



# Transforming grasslands to achieve insect diversity restorative goals and human well-being (DivRESTORE)



## Final Report

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## **Abstract**

Agricultural intensification is a major cause of biodiversity loss in European grassland. Research on the function of traditionally used grassland and the establishment of new flower strips as biodiversity refugia includes many features and unresolved details. Given a large number of interferences between insect groups as well as of different land-use practices, the topic rapidly gains in ecological complexity, especially if sites are surrounded by landscapes of high habitat diversity. The overarching goal of the study was to investigate whether newly established flower strips will transform intensive meadows into biodiversity-rich meadows to conserve native grassland insect diversity. We analyzed how quickly newly established flower strips enhance insect diversity compared to intensive and extensive meadows. Further, we involved local stakeholders for assessing in a participatory way how the restoration activities were perceived and if they had an impact on aspects such as beauty or attractiveness. Heteropteran bug abundance was similar in all habitat types, but species richness was found to be significantly highest in flower strips. Syrphid abundance and species richness were significantly highest in flower strips. There was a significant difference between management types regarding the number of bumblebee individuals. Contrary, butterfly abundance and species richness were significantly higher in extensive meadows compared to flower strips. By looking at the species assemblage's pattern, heteropteran bug species assemblages in extensive meadows were significantly different from flower strips, intensive and control meadows. However, syrphid and butterfly species assemblages were similar in all habitat types. Further, heteropteran bug abundance and species richness increased with an increase in flower frequency and plant height. Similarly, syrphid abundance and species richness significantly increased with flower frequency but decreased with vegetation structure. Flower cover, vegetation structure, and vegetation height were positively correlated with the number of bumblebee individuals. Butterfly abundance increased with plant species, however, species richness decreased with plant height. The extensive meadow was valued as being the most natural one and the expected relation between estimated species diversity and aesthetic valuation. Restoring biodiversity in intensive grasslands represents a real conservation challenge. Flower strips seem most effective to enhance syrphid abundance in intensively managed agricultural landscapes. Overall, restoration of insect diversity is a relatively slow process, in which colonization by each insect group is not only limited by local vegetation conditions but is also affected by the presence, distance, and connection to source populations. Local people appreciate extensive grassland ecosystems, which received the highest ratings for their aesthetic values and had the highest effect on derived well-being. The results of the present study could be used to push for more active implementation of new flower-rich areas as well as for the conservation of extensively managed grassland that allows both, productive agricultural land use while maintaining and promoting insect habitats and species diversity.

## **Zusammenfassung**

Die landwirtschaftliche Intensivierung ist eine der Hauptursachen für den Biodiversitätsverlust im europäischen Grünland. Die Erforschung der Funktion von traditionell genutztem Grünland und der Etablierung neuer Blühstreifen als Biodiversitätsrefugien

beinhaltet viele ungeklärte Details. Angesichts einer Vielzahl von Wechselwirkungen zwischen Insektengruppen sowie unterschiedlicher Landnutzungspraktiken gewinnt das Thema schnell an ökologischer Komplexität, insbesondere wenn Standorte von Landschaften mit hoher Lebensraumvielfalt umgeben sind. Das übergeordnete Ziel der Studie war es zu untersuchen, ob neu angelegte Blühstreifen intensive Wiesen in biodiversitätsreiche Wiesen verwandeln werden, um die heimische Grasland-Insektenvielfalt zu erhalten. Wir haben analysiert, wie schnell neu angelegte Blühstreifen die Insektenvielfalt im Vergleich zu intensiven und extensiven Wiesen verbessern. Darüber hinaus haben wir lokale Interessengruppen einbezogen, um auf partizipative Weise zu bewerten, wie die Restaurierungsaktivitäten wahrgenommen wurden und ob sie Auswirkungen auf Aspekte wie Schönheit oder Attraktivität hatten. Die Abundanz der Wanzen war in allen Lebensraumtypen ähnlich, aber der Artenreichtum war in den Blühstreifen signifikant am höchsten. Abundanz und Artenreichtum von Schwebfliegen waren in Blühstreifen signifikant am höchsten. Es gab einen signifikanten Unterschied zwischen den Managementtypen bezüglich der Anzahl der Hummelindividuen. Im Gegensatz dazu waren Individuenzahlen und Artenreichtum an Tagfaltern in extensiven Wiesen signifikant höher als in Blühstreifen. Betrachtet man das Muster der Artengemeinschaft, so unterschieden sich die Artengemeinschaften von Wanzen auf extensiven Wiesen signifikant von Blühstreifen, Intensiv- und Kontrollwiesen. Die Artengemeinschaft von Schwebfliegen und Tagfaltern waren jedoch in allen Lebensraumtypen ähnlich. Darüber hinaus nahmen die Häufigkeit und der Artenreichtum von Wanzen mit einer Zunahme der Blütenhäufigkeit und der Pflanzenhöhe zu. In ähnlicher Weise nahmen die Häufigkeit und der Artenreichtum von Schwebfliegen mit der Blütenfrequenz signifikant zu, nahmen jedoch mit der Vegetationsstruktur ab. Hummelindividuen waren positiv mit der Blütenbedeckung, Vegetationsstruktur und Vegetationshöhe korreliert. Die Tagfalterhäufigkeit nahm mit der Anzahl an Pflanzenarten zu, jedoch nahm der Artenreichtum mit der Pflanzenhöhe ab. Die extensive Wiese wurde als die natürlichste eingeschätzt, und ihre Beziehung mit geschätzter Artenvielfalt und ästhetischer Wertschätzung am höchsten bewertet. Die Wiederherstellung der Biodiversität in Intensivgrünland ist eine echte Herausforderung für den Naturschutz. Blühstreifen scheinen in intensiv bewirtschafteten Agrarlandschaften am effektivsten zu sein, um die Zahl der Schwebfliegen zu erhöhen. Insgesamt ist die Wiederherstellung der Insektenvielfalt ein relativ langsamer Prozess, bei dem die Besiedlung durch jede Insektengruppe nicht nur durch lokale Vegetationsbedingungen begrenzt wird, sondern auch durch die Anwesenheit, Entfernung und Verbindung zu Quellpopulationen beeinflusst wird. Die Menschen vor Ort schätzen extensive Grünlandökosysteme, die die höchsten Bewertungen für ihre ästhetischen Werte erhielten und die höchste Wirkung auf das abgeleitete Wohlbefinden hatten. Die Ergebnisse der vorliegenden Studie könnten genutzt werden, um eine aktivere Umsetzung neuer blütenreicher Flächen sowie die Erhaltung extensiv bewirtschafteter Grünlandflächen voranzutreiben, die sowohl eine produktive landwirtschaftliche Landnutzung ermöglichen als auch Insektenlebensräume und Artenvielfalt erhalten und fördern.

## 1. Introduction

Extensive meadows, traditionally mown once or twice a year and not fertilized (Tiefenbach et al. 2014), are important habitats not just for the diversity of vascular plants but also for invertebrate, fungal and microbial diversity (Binder et al. 2018; Kun et al. 2021). For humans, they have considerable cultural, economic and aesthetic importance (Arnberger et al. 2018, Hussain et al. 2019) due to high flower and plant species richness (Hussain et al. 2018). Extensive meadows not only enhance the aesthetic beauty of the landscape but also contribute to its unique character (Westphal et al. 2003). Intensive meadows are usually the dominant type of grasslands in many European countries but are generally of poor ecological value (Plantureux et al. 2005). Species diversity has been proved to be highly linked with infrequent cutting. For example, the total number of vascular plants and bryophytes of Austrian grasslands decreased from 11.3 to 5.6 per m<sup>2</sup> when the number of cuttings per year increased from two to more than three times. When only one cut was performed, species richness was 7.1 per m<sup>2</sup> (Zechmeister et al. 2003).

The term intensive meadow is used to indicate high stocking rate, high fertilizer input and several cuts per year (Buchgraber et al. 2011). Intensive meadow management has resulted in the loss of biodiversity and the specialist flora and fauna associated with the semi-natural grasslands of low-intensity farming throughout Europe (Plantureux et al. 2005). Intensive meadows appear to be incompatible with maintaining a high level of biodiversity, thus leading to the following key question: How to optimize meadows to restore insect diversity whose loss is caused by intensive meadow management?

In response to the reinstatement of extensive management and cessation of fertilizer inputs, changes in species richness have generally been positive, but relatively modest (Walker et al. 2004). The restoration of upland hay-meadows may take over 20 years using extensive management alone (assuming a linear increase in species richness) (Smith et al. 2002). Alternatively, restoration of grasslands depends on people's willingness to manage them because socio-economic factors are central, but often neglected, in grassland restoration (Waldén & Lindborg, 2018).

The overarching goal of DivRESTORE was to transform intensively used meadows into biodiversity rich meadows, to conserve native insect diversity and enhance landscape beauty by establishing flower strips. Local stakeholders will be involved for assessing the effect of the restoration on the local peoples' perception of concepts such as attractiveness and beauty of the landscape. DivRESTORE responds to the urgent need to rebalance grassland diversity in the context of major global challenges of insect diversity loss (Hallmann et al. 2017).

Human perceptions and preferences related to landscape are key for the sustainable development, tourism and also recreational values of Austrian biosphere reserves. Moreover, biosphere reserves are designed to deal with issues like how to reconcile biodiversity and

conservation of natural resources while allowing their sustainable use (Ishwaran et al. 2008). Newly established flower strips near to intensive meadows aim to restore high biodiversity (Potts et al. 2009) thereby enhancing landscape restoration. Providing a broad range of flowering plants could be an essential component of rebuilding and preserving a stable beneficial insect community in grasslands (Ouvrard et al. 2018). High availability of adult and larval food resources near to intensive meadows could act as refuge for many beneficial insects after intensive mowing (Wade et al. 2007). In this project, we will study the effectiveness of flower strips in conserving flower-visiting pollinator communities. Pollination, an essential ecosystem service, is an important aspect in grassland management systems. High density of pollinators effectively increases grassland yields. In Austria, insect pollination benefits for agriculture were estimated at about 298 million € in 2008 (Schwaiger et al. 2015). We complement these investigations by examining the response of primary and secondary consumers such as grasshoppers and heteropteran bugs (true bugs).

## 1.2. Study objectives and hypotheses

The goal of DivRESTORE was to investigate whether newly established flower strips will transform intensive meadows into biodiversity rich meadows to conserve native grassland insect diversity. We analyzed how quickly newly established flower strips enhance insect diversity compared to intensive and extensive meadows. Further, we involved local stakeholders for assessing in a participatory way how the restoration activities were perceived and if they had an impact on aspects such as beauty or attractiveness (Figure 1).

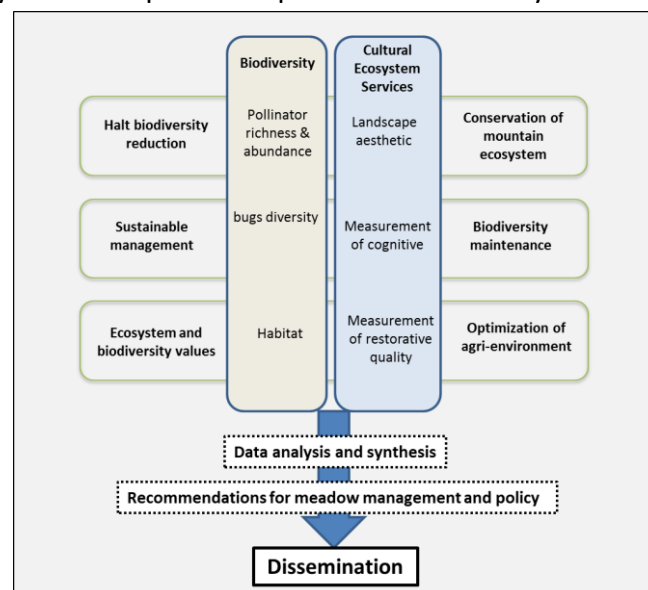


Figure 1. Conceptual model showing different biodiversity attributes to be measured and effects of newly established flower strips on the perception of local people on concepts such as beauty or attractiveness and well-being.

