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Master Thesis

Comparison of butterfly species richness, abundance and community composition in different grassland types

Submitted by

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Already published project papers:

- Brandl, M., Hussain, R., Maas, B., Rabl, D., Pachinger, B., Holzinger, W., Krautzer, B., Moser, D., Frank, T., et al. (2022). Improving insect conservation values of agri-environment schemes through diversified seed mixtures. *Biological Conservation*, *269*, p. 109530.
- Hussain, R., Brandl, M., Maas, B., Krautzer, B., Frank, T., Moser, D., Hussain, R. & Brandl, M. (2022). Establishing new grasslands on crop fields: short-term development of plant and arthropod communities. *Restoration Ecology*.
- Hussain, R., Brandl, M., Maas, B., Rabl, D., Walcher, R., Krautzer, B., Entling, M., Moser, D. & Frank, T. (2021). Re-established grasslands on farmland promote pollinators more than predators. *Agriculture, Ecosystems & Environment*, *319*, p. 107543. Retrieved from https://www.sciencedirect.com/science/article/pii/S0167880921002474;
- Hussain, R., Frank, T., Walcher, R., Vogel, N., Streisselberger, L., Vogl, C., Pölz, A. & Krautzer, B. (2022). DivRESTORE - Transforming grasslands to achieve insect diversity restorative goals and human well-being: Final report. Retrieved from http://www.austriaca.at/0xc1aa5576%200x003d3d84.pdf;
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Affidavit

I hereby declare that I have authored this master thesis independently, and that I have not used any assistance other than that which is permitted. The work contained herein is my own except where explicitly stated otherwise. All ideas taken in wording or in basic content from unpublished sources or from published literature are duly identified and cited and the precise references included.

I further declare that this master thesis has not been submitted, in whole or in part, in the same or a similar form, to any other educational institution as part of the requirements for an academic degree.

I hereby confirm that I am familiar with the standards of Scientific Integrity and with the guidelines of Good Scientific Practice, and that this work fully complies with these standards and guidelines.

Vienna, 26.05.2022 Nora VOGEL *(manu propria)*

Preface

The research presented in this master thesis was conducted in the framework of the project "REGRASS II: Re-Etablierung von Graslandstreifen zur Förderung von Biodiversität und Ökosystemleistungen im Agrarland", funded by Bundesministerium für Landwirtschaft, Regionen und Tourismus (Project number: 101565) and the project "DivRESTORE: transforming grasslands to achieve insect diversity restorative goals and human well-being", funded by Österreichische Akademie der Wissenschaft ÖAW (BOKU Project number: 7833013076).

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Abstract

Agricultural intensification and landscape homogeneity are major threats of biodiversity loss in agricultural grassland. One measure to counteract this loss are flower strips. Especially pollinators, such as butterflies, profit from flower strips or newly established grassland with local plant species, as these habitats provide nectar for adults, food and shelter for larvae. Pollinator biodiversity in grasslands can be effectively enhanced by introducing newly established flower-rich habitats.

This master thesis includes two studies. The first study, located in Lower Austria, compares the effect of grassland enhanced with autochthonous flower mixtures with long-term established meadows on butterfly species richness, abundance, community composition and butterfly traits. Further, biodiversity areas, which were subsidised by the ÖPUL (Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft) program 2015 were included in the study. The second study compares butterfly species richness, abundance and community composition on extensive grassland with intensive grassland with and without adjoining flower strip and flower strips. The study sites were in the biosphere reserves Vienna Woods and Salzburger Lungau / Carinthian Nockberge. Due to climatic and elevation differences of the two regions, regional effects were assessed too. The butterfly sampling was done once a month from May to August, and the butterflies were recorded over the whole grassland within 10 and 20 minutes, for the first and the second study, respectively. Data analysis was done with Generalized Linear Mixed Models (GLMM) and a multivariate statistical approach.

Total recorded species over the study years were 51 and 56 species for the first and the second study, respectively. The results of the first study showed differences in butterfly species richness, abundance and community composition among the grassland types. Highest butterfly abundance and species richness were found in the old, long-term established grasslands. In the second study highest butterfly abundance and species richness were found in the extensive meadows. The second study showed highly significant differences in butterfly species richness, abundance and community composition between the two biosphere regions, but not between the meadow types. Flower strips showed no effect on the adjacent grassland. For the butterfly traits, negative correlations between abundance of species hibernating as "egg" and newly established grassland were found. Regarding habitat moisture preferences, species preferring "fresh" habitats were positively correlated with biodiversity areas and species inhabiting "xerotherm" habitats were negatively correlated with this type of grassland. My findings suggest that flower strips might not be the only approach to promote butterfly abundance and species richness. A combination of flower strips with other restoration and conservation measures such as habitat connectivity and extensive grassland management will be needed to prevent further butterfly diversity decline.

Kurzfassung

Die Intensivierung der Landwirtschaft sowie die Homogenisierung der Landschaftsstruktur gelten als eine der Hauptursachen des Biodiversitätsverlustes in Agrarflächen. Blühstreifen sind eine Maßnahme, um diesem Biodiversitätsverlust entgegenzuwirken. Vor allem Bestäuber, wie z.B. Tagfalter, profitieren von solchen Ersatzhabitaten, welche Nektar für die adulten Tiere sowie Nahrung und Schutz für die Larven bieten. Die Bestäuberdiversität in Agrarflächen kann effektiv mittels Blühstreifen erhöht werden.

Diese Masterarbeit umfasst zwei Projekte. Das erste Projekt wurde im Tullnerfeld (Niederösterreich) durchgeführt und vergleicht die Artenvielfalt, Abundanz und Artenzusammensetzung von Tagfaltern sowie ökologische Gruppen der Tagfalter auf langjährig etablierten Wiesen, mit neu angelegten Wiesenstreifen. Zusätzlich wurden vom ÖPUL (Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft) Programm 2015 subventionierte Biodiversitätsflächen untersucht. Das zweite Projekt wurde in den Biosphärenparks Wienerwald und Salzburger Lungau / Kärntner Nockberge durchgeführt. Dieses Projekt vergleicht vier verschiedene Wiesentypen (extensive Wiesen, intensive Wiesen mit und ohne Blühstreifen und Blühstreifen) ebenfalls hinsichtlich der Artenvielfalt, Abundanz und Artenzusammensetzung von Tagfaltern. Zwischen den Flächen gab es klimatische Höhendifferenzen, weshalb in diesem Projekt auch der regionale Effekt auf die Tagfalterdiversität untersucht wurde. Die Felderhebungen der Tagfalter fanden einmal monatlich zwischen Mai und August statt. Die Falter wurden über die ganze Wiesenfläche während 20 Minuten im ersten Projekt bzw. 10 Minuten im zweiten Projekt erhoben. Die Datenanalyse wurde mittels GLMM (Generalized Linear Mixed Models) und multivariaten statistischen Methoden durchgeführt.

Insgesamt wurden 51 und 56 Arten im ersten bzw. zweiten Projekt nachgewiesen. Das erste Projekt zeigte klare Unterschiede bezüglich der Tagfalter Abundanz, Artenvielfalt und Artenzusammensetzung zwischen den verschiedenen Wiesentypen. Die höchste Abundanz und Artenvielfalt wurden in den langjährig etablierten Wiesen beobachtet. Das zweite Projekt hatte die höchste Tagfalter Abundanz und Artenvielfalt in den extensiven Wiesen. Es zeigte sich ein signifikanter Unterschied in Tagfalter Abundanz, Artenvielfalt und Artenzusammensetzung zwischen den zwei untersuchten Regionen. Es konnte jedoch kein signifikanter Unterschied der drei Faktoren zwischen den verschiedenen Wiesentypen festgestellt werden. Es wurde auch kein Einfluss der Blühstreifen auf die benachbarten Intensivwiesen festgestellt werden. Es wurde zusätzlich eine Merkmal-Analyse durchgeführt, bei welcher eine negative Korrelation zwischen Tagfalter Abundanz und Tagfalterarten, welche als «Ei» überwintern und den neu angelegten Wiesenstreifen, festgestellt wurde. Bezüglich Feuchtigkeit des Habitats, wurde eine positive Korrelationen zwischen Arten welche «frische» Habitate bevorzugen und den subventionierten Biodiversitätsflächen gefunden und eine negative Korrelation zwischen Arten mit «xerothermen» Habitatsansprüchen und demselben Wiesentyp. Die Resultate zeigen, dass Blühstreifen nicht die einzige Maßnahme sind, um Tagfalterartenvielfalt und -abundanz zu fördern. Eine Kombination von Blühstreifen mit anderen Erhaltungsmaßnahmen wie die Vernetzung von Habitaten und extensives Wiesenmanagement ist notwendig, um weiterem Artenverlust von Tagfaltern entgegenzuwirken.

Content

1 Introduction

1.1 Butterflies as indicator

Butterflies are among the most well-studied insect groups. They are important model insects, popular with the public, and most species in Europe are quite easy to identify in the field. Furthermore, butterfly species are valuable as indicators for environmental changes as their abundance, species richness and community composition respond quickly to land use or climate change (Lebeau, Wesselingh & van Dyck, 2015; Warren et al., 2021). Butterflies are highly mobile organisms with different habitat requirements in different life stages, therefore, changes in butterfly communities do not simply follow vegetation based indicators (Warren et al., 2021).

Butterfly observations performed over 160 years in Wuppertal (Germany) and related to land-use changes indicated a loss of nutrient-poor, flower-rich field margins and meadows over time. Consequently, this led to the loss of some common butterfly species such as *Boloria euphrosyne* (Linnaeus, 1758), *Boloria selene* (Denis & Schiffermüller, 1775) or *Melitaea athalia* (Rottemburg, 1775), which were formerly frequently observed in this region, but now have been gone completely (Laussmann, Dahl & Radtke, 2021).

Butterflies and their larvae are also important in food webs, e.g., as prey for birds and bats. So, a decrease of their biomass or a total loss of common species, as reported in Wuppertal, could have fatal consequences for organisms in higher trophic levels (Laussmann, Dahl & Radtke, 2021). Warren et al. (2021) found that mainly habitat loss and degradation, as well as chemical pollution are main causes for the decline of butterfly species in Europe.

Besides species recording, trait-based analyses are important to adapt conservation measures for species-groups and specific habitat communities. Previous trait-based analyses with traits such as overwintering strategy, voltinism, or food preferences showed correlations between habitat requirements and those traits. According to Habel et al. (2019) a high level of habitat connectivity supported the occurrence of sedentary, as well as monophagous species such as *Cupido minimus* (Fuessly, 1775) or *Melitaea diamina* (Lang, 1789). Similarly, Ibbe et al. (2011) found that generalist butterfly species with a high dispersal ability were able to colonise nutrient-rich patches, while sedentary specialist species were not able to use those spatially segregated nectar sources. Such trait based research approaches could therefore be applicable in agricultural ecosystems and beyond for risk analysis of land use changes and their impact on insect pollination (Butler, Vickery & Norris, 2007).

1.2 Agricultural intensification

Agricultural intensification leads to landscape simplification, being a major threat to farmland biodiversity and associated ecosystem services, resulting in the loss of pollinator diversity and abundance in agricultural landscapes (Albrecht et al., 2020; Stoate et al., 2001; Stoate et al., 2009). Most butterfly species depend on semi-natural grasslands (Ibbe et al., 2011; Warren et al., 2021), thus butterfly species richness has declined rapidly over the last few decades, due to agricultural intensification and the related loss of their habitats (Warren et al., 2021). In Finland 60% of butterfly species associated with semi-natural grasslands have declined during the last 50 years, (Stoate et al., 2009).

Landscape simplification leading to fragmentation of high-quality habitats is a result of land-use intensification (Lebeau, Wesselingh & van Dyck, 2016). This is especially problematic for specialist species with low dispersal ability, which need complex, small-structured land-scapes comprising different landscape elements, such as shrubs and forest-edges, for their reproduction cycle and occurrence (Aviron et al., 2011; Kwon et al., 2021). Also, high plant diversity on a small spatial scale is important for many specialised butterfly species to reduce searching time for food resources and cover their requirements for protein and amino acids (Rani & Aluri, 2016).

Additionally, widespread habitat loss, degradation and fragmentation lead to relatively small and isolated habitat patches, with possible adverse effects on butterfly populations breeding in those fragmented landscapes. Small isolated habitat patches are less likely to be colonised by a new population (Schwarz & Fartmann, 2021; Warren et al., 2021), and populations living in such patches can suffer from negative effects on demographic and genetic stochasticity, leading to decreased fitness and inbreeding depression, as well as geographic stochasticity (Schtickzelle & Baguette, 2009; Thomas, 2000). The latter becomes especially problematic with intermediate mobile species, which easily leave their natal habitat patch, but are unable to reach a suitable neighbouring patch (Thomas, 2000). These factors lead to an increased probability of species becoming locally or even regionally extinct (Schwarz & Fartmann, 2021). Besides that, specialised butterfly species have a high host-plant specificity during their lar-val stage. Their metapopulations usually depend on suitable habitats in close proximity as they occupy different ecological niches for different development stages (Schwarz & Fart-mann, 2021).

Due to agricultural intensification, management strategies such as traditional grazing and hay cutting have disappeared from many Western European countries in the first half of the 20th century and were replaced by large-scale, intensive farms. Consequently, many herbs and nectar sources on which many butterfly species rely, have decreased (Warren et al., 2021). Maintaining and restoring biodiversity in agricultural landscapes depend on managing, preserving and restoring habitats such as extensively managed grasslands, hedgerows, flower rich field margins, wetlands and other small non-cropped areas within a landscape mosaic (Bengtsson, Ahnstöm & Weibull, 2005).

1.3 Grassland management

Studying different grassland management types is important because studies showed significant difference in butterfly species richness and abundances between differently managed habitats (Aviron et al., 2011; Görn et al., 2014). Besides, landscape heterogeneity results in a higher number of habitat types consisting of open grassland, wetlands and forests, with different ecological niches sheltering a high biodiversity (Habel et al., 2021). The establishment of flower strips in simplified agricultural landscapes intends to increase floral diversity and abundance of insect pollinated plants (flowering plants from here on) and is one measure to counteract landscape fragmentation and diversity loss in agroecosystems (Potts et al., 2009). A recent meta-analysis (Lowe, Groves & Gratton, 2021) suggests that field-edge floral plantings, such as flower strips, are highly effective to increase on-field pollinator richness and abundance, yet no crop specific effect was found. Especially butterflies profit from flower strips or newly established grassland with high diversity of plant species, as those provide nectar resources for adults, food for larvae and shelter (Rani & Aluri, 2016). According to recent observations, wild flower strips provide suitable breeding habitats for various specialised butterfly species, if several rare larval host plants are represented in seed mixtures and consequently improve expansion of populations in arable landscapes (Aviron et al., 2011). However, according to the review by Albrecht et al. (2020) there are only three studies, which compared four years old or older flower strips with adjacent crop fields highlighting the positive effects of long-term floral plantings on ecosystem services like pollination by bees and crop yield.
Therefore, this thesis compares the butterfly species richness, abundance, community composition and ecological traits in different grassland types over five years.

1.4 Research objectives and questions

The setup for this thesis is based on two projects studying biodiversity in different grassland types. The two projects are analysed separately, but the joint discussion aims to draw overall applicable conclusions for butterfly conservation in agroecosystems. The first project "REGRASS II", investigates different grassland types in Lower Austria. The newly established grasslands are compared in terms of insect species richness, abundance, community composition and ecological traits with subsidised grasslands and long-term established grasslands (See 2.1 Methods for definitions of grassland types).

The following research questions were addressed:

Q1: Do newly established grasslands promote butterfly species richness and abundance more than long-term established old grasslands and subsidised grasslands, and how are butterfly species richness and abundance influenced by flower frequency and plant height?

Q2: Is there a difference in community composition between the different grassland types?

Q3: How are differently managed grasslands correlated with different butterfly traits?

The second project "DivRESTORE" is located in the two biosphere reserves Vienna Woods and Salzburger Lungau / Carinthian Nockberge. It investigates insect species richness, abundance and community composition in flower strips along intensively managed meadows and compares them to intensively managed control meadows and extensively managed meadows, both without adjacent flower strips.

