the summer of 2019 at all sites. The additional clearing (treatment) took place during the summers of 2023 and 2024, meaning the counts from the treatment sites conducted in 2024 are derived from populations which have recently been exposed to a major disturbance and are still within one year since the last clearing. Therefore, it is likely that this has negatively influenced the reported butterfly diversity in the treatment sites in 2024. A possible consequence of this is that the gap in butterfly diversity between the treatment and control groups is expected to have decreased from 2018, when the time since the last clearing was the same across both management groups. This trend is supported by the data from 2024, which may be attributed to the fact that populations within the control group have had more time to regrow since those sites have not been cleared for five to six years. Although non-significant, almost all the diversity metrics (both plants and butterflies) seem to have been slightly negatively affected by the altered management regime at this stage in time (see Table 3). To address this issue, future research should involve annual counts of butterflies over an extended period of time, since it would allow for a better understanding of population dynamics and annual fluctuations in plant and butterfly diversity, as well as a better understanding of the time-since-clearing effect.

The fraction of the total variance attributed to sites and plots differed between different diversity metrics and taxonomic groups. The variance in both plant and grassland-specific plant diversity metrics (especially species richness and Shannon diversity) proved to be strongly linked to the local conditions, with roughly equal proportions to the 2 × 2 m plots and the sites in which the plants were surveyed. This indicates that plant conservation efforts must not neglect the potential of local factors at different scales, and that microhabitats and their specific characteristics may be especially important to consider for a successful plant conservation strategy. In previous research it has been found that the success of altered management regimes like the one used in this study depends on environmental context (Steinert et al., 2018). Worth considering in the results from this study is that the exact same plots were not resurveyed in 2024 (See methods chapter), and that this may have affected the accuracy of the plot-variation, which should therefore be regarded with some caution.

General butterfly diversity seems to be only somewhat explained by local conditions, while grassland-specific butterfly diversity (especially abundance) seems to be more linked to the local conditions. This indicates that grassland-specific butterflies may be more restricted by the plant composition, which is known to be an important factor for butterfly community composition (Van Halder et al., 2016). Consequently, conservation efforts aimed at preserving grassland-specific butterflies may be more successful if directed towards maintaining sites where they already occur, or towards creating new habitats or dispersal zones especially suitable for them. However, the research is somewhat contradictory with some findings indicating that factors at the landscape scale better explain butterfly diversity, especially grassland specialist (Schneider & Fry, 2001), while others have found butterfly richness and community composition to be more dependent on local-scale habitat variables (Van Halder et al., 2016).

As previously noted in the methods chapter, notable (and in some cases significant) differences were observed between the control and treatment groups in many of the diversity metrics in 2018, prior to the implementation of the altered management regime. Therefore, investigating the difference only between control and treatment sites in a single year or relying entirely on a before-after study design would risk leading to biased results. In this case, such approaches would not capture the variability caused by the baseline difference between the control and treatment group. The use of the selected study design (BACI) was selected to mitigate these biases and control for such pre-existing differences (Christie et al., 2019). However, it could still be argued that the best-case scenario would have been to select control and treatment sites in which the diversity metrics were more similar. Unfortunately, such optimal scenarios can be challenging to achieve since treatment sites cannot always be assigned randomly for practical reasons (Conner et al., 2016). This study is no exception with the experiment being part of a collaboration with Svenska Kraftnät, making it more difficult to assign sites completely randomly. However, future research could benefit from careful site selection in which there are no baseline differences in the response variables.

As already discussed, the reliability of these data is limited by the fact that it is most likely too soon to detect many of the potential effects of the altered management regime; one management cycle under a conventional management regime is eight years (four years for the treatment), and only six years have passed since the start of the experiment. Therefore, it is very likely that more time is needed for any potential effects of the altered management regime to become apparent. Nonetheless, this study has served as an evaluation of how the experiment is progressing at this stage in time. The full experiment is planned to stretch for a total of 16 years (two full cycles under the conventional management regime), which greatly increases the chances of detecting any potential effects of the treatment and it should be long enough for proper evaluation of the altered management regime. Another approach to deal with the time aspect when it comes to plant diversity could be to include the plots in the inspection paths, as these areas have been subjected to the altered management regime for a longer duration than the treatment area. However, this comes with some challenges and discrepancies compared to the altered management regime, primarily due to the additional disturbances caused by ATVs driving along the inspection paths. If taking this approach, to more accurately evaluate the effects of the altered management regime it would be wise to exclude the wheel tracks in the inspection path from the surveying, and only count plants found between the tracks.

It is also worth acknowledging the potential influence of observer bias on the accuracy of the count data in this study since the counts were made by different surveyors in 2018 and in 2024. Especially, the difference in expertise on plants may have contributed to what taxonomic level was recorded in similar situations across the years, which could in turn affect how many species were included in the grassland-specific analyses. The cover-abundance recordings for plants may also have been more difficult to estimate similarly between surveyors. However, this bias has been found to be rather small in plant cover estimates (Milberg et al., 2008) and was further mitigated to the extent possible by using standardized survey methodologies and some initial training and calibration for new surveyors.