The present project was aimed to answer the following questions:

1. Do newly established flower strips increase insect species richness and abundance in the adjoining intensive meadows?

2. Do newly established flower strips promote insect diversity more than extensive meadows?
3. How do farmers and local stakeholders perceive restoration outcomes?
4. Are newly established flower strips perceived by local people as enhancing landscape aesthetic beauty, ecosystem services and well-being?

We hypothesized:

- 1) Higher insect species richness and abundance in intensive meadows adjoining newly established flower strips compared to intensive meadows without flower strips, thereby essentially counteracting the overall ongoing insect decline.
- 2) Newly established flower strips to contain similar insect diversity like extensive meadows. However, we expect to some extent other insect species in the flower strips compared to extensive meadows thus increasing regional species pool.
- 3) That newly established flower strips will be perceived by local people as opportunity to enhance insect diversity, landscape beauty, ecosystem services and well-being.

Although there are many studies on establishing flower strips near intensive meadows (Plantureux et al. 2005; Potts et al. 2009; Haaland et al. 2011; Ouvrard et al. 2018, Hussain et al. 2021, Maas et al. 2021, Scharnhorst et al. 2021), our approach simultaneously covered not only intensive meadows but also compared the potential of flower strips with extensive meadows in maintaining insect diversity. Moreover, establishing flower strips adjoining intensive meadows has never been done so far in Austrian biosphere reserves, thus we covered a regional novel scientific approach.

## **2. Methods**

### **2.1 study sites**

The study was conducted at the biosphere reserves Salzburger Lungau/Kärntner Nockberge and Wienerwald. The study sites were inspected on site after permission to access the meadows was obtained by the landowners and biosphere managers. The aims and objectives of DivRESTORE were sufficiently communicated to the landowners. Those sites which fulfilled the points of the criteria list were finally selected. The selection of the sites in the biosphere reserves was performed by team members of the Institute of Zoology (BOKU). Within each biosphere reserve, two meadow types of different level of land-use intensity (intensive and extensive) was selected involving local stakeholders. Flower strips adjoining intensive meadows were established. We selected intensive meadows without flower strips (as control), intensive meadows with flower strips (intensive), and extensive meadows (extensive) without flower strips with ten replicates each. In total, 15 meadows and five flower strips that served as study sites were used in each biosphere reserve.

## 2.2 Sampling site preparation and data collection

### 2.2.1. Flower-strip establishment and development

Establishment of flower strips was planned together with experts from biosphere reserves. Moreover, we collaborated with the expert Bernhard Krautzer from the Federal Agriculture Research and Education Centre (AREC) in Raumberg Gumpenstein, Austria ([www.raumberg-gumpenstein.at](http://www.raumberg-gumpenstein.at)), who helped to minimize risks with flower strips establishment. We prioritized precisely plant species for flower strips that support a broad range of flower visitors. In general, it is observed that easily accessible flowers like those of the families Apiaceae, Asteraceae and Malvaceae were preferred by syrphids and bees equally (Warzecha et al. 2018). Surprisingly, this was also the case for bumblebees, although Fabaceae and red clover have been identified as important pollen and nectar sources (Goulson et al. 2005). This was true for both short-tongued (adapted to open flowers) and long-tongued pollinator species (Warzecha et al. 2018). The seed bed was prepared according to the region and meadow location, and machine sowing was performed in Wienerwald and hand sowing was performed in Salzburger Lungau/Kärntner Nockberge (Figure 2).



Figure 2. A seed bed was prepared and hand sowing was performed in Salzburger Lungau/Kärntner Nockberge. After placing a specified number of seeds on the firm bases, a loose surface layer of soil was put on top provided by gentle hand spraying.

Seeding date of flower strips was September 2019. Late-summer sowing was generally preferred over spring sowing which ensured a satisfactory plant establishment. Moreover, in spring 2020, the time of first insect sampling, flowers strips were already covered by plants (Figure 3).





Figure 3. Developmental stages of one flower strip in the biosphere reserve Wienerwald.

### **2.2.2. Syrphid sampling**

We surveyed syrphid species richness and abundance using an observation plot method (Hussain et al. 2018) in June, July and August 2020 and 2021. For the observation plot method, five 2 m<sup>2</sup> observation plots were established in a straight line per study site with a distance of 5 meters between them. Observations were carried out over a period of 5 minutes for each plot. During the observations, we recorded every individual syrphid or, if it was not possible to identify them on site, collected them using a sweep net. The frequency with which a sweep net was used in the observation plots was depending on the number of unknown syrphids per plot. Sampling was performed between 10 a.m. and 5 p.m. when syrphids were most active, and identification of syrphids was carried out by an expert from the Institute of Zoology (BOKU) who has experience in identifying syrphids. Specimens that could not be identified on site were treated using ethyl acetate and stored in plastic vials. Identification was carried out in the laboratory using a stereomicroscope.

### **2.2.3. Heteropteran bug sampling**

A sweep net method was applied along defined transects for heteropteran bugs (true bugs), with sampling in June, July and August 2020 and 2021. We conducted a total of 90 sweeps per study site, separated in 3 x 30 sweeps. In the laboratory, identification of species was performed with reference to Wagner (1967) and Strauss (2010).

### **2.2.4. Bumblebee and butterfly sampling**

Species richness and abundance of bumblebees were surveyed in June, July and August 2020 and 2021. Bumblebees were recorded during standardized 10-minute transect walks within a total area of 150 m<sup>2</sup> (3 x 50 m) per meadow type. We walked at a slow pace through each meadow, counting and identifying each individual bumblebee that occurred in the area. For identification, individual bumblebee individuals were captured with a sweep net, transferred into plastic tubes, and identified using a hand lens and the field identification key proposed by Gokcezade et al. (2015).

For plant-bumblebee networks assessment within the different meadow types, the interaction between each individual bumblebee and its host plant was recorded. This was additionally done during the 10-minute transect walks. Each bumblebee visiting a flower was recorded, and the visited plant identified to species level.

#### **2.2.5. Measurement of human perception to flower strips, intensive and extensive meadows**

The survey of local people's perception and valuation of the established flower strips and different types of meadows was conducted in the municipalities Ebene-Reichenau, Tamsweg and Mauterndorf in the biosphere reserve Salzburger Lungau/Kärntner Nockberge. The sample strategy, known as convenience sample (Newing, 2011), included all local people who were willing to take the time to fill in the questionnaire. Altogether 65 questionnaires were answered and used for analysis. The sample consisted of 33 male and 32 female participants with an age range from 18 to 77 years old. All participants were locals from the biosphere reserve Salzburger Lungau/Kärntner Nockberge and represented different field of employments.

The originally planned transect walks through different types of meadows were replaced through a photo-based survey due to the unpredictable Covid-19 regulations. Prototypical photos that represented different types of studied meadows and flower strips were taken (Figure 4).

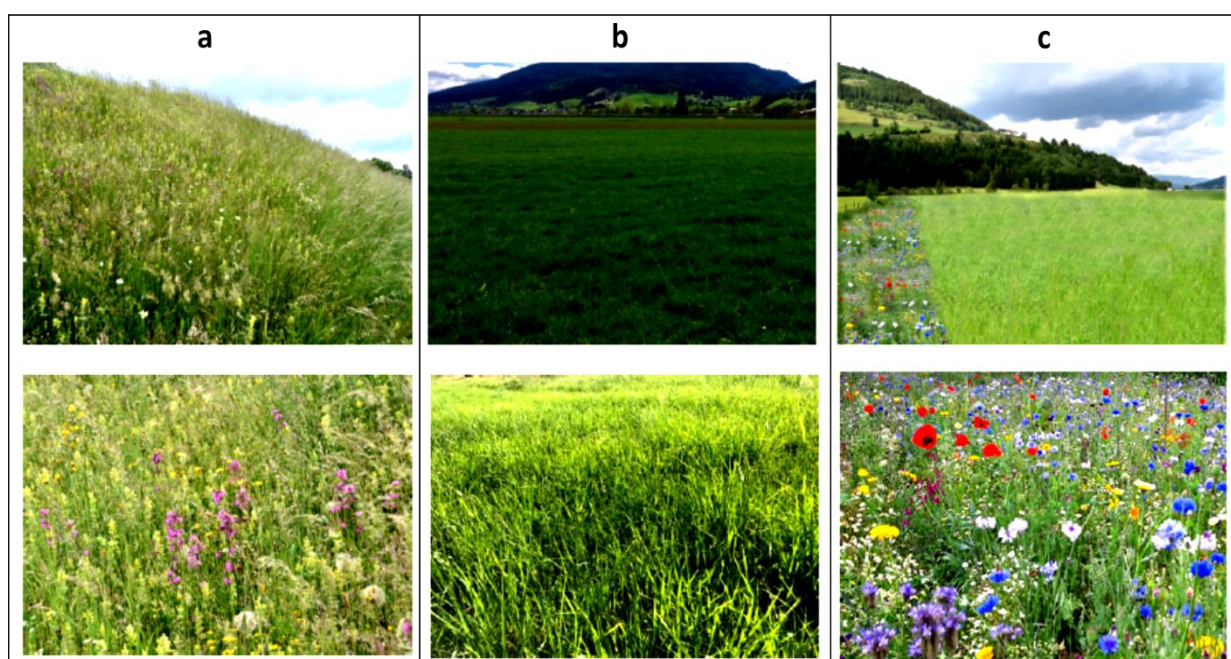



Figure 4. Photos used in the questionnaire to depict the different types of study sites: a) extensive meadow, b) intensive meadow. c) flower strip next to an intensive meadow.

The questionnaire was composed of multiple questions asking the participants to write down three terms that come to their mind when they look at the photos of the study sites. The perceived species diversity was assessed by asking the participants to estimate the number of plant and animal species living in the study sites. Possible responses were grouped on a six-point scale. Further, attitudinal Likert scale questions were used to assess the values people assign to the different types of meadows and the flower strip next to the intensive meadow. A species identification exercise was performed to assess the participants' ecological knowledges. The species were selected based on information from FiBL, a research institute for ecological agriculture (van de Poel & Zehm, 2014; FiBL, 2018). Afterward, participants answers were grouped to represent 'low', 'rather low', 'average low', 'average', 'average high', 'rather high', or 'high' level of ecological knowledge (Reyes-García et al. 2014). This variable was then correlated for assessing instrumental and aesthetic values for the different types of meadows (Cebrián-Piqueras et al. 2020).

Wahrnehmung von Wiesen und Blühstreifen

Wiese 1)



1) Welche drei Begriffe würden Sie zur Beschreibung dieser Fläche nennen?  
 1) ..... 2) ..... 3) .....