The following research questions were addressed:

Q1: Do newly established flower strips increase butterfly species richness and abundance in the adjacent intensively managed meadows compared to the control meadows and extensively managed meadows?

Q2: How do butterfly species richness, abundance and community composition differ among grasslands of the mountainous to alpine region compared to the lowland?

2 REGRASS II

2.1 Methods

Butterflies were sampled in the region Vienna Woods in Lower Austria (central study site locations: 48°16'02.5" N 16°05'07.9" E and 48°15'08.3" N 16°02'56.9" E, Figure 1a). The mean annual precipitation amount was 673 mm, and the mean annual air temperature was 9.9 °C (ZAMG, 2021). The region is part of the Tullnerfeld, an area characterized by high crop production and intensive agricultural management practices (Amt der NÖ Landesregierung, 2015). However, the landscape surrounding the study sites still included heterogeneous structures, such as meadows, hedgerows, arable crops, and forest patches (Figure 1b).

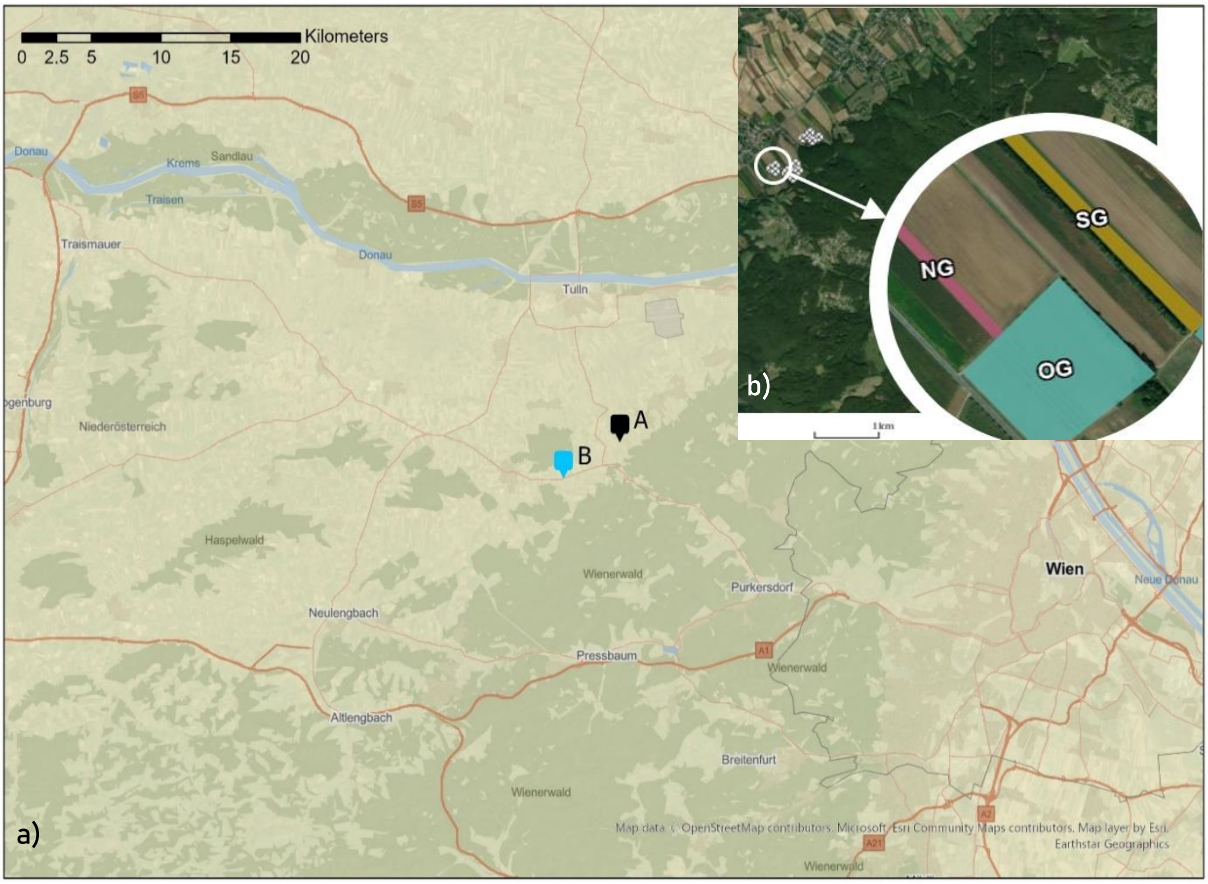

Figure 1: a) Study sites, A: Ollern (48°16'02.5"N 16°05'07.9"E), B: Elsbach (48°15'08.3"N 16°02'56.9"E); b) close up of one study site in Ollern: NG = new grassland, OG = old grassland, SG = subsidized grassland; Source: ESRI (2022). Map data © OpenStreetMap (Esri Street style). Map layer by Esri. Retrieved from https://www.arcgis.com/home/item.html?id=d167e0b1e9ed4abf982ab1aecc97e3ce

2.1.1 Treatments

Three different grassland types were compared: old grassland (OG), new grassland (NG) and subsidized grassland (SG). For each grassland type five replicates (5 x 3 = 15 study sites) were investigated. The old grasslands (OG) are well established long-existing meadows, which are characteristic grasslands of this region. Farmers use them for conventional hay production and cut them 2-3 times per year. The studied OG were adjacent to winter cereal fields for the duration of this work. Additionally, the OG were adjacent to the forest or close to hedges. The new grasslands (NG) were established in August 2016 on 165 - 400 m x 10 m plots on former arable land. The seed mixture was specifically compiled for the project and included 41 native plant species (34.0% grass species, 14.6% legumes and 51.2% herbaceous plants) of regional origin (Appendix Table A1). The plant species were selected to mimic the plant community composition of previously investigated grasslands (Holzer, Zuna-Kratky & Bieringer, 2019; Meindl, Pachinger & Seiberl, 2012) aiming to establish highly diverse plant species communities. A high percentage of insect pollinated plant species was chosen to maximise the attractiveness for pollinators. Seed bed preparation was accomplished by deep ploughing and two times rolling of the ground with a rotary harrow. To ensure successful plant establishment in the NG, late-summer sowing in August 2016 was done (2021). During the study period (2017-2021) the NG were mown once per year, after the 1st of July, and they were adjacent to winter cereals and bordered by OG on the narrow side (Figure 1b). Apart from the different management, the NG and OG also differed in plant community composition. The OG were dominated by grasses with few herbaceous plants, while almost 70% of the seed mixture in the NG consisted of herbs and legumes. The subsidized grasslands (SG) were established between 2015 and 2019 as so called biodiversity areas, which are part of the measure "UBB" (Umweltgerechte und biodiversitätsfördernde Bewirtschaftung) in the ÖPUL (Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft) program period 2015 (Grandl, Weber-Hajszan & Neudorfer, 2016). The ÖPUL promotes agricultural management, which enhances natural habitats and intends to foster the environmentally sound management of agricultural areas in Austria. According to the program specifications the SG have to be mown 1-2 times per year. Half of the farmer's subsidized grassland area must be mown after the 1st of August, and fertilizer or pesticide use are strictly prohibited (Bauer, 2015). The seed mixture must consist of a minimum of four insect pollinated plant species, thus usually comprises a low plant species richness. SG have to persist for 2-6 years after establishment (Grandl, Weber-Hajszan & Neudorfer, 2016). The SG studied in this work were mainly adjacent to winter cereal fields and hedges.

2.1.2 Field work

Butterfly sampling was carried out once every month from May to August. I collected the data in 2021, however in 2017 and 2018 the data were collected by another person. To ensure sufficient butterfly activity, sampling was only conducted between 9 a.m.-6 p.m. on sunny days

with a minimum of 17 °C air temperature, no or slight wind and dry vegetation (Pollard & Yates, 1993).
The butterflies were recorded over the entire grassland (140 m x 5 m transect, starting 10 m from the border) for 20 minutes. The butterflies were identified in the field, if possible, to species level. Stettmer et al. (2006) was used for the identification. The nomenclature followed Karsholt & Razowski (1996). Butterfly ecological trait information (Table 1) was gathered from literature (Höttinger & Pennerstorfer, 2005; Slamka, 2004; Stettmer et al., 2006; Tolman & Lewington, 2012; Ulrich, 2018).

Table 1: Butterfly functional traits explanations used for the trait analysis

Trait	**Description of traits**
Voltinism	Number of generations per year grouped in “univoltine” = one generation / year “bivoltine” = two generations / year “trivoltine” = three generations / year
Larval host plant	Larval host plant preferences grouped in “wood” = plants with woody structures “herb” = dicotyledon plants without woody structures “grass” = monocotyledon plants, grasses
Habitat	Habitat type preference grouped in “open land” = open area (arable fields, structures with a short turn over, bare fields, lynchets), no permanent grassland “meadow” = permanent grasslands, meadows “forest edge” = near forest, on the edge of the forest “forest” = in forests “open land / forest” = no special habitat preferences
Moisture preferences	Moisture preference of habitat grouped in “xerotherm” = dry “xero-mesophil” = medium dry to dry “ubiquitous” = no special humidity preferences “moist-fresh” = moist to fresh “dry-fresh” = dry to fresh
Hibernation	Hibernation stage overwintering as “egg”, “larva”, “pupa”, “imago” or “all stages”

To estimate the availability of pollen and nectar resources the flower frequency was estimated using a 1 m^2 wooden grid, divided into 25 squares. The flower frequency was measured 10 times per grassland along a transect in the middle of the grassland. At every 35 m the grid was place once 2 m left from the transect and once 2 m right from the transect (2 x 5 measurements = 10 per survey site). The number of squares containing at least one flower was counted. The measurements were summed up and extrapolated to 100 %. All plant species within a 2 m^2 sampling plot of all three grassland types were recorded and identified once per year in June following the nomenclature of Fischer et al. (2008). This allowed to compare the plant species richness and the proportions of herbs and grasses among the grassland types studied.

2.1.3 Data analysis

All statistical analyses were performed in R (R Core Team, 2021). Data exploration was done according to Zuur, Leno & Elphick (2010). To analyse how grassland types (NG, SG, OG), survey year (2017, 2018, 2021) and vegetation parameters (flower frequency, plant height) affected butterfly abundance and species richness, Generalized Linear Mixed Models (GLMMs) with Poisson distribution were formulated using the R package "lme4" (Bates et al., 2021). To account for temporal non-independent observations within the same grassland type as well as to analyse all study years together, the months (May-August) of each year were nested within each year and chosen as random factors. Additionally, where overdispersion was a problem, the single observations were added as a random factor. The most parsimonious models within each model set (Table 2) were selected using the second order Akaike Information Criterion (AICc), which is corrected for small sample size (Motulsky & Christopoulos, 2004). To decide whether a model is more appropriate over another the cut-off difference was set at ΔAICc ≥ 2 (R package "AICcmodavg", Mazerolle, 2020). The model quality of the most parsimonious models was assessed with the "DHARMa" R package (Hartig, 2021) and calculation of the marginal and conditional R^2 was done with the "MuMIn" R package (Bartón, 2022). The effects of covariables from most parsimonious models were visualised graphically with the "effects" R package (Fox et al., 2020). To test for significant differences between the grassland types the pairwise.t.test () function of the R package "stats" was used (R Core Team, 2021).
To analyse differences in butterfly community compositions among the different grassland types a principal component analysis (PCA) was done with the R package "vegan" (Oksanen et al., 2021). A matrix with the species x abundance data, aggregated per study site and year, was used for the PCA. The Hellinger transformation using the rda () function of the R package "vegan" was applied to account for low counts and double zeros (Oksanen et al., 2021). To check whether the PCA results were appropriate, a Nonmetric multidimensional scaling

(NMDS) was calculated too (Appendix Figure A1) using the R package “vegan” (Oksanen et al., 2021). The results appeared similar, thus the results from the PCA are presented (Figure 3). A Permanova (99 permutations) was calculated with the function adonis () from the R package “vegan” (Oksanen et al., 2021). Using the function betadisper () from the same package, data was tested for equal multivariate dispersion. To calculate pairwise differences the function pairwise.adonis () from the R package “pairwiseAdonis” was used (Martinez Arbizu, 2020).
For the analysis of butterfly traits and their association with vegetation parameters as well as the difference between the grassland types, a fourth-corner model was conducted (Brown et al., 2014), using the traitglm () function of the R package “mvabund” (Wang et al., 2021). To reduce the relationship to 0 when correlations between response and co-variables were small, a LASSO penalty was applied, which directly improves the model result interpretability (Krueger, 2021).

2.2 Results

In total 51 species and 4864 individuals were found during the three years of sampling (Appendix Table A3). The highest mean (±SD) butterfly species richness and abundance were documented in OG (species richness: 6.95 ± 3.69; abundance: 31.6 ± 26.3), followed by NG (species richness: 5.95 ± 3.93; abundance: 26.4± 37.9) and SG (species richness: 6.02 ± 5.01; abundance: 23.1 ± 27.3). The most abundant species (mean ±SD) across all grassland types were *Maniola jurtina* (6.35 ± 13.04, Linnaeus, 1758) and *Polyommatus icarus* (3.86 ± 4.78, Rottemburg, 1775). Additionally, *Coenonympha glycerion* (5.67 ± 8.90, Borkhausen, 1788) showed a high abundance in the OG, while *Pieris rapae* (3.18 ± 4.99, Linnaeus, 1758) was highly abundant in the SG and *Melanargia galathea* (2.85 ± 10.60, Linnaeus, 1758) in the NG (Appendix Table A3).
The GLMM model selection resulted in two most parsimonious models (Appendix Table A4) for each response variable (Table 2). Butterfly species richness and abundance were higher in OG compared to NG and SG (Figure 2b, e). Butterfly species richness and abundance were positively but not significantly affected by increasing flower frequency (Figure 2a, d) in all grassland types (Figure 2g, h). However, increasing flower frequency in the SG had the weakest positive effect on both response variables. Vegetation height showed no effect on species richness nor on abundance (Figure 2c, f), but improved model fit.

Table 2: Model sets for butterfly abundance and butterfly species richness including AICc values, marginal R^2, and conditional R^2. Most parsimonious models in bold. Random factors are month nested in year and all single observations if models were overdispersed. Intercept - only models: ~1; Abbreviations: AICc = Akaike information criterion corrected; R^2m = marginal R^2; R^2c = conditional R^2

Response	**Fixed factors**	**AICc**	**R^2m**	**R^2c**
Butterfly abundance	Grassland type	1476.08	0.04	0.98
	Grassland type + flower frequency + vegetation height	**1220.20**	**0.09**	**0.98**
	Grassland type * year	1475.02	0.31	0.98
	Grassland type * flower frequency	**1220.55**	**0.10**	**0.98**
	~1	1488.02	0	0.98
Butterfly species richness	Grassland type	939.29	0.01	0.71
	Grassland type + flower frequency + vegetation height	**775.78**	**0.06**	**0.70**
	Grassland type * year	938.09	0.39	0.72
	Grassland type * flower frequency	**775.55**	**0.06**	**0.70**
	~1	940.99	0	0.71

The PCA and the results of the Permanova revealed clear clustering of the species communities among the grassland types (NG-SG: $R^2 = 0.27$, P = 0.003; NG-OG: $R^2 = 0.47$, P = 0.003; SG-OG: $R^2 = 0.31$, P = 0.003, Figure 3a), however among the years there was only one cluster for the year 2021 detected (P = 0.003, Figure 3b). The species communities did still differ, but not significantly, among grassland types when analysing the study years separately (Figure 3b). The fourth-corner model showed a strong negative correlation between NGs and butterflies hibernating as “egg” (Figure 4). Flower frequency was positively correlated with butterflies preferring “meadow” as habitat. Flower frequency was also positively correlated with species requiring “herbs” as larval host plant and “univoltine” species but was negatively correlated with “bivoltine” species. SG were positively correlated with “moist-fresh” habitat moisture preferences and negatively correlated with "xerotherm" habitat moisture preferences of butterfly species (Figure 4).