Although more data from extended time periods would be beneficial for evaluations of the altered management regime, the results still provide valuable insight into how an increased clearing frequency combined with removal of cleared residuals effects general and grassland-specific butterfly and plant diversity within powerline corridors in the short term. As already discussed, it would be advisable for future research to evaluate the effects of the altered management regime after at least one full management cycle (eight years), but ideally after multiple cycles. This would enable a more comprehensive understanding of the impacts of the altered management regime since ecological responses are not always immediately apparent.

For a deepened understanding of the ecosystem dynamics within these semi-natural habitats, it would be of interest to investigate how (and if) butterfly and plant diversity may relate to and respond in relation to each other following the implementation of an altered management regime. Since butterfly species richness has previously been found to be largely dependent on the plant species richness within linear infrastructures (Horstmann et al., 2023), butterfly diversity should be expected to increase following a management regime that successfully promotes grassland-specific plants. Although no effects of the altered management regime were evident in this study, several other studies have in fact found evidence of an increased plant and butterfly diversity following a shortened management cycle of powerline corridors (Komonen et al., 2013; Eldegard et al., 2017; Steinert et al., 2018). One way to investigate this could be to use plant diversity as a predictor variable for butterfly diversity under a similar BACI study design as employed in this study.

Furthermore, expanding the experimental design to incorporate landscape scales could potentially increase the robustness of the findings. This study did not capture much of the variability in the response variables, especially for butterflies (Table 4), indicating that more variables should be included in the analyses. For example, grassland-specific butterflies have been found to benefit from more habitat variability within the landscape (Schneider & Fry, 2001). Analyses incorporating both landscape variables and smaller scale habitat variables should capture more of the variability in the diversity response variables and thereby provide more robust statistical models.

In addition to the focus in this study, which was on general and grassland-specific butterflies and plants, there is more to understand from investigating the responses of individual species or functional groups, and perhaps especially those most severely threatened by deteriorating or lost grassland habitats. Better understanding of these vulnerable species could help target conservation actions to prevent further losses. The data from this study should be sufficient to conduct single-species analyses, although such responses would also be more accurate after at least one full management cycle.

4.1 Conclusion

This thesis provides insight into the effects of an altered management regime of powerline corridors on plant and butterfly diversity metrics. Despite the shortened clearing frequency and removal of cleared residuals, no significant effects were observed. This suggests that the implemented management regime is not sufficient to induce shifts in the diversity metrics analysed or that the potential impacts of the management regime require more time to manifest. These findings are in contrast with those of previous studies, indicating the need for further research with more robust study designs to evaluate the impact of similar clearing alterations. Further research should extend over longer time periods, analyse counts from more years, and include factors at different local scales and different habitat characteristics.

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Popular science summary

During the last century, modernisation of agricultural practices has caused rapid and extensive declines in traditionally managed grasslands throughout most of Western Europe. This, in turn, has led to substantial declines in plants and butterflies, especially for grassland-dependent species. Interestingly, land areas used for infrastructure can mitigate such declines to some extent. Powerline corridors is an example of such an area, providing suitable habitats for many plants and butterflies. These corridors are regularly cleared to prevent the vegetation within them from reaching to high and develop into forested land.

In Sweden, powerline corridors are typically cleared every eight years. However, it has been found that as vegetation grows taller within these corridors, plant and butterfly diversity tends to decrease. Researchers have therefore started to investigate the effects of more frequent clearings, with results so far indicating that a more frequent clearing interval is beneficial for butterfly diversity, and some researchers have suggesting that they should also be beneficial for plant diversity. Some studies also suggest that the removal of cleared vegetation should provide additional benefits for plant and butterfly diversity.

This study aimed to evaluate the effects on plant and butterfly diversity of an altered management regime in which the vegetation was cleared every fourth year instead of eight years, and in which the cleared vegetation was removed from the powerline corridor. The diversity of plants and butterflies was studied in comparison to the conventional management regime of powerline corridors, with baseline data collected in 2018 and follow-up data collected in 2024.

Contrary to what has been suggested in previous literature, the altered management regime was not found to significantly affect the diversity of plants or butterflies. Similarly, no significant effects were observed in grassland-specific plants or butterflies. These findings suggest that the altered management regime was not different enough from the conventional regime to induce a change in plant and butterfly diversity, or that more time is needed for proper evaluation of its true effects, since ecological processes can take a long time to both manifest and detect.

I suggest that future studies should analyse the effects from extended time periods, which is usually desirable in ecological studies, and that data collection from more time steps should be included in the analyses. It is also advised to investigate how specific species respond to the altered management, as such knowledge could provide valuable insight into the conservation of threatened grassland plants and butterflies.

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