2) Wie hoch schätzen Sie die Anzahl der unterschiedlichen Pflanzenarten auf dieser Fläche ein? Kreuzen Sie an.  
 O 0-5    O 6-10    O 11-20    O 21-30    O 31-40    O 41 und mehr

3) Wie hoch schätzen Sie die Anzahl an unterschiedlichen Tierarten die auf dieser Fläche beheimatet sind ein? Kreuzen Sie an.  
 O 0-5    O 6-10    O 11-20    O 21-30    O 31-40    O 41 und mehr

4) Wie sehr treffen Ihrer Meinung nach folgende Aussagen auf diese Fläche zu?  
 Lesen Sie jede Aussage genau durch und kreuzen Sie eine Antwortkategorie an.  
 (1) trifft voll und ganz zu, (2) trifft eher zu, (3) trifft eher nicht zu, (4) trifft ganz und gar nicht zu

		VOLL UND GANZ (1)	EHER NICHT (2)	EHER NICHT (3)	GANZ UND GAR NICHT (4)
1	In dieser Fläche finden nur wenige Tierarten einen guten Lebensraum.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2	Diese Fläche bietet einen guten Lebensraum für viele Insekten.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3	Diese Fläche ist wichtig für die Bestäubung von Nutzpflanzen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4	Das Heu dieser Fläche ist eine gute Basis für eine große Milchmenge.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5	Mit dem Heu dieser Fläche kann man niemals ausreichende Mengen an Milch produzieren.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6	Diese Fläche sieht schön aus.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7	Diese Fläche sieht ungepflegt aus.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8	Diese Fläche sieht natürlich aus.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9	Auf dieser Fläche wächst nur Unkraut.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10	Die Pflanzen auf dieser Fläche verursachen Heuschnupfen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11	In der Nähe dieser Fläche habe ich Angst vor Bienenstichen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12	Diese Fläche zieht ungewollte Schädlinge an.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### 2.2.6. Plant parameters

To assess the influence of several plant parameters on biodiversity attributes, we investigated plant height and flower frequency in five randomly chosen 1x1 m study plots per habitat type. A frame of 1x1 m size was placed on the ground (Karrer, 2015) to estimate flower frequency. Plant height was measured using a measuring tape. For each study plot and treatment, a representative 4 m<sup>2</sup> releve (2 x 2 m) was randomly chosen in the middle of each meadow type. Abundance of plant species was estimated following the Braun-Blanquet scale (Braun-Blanquet, 1964), modified according to Dierßen (1990). Further, vegetation structure was measured using a modified point quadrat method. This method is considered a good criterion to measure vegetation changes and widely used to measure plant cover (e.g. Frank & Künzle, 2006; Zurbrügg & Frank, 2006). The iron rod was inserted vertically into the soil and every plant that was in contact with the rod was counted, beginning at the top.



### 2.2.7. Statistical analyses

To test whether habitat types differed in abundance and species richness of heteropteran bugs, syrphids and butterflies, we used generalized linear mixed models (GLMMs) from the R package lme4 (Bates et al. 2015). In our dataset, response variables (abundance and species richness) were count data so we included Poisson family in GLMMs models. We nested all sampling plots (N=200) in transects (N=40) as a random effect in all models to account multiple samples within each sampling site. Where models showed overdispersion, i.e. when residual has larger deviance than degree of freedom, we used dispersiontest function from the AER library (Kleiber and Zeileis, 2008) and the dispersion\_glmmer function of the blmecc library (Korner-Nievergelt et al. 2015) on all models. If a model showed overdispersion, an additional observation-level random effect was used to account for overdispersion (Harrison, 2014).

To test how abundance and species richness changed over time and region, we tested the interaction of habitat types with year (2020, 2021 as numeric) and region as fixed effect and sample plots nested in transects as random effects. Flower strip was used as a reference level, and we tested whether intensive, control and extensive meadows sampling plots for the year and region had a different slope compared to flower strips.

We used principal component analysis (PCA) based on a resemblance matrix of Bray-Curtis similarity to assess the difference in species assemblages between habitat types (Leyer & Wesche, 2007). To decrease the common zero problem of assemblage data, the species densities were Hellinger-transformed (Sławska et al. 2017). We pooled all sampling data for every plot and year. A PERMANOVA (Bray-Curtis dissimilarities, 999 permutations) was calculated with the function adonis in the R package vegan (as performed in Hussain et al. 2021). Data were tested for equal multivariate dispersion using the function betadisper. Furthermore, multilevel pairwise comparison using adonis was applied (pairwise.adonis) to test for differences in species assemblages between habitat types.

In order to assess the differences between habitat types regarding species richness and abundance of bumblebees, GLMMs were calculated, with habitat type (flower strip, intensive, intensive control, extensive) as a fixed factor and sampling month as a random factor. Furthermore, GLMs with a poisson error distribution were used to analyze the effects of plant parameters (flower cover, plant species richness, vegetation height and vegetation structure) on the species richness and abundance of bumblebees. In the case of overdispersion, GLMs with a quasi-poisson error distribution were computed. Variance inflation factors (VIFs) were calculated to evaluate possible multicollinearity among plant parameters.

In order to assess possible differences in species assemblages of bumblebees between the different habitat types, a Principal Coordinate Analysis (PCO) was performed. Further, to test for significant differences in species assemblages, a permutational ANOVA (PERMANOVA) was performed. For the analysis and visualization of plant-bumblebee networks in the studied

meadows, we will use the R-package bipartite. However, the search for an appropriate analysis for bumblebee-plant networks is currently in progress. All statistical analyses were performed with the R program version 3.5.1 (R Core Team, 2018).

The terms used to describe the different types of habitats were coded, grouped and categorized (Mayring, 2000). The defined categories 'perceptions', 'assigned values', 'assigned context', 'derived well-being' and 'other terms' were used for all habitats. The variables 'instrumental value', aesthetic value and 'derived well-being', were defined as the mean value of the ratings of the corresponding attitudinal statements. They can range from 1 to 4, according to the level of agreement the participants expressed with the statements. For inferential statistical analysis, the data were checked for normal distribution. The Spearman's rank correlation was used to check the correlation of different combinations of ordinal variables (Döring & Bortz, 2016). The Mann-Whitney-U-Test was used to compare the ratings of two independent sample groups. This was applied to test whether men and women rated the meadows differently (Döring & Bortz, 2016). In order to validate the results, SPSS 27 were used for data analysis.

### 3. Results

In total, we recorded 5863 heteropteran bugs belonging to 125 species. The most abundant species were *Leptopterna dolabrata* and *Megaloceroea recticornis*, representing 37% of all heteropteran bugs. We collected 1175 syrphids belonging to 77 species. The most abundant syrphid species were *Sphaerophoria scripta* and *Melanostoma mellinum*, representing 55% of the total syrphid abundance. In total, 60 butterfly bee species and 1411 individuals were found. The most abundant butterflies were *Maniola jurtina* and *Melanargia galathea*, representing 48% of the total butterfly abundance. We found 10 bumblebee species with 400 individuals in both years. The most abundant species in both years were *Bombus terrestris* and *Bombus lapidarius*, representing 49 % of the total bumblebee abundance.

Heteropteran bug abundance was similar in all habitat types, but species richness was found to be significantly highest in flower strips ( $p < 0.05$ , Figure 5). Syrphid abundance and species richness were significantly highest in flower strips ( $p < 0.05$ , Figure 5). Butterfly abundance and species richness were significantly higher in extensive meadows compared to flower strips ( $p < 0.05$ , Figure 5). By looking at the species assemblage's pattern, heteropteran bug species assemblages in extensive meadows were significantly different from flower strips ( $p = 0.036$ , Table 1), intensive ( $p = 0.006$ , Table 1) and control meadows ( $p = 0.006$ , Table 1). However, flower strips and extensive meadows had similar heteropteran bug species assemblages. Syrphid and butterfly species assemblages were similar in all habitat types. Further, heteropteran bug abundance and species richness increased with increase in flower frequency ( $p < 0.05$ , Figure 6) and plant height ( $p < 0.05$ , Figure 6). Similarly, syrphid abundance and species richness significantly increased with flower frequency but decreased with vegetation structure (Figure 7). Butterfly abundance increased with plant species, however, species richness decreased with plant height (Figure 8).

We did not find any change in heteropteran bug abundance in the two years of sampling (2020+2021). However, species richness significantly decreased in flower strips in 2021. Interestingly, syrphid abundance significantly increased in intensive and extensive meadows in 2021. Concerning sampling region, the regions Salzburger Lungau and Wienerwald had significantly higher heteropteran bug and butterfly abundance and species richness compared to the Kärntner Nockberge region. However, the Salzburger Lungau and Kärntner Nockberge region had significantly higher syrphid abundance and species richness than the biosphere reserve Wienerwald.

There was a significant difference between management types regarding number of bumblebee individuals ( $p=0.007$ , Figure 9a). Additionally, there was a significant difference in species richness between the habitat types ( $p=0.0246$ , Figure 9b). Flower cover, vegetation structure and vegetation height were positively correlated with the number of bumblebee individuals ( $p$ -values  $< 0.0001$ ; Figure 10 a, b and c). The number of bumblebee species was positively correlated with flower cover and vegetation height ( $p$ -values  $< 0.0001$ ; Figure 11 a and b), however, only marginally correlated with vegetation structure ( $p=0.059$ ). Measured plant species richness did not correlate with either number of species or individuals of bumblebees ( $p=0.572$  and  $p=0.929$ , respectively). In addition, PERMANOVA-analysis revealed no significant difference in species assemblages between habitat types ( $p=0.301$ ).

Table 1. PERMANOVA (Pairwise-adonis) between measured biodiversity attributes in studied habitat types ( $p$ : significant  $p$ -values ( $< 0.05$ ) are shown in bold).