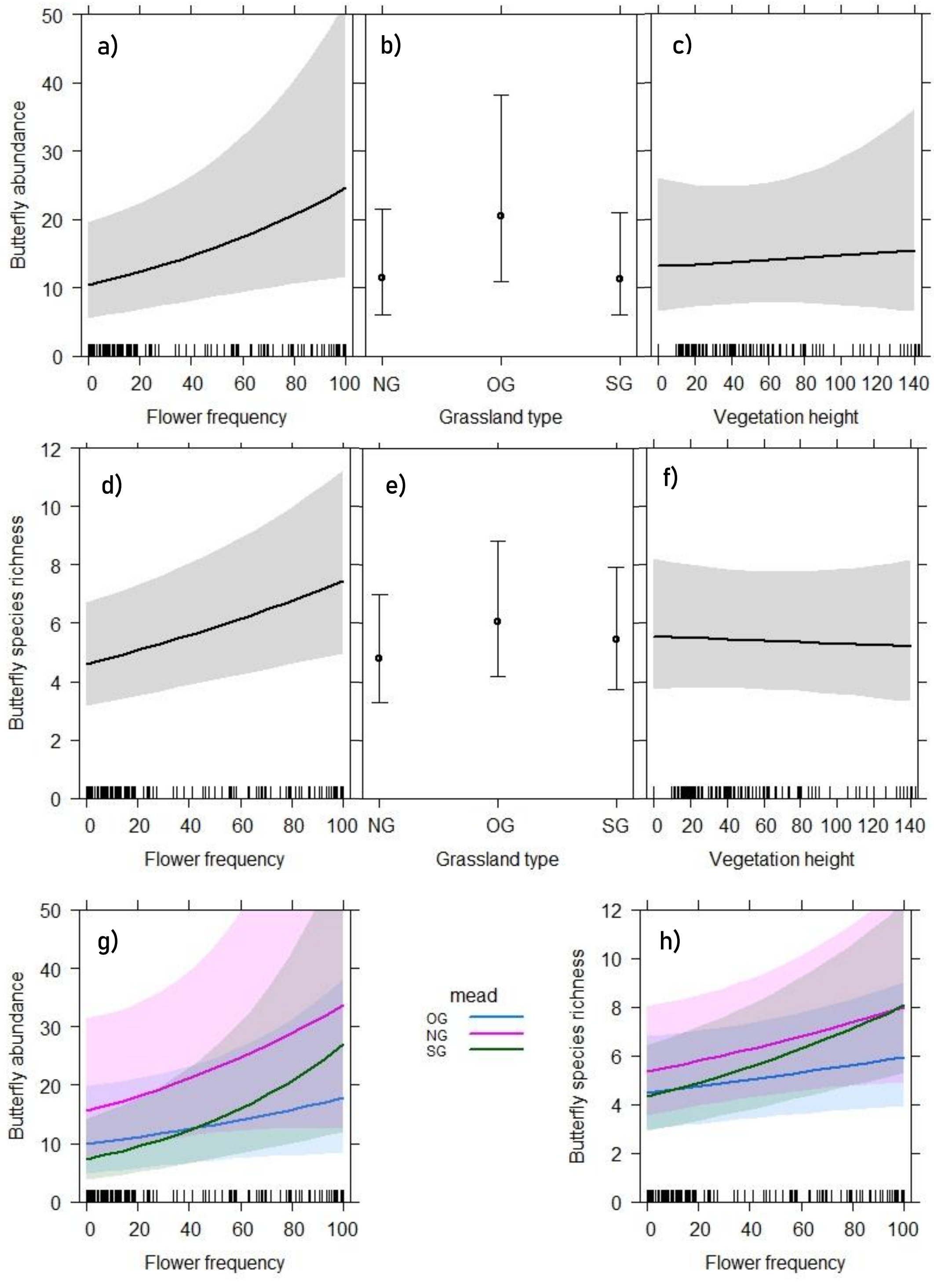

Figure 2: Butterfly abundance (a-c) and species richness (d-f) in response to a) & d) flower frequency; b) & e) grassland type (NG: new grassland; OG: old grassland; SG: subsidized grassland) and c) & f) vegetation height. Butterfly abundance (g) and species richness (h) in response to the interaction of flower frequency and grassland type. Gray/ colour shading: 95 % confidence intervals

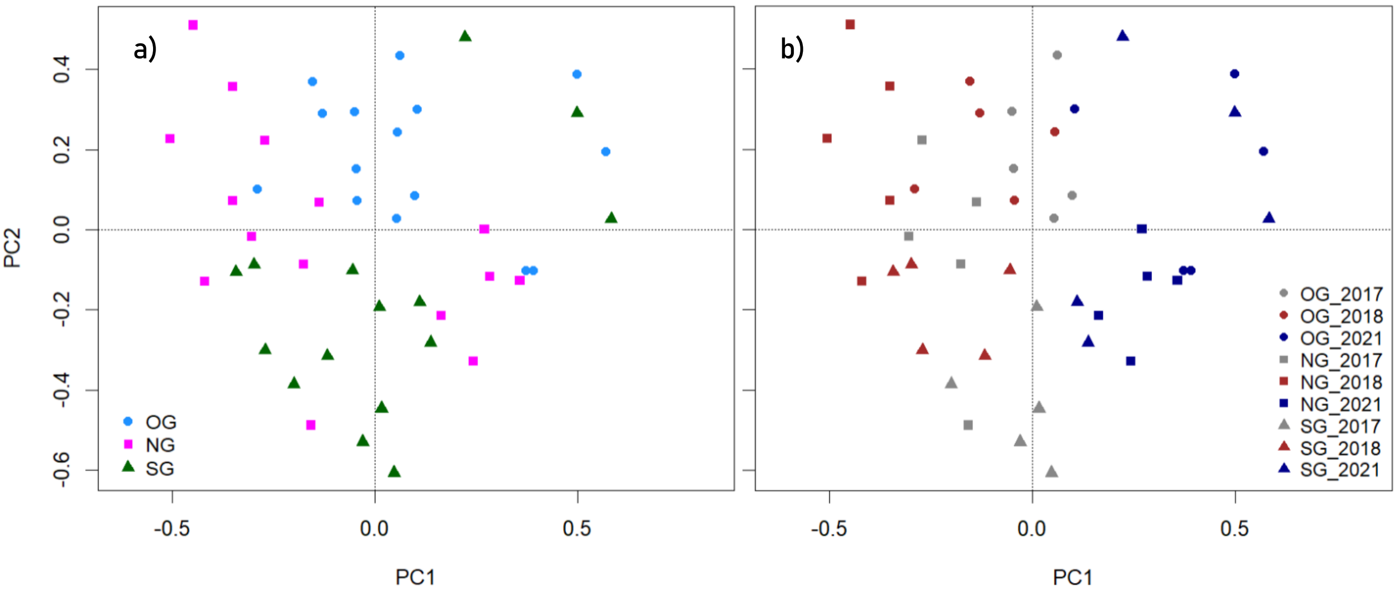

Figure 4: Results of the principal component analysis, a) & b) points: old grassland (OG), squares: new grassland (NG), triangles: subsidised grasslands (SG); a) grassland types, blue: OG, pink: NG, green: SG. Adonis results: NG-SG: $R^2 = 0.27$, $P = 0.003$; NG-OG: $R^2 = 0.47$, $P = 0.003$; SG-OG: $R^2 = 0.31$, $P = 0.003$; b) grassland types including year, grey: 2017, red: 2018, dark blue: 2021

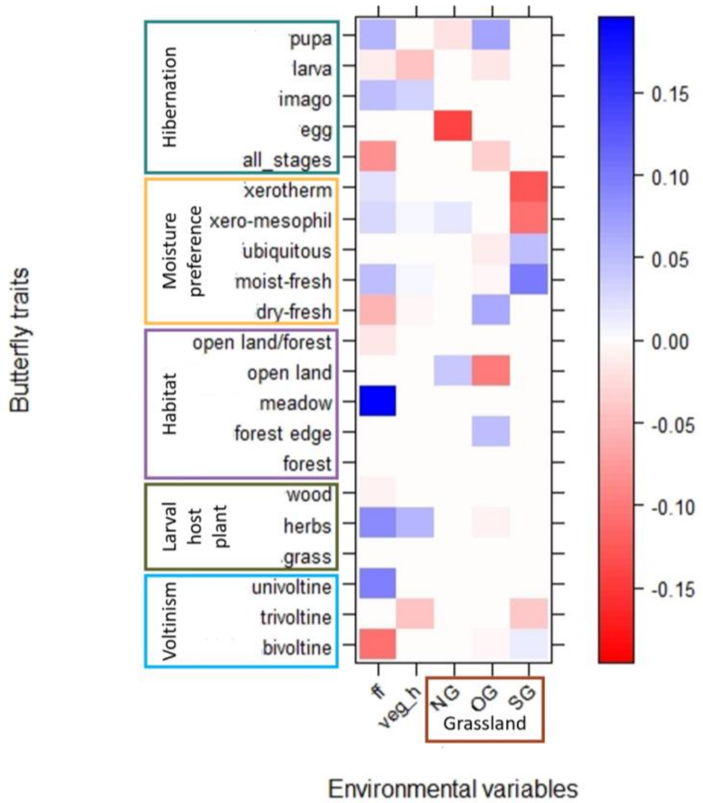

Figure 3: Correlation of grassland type and vegetation parameters with butterfly traits; darker colours represent a stronger correlation: red = negative correlation, blue = positive correlation. Abbreviations: ff: flower frequency; veg_h: vegetation height; NG: new grassland; OG: old grassland; SG: subsidised grassland

3 DivRESTORE

3.1 Methods

Study sites were located in the Vienna Woods in Lower Austria (N 48.154024 E 16.114645, Figure 5a) and in the Salzburger Lungau / Carinthian Nockberge (N 46.91865 E 13.873951, Figure 5b). The mean annual air temperature of the Vienna Woods region was 9.9 °C, and the mean annual precipitation amount was 673 mm (ZAMG, 2021). In Lungau / Nockberge the mean annual air temperature was 6.8 °C, and the mean annual precipitation was around 762 mm (weather station: Tamsweg, ZAMG, 2021). The farming intensity in the area of Lungau / Nockberge is rather low compared to Vienna Woods, because there are many small scaled farms (Regionalbüro Lungau, 2020). The Vienna Woods are part of the Tullnerfeld, which is an area characterized by high crop production and intensive agricultural management practices (Amt der NÖ Landesregierung, 2015). However, the landscape structure is characterized by heterogeneous structures, including meadows, hedgerows, arable crops, and forests (Figure 5c).

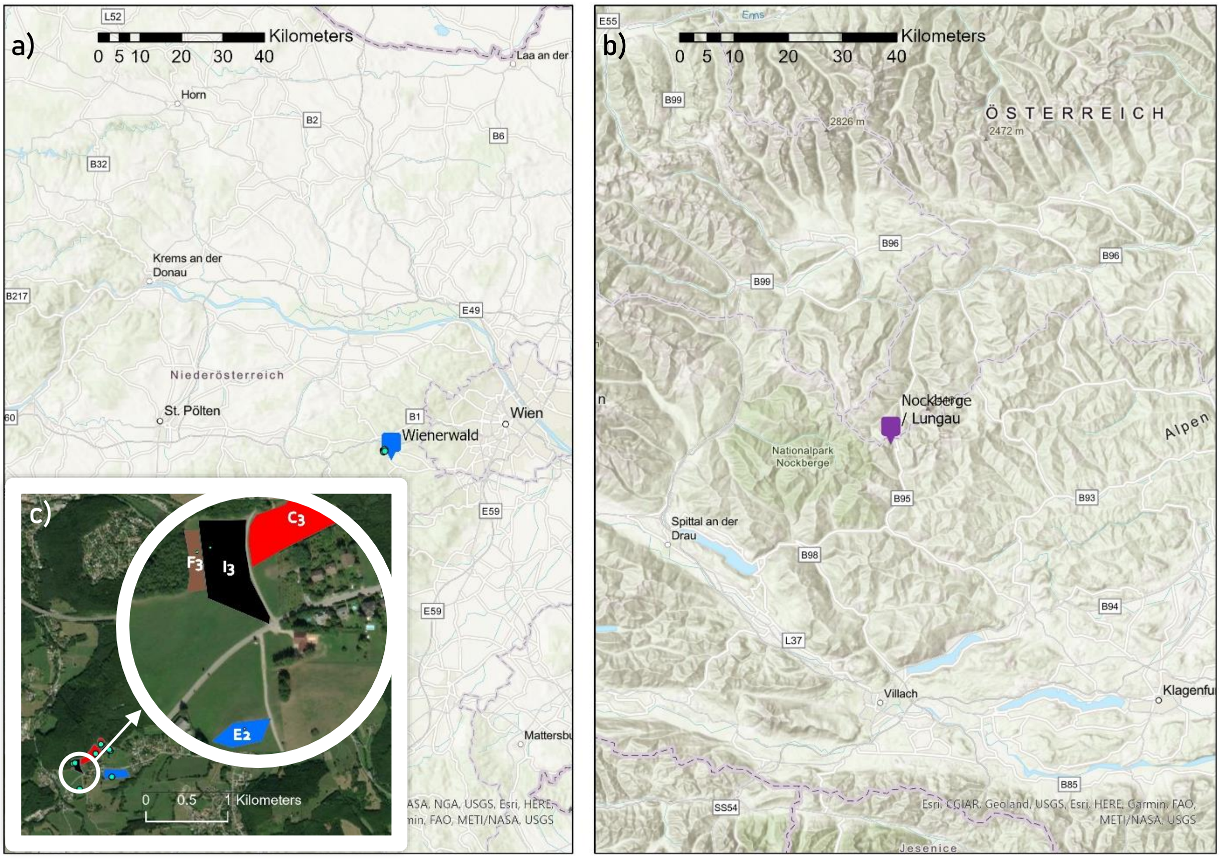

Figure 5: Study sites, a) Vienna Woods (N 48.154024 E 16.114645), b) Lungau / Nockberge (N 46.91865 E 13.873951), c) detailed view of one study site in Vienna Woods, E = extensive meadow (E), F = flower strip (FS), I = intensive meadow with flower strip (I+), C = intensive control meadow (I-), numbers = replicate number; source: ESRI (2022). Map data © OpenStreetMap (Esri Street style). Map layer by Esri. Retrieved from https://www.arcgis.com/home/item.html?id=d167e0b1e9ed4abf982ab1aecc97e3ce

3.1.1 Treatments

Four different grassland types were compared in this study: extensively managed meadows (E), intensively managed meadows far from flower strips (I-), intensively managed meadows next to a flower strip (I+) and the flower strips (FS). For the duration of the study, the extensive meadows (E) were mown 1-2 times per year after the 15th of July., the intensive meadows (I- & I+) were mown 3-4 times per year and the flower strips (FS) were mown once a year. The biomass was removed from all grassland types after mowing. The FS were established adjacent to intensively managed meadows (I+) in autumn 2019 and were 50 m x 3 m (150m^2) large. The FS in Vienna Woods were prepared using a harrow and seeded with a regional seed mixture compiled by the HBLFA Raumberg-Gumpenstein (Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft Raumberg-Gumpenstein, Appendix Table A5). The FS in Lungau / Nockberge were prepared, using a harrow and seeded with the seeds from hay, which was harvested from local, species rich, extensive meadows in 2019. The intensive meadows (I-, I+) were fertilized with manure after mowing. The intensive meadows in Lungau / Nockberge were fertilized more intensively (3-4 times) than the ones in Vienna Woods (1-2 times).

3.1.2 Field work

Butterfly data were collected in 2020 and 2021. For each grassland type (E, I-, I+, and FS) five replicates per region were investigated (5 x 4 x 2 = 40 study sites). Sampling was carried out once a month from June to August in both study years. I collected the data in 2021, however in 2020 data were collected by another person. The butterflies were recorded by walking along one standardized transect (50 x 3 m) per sampling site for 10 minutes. The butterfly identification and the flower frequency measurements were done similar to the "REGRASS II" project (described above, Appendix Table A6). Further, sampling conditions (minimum air temperature, wind, sun) were set to the same standards as described in the "REGRASS II" project.

3.1.3 Data analysis

All statistical analyses were performed in R. To analyse differences in butterfly species richness and abundance between the grassland types GLMMs were calculated as described in 2.1.3. Model selection and validation was done as described in 2.1.3. To assess differences in community composition among the grassland types and between the two regions, a multivariate statistical approach was chosen identical as described previously in 2.1.3. As the results of the PCA showed kind of a horseshoe effect (Appendix Figure A2), an NMDS was included instead.

3.2 Results

In total 56 species and 1464 individuals were found over the two sampling years (Appendix Table A7). Vienna Woods had significantly (pairwise t-test: $p < 0.001$) higher butterfly species richness and abundance (mean ± SD: species richness: 3.15 ± 1.88; abundance: 8.88 ± 8.55), compared to Lungau / Nockberge (mean ± SD: species richness: 1.65 ± 1.62; abundance: 3.32 ± 4.70). The significantly highest mean (± SD) butterfly species richness and abundance per grassland types were documented in E (species richness: 3.37 ± 2.03; abundance: 10.4 ± 9.16, pairwise t-test: $p < 0.001$), followed by FS (species richness: 2.12 ± 1.47; abundance: 5.08 ± 7.41), I+ (species richness: 2.1 ± 1.96; abundance: 4.5 ± 5.65) and I- (species richness: 2.02 ± 1.82; abundance: 4.4 ± 5.23). Butterfly species richness and abundance between FS, I+ and I- did not differ significantly. The most abundant species (mean ±SD) over both regions was *Maniola jurtina* (2.01 ± 3.93, Linnaeus, 1758). The second and third most abundant species, respectively, in Lungau / Nockberge were *Aphanthopus hyperantus* (0.92 ± 2.75, Linnaeus, 1758) and *Pieris rapae* (0.20 ± 0.20, Linnaeus, 1758). In Vienna Woods the second and third most abundant species were *Melanargia galathea* (1.52 ± 3.85, Linnaeus, 1758) and *Coeno-nympha pamphilus* (0.775 ± 1.20, Linnaeus, 1758), respectively (Appendix, Table A7).

The GLMM model selection resulted in one most parsimonious model (Appendix Table A8) for each response variable (Table 3). Butterfly species richness and abundance were higher in Vienna Woods than in Lungau / Nockberge (Figure 6a, d), across all the four grassland types (I+, I-, FS, E, Figure 6c, f). Butterfly species richness and abundance in I-, I+ and FS were similar, and in E they were significantly higher (pairwise t-test: $p < 0.001$; Figure 6b, c, e, f).

The NMDS and the results of the Permanova showed a clear clustering of butterfly community compositions among the regions (pairwise Adonis: $R^2 = 0.999$, $p = 0.001$, Figure 7a), however butterfly community composition did not differ significantly from each other among grassland types (Figure 7b). Also when split up into region and grassland type there was no significant difference found between the grassland types (Figure 7c).

Table 3: Model sets for butterfly abundance and butterfly species richness including AICc values, marginal R^2, and conditional R^2. Most parsimonious models highlighted in bold. Random factors are month nested in year and all single observation if models were overdispersed. Intercept-only models: ~1; Abbreviations: AICc: Akaike information criterion corrected; R^2m: marginal R^2; R^2c: conditional R^2

Response	Fixed factors	AICc	R2m	R2c
Butterfly abundance	Grassland type	1364.77	0.13	0.89
	Grassland type * region	**1289.69**	**0.43**	**0.89**
	Vegetation height * region	1334.65	0.24	0.89
	Region	1337.98	0.22	0.90
	Region + year	1339.75	0.22	0.89
	Grassland type + year	1366.68	0.12	0.89
	~1	1392.01	0	0.89
Butterfly species richness	Grassland type	940.22	0.09	0.17
	Grassland type * region	**871.90**	**0.35**	**0.41**
	Flower frequency * region	887.60	0.25	0.36
	Vegetation height * region	910.98	0.19	0.27
	Region	907.93	0.19	0.26
	Region + year	909.72	0.19	0.26
	Grassland type + year	942.05	0.09	0.17
	~1	963.08	0	0.09

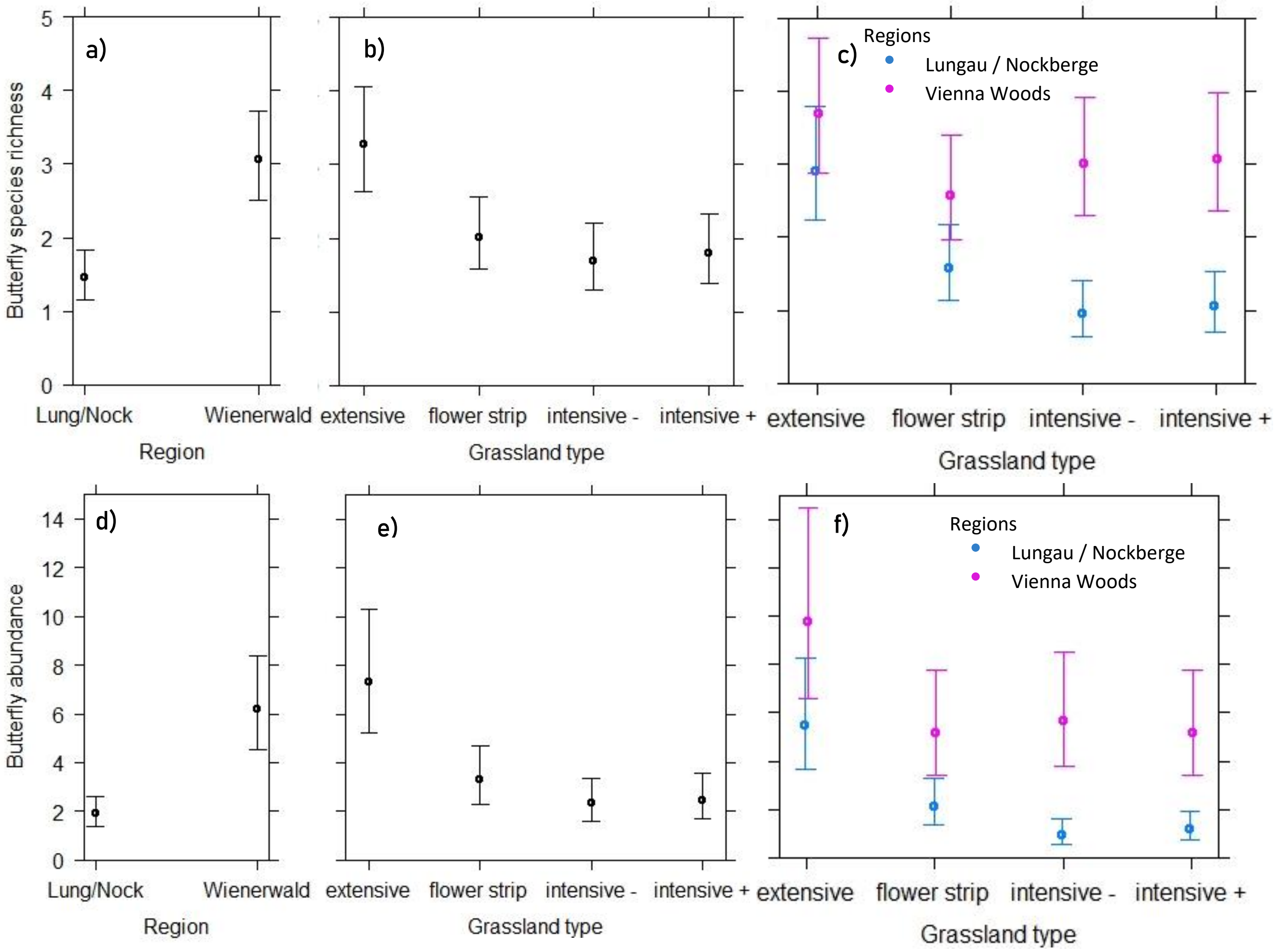

Figure 6: Butterfly species richness (a-b) and abundance (d-e) in response to a) & d) region, b) & e) grassland type (E = extensive meadow; FS = flower strip; I+ = intensive meadow with FS; I- = intensive control meadow); Butterfly species richness (c) and abundance (f) in response to the interaction of region and grassland type; blue: Lungau / Nockberge, pink: Vienna Woods

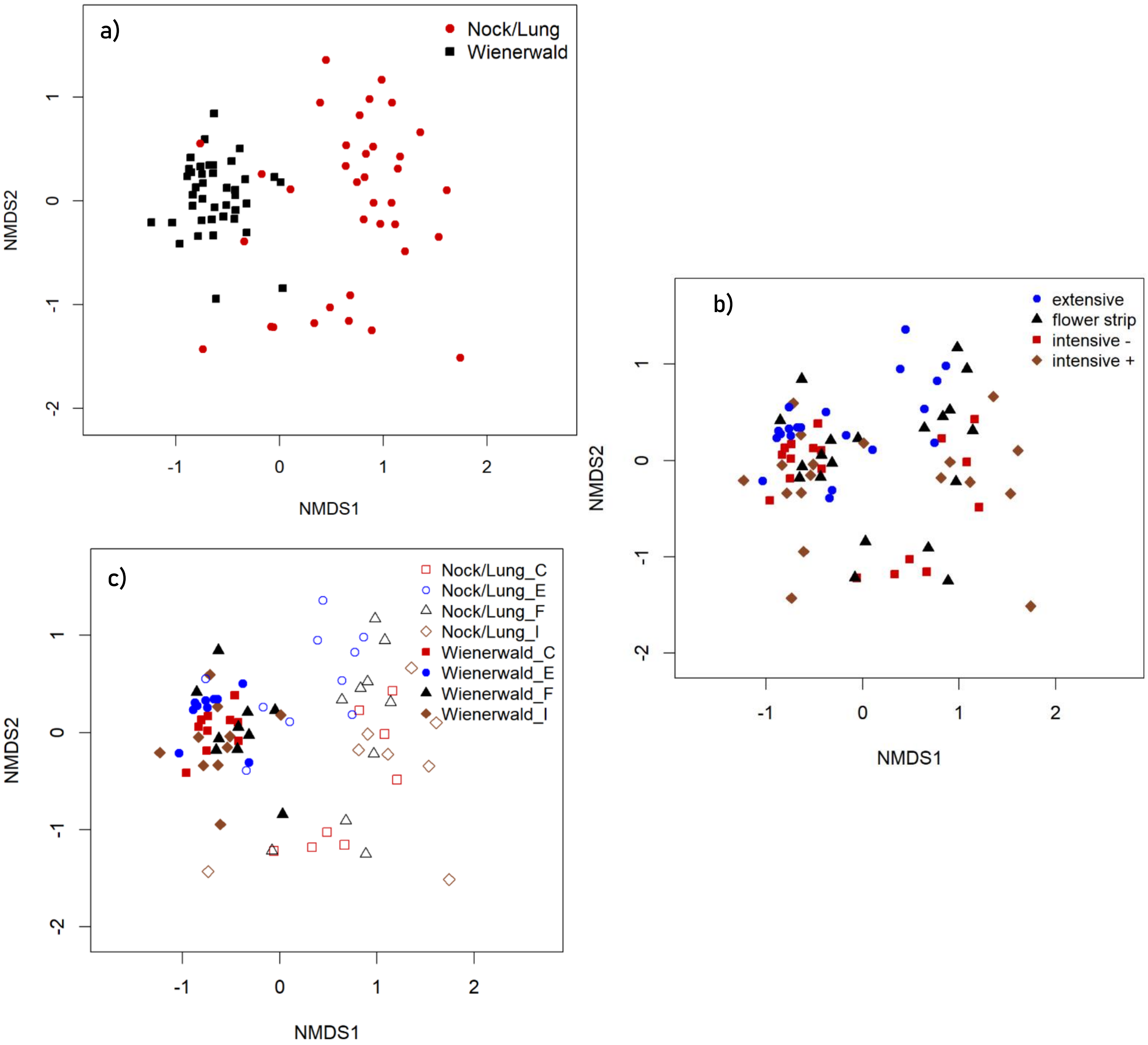

Figure 7: Results of the Nonmetric multidimensional scaling split up into a) region, red points = Lungau / Nockberge, black squares = Vienna Woods; Adonis results: R^2 = 0.999, P = 0.001; b) grassland type, red squares = Intensive control meadow (I-), blue points = extensive meadow (E), black triangles = flower strips (FS), brown rhombi = Intensive meadows with flower strips (I+), c) region & grassland type, empty symbols: Lungau / Nockberge, filled symbols = Vienna Woods, red squares: Intensive control meadow (I-), blue points: extensive meadow (E), black triangles: flower strips (FS), brown rhombi: Intensive meadows with flower strips (I+)

4 Discussion

4.1 Comparison of the two studies

In total, 56 butterfly species were found in DivRESTORE across two study years while in REGRASS II only 51 species were found in three study years. The number of individuals was much higher in REGRASS II with 4864 individuals compared to DivRESTORE with 1464 individuals. The much higher number of individuals in REGRASS II could be explained by the longer observation time per transect, four instead of three runs per year and three years of data collection instead of two years. The higher species richness in DivRESTORE is explainable as we have, additionally to the lowland, also a mountainous study area, which is characterized by a different community composition due to different climatic conditions (Lepidopterologen-Arbeitsgruppe, 1988).

Maniola jurtina was the most abundant butterfly species in both projects and all grassland types. *Pieris rapae*, also, showed a high abundance in the mountainous region in DivRESTORE as well as in the lowland in the SG in the REGRASS II project. *Melanargia galathea*, however, was only frequent in the lowland. According to Stettmer et al. (2006) these three species are common in lowland as well as in mountainous habitats, therefore it is not surprising to find them as the most abundant species over both projects. They all have no specific habitat and larval food plant preferences (Settele et al., 2015).

4.2 Influence of grassland type on butterfly abundance, species richness and community composition

The butterfly species richness and abundance in REGRASS II was highest in the old, long-term established grassland (OG), while in DivRESTORE the highest butterfly species richness and abundance was found in the extensive grassland (E). Both grasslands show a high abundance of grass plant species (personal observation). Previous findings confirm high butterfly abundance in grass dominated plots (Blake et al., 2011) and calcareous grasslands (Boetzl et al., 2021). One explanation for the results found could be the long-term establishment of the OG. While for the E the more extensive management compared to the other grassland types of DivRESTORE could be an explanation. There is a higher chance for species to complete their full life cycle and to establish a population over a long time, when the grassland is mown on a low frequency and late in the year (Walter, Schneider & Gonseth, 2007). Additionally, the butterflies in the grassland types OG and E might already have had a long time to establish, which could lead to the higher species richness and characteristic community composition. Indeed, previous research suggested that it takes at least 10 years of restoration for butterfly communities to establish similar species richness as in targeted grasslands (Woodcock et al., 2012).

The adjacent FS had, opposed to the expectations, no positive effect on the species richness and abundance in intensive meadow (I+), despite the more extensive management of the FS compared to I+. Also, NG did not contain significantly more butterfly individuals and species compared to SG, even though a special seed mixture was used for NG. For the FS an explanation could be the poor establishment and management of the strips, especially in the Lungau / Nockberge region. In the second study year most of them could not be identified as flower strips anymore. The strips were often established where the soil conditions were unfavourable (too humid or high weed pressure), therefore the sown seed mixture was not able to establish on long term (personal communication with Ronnie Walcher). Also, the effect of age of sown flower strips on butterfly diversity is quite controversially discussed in the literature (Albrecht et al., 2020; Aviron et al., 2011; Boetzl et al., 2021; Lowe, Groves & Gratton, 2021). Jeanneret et al. (2000) found no effect of wildflower strips on butterfly species richness, compared to other landscape elements. While Aviron et al. (2007) recorded butterfly species in wildflower strips, conventional grasslands as well as wheat fields, and they found the highest species richness in the wildflower strips.

While SG and OG were close to forests or hedges, NG were located between crop fields. This could be one reason for the marginal difference between NG and SG, as butterflies need heterogeneous landscape structures for their development (Agrarforschung Schweiz, 2019; Gaigher, Pryke & Samways, 2021). Aviron et al. (2011) confirm that butterfly abundance increased with increasing cover of grassland within a 200m radius. Not only grassland cover but also percentage of forest cover in close proximity to grasslands influences butterfly species richness positively (Agrarforschung Schweiz, 2019; Gaigher, Pryke & Samways, 2021).