<b>Heteropteran bugs</b>	<b>Habitat</b>	<b>F.Model</b>	<b>R2</b>	<b>p.value</b>	<b>p.adjusted</b>
	Control vs Extensive	4.064905	0.184225	0.001	<b>0.006</b>
	Control vs Flower strip	2.337634	0.114941	0.018	0.108
	Control vs Intensive	0.886264	0.046926	0.492	1
	Extensive vs flower strips	2.092252	0.104132	0.006	<b>0.036</b>
	Extensive vs Intensive	3.471642	0.161685	0.001	<b>0.006</b>
	Flower strip vs Intensive	1.756699	0.088917	0.059	0.354
<b>Syrphids</b>	Control vs Extensive	0.5854755	0.031502	0.907	1
	Control vs Flower strip	1.3702709	0.070741	0.141	0.846
	Control vs Intensive	0.5818664	0.031314	0.848	1
	Extensive vs flower strips	1.0121215	0.053236	0.412	1
	Extensive vs Intensive	0.8778062	0.046499	0.593	1
	Flower strip vs Intensive	1.1502564	0.060065	0.286	1
<b>Butterflies</b>	Control vs Extensive	1.677963	0.085271	0.114	0.684
	Control vs Flower strip	0.2545924	0.013947	0.975	1
	Control vs Intensive	0.6504002	0.034873	0.764	1
	Extensive vs flower strips	1.2569397	0.065272	0.242	1
	Extensive vs Intensive	1.312342	0.067954	0.201	1
	Flower strip vs Intensive	0.5965066	0.032076	0.803	1

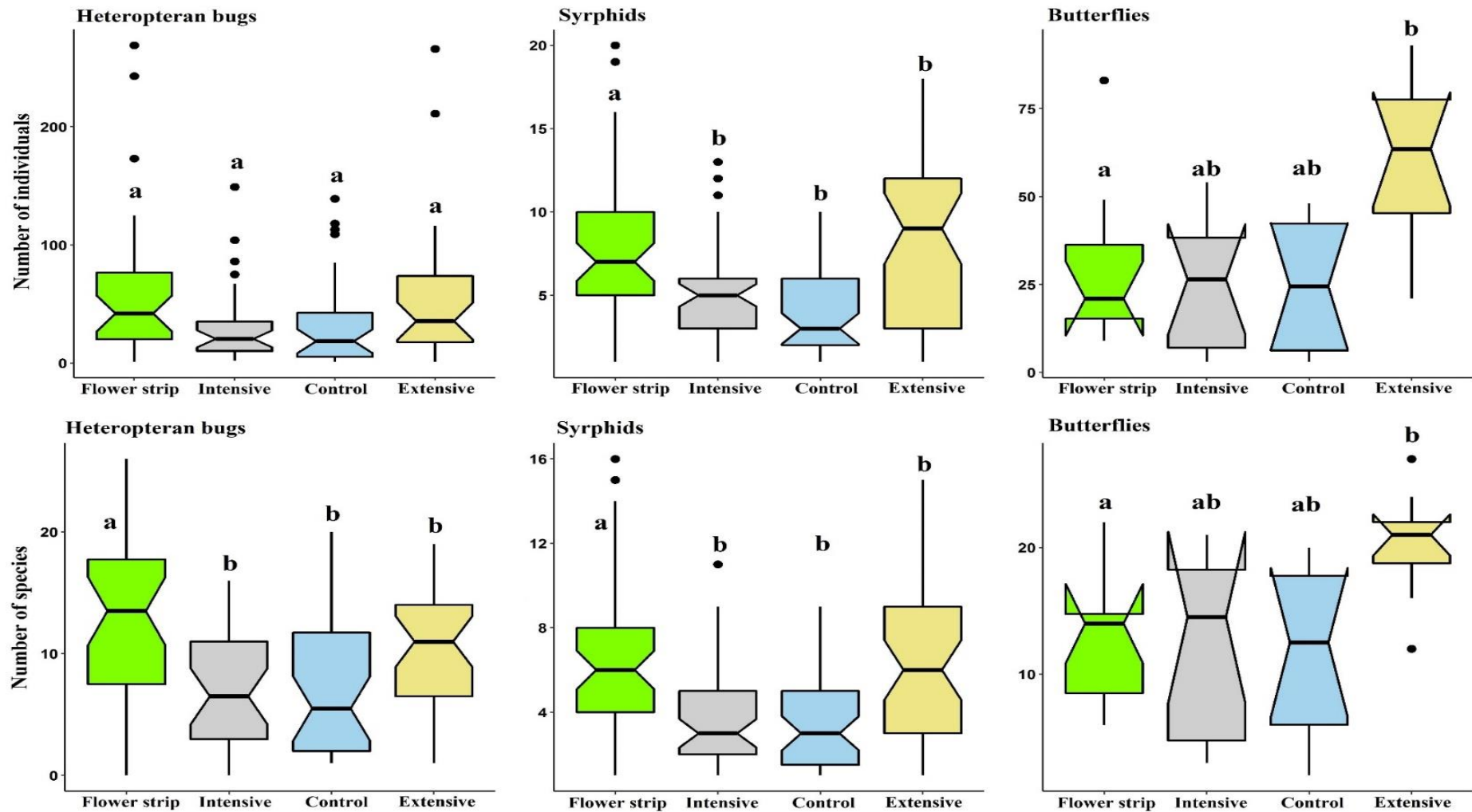


Figure 5. Effects of habitat type on the abundance and species richness of heteropteran bugs, syrphids and butterflies in the studied habitat types. Habitat types sharing the same letter are not significantly different from each other ( $p > 0.05$ ).

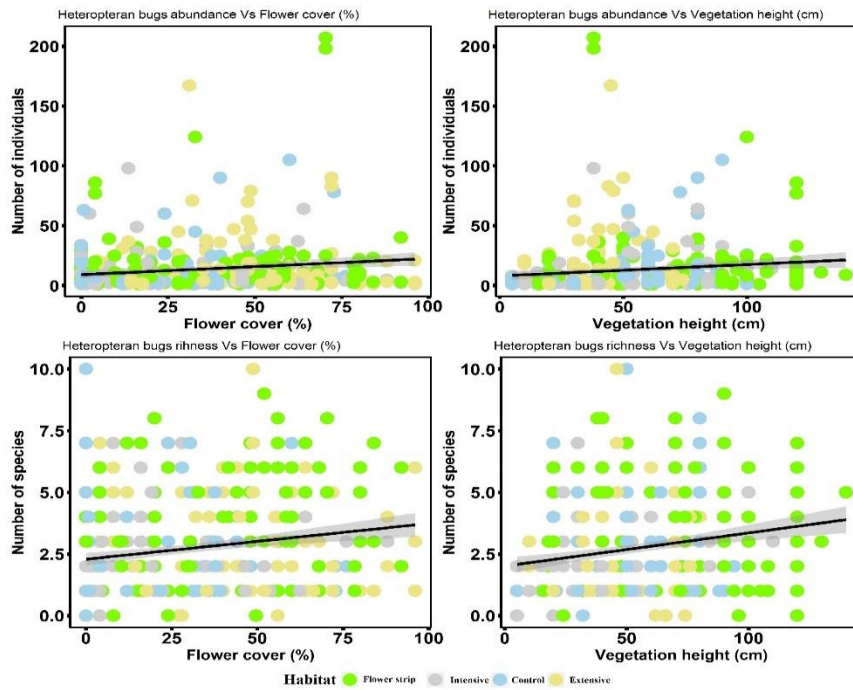


Figure 6. Linear regressions showing positive significant relationships ( $p < 0.05$ ) of heteropteran bug abundance and species richness with flower cover (%) and vegetation height for studied habitat types.

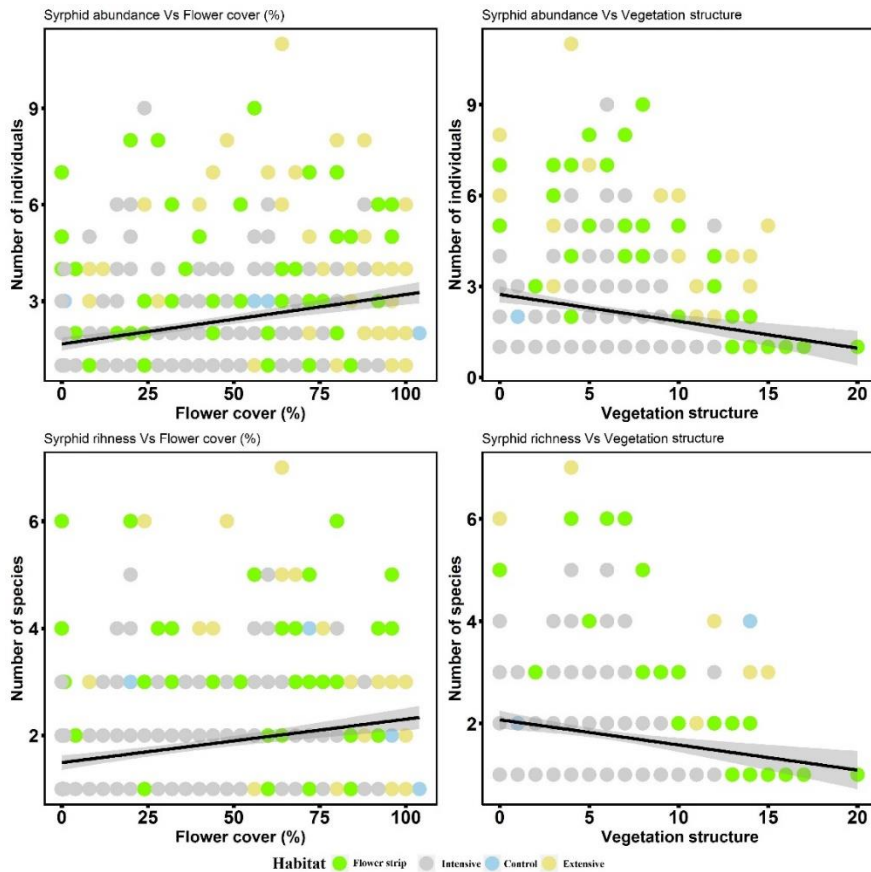


Figure 7. Linear regressions showing positive significant relationships ( $p < 0.05$ ) of syrphid abundance and species richness with flower cover (%) and negative relationships with vegetation structure for studied habitat types.



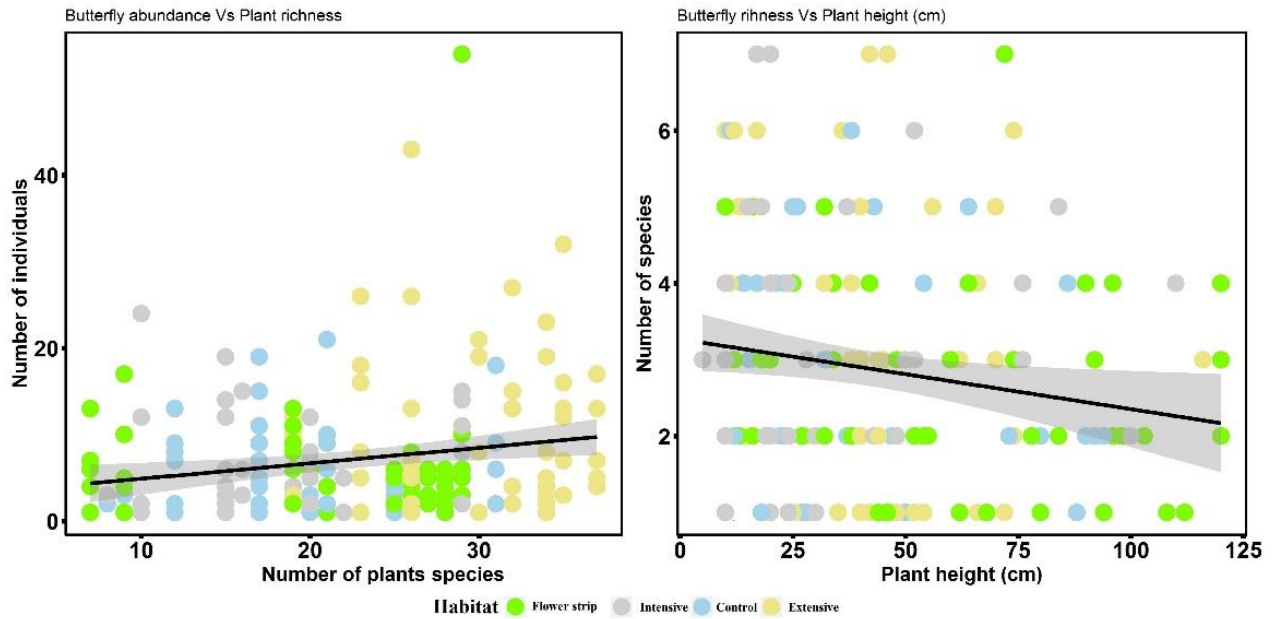


Figure 8. Linear regression showing a positive significant relationship ( $p < 0.05$ ) between butterfly abundance and number of plant species, and a negative relationship between species richness and plant height for studied habitat types.