Regarding butterfly community composition, significant differences were found between the three grassland types in REGRASS II, but not between the grassland types in DivRESTORE. Possible reasons for the findings in DivRESTORE are described in chapter 4.4. For REGRASS II one reason could be the different times of mowing. According to literature late mowing and a low mowing frequency increases the surviving chances of butterfly larvae and allows many butterfly species to complete their life cycle (Walter, Schneider & Gonseth, 2007). Also, grasslands which are mown only early or very late during the vegetation period provide a continuous source of nectar for adults and are suitable for oviposition (Feber & Smith, 1995). However, my results are astonishing as NG were only cut once after the 1st of July and had lower species richness than OG which were mown 2-3 times per season and, contradictory to literature, had the highest butterfly species richness. Another explanation could be the plant community composition, but this needs further investigation of the data, as it was not done in this thesis. However, an earlier study found that grasslands offer specific larval food plants for butterflies (Boetzl et al., 2021), which were not available in the seeded flower strips. Also, strip which were sown with grass species and insect pollinated plants had a higher butterfly species richness and abundance than strips which were only sown with insect pollinated plants (Jacot et al., 2007). This could be a better explanation for the differences in butterfly community composition.

4.3 Effect of flower frequency and vegetation height in REGRASS II

With increasing flower frequency, the butterfly species richness as well as the abundance increased over all grassland types. Several studies found that a higher flower frequency leads to a higher food availability for adults of most butterfly species (Kral-O'Brien et al., 2021; Ouvrard, Transon & Jacquemart, 2018; Wix, Reich & Schaarschmidt, 2019). In a meta-analysis Kral-O'Brien et al. (2021) found that butterflies had a strong positive correlation with flowering plant species richness. A reason for that could be that butterflies are often larval specialists, but the adults are nectar generalists (Waltz & Wallace Covington, 2004). However, their foraging preferences are not fully understood until today. Pohl, van Wyk & Campbell (2011) found a color preference of *Melitaea campestris* (Behr, 1963) for orange colored flowers over yellow ones, but no foraging consistency.

Another explanation could be the habitat preferences of the documented species. More than 50 % of the species found are described to prefer the habitat "meadow" (26 of 51), and effectively 9 of the 10 most abundant butterfly species of REGRASS II prefer this habitat type. This could indicate that those butterfly species forage on nectar of insect pollinated plants and show the following trend: The higher the flower frequency the higher the abundance of species in permanent grasslands (Schlegel & Hofstetter, 2021). Curtis et al. (2015) found a similar trend for the abundance of species, however they did not consider correlations between habitat preference and host plant abundance or nectar availability. Another reason for the high occurrence of species with "meadow" habitat preferences could be that species richness of butterflies rather depends on larval host plant occurrence, than on flower frequency, as many butterflies reproduce few days after hatching (Cushman et al., 1994) and therefore their survival is rather determined by nutrient availability, found in permanent grasslands, during larval stages (Hughes, 2000).

Contrary to flower frequency, vegetation height had no effect on butterfly species richness and abundance. An interesting finding was published by Woodcock et al. (2021): They found an interaction between vegetation height and loss of pollinator species rich grassland. Pollinator species richness in areas with a high and low, respectively, historic loss of plant species rich grassland, was highest only where vegetation height was tall and short, respectively.

Contrary to my findings, Milberg et al. (2016) found a positive correlation between vegetation height and butterfly species richness. According to Reid & Hochuli (2007) a higher vegetation height has multiple vegetation layers which leads to a larger variation in vegetation structure. However if vegetation height exceeds 30 cm of height, butterfly species richness starts to decline (Pöyry et al., 2006). This might explain the missing effect of the vegetation height on butterfly species richness and abundance in my study, as vegetation height often exceeded 30 cm.

4.4 Differences in butterfly abundance, species richness and community composition between the regions in DivRESTORE

In DivRESTORE, the region had a stronger effect on butterfly abundance, species richness and community composition than the grassland type. One reason could be the different grassland management intensities in the two regions: The intensive meadows in Vienna Woods were less intensively managed (less fertilized) than in Lungau / Nockberge. Another point is the seed mixture used for the FS: While a seed mixture from Raumberg-Gumpenstein was established on the study sites in the Vienna Woods region, in Lungau / Nockberge hay from local extensive meadows was used. Additionally, the FS in Lungau / Nockberge were not that properly established (as mentioned above) and managed as in Vienna Woods, and therefore hardly recognisable as flower strips in the second study year. This may also explain why there was no effect of the FS on the adjacent intensive meadows (I+).
Also, climatic differences could explain the difference in butterfly abundance and species richness. The lowland has a longer vegetation period than the mountainous region and therefore butterfly's activity starts earlier in the year in the lowland. This could explain the higher species richness in Vienna Woods. Also van Lien & Yuan (2003) found higher butterfly abundances in the lowland than in the mountainous region. However, Habel et al. (2021) found the opposite: butterfly species richness increased with higher elevations. This is confirmed by Lepidopterologen-Arbeitsgruppe (1988), who claim that the highest butterfly species richness is to be found in the montane zone.

4.5 Trait analysis in REGRASS II

The negative correlation between NG and the hibernation in the "egg" stage should not be overinterpreted, as with *Argynnis paphia* (Linnaeus, 1758) only one of the recorded species overwinters as "egg". This species had its lowest abundance in the NG why a negative correlation was observed.

The different correlations in SG with different habitat moisture preferences can be explained by the microclimate in SG. The vegetation structure and high plant density in SG might lead to a cool and fresh microclimate which, on one hand, promotes mesophilic species (*Argynnis paphia, Lycaena dispar* (Haworth, 1802)), leading to a positive correlation between SG and "moist-fresh" habitat moisture preferences. Also, Görn et al. (2014) found a positive correlation between moist habitats and butterfly species richness with the highest species richness in moist meadows. On the other hand, SG are the opposite of xerotherm dry grasslands, which likely explains the negative correlation between SG and xerotherm species (*Boloria dia* (Linnaeus, 1767), *Cupido argiades* (Pallas, 1771), *Plebeius argus*). This strong correlation between habitat moisture preferences and SG might indicate the importance of the microclimate for butterfly community composition and should be investigated in further studies.

4.6 Study shortcomings and further studies

One shortcoming of both is clearly the missing continuity of the observation years and / or the short study period. The project REGRASS II was conducted over 5 years, however butterfly data were only collected over three years of the study, which first leads to a gap in the data set and second can lead to an annual bias. Certainly, the effect of different grassland types could be observed more closely if the study is conducted continuously over more than 4 years. In that way also the successional progress and establishment of long-term floral plantings could be compared to subsidised ÖPUL biodiversity areas which often are only established for two or three years (Grandl, Weber-Hajszan & Neudorfer, 2016).
Besides that, the biggest shortcoming in DivRESTORE is the circumstances under which the flower strips were established (Ronnie Walcher personal communication).
Another shortcoming is the rather small R^2m of the GLMM perhaps indicating that some co-variables are missing, which might probably better explain the abundance and species richness of butterflies, e.g., landscape structure or larval host-plant availability (Aviron et al., 2011; Gaigher, Pryke & Samways, 2021; Wix, Reich & Schaarschmidt, 2019).
For further studies, I would suggest to not only consider the vegetation height and the flower frequency but also the percentage of available larval host plants, plant species richness, the landscape structure in the surrounding area as well as the microclimate of the different grassland types. I would also suggest to conduct insect diversity studies over at least four continuous years.

5 Conclusion

To conclude, the results of DivRESTORE show how crucial it is for potential flower strips to choose suitable plant communities adapted to site conditions. Their proper establishment and management are important to promote butterfly species richness and abundance. Additionally, the REGRASS II project showed that high flower frequency in newly established grasslands might not be the only option to promote butterfly abundance and species richness. Another option to promote butterfly abundance and species richness might be a cool and fresh microclimate of the habitat. The results of the DivRESTORE project, showed that there are highly regional effects on butterfly abundance, species richness and community composition. This highlights the importance of suitable conservation measures in the different regions. Despite the controversial results of the effect of flower strips on the adjacent grassland, I would still suggest that flower strips are a good management measure to counteract overall pollinator loss – a measure from which especially bees and bumblebees do highly profit too (Hussain et al., 2021; Hussain et al., 2022; Maas et al., 2021). Therefore, a combination of flower strips with other restoration and conservation measures is needed to prevent further insect diversity decline (Aviron et al., 2011).

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8 Appendix

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8.1 Flower mixture REGRASS II

Table A1: Seeded flower mixture in autumn 2016 for the new grassland (NG) in REGRASS II, Num. = number of species, following the nomenclature of Fischer et al. (2008)

Num.	Group	Family	Species name
1	Grass	Poaceae	*Anthoxanthum odoratum*
2	Grass	Poaceae	*Arrhenatherum elatius*
3	Grass	Poaceae	*Brachypodium pinnatum*
4	Grass	Poaceae	*Briza media*
5	Grass	Poaceae	*Bromus erectus*
6	Grass	Poaceae	*Festuca pratensis*
7	Grass	Poaceae	*Festuca rubra agg.*
8	Grass	Poaceae	*Festuca rupicola*
9	Grass	Poaceae	*Holcus lanatus*
10	Grass	Poaceae	*Koeleria pyramidata*
11	Grass	Poaceae	*Poa pratensis agg.*
12	Legume	Fabaceae	*Anthyllis vulneraria*
13	Legume	Fabaceae	*Lotus corniculatus*
14	Legume	Fabaceae	*Medicago lupulina*

15	Legume	Fabaceae	*Onobrychis viciifolia*
16	Legume	Fabaceae	*Trifolium pratense*
17	Legume	Fabaceae	*Trifolium repens*
18	Herb	Asteraceae	*Achillea millefolium*
19	Herb	Asteraceae	*Buphthalmum salicifolium*
20	Herb	Campanulaceae	*Campanula patula*
21	Herb	Asteraceae	*Centaurea jacea*
22	Herb	Asteraceae	*Centaurea scabiosa*
23	Herb	Asteraceae	*Centaurea stoebe*
24	Herb	Asteraceae	*Crepis biennis*
25	Herb	Asteraceae	*Daucus carota*
26	Herb	Caryophyllaceae	*Dianthus carthusianorum*
27	Herb	Rubiaceae	*Galium mollugo*
28	Herb	Rubiaceae	*Galium verum*
29	Herb	Hypericaceae	*Hypericum perforatum*
30	Herb	Caprifoliaceae	*Knautia arvensis*
31	Herb	Asteraceae	*Leontodon hispidus*
32	Herb	Asteraceae	*Leucanthemum vulgare*
33	Herb	Plantaginaceae	*Plantago lanceolata*
34	Herb	Plantaginaceae	*Plantago media*
35	Herb	Lamiaceae	*Prunella grandiflora*
36	Herb	Ranunculaceae	*Ranunculus bulbosus*
37	Herb	Polygonaceae	*Rumex acetosa*
38	Herb	Lamiaceae	*Salvia pratensis*
39	Herb	Rosaceae	*Sanguisorba minor*
40	Herb	Caryophyllaceae	*Silene nutans*
41	Herb	Caryophyllaceae	*Silene vulgaris*

8.2 Vegetation recordings REGRASS II

Table A2: Recorded plant species, number of individuals per management type and year in the REGRASS II project, data by Dietmar Moser, NG = new grassland, OG = old grassland, SG = subsidised grassland, following the nomenclature of Fischer et al. (2008)

Species	**2017**			**2018**		**2019**		**2021**			**Total**		
	NG	OG	SG	NG	OG	NG	OG	NG	OG	SG	**NG**	**OG**	**SG**
Acer campestre	0	0	0	0	0	0	0	0	0	1	**0**	**0**	**1**

Acer pseudoplatanus	0	0	0	0	0	0	0	0	0	1	**0**	**0**	**1**
Achillea millefolium	20	8	0	18	10	19	8	19	7	2	**76**	**33**	**2**
Aethusa cynapium	10	0	0	1	0	0	0	0	0	0	**11**	**0**	**0**
Agrostis gigantea	0	0	0	0	0	0	0	1	0	0	**1**	**0**	**0**
Ajuga reptans	0	8	0	0	0	0	2	0	2	0	**0**	**12**	**0**
Alopecurus pratensis	0	2	0	0	0	1	3	9	6	0	**10**	**11**	**0**
Ambrosia artemisiifolia	4	0	0	0	0	0	0	0	0	0	**4**	**0**	**0**
Anagallis arvensis	3	0	0	0	0	0	0	0	0	0	**3**	**0**	**0**
Anthemis austriaca	3	0	0	0	0	0	0	0	0	0	**3**	**0**	**0**
Anthoxanthum odoratum	16	15	0	6	14	4	12	19	9	0	**45**	**50**	**0**
Anthyllis vulneraria	24	0	0	20	0	10	0	4	0	0	**58**	**0**	**0**
Apera spica-venti	5	0	1	0	0	0	0	0	0	0	**5**	**0**	**1**
Arabis hirsuta	0	0	0	0	0	0	1	0	0	0	**0**	**1**	**0**
Arrhenatherum elatius	25	10	1	25	14	25	12	24	10	3	**99**	**46**	**4**
Artemisia vulgaris	0	0	0	0	0	0	0	0	0	1	**0**	**0**	**1**
Avena fatua	10	0	0	0	0	0	0	0	0	0	**10**	**0**	**0**
Avenula pubescens	0	13	0	0	11	0	15	0	10	0	**0**	**49**	**0**
Bellis perennis	0	1	0	0	1	0	1	0	0	0	**0**	**3**	**0**
Betonica officinalis	0	0	0	0	1	0	0	0	0	0	**0**	**1**	**0**
Briza media	0	1	0	1	3	5	4	8	3	0	**14**	**11**	**0**
Bromus erectus	11	13	0	10	13	4	13	9	11	0	**34**	**50**	**0**
Bromus hordeaceus	23	1	0	17	1	10	3	17	0	2	**67**	**5**	**2**
Bromus sterilis	10	0	1	1	0	0	0	3	0	2	**14**	**0**	**3**
Calamagrostis sp.	0	1	0	0	0	0	0	0	0	0	**0**	**1**	**0**
Campanula patula	0	13	0	0	11	0	13	0	11	1	**0**	**48**	**1**
Capsella bursa-pastoris	5	0	0	0	0	0	0	0	0	1	**5**	**0**	**1**
Cardamine matthioli	0	5	0	0	5	0	5	0	4	0	**0**	**19**	**0**
Carduus acanthoides	1	0	0	0	0	0	0	0	0	0	**1**	**0**	**0**
Carex caryophyllea	0	2	0	0	2	0	2	0	0	0	**0**	**6**	**0**
Carex flacca	0	1	0	0	0	0	2	0	0	0	**0**	**3**	**0**
Carex hirta	0	0	0	0	1	0	0	0	2	0	**0**	**3**	**0**
Carex pallescens	0	2	0	0	2	0	2	0	2	0	**0**	**8**	**0**
Centaurea cyanus	0	0	0	2	0	0	0	0	0	0	**2**	**0**	**0**