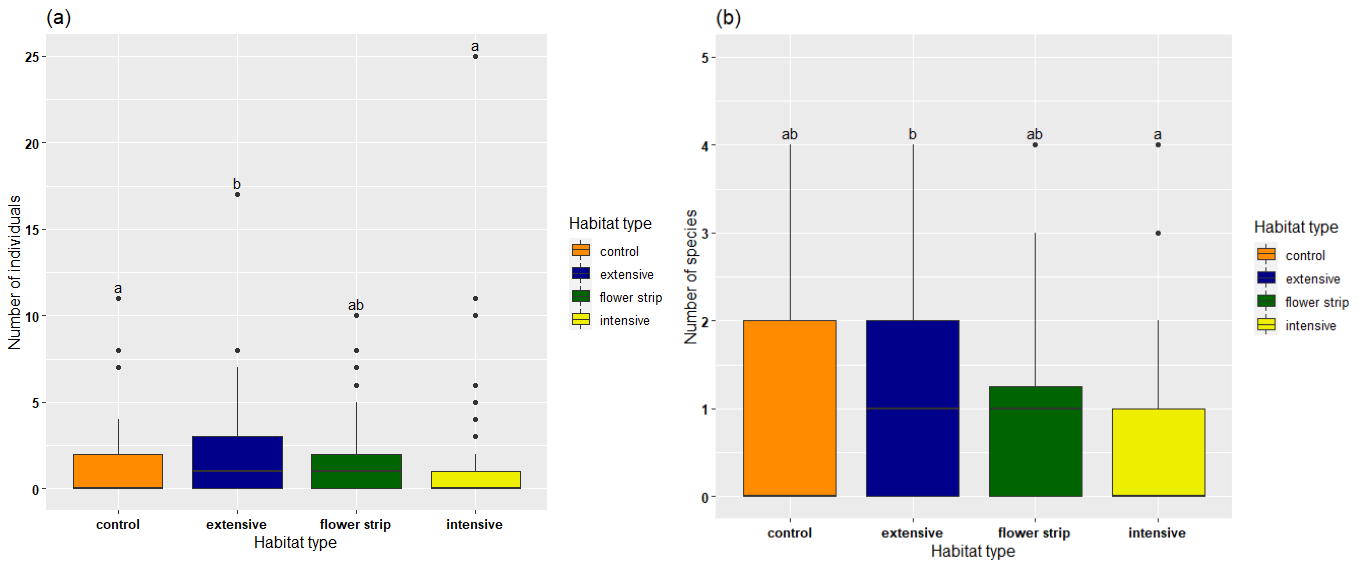


Figure 9: Effects of habitat type on number of (a) bumblebee individuals and (b) bumblebee species.

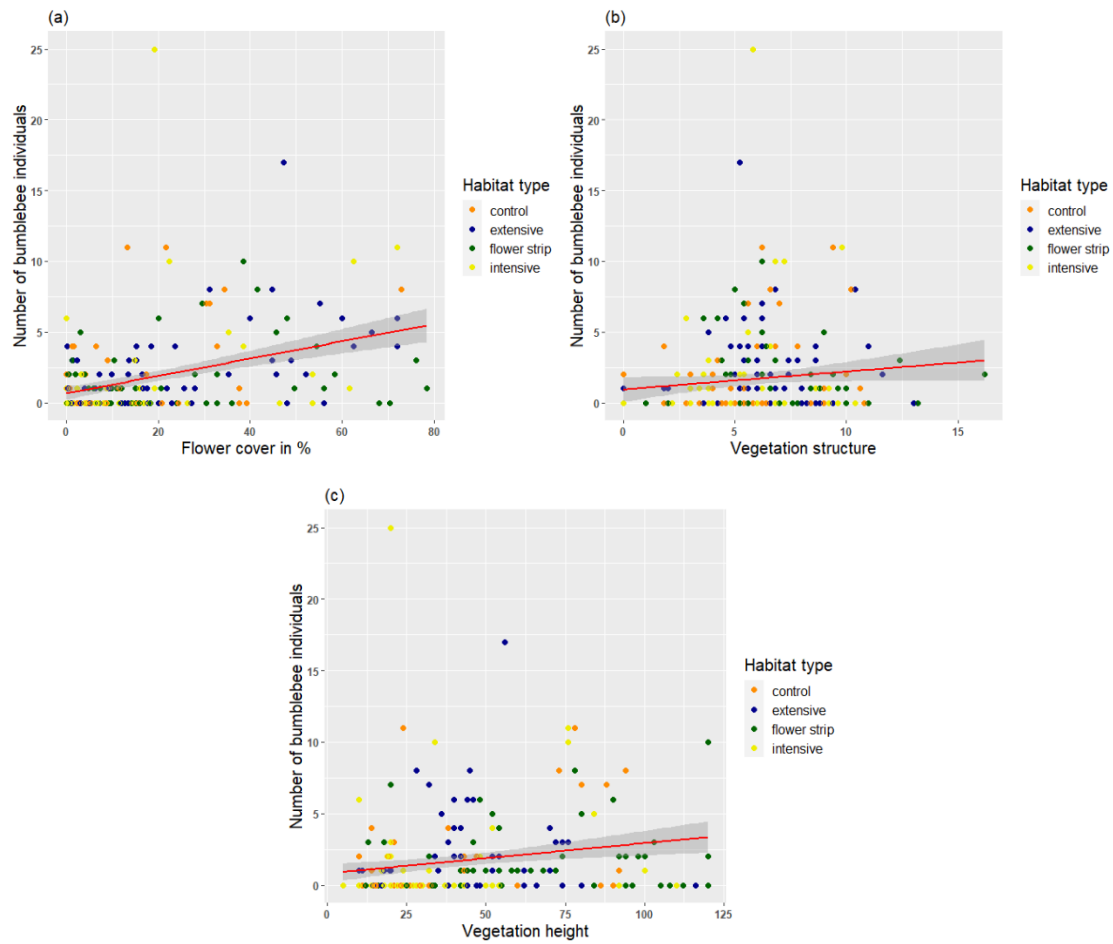


Figure 10. Positive relationships between number of bumblebee individuals and (a) flower cover, (b) vegetation structure and (c) vegetation height.

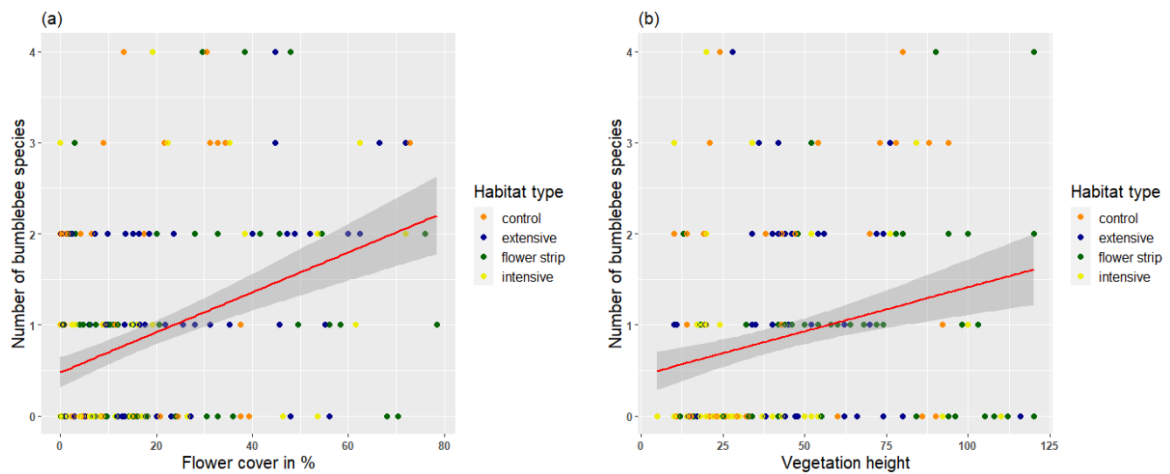


Figure 11. Positive relationships between number of bumblebee species and (a) flower cover and (b) vegetation height.

For the whole presentation of the study results the different types of meadows that were referred to in the socio-economic survey and illustrated with the photos in the questionnaire will be referred to in the following way: the extensive meadow as Meadow 1, the intensive meadow as Meadow 2 and the flower strip next to the intensive meadow as Meadow 3.

The estimated number of species was clearly the lowest for Meadow 2 where 16.9% of the participants took the option of 0-5 and 35.4% the option of 6-10 species inhabiting the depicted meadow. The ratings for Meadow 1 and Meadow 3 were quite similar (Figure 12).

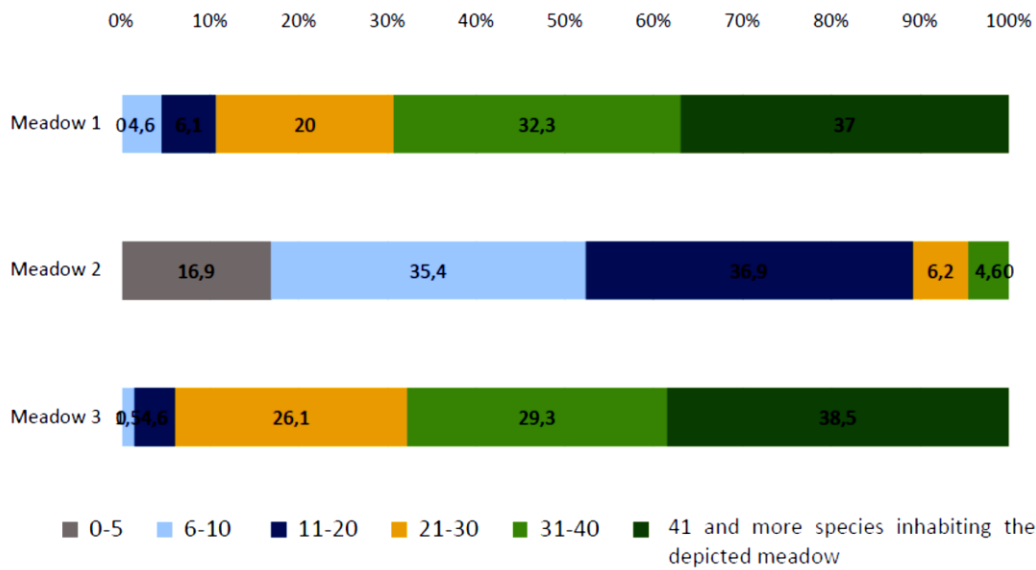


Figure 12. Percentage of chosen options by the participants for the estimated number of species.

The participants assigned high, similar levels of instrumental value to Meadow 1 and Meadow 3. (Figure 13). 97% and 95% of the participants ‘totally’ or ‘partially agreed’ with the statements, referring to Meadow 1 and Meadow 3. For Meadow 2, 80% of the participants ‘partially disagreed’ with the provision of instrumental values (Figure 13).

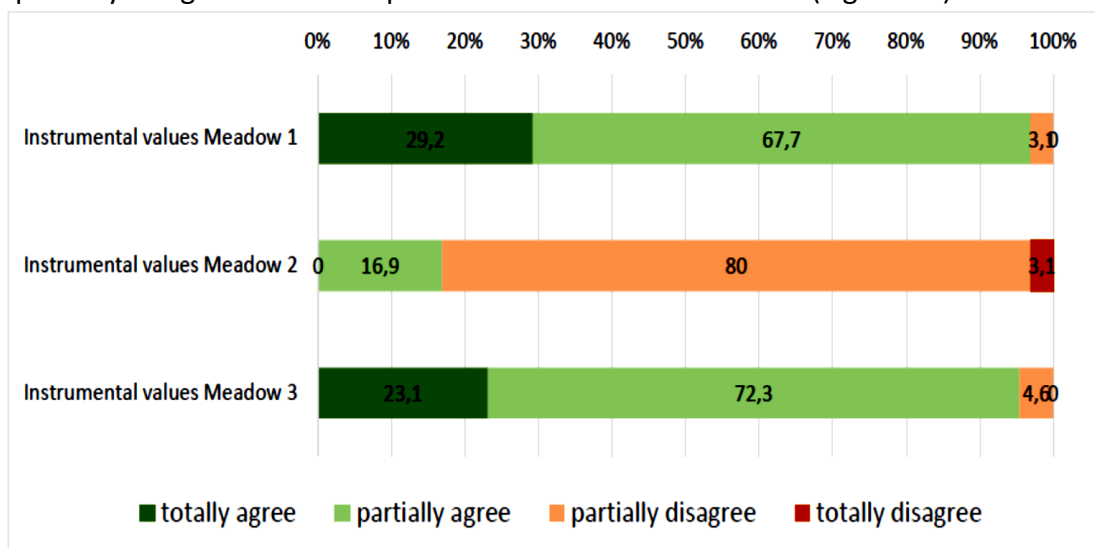


Figure 13. Percentages of selected degree of agreement to the attitudinal statements referring to the instrumental value for Meadow 1, 2 and 3 (65 participants = 100%).

The highest aesthetic values were assigned to Meadow 1. 64.6% of the participants ‘totally agreed’ to the statements, another 32.3% ‘partially agreed’ (Figure 14). For Meadow 2, ratings of the participants were more divided, around 40% ‘partially agreed’ and around 60% ‘partially disagreed’ with the given statements (Figure 14).

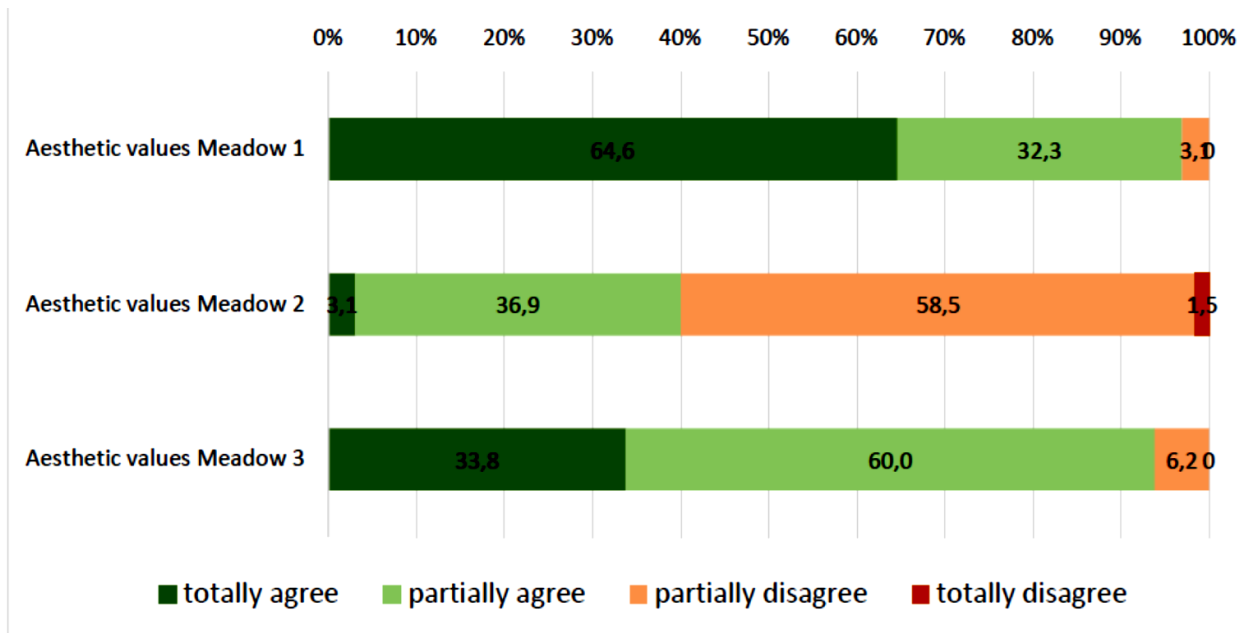


Figure 14. Percentages of selected degree of agreement to the attitudinal statements referring to the aesthetic value for Meadow 1, 2 and 3 (65 participants = 100%).

A detailed view on the rating of the assigned value of 'naturalness' showed that Meadow 1 received a very high rating because of its naturalness. 76.9% of the participants 'totally agreed' to the corresponding statement and another 16.9% 'partially agreed' (Figure 15). Meadow 2 was rated rather unnatural; 44.6% of the participants 'partially disagreed' and another 41.5% 'totally disagreed' with the statements (Figure15).

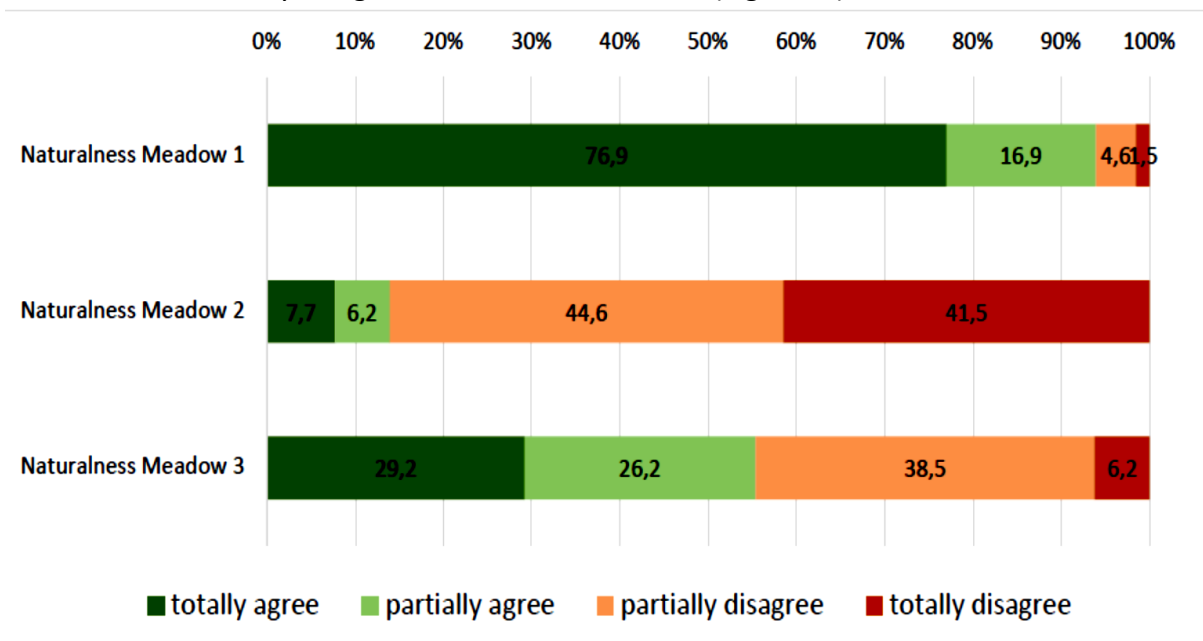


Figure 15. Percentages of selected degree of agreement to the attitudinal statements referring to the naturalness of Meadow 1, 2 and 3 (65 participants = 100%).

The highest rating for derived well-being was assigned to Meadow 1. 61.5% of the participants 'totally agreed' with the given statements, another 29.2% 'partially agreed' (Figure 16).

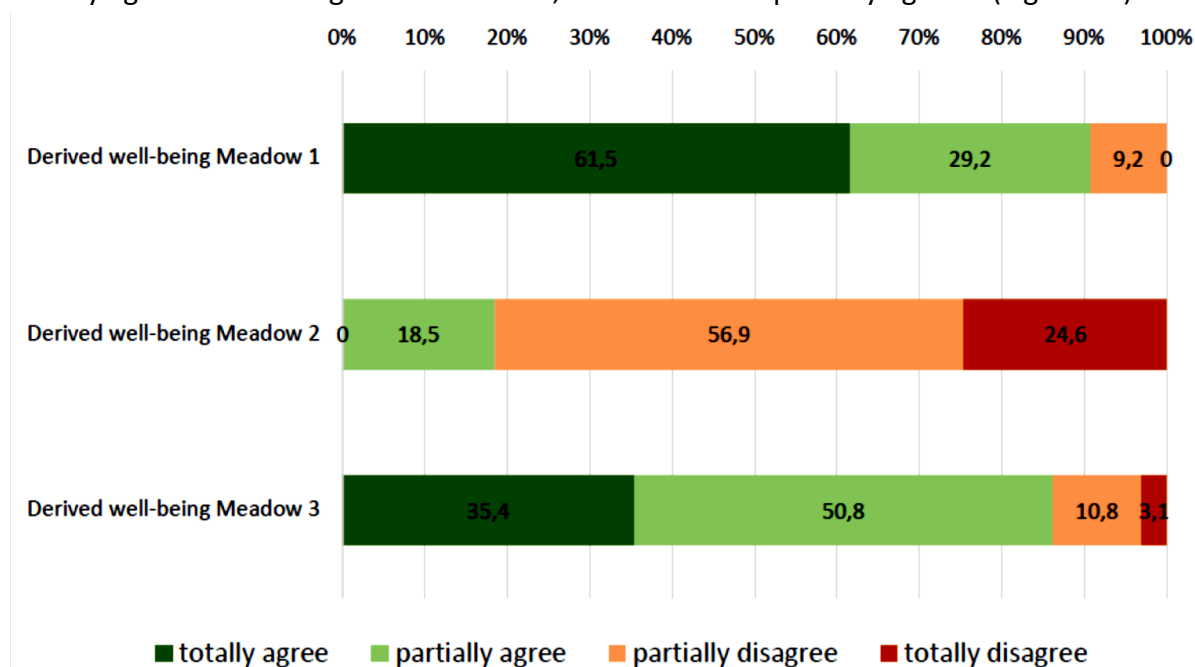


Figure 16. Percentages of selected degree of agreement to the attitudinal statements indicating the participants' derived well-being for Meadow 1, 2 and 3 (65 participants = 100%)

#### 4. Discussion and recommendations

Heteropteran bug abundance was unaffected by different habitat types. Our explanation for this result is twofold. First, the present results are in the line with Tscharrntke et al. (2005) that the effect of habitat intensity is low in a landscape where abundance is high (in this sense all our habitat types). Secondly, the regions with high variance may have hindered the finding of significant habitat effects. For example, there is a clear tendency towards higher abundance in the regions of Salzburger Lungau and Wienerwald, but the opposite was found in the region of Kärntner Nockberge. These outcomes showed that the responses of some taxa to habitat type may depend on regional factors (Batáry et al. 2007). High species richness of heteropteran bugs was found in the flower strips. This finding suggests the importance of flower strip areas as remnants and shelters for heteropteran bugs. Moreover, heteropteran bugs could be influenced by various other factors, e.g succession age (Frank & Künzle, 2006), connectivity (Nicholls et al. 2001), and grassland management (Nickel & Hildebrandt, 2003). Grassland management, like mowing once in extensive meadows and more than once in the intensive and control meadows, can change the structure and species composition of vegetation (Kun et al. 2021) and thereby has an indirect effect on insects by affecting habitat conditions and host availability (Nickel & Hildebrandt, 2003).