Centaurea jacea	24	9	0	24	10	25	8	25	9	0	**98**	**36**	**0**
Centaurea scabiosa	2	0	0	4	0	6	0	0	0	0	**12**	**0**	**0**
Centaurea stoebe	19	0	0	22	0	17	0	3	0	0	**61**	**0**	**0**
Cerastium holosteoides	1	12	0	0	15	0	12	3	12	0	**4**	**51**	**0**
Chenopodium album	10	0	1	0	0	0	0	0	0	0	**10**	**0**	**1**
Cirsium arvense	3	0	3	3	2	5	1	2	2	2	**13**	**5**	**5**
Clematis vitalba	0	0	0	0	0	0	0	0	0	2	**0**	**0**	**2**
Colchicum autumnale	0	7	0	0	8	0	8	0	9	0	**0**	**32**	**0**
Convolvulus arvensis	2	1	0	3	0	1	2	2	0	1	**8**	**3**	**1**
Crepis biennis	12	5	0	14	11	2	6	12	4	2	**40**	**26**	**2**
Cruciata laevipes	0	2	0	0	1	0	2	0	3	0	**0**	**8**	**0**
Cynosurus cristatus	0	0	0	1	1	0	0	0	1	0	**1**	**2**	**0**
Dactylis glomerata	1	12	4	1	9	9	11	9	12	3	**20**	**44**	**7**
Daucus carota	25	2	0	23	0	22	2	17	1	0	**87**	**5**	**0**
Dianthus carthusiano-rum	16	1	0	8	1	2	0	16	2	0	**42**	**4**	**0**
Equisetum arvense	4	0	0	5	0	5	0	5	1	1	**19**	**1**	**1**
Equisetum pratense	0	0	0	0	1	1	0	0	0	0	**1**	**1**	**0**
Fallopia convolvulus	3	0	0	0	0	0	0	0	1	0	**3**	**1**	**0**
Festuca arundinacea	0	0	0	0	0	0	0	0	1	0	**0**	**1**	**0**
Festuca pratensis	6	7	2	9	9	13	8	20	12	3	**48**	**36**	**5**
Festuca rubra	11	11	1	2	9	2	3	6	4	1	**21**	**27**	**2**
Festuca rupicaprina	0	0	0	1	0	0	0	0	0	0	**1**	**0**	**0**
Festuca rupicola	12	4	0	16	10	12	7	16	4	0	**56**	**25**	**0**
Festuca valesiaca	7	0	0	0	0	0	0	10	0	0	**17**	**0**	**0**
Filago vulgaris	0	1	0	0	0	0	0	0	1	0	**0**	**2**	**0**
Filipendula vulgaris	0	6	0	0	5	0	6	0	3	0	**0**	**20**	**0**
Galium album	0	0	0	0	0	1	0	0	0	0	**1**	**0**	**0**
Galium aparine	15	2	0	0	0	0	0	0	0	2	**15**	**2**	**2**
Galium mollugo	15	15	0	15	12	20	12	25	14	1	**75**	**53**	**1**
Galium verum	1	5	0	1	5	15	4	12	4	0	**29**	**18**	**0**
Geranium dissectum	3	0	0	0	0	0	0	4	0	3	**7**	**0**	**3**
Geranium pyrenaicum	0	0	0	0	0	0	1	0	1	0	**0**	**2**	**0**
Geum urbanum	0	1	0	0	2	0	0	0	2	0	**0**	**5**	**0**
Glechoma hederacea	0	1	0	0	0	0	0	0	0	0	**0**	**1**	**0**

Helianthemum canum	0	0	0	0	0	0	0	0	1	0	**0**	**1**	**0**
Helianthemum num-mularium	0	0	0	0	0	0	1	0	0	0	**0**	**1**	**0**
Heracleum sphon-dylium	0	4	0	0	4	0	3	0	3	0	**0**	**14**	**0**
Holcus lanatus	8	13	0	16	14	21	9	24	12	1	**69**	**48**	**1**
Hypericum perforatum	0	1	0	0	0	4	2	2	0	0	**6**	**3**	**0**
Hypochoeris radicata	0	0	0	0	0	1	0	0	0	0	**1**	**0**	**0**
Inula oculus-christi	0	0	0	0	0	4	0	3	0	0	**7**	**0**	**0**
Inula salicina	0	0	0	0	1	0	1	0	0	0	**0**	**2**	**0**
Knautia arvensis	13	6	0	20	6	22	5	23	6	0	**78**	**23**	**0**
Knautia maxima	0	3	0	0	2	0	3	0	3	0	**0**	**11**	**0**
Lactuca serriola	12	0	0	0	0	0	0	1	0	0	**13**	**0**	**0**
Lathyrus pannonicus	0	1	0	0	0	0	0	0	0	0	**0**	**1**	**0**
Lathyrus pratensis	0	13	0	0	13	0	12	4	12	0	**4**	**50**	**0**
Lathyrus tuberosus	1	0	0	0	1	0	0	0	0	0	**1**	**1**	**0**
Leontodon hispidus	9	6	0	3	5	2	7	7	8	1	**21**	**26**	**1**
Leucanthemum vulgare	22	3	0	23	6	6	8	20	9	2	**71**	**26**	**2**
Linum catharticum	0	0	0	0	0	0	1	0	1	0	**0**	**2**	**0**
Lolium perenne	15	0	4	12	1	10	0	10	0	2	**47**	**1**	**6**
Lotus corniculatus	22	7	1	24	8	24	6	9	8	0	**79**	**29**	**1**
Luzula campestris	0	9	0	0	7	0	6	0	7	0	**0**	**29**	**0**
Lychnis flos-cuculi	0	5	0	0	3	0	3	0	4	0	**0**	**15**	**0**
Lysimachia nummu-laria	0	0	0	0	0	0	1	0	0	0	**0**	**1**	**0**
Matricaria chamomilla	6	0	0	0	0	0	0	0	0	0	**6**	**0**	**0**
Medicago lupulina	16	1	0	18	4	13	5	15	1	0	**62**	**11**	**0**
Medicago sativa	1	0	5	0	1	0	2	1	1	3	**2**	**4**	**8**
Melica ciliata	0	0	0	0	0	0	0	3	0	0	**3**	**0**	**0**
Melilotus albus	0	0	0	0	0	1	0	0	0	0	**1**	**0**	**0**
Melilotus officinalis	0	0	0	0	0	1	0	0	0	0	**1**	**0**	**0**
Mycelis muralis	0	0	0	0	0	0	0	0	0	1	**0**	**0**	**1**
Myosotis arvensis	13	5	0	0	0	0	1	2	5	0	**15**	**11**	**0**
Onobrychis viciifolia	18	0	0	20	1	21	0	12	1	0	**71**	**2**	**0**
Ononis spinosa	0	3	0	0	1	0	2	0	3	0	**0**	**9**	**0**

Orobanche gracilis	0	0	0	0	1	2	2	0	0	0	**2**	**3**	**0**
Oxalis sp.	0	0	0	0	0	0	0	0	0	1	**0**	**0**	**1**
Papaver rhoeas	12	0	0	0	0	0	0	0	0	0	**12**	**0**	**0**
Phleum pratense	0	0	3	1	0	1	0	3	0	0	**5**	**0**	**3**
Pimpinella major	0	1	0	0	1	0	1	0	0	0	**0**	**3**	**0**
Plantago lanceolata	23	13	0	24	11	11	12	14	12	2	**72**	**48**	**2**
Plantago media	0	0	0	0	0	0	0	3	0	1	**3**	**0**	**1**
Poa annua	0	0	0	0	0	0	1	0	1	0	**0**	**2**	**0**
Poa nemoralis	0	0	0	0	0	0	0	0	1	0	**0**	**1**	**0**
Poa pratensis	18	13	1	24	15	21	15	25	10	0	**88**	**53**	**1**
Poa trivialis	0	0	4	6	0	0	0	25	7	5	**31**	**7**	**9**
Polygala amara	0	0	0	0	0	0	0	0	1	0	**0**	**1**	**0**
Polygonum aviculare	10	0	0	0	0	0	0	0	0	0	**10**	**0**	**0**
Potentilla alba	0	6	0	0	3	0	3	0	3	0	**0**	**15**	**0**
Potentilla reptans	0	0	0	0	0	0	0	0	1	0	**0**	**1**	**0**
Primula veris	0	6	0	0	1	0	2	0	1	0	**0**	**10**	**0**
Prunella vulgaris	0	3	0	0	2	2	4	0	2	0	**2**	**11**	**0**
Ranunculus acris	0	14	0	0	10	0	11	0	12	0	**0**	**47**	**0**
Ranunculus bulbosus	0	14	0	0	11	0	9	4	11	0	**4**	**45**	**0**
Rhinanthus minor	0	10	0	0	7	0	9	0	11	0	**0**	**37**	**0**
Rosa canina	0	0	0	0	1	0	0	0	0	0	**0**	**1**	**0**
Rumex acetosa	0	14	0	0	9	0	13	0	6	0	**0**	**42**	**0**
Rumex obtusifolius	0	0	1	0	0	1	1	1	0	2	**2**	**1**	**3**
Salvia pratensis	5	5	0	1	5	7	4	10	4	0	**23**	**18**	**0**
Sanguisorba minor	15	2	0	7	1	6	2	9	0	0	**37**	**5**	**0**
Scorzonera humilis	0	1	0	0	0	0	0	0	0	0	**0**	**1**	**0**
Silene nutans	0	0	0	2	0	3	0	1	0	0	**6**	**0**	**0**
Silene vulgaris	25	0	0	18	0	11	0	7	0	0	**61**	**0**	**0**
Sonchus asper	1	0	0	0	0	0	0	0	0	1	**1**	**0**	**1**
Stellaria graminea	0	0	0	0	3	0	1	0	0	0	**0**	**4**	**0**
Stellaria media	6	0	0	0	0	0	0	0	0	0	**6**	**0**	**0**
Succisa pratensis	0	2	0	0	1	0	0	0	0	0	**0**	**3**	**0**
Symphytum officinale	0	0	0	0	2	0	1	0	0	0	**0**	**3**	**0**
Taraxacum officinale	4	6	1	6	4	4	8	17	5	5	**31**	**23**	**6**
Thlaspi arvense	4	0	0	0	0	0	0	0	0	0	**4**	**0**	**0**

Tragopogon orientalis	0	2	0	0	6	0	11	0	11	1	**0**	**30**	**1**
Trifolium campestre	2	3	0	0	6	0	11	1	8	0	**3**	**28**	**0**
Trifolium dubium	0	0	0	0	0	0	0	0	1	0	**0**	**1**	**0**
Trifolium incarnatum	0	1	1	0	0	0	0	0	0	0	**0**	**1**	**1**
Trifolium montanum	0	2	0	0	2	0	3	0	2	0	**0**	**9**	**0**
Trifolium pratense	22	5	3	19	14	19	14	19	12	3	**79**	**45**	**6**
Trifolium repens	24	5	3	23	14	21	14	21	8	3	**89**	**41**	**6**
Tripleurospermum ino-dorum	8	0	0	0	0	0	0	0	0	0	**8**	**0**	**0**
Trisetum flavescens	0	5	1	6	11	6	7	21	10	2	**33**	**33**	**3**
Triticum aestivum	0	0	1	0	0	0	0	0	0	0	**0**	**0**	**1**
Urtica dioica	0	1	0	0	1	0	1	0	0	1	**0**	**3**	**1**
Veronica agrestis	8	0	0	0	0	0	0	0	0	0	**8**	**0**	**0**
Veronica arvensis	7	4	0	0	1	0	0	6	3	0	**13**	**8**	**0**
Veronica chamaedrys	0	12	0	0	10	0	11	0	12	1	**0**	**45**	**1**
Veronica persica	3	0	0	0	0	0	0	0	0	0	**3**	**0**	**0**
Vicia cordata	0	5	0	0	3	0	3	0	2	0	**0**	**13**	**0**
Vicia cracca	0	0	0	0	2	1	2	0	0	0	**1**	**4**	**0**
Vicia hirsuta	0	8	0	0	5	0	7	0	9	0	**0**	**29**	**0**
Vicia sepium	0	7	0	0	6	0	8	1	11	0	**1**	**32**	**0**
Vicia tetrasperma	0	0	0	0	0	0	0	0	0	1	**0**	**0**	**1**
Viola arvensis	16	0	0	0	0	0	0	0	0	0	**16**	**0**	**0**
Viola hirta	0	0	0	0	1	0	3	0	1	0	**0**	**5**	**0**
Vulpia myuros	0	0	0	0	0	0	0	1	0	0	**1**	**0**	**0**

8.3 Butterfly species REGRASS II

Table A3: Recorded butterfly abundance per management type and ecological traits per species, NG = new grassland, OG = old grassland, SG = subsidised grassland, the nomenclature followed Karsholt & Razowski (1996).

Species	**Voltinism**	**Larval host plant**	**habitat**	**Moisture preferences**	**hiberna-tion**	**NG**	**OG**	**SG**
Aglais io	bivoltine	herbs	open land	ubiquitous	imago	20	15	24
Aglais urticae	trivoltine	herbs	open land	ubiquitous	imago	8	1	2
Aphantopus hyperantus	univoltine	grass	meadow	dry-fresh	larva	2	4	7
Araschnia levana	bivoltine	herbs	forest edge	moist-fresh	pupa	1	2	3

Argynnis paphia	univoltine	herbs	forest edge	moist-fresh	egg	2	29	51
Aricia agestis	bivoltine	herbs	meadow	xerotherm	larva	1	2	5
Boloria dia	trivoltine	herbs	meadow	xerotherm	larva	23	106	18
Boloria euphrosyne	univoltine	herbs	forest edge	dry-fresh	larva	0	1	0
Brintesia circe	univoltine	grass	meadow	xerotherm	larva	0	4	2
Carcharodes alceae	trivoltine	herbs	open land	xerotherm	larva	1	0	0
Carterocephalus palaemon	univoltine	grass	meadow	dry-fresh	larva	0	1	1
Celastrina argioulus	trivoltine	herbs/ wood	forest edge	ubiquitous	pupa	3	7	3
Coenonympha arcania	univoltine	grass	forest edge	dry-fresh	larva	0	3	0
Coenonympha glycerion	bivoltine	grass	meadow	dry-fresh	larva	106	340	90
Coenonympha pamphilus	trivoltine	grass	meadow	dry-fresh	larva	83	160	94
Colias alfacariensis / hyale	trivoltine	herbs	meadow	dry-fresh	larva	37	44	46
Colias crocea	trivoltine	herbs	open land	ubiquitous	larva	19	11	7
Cupido argiades	bivoltine	herbs	meadow	xerotherm	larva	150	56	64
Cupido decolorata	bivoltine	herbs	open land	xerotherm	larva	0	0	1
Cupido minimus	bivoltine	herbs	meadow	xerotherm	larva	22	0	1
Erynnis tages	bivoltine	herbs	meadow	xerotherm	larva	9	6	10
Gonepteryx rhamni	univoltine	wood	forest edge	ubiquitous	imago	1	6	4
Heteropterus morpheus	univoltine	grass	meadow	dry-fresh	larva	0	1	3
Iphiclides podalirius	trivoltine	wood	open land	xerotherm	pupa	0	1	2
Issoria lathonia	trivoltine	herbs	open land	ubiquitous	all_stages	41	10	27
Lasiommata megera	trivoltine	grass	open land	dry-fresh	larva	3	4	1
Leptidea sinapis agg.	bivoltine	herbs	meadow	dry-fresh	pupa	28	60	31
Limenitis camilla	univoltine	wood	forest	moist-fresh	larva	0	1	0
Lycaena dispar	bivoltine	herbs	meadow	moist-fresh	larva	8	2	23
Lycaena phlaeas	bivoltine	herbs	meadow	ubiquitous	larva	2	2	18
Lycaena tityrus	trivoltine	herbs	meadow	dry-fresh	larva	1	30	4
Maniola jurtina	univoltine	grass	meadow	ubiquitous	larva	419	443	281
Melanargia galathea	univoltine	grass	meadow	xero-/meso-phil	larva	171	97	14
Melitaea phoebe	bivoltine	herbs	open land	xerotherm	larva	1	0	0
Ochlodes sylvanus	univoltine	grass	meadow	ubiquitous	larva	1	6	13

Papilio machaon	trivoltine	herbs	meadow	ubiquitous	pupa	11	0	2
Pieris brassicae	bivoltine	herbs	open land	ubiquitous	pupa	6	10	17
Pieris napi	trivoltine	herbs	open land	ubiquitous	pupa	15	20	18
Pieris rapae	trivoltine	herbs	open land	ubiquitous	pupa	138	84	191
Plebejus argus	bivoltine	herbs	meadow	xerotherm	pupa	6	53	3
Plebejus argyrognomon	bivoltine	herbs	open land	xerotherm	larva	0	1	0
Polyommatus icarus	trivoltine	herbs	meadow	ubiquitous	larva	191	244	260
Polyommatus therisites	bivoltine	herbs	meadow	xerotherm	larva	2	1	3
Pontia edusa	trivoltine	herbs	open land	xerotherm	pupa	5	0	0
Pyrgus alveus / amoricanus	bivoltine	herbs	meadow	xerotherm	larva	1	0	0
Thymelicus lineola	univoltine	grass	meadow	dry-fresh	larva	28	13	17
Thymelicus sylvestris	univoltine	grass	meadow	dry-fresh	larva	4	9	10
Vanessa atalanta	bivoltine	herbs	open land/ forest	ubiquitous	imago	1	1	2
Vanessa cardui	trivoltine	herbs	open land	ubiquitous	imago	10	2	11
Zygaena ephialtes	univoltine	herbs	open land/ forest	xerotherm	larva	0	1	0
Zygaena filipendulae	univoltine	herbs	open land	ubiquitous	larva	0	1	0