Plant height and flower frequency proved to be important factors affecting the species richness and abundance of heteropteran bugs. Plant height can be used as a simple proxy for the architectural density of the vegetation in the studied meadow types. Literature showed that both species richness and abundance of heteropteran bugs benefit from the greater

structural complexity of vegetation (Di Giulio et al. 2001; Kruess & Tschardtke, 2002; Zurbrügg & Frank, 2006; Woodcock et al. 2007) and flower frequency (Walcher et al. 2017; Walcher et al. 2019). This is because highly structured vegetation can provide a larger potential surface for colonization and more resources, such as feeding, oviposition, resting and overwintering sites (Dennis et al. 2003). Management may alter several factors like flower cover and plant height leading to changes in heteropteran bug assemblages that often show high site-specificity (Hudewenz et al. 2012; Milberg et al. 2016). We suppose that the different structural complexity between flower strips and intensive and control meadows could be a reason. This might be because true bug assemblages were highly affected by flower cover (Walcher et al. 2017), which is a local factor and varies at the smallest spatial scale among the studied meadow types.

Flower strips attracted the highest abundance and richness of syrphids from all studied habitat types. It is known that syrphids need pollen and nectar as food source (Almohamad et al. 2009) and a variability of floral resources showed positive influences on syrphid species richness and abundance (Sutherland et al. 2001; Meyer et al. 2009). In our study, syrphid abundance increased in intensive meadows with flower strips in the second year. High abundance of syrphids in flower strips probably increased the activity range of the syrphids that resulted in an increase of abundance in the nearby intensive meadows. Further, presence of many easily accessible flowers from Apiaceae and Asteraceae in the flower strips (Branquart & Hemptinne, 2000), which are preferred by syrphids, might play a role in such increase. Yet, with more than 85% of the aphidophagous syrphids in our study, which is common in landscapes of high level agricultural intensification (Pfister et al. 2017), aphid population variability might be the driver of our observations. Several studies have shown that vegetation that provides shelter and foraging sites is more attractive to syrphids (Haenke et al. 2014; Pfister et al. 2017; Schirmel et al. 2018). However, we found negative relationships between syrphid abundance and species richness with vegetation structure. Increase in vegetation structure may provide resources for predatory insects (Kemp & Ellis, 2017) that might cause such negative relationships.

Grass margins are recognized as a valuable source for butterfly populations by providing larval food plants, but the effects would be larger if wildflowers were added in these margins as butterfly's food source (Haaland et al. 2011). Even though we have high flower resources in the flower strips, however these strips were established in the last two years. Extensive meadows are considered as biodiversity rich habitats (Veen et al. 2009). They exist for a long time and are characterized by lower management intensities which could have been a reason for high butterfly abundance and richness in the extensive meadows. The delayed mowing regime extends the feeding sources availability at that time when mowing reduced important resources across the habitat. Another collateral effect of the delayed mowing regime is a reduction in the number of cuts per season in extensive meadows, which favors butterfly species that naturally have a low resilience to habitat disturbance (Konvicka et al. 2008; Hudewenz et al. 2012). The low cutting regime in extensive meadows could provide a stable

vegetation cover throughout the season for caterpillars and pupae, as well as for species with restricted feeding and dispersal potential, notably those which are typically impacted by the mowing process in intensive and control meadows (Johst et al. 2006; Humbert et al. 2010).

Bumblebees abundance and richness was found similar in extensive meadows and flower strips. These stable habitats possibly increased foraging success and colony growth, signifying potential benefits for bumblebees within and between seasons (Klatt et al. 2020). However, simplified landscapes characterized by a very intensive land-use have limited or no potential nesting sites (Goulson et al. 2008). It might be the spatial relationship between potential nesting sites and available flower resources that are critical for population development (Häussler et al. 2017). Based on our finding, high grassland management in intensive meadows did not favor bumblebee abundance and richness. Perhaps, vegetation structure and flower frequency are the driving factors to improve bumblebee abundance and richness. Although the results showed that bumblebees prefer higher vegetation height, which is obtained by seldom mowing in flower strips and extensive meadows, grasslands still need to be regularly managed or they will be overgrown by shrubs, and bumblebee numbers will start to decline (Carvell, 2002). It is expected that high flower abundance would favor bumblebee abundance and richness, as they would not have to travel long distances to forage. It would be advantageous for bumblebees to fly the shortest possible distances to forage, as their metabolic rate has been shown to be the highest recorded (Goulson, 2010).

Our study results of the socio-economic part showed that the descriptive terms for the type of vegetation were the terms most often mentioned for each meadow, followed by the type of landscape and the type of management. Consistent with the literature this study furthermore indicated that participants used the perceived structural diversity to draw assumption for the species diversity of the place (Meyer-Grandbastien et al. 2021). The descriptive terms used for the extensive meadow and the flower strip next to the intensive meadow referred to a high diversity of the vegetation and the two sites also received high estimation for the level of species diversity. The flower strip received similarly high ratings as the extensive meadow which in fact is an overestimation of the actual species diversity. Overestimation of the actual species diversity has been reported in prior research and can possibly be due to the high flower color diversity and flower density (Southon et al. 2018).

This study was not able to demonstrate the relation between the estimated species diversity and higher assigned aesthetic ratings, which has been reported previously (Hoyle et al. 2018). It might be related to the perceived naturalness of the depicted meadows. The extensive meadow was clearly valued as being the most natural one and the expected relation between estimated species diversity and aesthetic valuation proved to be valid for this type of meadow (Hoyle et al. 2018). Although the flower strip next to the intensive meadow also received rather high aesthetic ratings, its naturalness was rated rather low. This could have influenced the possible correlation between the estimated level of species diversity and the aesthetic rating. It may be that the high assigned aesthetic rating for the flower strip next to the

intensive meadow was due to other factors like the abundance of flowers on the close-up photos or the high number of colors in the flower strip (Graves et al. 2017).

Our results showed a positive correlation between the estimated level of species diversity and the derived well-being for the extensive and the intensive meadow, but not for the flower strip next to the intensive meadow. Other studies on derived well-being were done directly on the field sites where it is probably easier for the participants to make valuations on the well-being derived from the place. Still, for two out of the three meadows, a correlation was shown which is in line and supporting prior research results (Dallimer et al. 2012). Prior research results furthermore indicated that people's feeling of well-being is rather related to their general impression of the landscape than to a number of species or elements within a flower strip or meadow (Marselle et al. 2016), a statement that can help to explain the ambiguous result of this study.

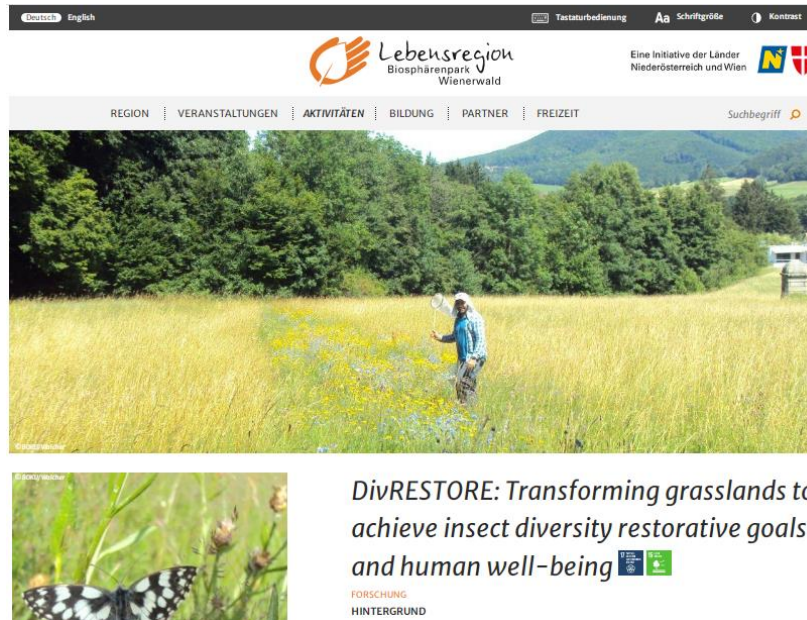
Conducting the survey with photos and not directly in the field sites is a limitation of the survey which made it not possible for the participants to perceive the overall species diversity of insects and other animals, since they were not visible on the photos. Plant diversity was only visible with limitations because of the size of the photos, furthermore, only a part of the meadows was shown. It is therefore not surprising that the participants only perceived biodiversity on the structural level. However, the fact that many people used terms that referred to the levels of species diversity also supports the statement that people conclude from the structural diversity on the level of species richness of the meadows (Meyer-Grandbastien et al. 2021).

Restoring biodiversity in intensive grasslands represents a real conservation challenge. Flower strips seem most effective to enhance syrphid abundance in intensively managed agricultural landscapes. Overall, restoration of insect diversity is a relatively slow process, in which colonization by each insect group is not only limited by local vegetation conditions, but is also affected by the presence, distance and connection to source populations (Öckinger & Smith, 2006; Woodcock et al. 2012). The response of syrphids in intensive meadows due to flower strips can be expected to increase with the duration of the experiment. Further, it can also be assumed that the probability of colonization increases over time for the other insect groups studied (Collinge, 2000). Local people really appreciate extensive grassland ecosystems, which received the highest ratings for their aesthetic values and had the highest effect on derived well-being. Nevertheless, the assigned instrumental, aesthetic values and the derived effect on people's well-being should not be underestimated for their overall value. Extensively managed grasslands are extremely valuable habitats for a great number of different plant and animal species and additionally can have positive impacts on aesthetic aspects of the landscape and on people's well-being. Still, the establishment of flower strips next to intensive grassland are a very rarely used method for habitat creation and restoration. The main reason is probably the loss of productive areas. The results of the present study and similar studies could be used to push for a more active implementation of such areas as well

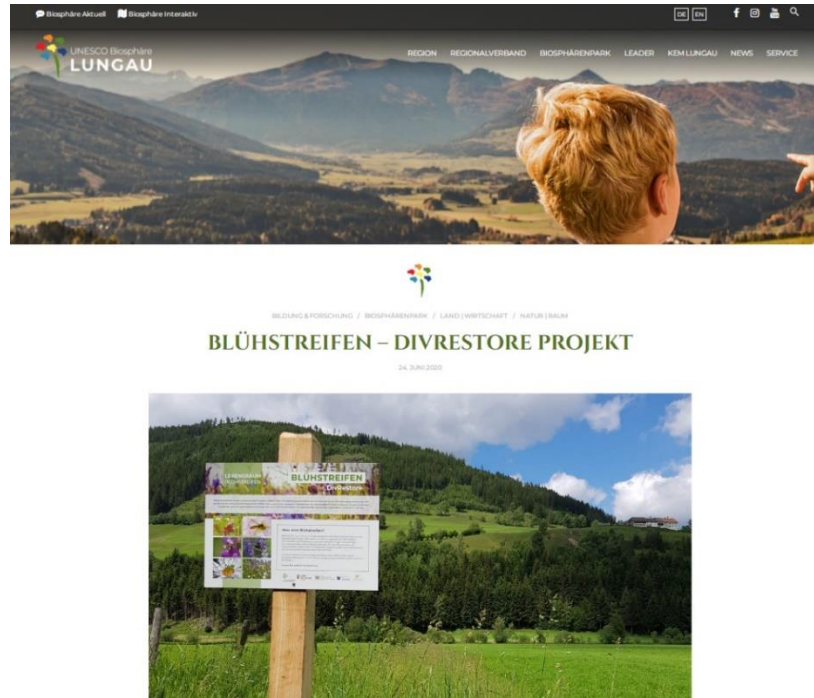


as for the conservation of extensively managed grassland. Therefore, research like it was carried out in the DivRESTORE project is strongly needed to find ways and measures that allow both, a productive agricultural land use while maintaining and promoting insect habitats and species diversity.