8.4 GLM Models REGRASS II

Table A4: REGRASS II most parsimonious models for butterfly abundance and species richness, K: Number of estimated parameters, AICc: Second order Akaike Information Criterion, ΔAICc: Difference between AICc to the next most parsimonious model, ω_i: Akaike weight, LL: Laplace Likelihood, R^2m: R^2 marginal, R^2c: R^2 conditional

Response	Fixed factors	K	AICc	ΔAICc	ω_i	LL	R^2m	R^2c
Butterfly abundance	Grassland type + flower frequency + vegetation height	7	1220.20	0	0.54	-602.70	0.09	0.98
	Grassland type * flower frequency	8	1220.55	0.36	0.46	-601.76	0.10	0.98
Butterfly species richness	Grassland type * flower frequency	7	775.55	0	0.53	-380.37	0.60	0.70
	Grassland type + flower frequency + vegetation height	6	775.78	0.23	0.47	-381.59	0.06	0.70

8.5 Flower mixture DivRESTORE (Vienna Woods)

Table A5: Seed mixture used for Flower strips (FS) in Vienna Woods, Num. = number of species, following the nomenclature of Fischer et al. (2008)

Num.	Group	Family	Species name
1	Grass	Poaceae	*Festuca ovina*
2	Grass	Poaceae	*Festuca rubra ssp. commutata*
3	Grass	Poaceae	*Festuca rupicola*
4	Grass	Poaceae	*Koeleria pyramidata*
5	Legume	Fabaceae	*Lotus corniculatus*
6	Legume	Fabaceae	*Securigera varia*
7	Legume	Fabaceae	*Trifolium pratense*
8	Legume	Fabaceae	*Trifolium repens*
9	Herb	Caryophyllaceae	*Agrostemma githago*
10	Herb	Asteraceae	*Anthemis tinctoria*
11	Herb	Asteraceae	*Buphthalmum salicifolium*
12	Herb	Apiaceae	*Carum carvi*
13	Herb	Asteraceae	*Centaurea cyanus*
14	Herb	Asteraceae	*Centaurea pseudophrygia*
15	Herb	Asteraceae	*Centaurea scabiosa*
16	Herb	Asteraceae	*Crepis biennis*
17	Herb	Apiaceae	*Daucus carota*
18	Herb	Caryophyllaceae	*Dianthus carthusianorum*
19	Herb	Caryophyllaceae	*Dianthus superbus*
20	Herb	Rubiaceae	*Galium album*
21	Herb	Rubiaceae	*Galium verum*
22	Herb	Apiaceae	*Heracleum sphondylium*
23	Herb	Hypericaceae	*Hypericum maculatum*
24	Herb	Asteraceae	*Leontodon hispidus*
25	Herb	Asteraceae	*Leucanthemum vulgare*
26	Herb	Caryophyllaceae	*Lychnis flos-cuculi*
27	Herb	Apiaceae	*Pastinaca sativa*
28	Herb	Caryophyllaceae	*Petrorhagia saxifraga*
29	Herb	Plantaginaceae	*Plantago lanceolata*
30	Herb	Plantaginaceae	*Plantago media*

31	Herb	Lamiaceae	*Prunella grandiflora*
32	Herb	Lamiaceae	*Prunella vulgaris*
33	Herb	Rosaceae	*Sanguisorba minor*
34	Herb	Caryophyllaceae	*Silene dioica*
35	Herb	Caryophyllaceae	*Stellaria graminea*
36	Herb	Asteraceae	*Tragopogon orientalis*
37	Herb	Scrophulariaceae	*Verbascum nigrum*

8.6 Vegetation recordings DivRESTORE

Table A6: Recorded plant species, absence / presence data per transect summed up per management type and region, W = Vienna Woods, LN = Lungau / Nockberge, I - = intensive control meadow, I + = intensive meadow next to FS, FS = flower strip, E = extensive meadow, data by Leonid Rasran, following the nomenclature of Fischer et al. (2008)

Species	**W-I⁻**	**W-E**	**W-F**	**W-I⁺**	**Total W**	**LN-I⁻**	**LN-E**	**LN-F**	**LN-I⁺**	**Total LN**
Achillea millefolium	2	2	1	3	**8**	3	4	3	0	**10**
Aegopodium podagraria	0	0	0	0	**0**	3	3	1	0	**7**
Agrostemma githago	0	0	1	0	**1**	0	0	0	0	**0**
Agrostis stolonifera	0	0	0	0	**0**	0	0	3	1	**4**
Ajuga reptans	1	1	0	0	**2**	0	0	0	0	**0**
Alchemilla vulgaris	0	1	0	0	**1**	2	4	3	2	**11**
Allium carinatum	0	2	1	1	**4**	0	0	0	0	**0**
Allium vineale	1	3	1	0	**5**	0	0	0	0	**0**
Alopecurus geniculatus	0	0	0	0	**0**	0	0	1	0	**1**
Alopecurus pratensis	1	0	1	0	**2**	1	2	3	3	**9**
Angelica sylvestris	0	0	0	0	**0**	0	2	1	0	**3**
Anthemis tinctoria	0	0	4	0	**4**	0	0	0	0	**0**
Anthericum ramosum	0	0	0	0	**0**	0	1	0	0	**1**
Anthoxanthum odoratum	1	4	2	1	**8**	1	3	1	1	**6**
Anthriscus sylvestris	0	0	0	0	**0**	1	1	1	2	**5**
Armoracia rusticana	0	0	0	0	**0**	1	0	0	0	**1**
Arrhenatherum elatius	3	5	3	2	**13**	0	4	0	0	**4**
Artemisia vulgaris	0	0	0	0	**0**	0	0	1	0	**1**
Betonica officinalis	0	1	0	0	**1**	0	0	0	0	**0**
Brachypodium pinnatum	0	1	0	0	**1**	0	0	0	0	**0**

Briza media	0	3	1	1	**5**	0	3	0	0	**3**
Bromus erectus	0	4	1	1	**6**	0	1	0	0	**1**
Bromus inermis	0	0	0	0	**0**	0	0	1	0	**1**
Bromus sterilis	1	0	0	0	**1**	0	0	0	0	**0**
Calamagrostis epigejos	2	0	0	0	**2**	0	0	0	0	**0**
Caltha palustris	0	0	0	0	**0**	0	0	1	0	**1**
Calystegia sepium	0	0	1	0	**1**	0	0	0	0	**0**
Campanula patula	1	1	0	0	**2**	2	4	0	0	**6**
Campanula rotundifolia	0	1	0	0	**1**	0	0	0	0	**0**
Capsella bursa-pastoris	0	0	0	0	**0**	1	0	0	0	**1**
Cardamine pratensis	0	0	0	0	**0**	1	0	0	0	**1**
Carduus acanthoides	0	1	0	0	**1**	0	1	0	0	**1**
Carex caryophyllea	0	1	0	0	**1**	0	0	0	0	**0**
Carex hirta	0	0	1	1	**2**	0	0	0	0	**0**
Carex leporina	0	0	0	0	**0**	0	0	1	0	**1**
Carex montana	0	0	0	0	**0**	1	0	0	0	**1**
Carex pallescens	1	1	1	1	**4**	0	1	0	0	**1**
Carex panicea	0	0	0	1	**1**	0	0	0	0	**0**
Carex sylvatica	0	0	1	0	**1**	0	0	0	0	**0**
Carex tomentosa	0	0	0	1	**1**	0	0	0	0	**0**
Carpinus betulus	1	0	1	0	**2**	0	0	0	0	**0**
Carum carvi	0	0	0	0	**0**	3	2	0	2	**7**
Centaurea cyanus	0	0	1	0	**1**	0	0	0	0	**0**
Centaurea jacea	2	5	1	3	**11**	0	0	0	0	**0**
Centaurea phrygia	0	0	1	0	**1**	0	0	0	0	**0**
Centaurea scabiosa	0	0	1	0	**1**	0	0	0	0	**0**
Cerastium fontanum	1	1	2	1	**5**	2	1	1	2	**6**
Chaerophyllum aureum	0	0	0	0	**0**	0	2	1	0	**3**
Chenopodium bonus-henri-cus	0	0	0	0	**0**	1	0	0	1	**2**
Cirsium arvense	0	1	0	1	**2**	0	0	0	0	**0**
Cirsium heterophyllum	0	0	1	0	**1**	1	2	1	0	**4**
Cirsium oleraceum	0	0	1	1	**2**	0	1	3	1	**5**
Clinopodium vulgare	0	3	0	1	**4**	0	1	0	0	**1**
Colchicum autumnale	1	0	1	0	**2**	0	0	0	0	**0**

Convolvulus arvensis	0	0	0	1	**1**	0	0	0	0	**0**
Crepis biennis	1	0	0	0	**1**	1	0	1	0	**2**
Crepis capillaris	1	1	0	1	**3**	0	0	0	0	**0**
Cruciata laevipes	1	1	0	0	**2**	1	0	0	0	**1**
Cynosurus cristatus	1	3	1	2	**7**	0	0	0	0	**0**
Dactylis glomerata	3	3	5	4	**15**	5	5	3	5	**18**
Dactylorhiza fuchsii	0	0	0	0	**0**	0	1	0	0	**1**
Daucus carota	2	2	3	1	**8**	0	1	0	0	**1**
Deschampsia cespitosa	0	0	0	0	**0**	1	3	2	1	**7**
Deschampsia flexuosa	0	0	0	0	**0**	0	1	0	0	**1**
Elymus repens	0	0	1	1	**2**	0	0	2	0	**2**
Epilobium c.f. parviflorum	0	0	0	0	**0**	0	0	3	0	**3**
Equisetum palustre	0	0	0	0	**0**	0	0	2	0	**2**
Erigeron annuus	1	0	0	0	**1**	0	0	0	0	**0**
Euphorbia cyparissias	0	1	0	0	**1**	0	0	0	0	**0**
Euphrasia stricta	0	0	0	0	**0**	1	1	1	0	**3**
Festuca arundinacea	0	0	1	1	**2**	0	0	0	0	**0**
Festuca ovina	0	0	0	0	**0**	0	1	0	0	**1**
Festuca pratensis	3	2	3	2	**10**	0	1	2	0	**3**
Festuca rubra	2	4	1	3	**10**	1	4	2	0	**7**
Filipendula ulmaria	0	0	0	0	**0**	0	0	3	0	**3**
Filipendula vulgaris	1	4	1	0	**6**	0	0	0	0	**0**
Fragaria spec.	0	1	1	0	**2**	0	0	0	0	**0**
Galeopsis pubescens	0	0	0	0	**0**	0	1	1	0	**2**
Galeopsis speciosa	0	0	0	0	**0**	0	0	2	0	**2**
Galium album × verum	0	0	0	0	**0**	0	1	0	0	**1**
Galium album	0	0	0	0	**0**	0	1	0	0	**1**
Galium boreale	1	2	0	1	**4**	0	1	0	0	**1**
Galium mollugo	5	2	4	4	**15**	0	2	1	0	**3**
Galium palustre	0	0	0	0	**0**	0	0	1	0	**1**
Galium verum	0	1	1	0	**2**	0	1	0	0	**1**
Geranium pratense	0	0	0	0	**0**	0	4	2	0	**6**
Geranium pyrenaicum	0	0	1	1	**2**	0	0	0	0	**0**
Glechoma hederacea	1	1	1	1	**4**	0	0	0	1	**1**
Glyceria fluitans	0	0	0	0	**0**	0	0	2	1	**3**

Glyceria maxima	0	0	0	0	**0**	0	0	0	1	**1**
Helictotrichon pubescens	1	2	0	0	**3**	0	1	0	0	**1**
Heracleum sphondylium	0	2	1	1	**4**	0	0	1	0	**1**
Hieracium spec.	0	0	0	0	**0**	0	1	0	1	**2**
Hieracium subg. Pilosella	0	0	0	0	**0**	0	1	0	0	**1**
Holcus lanatus	3	4	2	2	**11**	0	1	1	0	**2**
Holcus mollis	0	0	0	0	**0**	0	1	0	0	**1**
Hypericum perforatum	0	2	1	0	**3**	0	2	0	0	**2**
Juncus articulatus	0	0	0	1	**1**	0	0	2	0	**2**
Juncus conglomeratus	0	0	0	1	**1**	0	0	0	0	**0**
Juncus effusus	0	0	0	0	**0**	0	0	1	0	**1**
Juncus inflexus	0	0	0	1	**1**	0	0	0	0	**0**
Knautia arvensis	1	4	1	0	**6**	0	1	1	0	**2**
Knautia maxima	0	0	0	0	**0**	0	2	0	0	**2**
Lathyrus pratensis	1	2	2	2	**7**	2	4	1	0	**7**
Leontodon hispidus	2	4	1	0	**7**	0	4	0	1	**5**
Leucanthemum vulgare	0	0	0	0	**0**	0	2	1	1	**4**
Linum catharticum	0	0	0	0	**0**	0	1	0	0	**1**
Lolium perenne	4	0	2	2	**8**	3	0	1	4	**8**
Lotus corniculatus	4	3	2	4	**13**	0	1	0	0	**1**
Luzula campestris	1	2	0	0	**3**	0	0	0	0	**0**
Luzula luzuloides	0	0	0	0	**0**	0	2	0	0	**2**
Luzula multiflora	0	0	0	0	**0**	0	3	0	0	**3**
Lysimachia nummularia	2	0	0	2	**4**	0	0	0	0	**0**
Melampyrum sylvaticum	0	0	0	0	**0**	0	1	0	0	**1**
Myosotis arvensis	1	0	0	0	**1**	0	0	0	0	**0**
Myosotis scorpioides	0	0	0	0	**0**	0	1	2	1	**4**
Pastinaca sativa	0	0	2	1	**3**	0	0	0	0	**0**
Persicaria hydropiper	0	0	0	0	**0**	0	0	1	1	**2**
Phleum pratense	1	0	3	2	**6**	2	2	5	3	**12**
Pimpinella major	0	0	0	0	**0**	1	3	0	0	**4**
Pimpinella saxifraga	1	1	1	0	**3**	0	2	0	0	**2**
Plantago lanceolata	5	5	3	4	**17**	1	1	0	0	**2**
Plantago major	0	0	0	0	**0**	0	0	0	1	**1**
Plantago media	0	1	0	0	**1**	0	1	0	0	**1**

Poa annua	0	0	0	1	**1**	1	0	0	1	**2**
Poa pratensis	1	2	1	1	**5**	0	0	1	0	**1**
Poa trivialis	0	0	0	0	**0**	2	1	5	3	**11**
Polygala vulgaris	1	0	0	0	**1**	0	0	0	0	**0**
Potentilla argentea	1	0	0	0	**1**	0	0	0	0	**0**
Potentilla erecta	0	0	0	0	**0**	1	2	0	0	**3**
Potentilla recta	0	0	0	0	**0**	0	1	0	0	**1**
Potentilla reptans	1	0	0	1	**2**	0	0	0	0	**0**
Primula veris	0	3	0	0	**3**	0	0	0	0	**0**
Prunella vulgaris	1	1	0	2	**4**	1	1	1	2	**5**
Ranunculus acris	4	2	2	3	**11**	3	5	4	3	**15**
Ranunculus reptans	0	0	1	0	**1**	1	0	2	1	**4**
Rhinanthus cf. alec-torolophus	0	1	1	0	**2**	0	1	0	0	**1**
Rhinanthus glacialis	0	0	0	0	**0**	0	1	1	0	**2**
Rhinanthus minor	0	1	1	0	**2**	0	1	0	0	**1**
Rorippa palustris	0	0	0	0	**0**	0	0	0	1	**1**
Rubus fruticosus	1	0	0	0	**1**	0	0	0	0	**0**
Rumex acetosa	1	1	0	2	**4**	3	3	4	2	**12**
Rumex crispus	1	0	0	0	**1**	0	0	1	0	**1**
Rumex obtusifolius	0	0	1	0	**1**	3	0	0	3	**6**
Sanguisorba minor	0	0	1	0	**1**	0	0	0	0	**0**
Scirpus sylvaticus	0	0	0	0	**0**	0	0	1	1	**2**
Silene flos-cuculi	0	0	0	1	**1**	0	0	2	0	**2**
Silene latifolia Poir.	0	0	0	0	**0**	0	0	1	0	**1**
Silene nutans	0	0	0	0	**0**	0	1	0	0	**1**
Silene vulgaris	0	0	0	0	**0**	0	0	1	0	**1**
Stellaria graminea	0	0	0	0	**0**	0	4	2	0	**6**
Taraxacum officinale	3	2	0	3	**8**	5	2	2	5	**14**
Teucrium chamaedrys	0	2	0	0	**2**	0	0	0	0	**0**
Thymus vulgaris	0	0	0	0	**0**	0	1	0	0	**1**
Tragopogon pratensis	0	1	2	1	**4**	0	2	2	0	**4**
Trifolium hybridum	0	0	0	0	**0**	0	0	1	0	**1**
Trifolium medium	0	2	0	0	**2**	0	1	0	0	**1**
Trifolium montanum	0	2	0	0	**2**	0	0	0	0	**0**

Trifolium pratense	4	3	3	5	**15**	2	3	1	3	**9**
Trifolium repens	3	0	1	2	**6**	5	1	1	4	**11**
Triglochin palustris	0	0	0	0	**0**	0	0	1	0	**1**
Trisetum flavescens	0	1	0	1	**2**	3	4	2	2	**11**
Trollius europaeus	0	0	0	0	**0**	0	1	0	0	**1**
Urtica dioica	0	0	0	0	**0**	0	0	1	1	**2**
Valeriana officinalis	0	0	0	0	**0**	0	0	2	0	**2**
Veratrum album	0	0	0	0	**0**	0	1	0	0	**1**
Veronica chamaedrys	1	3	1	0	**5**	0	4	0	0	**4**
Vicia cracca	2	1	0	0	**3**	2	3	4	1	**10**
Vicia sepium	3	0	0	0	**3**	1	1	0	0	**2**
Vicia villosa	0	0	0	0	**0**	0	1	0	0	**1**
Viola spec.	0	2	1	1	**4**	0	0	0	0	**0**
Viola tricolor	0	0	0	0	**0**	0	0	1	0	**1**

8.7 Butterfly species DivRESTORE

Table A7: Recorded butterfly species with ecological traits, number of individuals per management type and region in the DivRESTORE project, the nomenclature followed Karsholt & Razowski (1996)

Species	**Voltinism**	**Larval host plant**	**habitat**	**Moisture prefer-ences**	**hiberna-tion**	**Lungau / Nockberge**				**Vienna Woods**			
						exten-sive	flower strip	inten-sive -	inten-sive +	exten-sive	flower strip	inten-sive -	inten-sive +
Aglais io	bivoltine	herbs	open land	ubiqui-tous	imago	0	2	3	1	0	0	1	0
Aglais urticae	trivoltine	herbs	open land	ubiqui-tous	imago	4	4	3	0	1	0	0	0
Aphantopus hyperantus	univoltine	grass	meadow	dry-fresh	larva	74	22	5	9	13	15	1	8
Aporia crataegi	univoltine	wood	forest edge	dry-fresh	imago	0	1	0	2	0	0	0	0
Araschnia levana	bivoltine	herbs	forest edge	moist-fresh	pupa	0	0	0	0	0	0	2	0
Argynnis adippe	univoltine	herbs	open land	ubiqui-tous	egg	0	0	0	0	0	0	1	0
Argynnis aglaja	univoltine	herbs	forest edge	ubiqui-tous	larva	2	2	1	0	6	1	0	1
Argynnis paphia	univoltine	herbs	forest edge	moist-fresh	egg	3	0	1	1	1	12	8	8
Aricia agestis / artaxerxes	bivoltine	herbs	meadow	xe-rotherm	larva	0	0	0	0	0	0	0	4
Boloria dia	trivoltine	herbs	meadow	xe-rotherm	larva	0	0	0	0	9	2	3	3
Boloria euphrosyne	univoltine	herbs	forest edge	dry-fresh	larva	0	0	0	1	0	0	0	0
Boloria selene	bivoltine	herbs	forest edge	dry-fresh	larva	4	0	0	0	0	0	0	0

Boloria sp.	bivoltine	herbs	forest edge	dry-fresh	larva	0	0	0	1	0	0	0	0
Brenthis hecate	univoltine	herbs	forest edge	dry-fresh	larva	0	0	0	0	2	0	0	0
Brenthis ino	univoltine	herbs	open land	dry-fresh	egg	1	0	0	0	0	0	0	0
Brintesia circe	univoltine	grass	meadow	xe-rotherm	larva	0	0	0	0	6	0	1	1
Caterocephalus palaemon	univoltine	grass	meadow	dry-fresh	larva	0	5	1	0	0	0	0	0
Coenonympha pamphilus	trivoltine	grass	meadow	dry-fresh	larva	5	3	3	0	32	17	26	18
Coenonympha sp.	univoltine	grass	meadow	dry-fresh	larva	0	0	0	0	0	0	1	0
Colias alfacariensis / hy-ale	trivoltine	herbs	meadow	dry-fresh	larva	1	0	0	1	2	0	5	4
Colias crocea	trivoltine	herbs	open land	ubiqui-tous	larva	2	0	1	0	0	0	0	0
Cupido argiades	bivoltine	herbs	meadow	xe-rotherm	larva	0	0	0	0	3	0	2	6
Cyaniris semiargus	bivoltine	herbs	forest edge	moist-fresh	larva	2	0	0	0	0	0	0	0
Erebia aethiops	univoltine	grass	forest edge	dry-fresh	larva	0	5	1	2	0	0	0	0
Erebia medusa	univoltine	grass	open land / forest	dry-fresh	larva	16	4	1	0	0	0	0	0
Erebia medusa / oeme	univoltine	grass	open land	dry-fresh	larva	1	0	1	0	0	0	0	0
Erebia oeme	univoltine	grass	open land	dry-fresh	larva	0	0	0	1	0	0	0	0
Erebia sp.	univoltine	grass	open land	dry-fresh	larva	0	0	1	0	0	0	0	0
Erynnis tages	bivoltine	herbs	meadow	xe-rotherm	larva	0	0	0	1	0	0	0	0
Hesperia comma	univoltine	grass	meadow	dry-fresh	egg	1	0	0	0	0	0	0	0

Iphiclides podalirius	trivoltine	wood	open land	xe-rotherm	pupa	1	0	0	0	0	0	0	1
Issoria lathonia	trivoltine	herbs	open land	ubiqui-tous	all_stages	5	2	0	1	10	0	0	3
Lasiommata megera	trivoltine	grass	open land	dry-fresh	larva	0	0	0	0	0	0	0	1
Leptidea sinapsis agg.	bivoltine	herbs	meadow	dry-fresh	pupa	7	5	3	0	8	7	7	14
Lycaena dispar	bivoltine	herbs	meadow	moist-fresh	larva	0	0	0	0	0	2	0	1
Lycaena phlaeas	bivoltine	herbs	meadow	ubiqui-tous	larva	0	0	0	0	0	4	1	0
Lycaena tityrus	trivoltine	herbs	meadow	dry-fresh	larva	0	0	0	0	0	2	3	2
Maniola jurtina	univoltine	grass	meadow	ubiqui-tous	larva	45	0	1	2	128	126	94	87
Melanargia galathea	univoltine	grass	meadow	xero-mesophil	larva	22	0	0	0	124	16	20	23
Melitaea athalia	univoltine	herbs	meadow	xero-mesophil	imago	1	0	0	0	0	0	0	0
Melitaea athalia / aurelia	univoltine	herbs	open land	xero-mesophil	imago	0	2	0	0	0	0	0	0
Ochlodes sylvanus	univoltine	grass	meadow	ubiqui-tous	larva	2	2	0	1	0	2	3	2
Papilio machaon	trivoltine	herbs	meadow	ubiqui-tous	pupa	1	0	0	1	0	0	0	0
Pararge aegeria	trivoltine	grass	forest	moist-fresh	larva / pupa	0	0	0	0	0	0	1	0
Pieris brassicae	bivoltine	herbs	open land	ubiqui-tous	pupa	2	2	1	1	0	0	1	4
Pieris napi	trivoltine	herbs	open land	ubiqui-tous	pupa	2	1	3	7	0	3	0	0
Pieris rapae	trivoltine	herbs	open land	ubiqui-tous	pupa	4	10	6	4	6	4	10	2

Pieris sp.	trivoltine	herbs	open land	ubiqui-tous	pupa	0	1	1	1	0	0	0	0
Polyommatus amandus	univoltine	herbs	meadow	dry-fresh	larva	0	1	0	0	0	0	0	0
Polyommatus icarus	trivoltine	herbs	meadow	ubiqui-tous	larva	1	0	0	0	14	4	20	19
Pyrgus amoricanus	bivoltine	herbs	meadow	xe-rotherm	larva	0	0	0	0	1	1	0	0
Thymelicus lineola	univoltine	grass	meadow	dry-fresh	larva	3	2	0	3	1	0	0	0
Thymelicus sylvestris	univoltine	grass	meadow	dry-fresh	larva	1	1	0	0	0	0	0	1
Vanessa atalanta	bivoltine	herbs	open land / forest	ubiqui-tous	imago	2	3	6	6	0	1	0	0
Vanessa cardui	trivoltine	herbs	open land	ubiqui-tous	imago	1	0	0	0	0	0	0	0
Zygaena ephialtes	univoltine	herbs	open land / forest	xe-rotherm	larva	0	0	0	0	0	1	1	0
Zygaena filipendulae	univoltine	herbs	open land	ubiqui-tous	larva	1	0	0	0	9	1	9	5
Zygaena minos / purpu-ralis	univoltine	herbs	meadow	xe-rotherm	larva	6	0	0	0	0	0	0	0
Zygaena sp.	univoltine	herbs	meadow	dry-fresh	larva	0	0	0	0	1	0	0	0
Zygaena viciae	univoltine	herbs	meadow	dry-fresh	larva	8	0	0	0	12	0	2	2

8.8 GLM Models DivRESTORE

Table A8: DivRESTORE most parsimonious models for butterfly abundance and species richness, K: Number of estimated parameters, AICc: Second order Akaike Information Criterion, ΔAICc: Difference between AICc to the next most parsimonious model, ω_i: Akaike weight, LL: Laplace Likelihood, R^2m: R^2 marginal, R^2c: R^2 conditional

Response	Fixed factors	K	AICc	ΔAICc	ω_i	LL	R^2m	R^2c
Butterfly abundance	Grassland type * region	10	1289.69	0	1	-634.36	0.43	0.89
Butterfly species richness	Grassland type * region	9	871.90	0	1	-426.56	0.35	0.41

8.9 NMDS REGRASS II

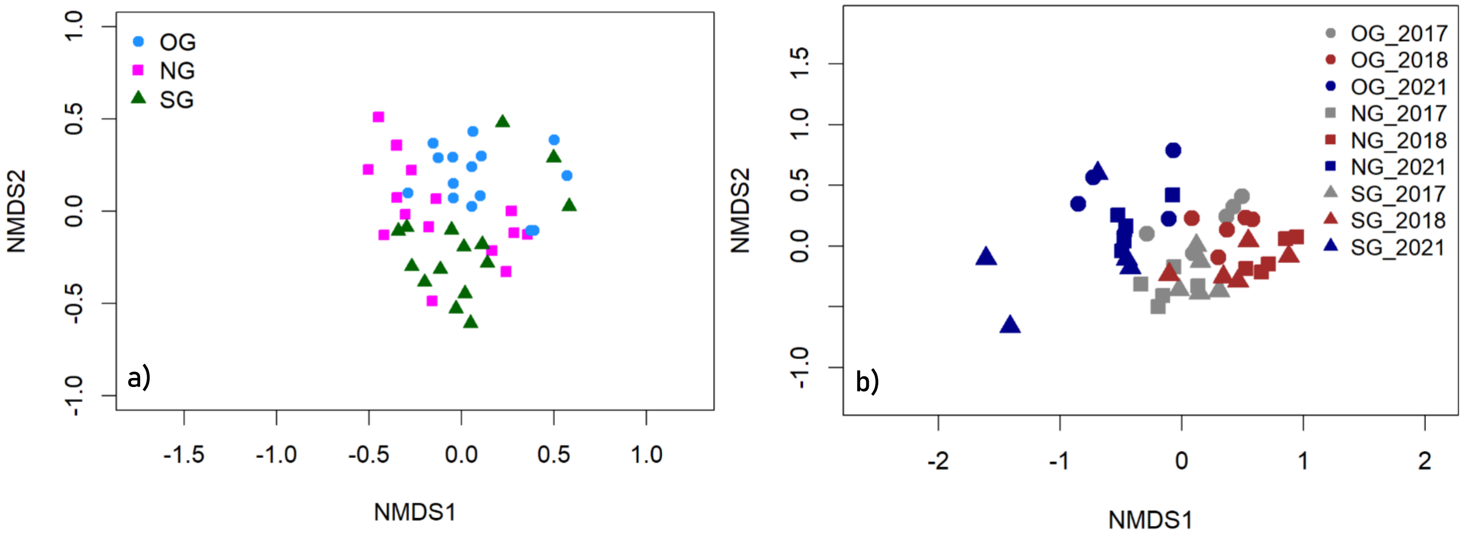

Figure A1: Results of the Nonmetric multidimensional scaling (NMDS); points: new grassland (NG), squares: old grassland (OG), triangles: subsidised grassland (SG); a) grassland types, blue: NG, pink: OG, green: SG; b) split in year and grassland type, grey: 2017, red: 2018, blue: 2021

8.10 PCA DivRESTORE

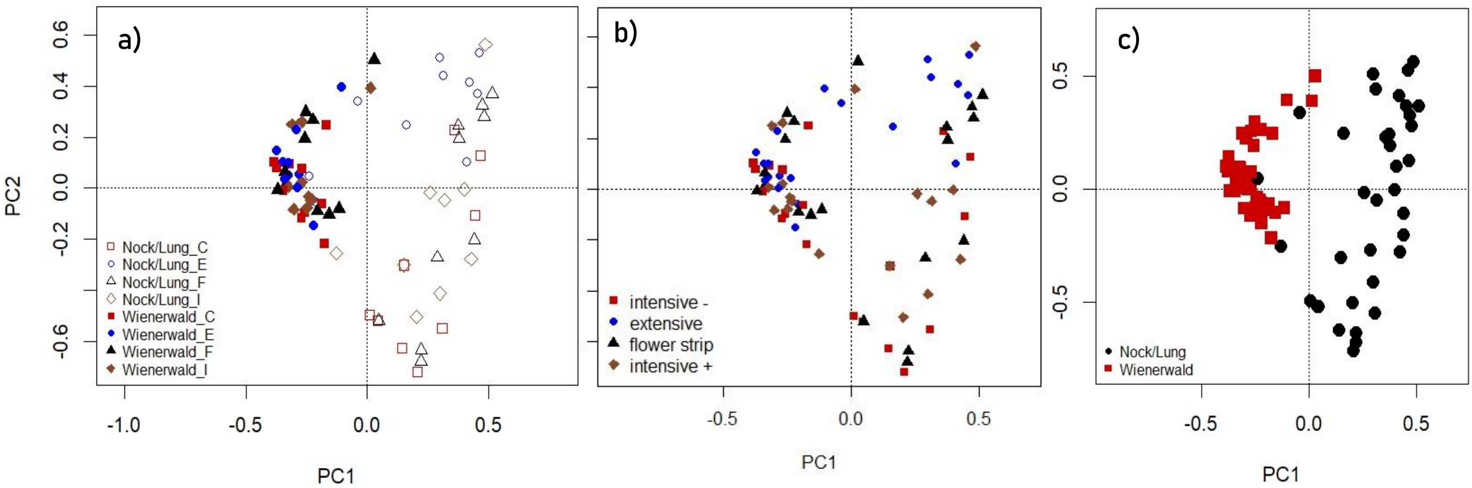

Figure A2: Results of the principal component analysis (PCA), a) region & grassland types, filled symbols = Vienna Woods, empty symbols: Lungau / Nockberge; a) & b) red squares: intensive control meadow (I-), blue points: extensive meadow (E), black triangles: flower strip (FS), brown rhombi: intensive meadow next to FS (I+); b) grassland types; c) regions, black points: Lungau / Nockberge, red squares: Vienna Woods; Eigenvalue PC1 + PC2: 0.25342

8.11 Appendix tables and figures

FIGURES

TABLES