## 5. Dissemination



<https://www.bpww.at/de/aktivitaeten/divrestore-transforming-grasslands-to-achieve-insect-diversity-restorative-goals-and>



<https://www.biosphaerenpark.eu/bluehstreifen-divrestore-projekt/?cookie-state-change=1643052263467>



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Dr. Ronnie Walcher elaborated the DivRESTORE results and future recommendations in an event “Forschungsvormittag” in the Biosphere Reserve Wienerwald which took place on the 11th of November 2021 in the lecture hall of the agricultural school in Tullnerbach (<https://www.bpww.at/de/artikel/von-bluehstreifen-und-rinder-dung-forschungsvormittag-im-bpww>).

### 5.1. Master theses:

1. Andrea Pölz:

Title: Local people’s perception and valuation of flowering strips and meadows and derived effects on well-being

2. Nora Vogel

Title: Comparison of butterflies in different grassland types

3. Lukas Streißelberger

Title: Comparison of heteropteran bugs in different grassland types

### 5.2. Scientific papers in preparation

1. Hussain et al. Can new flower strips enhance arthropods in intensive grassland and behave like extensive grassland?
2. Walcher et al: Efficiency of flower strips to support bumblebees in intensively managed grasslands: studies in two Austrian Biosphere Reserves
3. Pölz et al: Local people’s perception and valuation of flowering strips and meadows and derived effects

## 6. References

- Almohamad, R., Verheggen, F., & Haubruge, É. (2009). Searching and oviposition behavior of aphidophagous hoverflies (Diptera: Syrphidae): a review. *Biotechnologie, Agronomie, Société et Environnement*, 13, 467-481.
- Arnberger, A., Eder, R., Allex, B., Hutter, H. P., Wallner, P., Bauer, N., ... & Frank, T. (2018). Perceived health benefits of managed and unmanaged meadows in a mountain biosphere reserve—an experimental study in the Austrian Alps. *ECO MONT-Journal on Protected Mountain Areas Research*, 10, 5-14.
- Batáry, P., Orci, K. M., Báldi, A., Kleijn, D., Kisbenedek, T., & Erdős, S. (2007). Effects of local and landscape scale and cattle grazing intensity on Orthoptera assemblages of the Hungarian Great Plain. *Basic and Applied Ecology*, 8, 280-290.
- Bates, D., Maechler, M., & Bolker, B. (2015). Walker., S. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67, 1-48.
- Binder, S., Isbell, F., Polasky, S., Catford, J. A., & Tilman, D. (2018). Grassland biodiversity can pay. *Proceedings of the National Academy of Sciences*, 115, 3876-3881.
- Branquart, E., & Hemptinne, J. L. (2000). Selectivity in the exploitation of floral resources by hoverflies (Diptera: Syrphinae). *Ecography*, 23, 732-742.
- Braun-Blanquet, J. (1964). *Pflanzensoziologie, Grundzüge der Vegetationskunde* 3rd.
- Buchgraber, K., Schaumberger, A., Pötsch, E. M., Krautzer, B., & Hopkins, A. (2011). Grassland farming in Austria—status quo and future prospective. *Grassland Science in Europe*, 16, 13-24.
- Carvell, C. (2002). Habitat use and conservation of bumblebees (*Bombus* spp.) under different grassland management regimes. *Biological Conservation*, 103, 33-49.
- Cebrián-Piqueras, M. A., Filyushkina, A., Johnson, D. N., Lo, V. B., López-Rodríguez, M. D., March, H., ... & Plieninger, T. (2020). Scientific and local ecological knowledge, shaping perceptions towards protected areas and related ecosystem services. *Landscape Ecology*, 35, 2549-2567.
- Collinge, S. K. (2000). Effects of grassland fragmentation on insect species loss, colonization, and movement patterns. *Ecology*, 81, 2211-2226.
- Dallimer, M., Irvine, K. N., Skinner, A. M., Davies, Z. G., Rouquette, J. R., Maltby, L. L., ... & Gaston, K. J. (2012). Biodiversity and the feel-good factor: understanding associations between self-reported human well-being and species richness. *BioScience*, 62(1), 47-55.
- Di Giulio, M., Edwards, P. J., & Meister, E. (2001). Enhancing insect diversity in agricultural grasslands: the roles of management and landscape structure. *Journal of Applied Ecology*, 310-319.
- Dennis, R. L., Shreeve, T. G., & Van Dyck, H. (2003). Towards a functional resource-based concept for habitat: a butterfly biology viewpoint. *Oikos*, 417-426.
- Dierßen, K. (1990). *Einführung in die Pflanzensoziologie*. Wissenschaftliche Buchgesellschaft, Darmstadt, DE.
- Döring, Nicola; Bortz, Jürgen (2016): *Forschungsmethoden und Evaluation* (5th Edition). Berlin: Springer.

- FiBL (2018): Die 55 wichtigsten Blühstreifenpflanzen. Wien: Ländliches Fortbildungsinstitut Österreich.
- Frank, T., & Künzle, I. (2006). Effect of early succession in wildflower areas on bug assemblages (Insecta: Heteroptera). *European Journal of Entomology*, 103, 61-70.
- Gokcezade, J. F., Gereben-Krenn B. A, Neumayer J, & Krenn HW. (2015). Feldbestimmungsschlüssel für die Hummeln Österreichs, Deutschlands und der Schweiz (Hymenoptera, Apidae)-Linz Biolo Beitr 0047\_1:5–42.
- Goulson, D., Hanley, M. E., Darvill, B., Ellis, J. S., & Knight, M. E. (2005). Causes of rarity in bumblebees. *Biological Conservation*, 122(1), 1-8.
- Goulson, D., Lye, G. C., & Darvill, B. (2008). Decline and conservation of bumble bees. *Annual Review of Entomology*, 53, 191-208.
- Goulson, D. (2010). *Bumblebees: behaviour, ecology, and conservation*. Oxford University Press on Demand.
- Graves, R. A., Pearson, S. M., & Turner, M. G. (2017). Species richness alone does not predict cultural ecosystem service value. *Proceedings of the National Academy of Sciences*, 114, 3774-3779.
- Haaland, C., Naisbit, R. E., & Bersier, L. F. (2011). Sown wildflower strips for insect conservation: a review. *Insect Conservation and Diversity*, 4, 60-80.
- Haenke, S., Kovács-Hostyánszki, A., Fründ, J., Batáry, P., Jauker, B., Tschardtke, T., & Holzschuh, A. (2014). Landscape configuration of crops and hedgerows drives local syrphid fly abundance. *Journal of Applied Ecology*, 51, 505-513.
- Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., ... & Goulson, D. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PloS One*, 12, e0185809.
- Harrison, X. A. (2014). Using observation-level random effects to model overdispersion in count data in ecology and evolution. *PeerJ*, 2, e616.
- Häussler, J., Sahlin, U., Baey, C., Smith, H. G., & Clough, Y. (2017). Pollinator population size and pollination ecosystem service responses to enhancing floral and nesting resources. *Ecology and Evolution*, 7, 1898-1908.
- Hoyle, H., Norton, B., Dunnett, N., Richards, J. P., Russell, J. M., & Warren, P. (2018). Plant species or flower colour diversity? Identifying the drivers of public and invertebrate response to designed annual meadows. *Landscape and Urban Planning*, 180, 103-113.
- Hudewenz, A., Klein, A. M., Scherber, C., Stanke, L., Tschardtke, T., Vogel, A., ... & Ebeling, A. (2012). Herbivore and pollinator responses to grassland management intensity along experimental changes in plant species richness. *Biological Conservation*, 150, 42-52.
- Humbert, J. Y., Ghazoul, J., Sauter, G. J., & Walter, T. (2010). Impact of different meadow mowing techniques on field invertebrates. *Journal of Applied Entomology*, 134, 592-599.
- Hussain, R. I., Walcher, R., Brandl, D., Jernej, I., Arnberger, A., Zaller, J. G., & Frank, T. (2018). Influence of abandonment on syrphid assemblages in mountainous meadows. *Journal of Applied Entomology*, 142, 450-456.

- Hussain, R. I., Walcher, R., Eder, R., Allex, B., Wallner, P., Hutter, H. P., ... & Frank, T. (2019). Management of mountainous meadows associated with biodiversity attributes, perceived health benefits and cultural ecosystem services. *Scientific Reports*, 9, 1-9.
- Hussain, R. I., Brandl, M., Maas, B., Rabl, D., Walcher, R., Krautzer, B., ... & Frank, T. (2021). Re-established grasslands on farmland promote pollinators more than predators. *Agriculture, Ecosystems & Environment*, 319, 107543.
- Ishwaran, N., Persic, A., & Tri, N. H. (2008). Concept and practice: the case of UNESCO biosphere reserves. *International Journal of Environment and Sustainable Development*, 7, 118-131.
- Johst, K., Drechsler, M., Thomas, J., & Settele, J. (2006). Influence of mowing on the persistence of two endangered large blue butterfly species. *Journal of Applied Ecology*, 43, 333-342.
- Karrer, J. (2015) Abandonment of nutrient poor meadows: Impacts on regulating ecosystem services (decomposition, greenhouse gas efflux) and plant diversity. Master-thesis, University of Natural Resources and Life Sciences (BOKU), Vienna.
- Kemp, J. E., & Ellis, A. G. (2017). Significant local-scale plant-insect species richness relationship independent of abiotic effects in the temperate Cape Floristic Region biodiversity hotspot. *PLoS One*, 12, e0168033.
- Klatt, B. K., Nilsson, L., & Smith, H. G. (2020). Annual flowers strips benefit bumble bee colony growth and reproduction. *Biological Conservation*, 252, 108814.
- Kleiber, C., & Zeileis, A. (2008). *Applied econometrics with R*. Springer Science & Business Media.
- Konvicka, M., Benes, J., Cizek, O., Kopecek, F., Konvicka, O., & Vitaz, L. (2008). How too much care kills species: Grassland reserves, agri-environmental schemes and extinction of *Colias myrmidone* (Lepidoptera: Pieridae) from its former stronghold. *Journal of Insect Conservation*, 12, 519-525.
- Korner-Nievergelt, F., Roth, T., Von Felten, S., Guélat, J., Almasi, B., & Korner-Nievergelt, P. (2015). *Bayesian data analysis in ecology using linear models with R, BUGS, and Stan*. Academic Press.
- Kruess, A., & Tschardtke, T. (2002). Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biological Conservation*, 106, 293-302.
- Kun, R., Babai, D., Csathó, A. I., Vadász, C., Kálmán, N., Máté, A., & Malatinszky, Á. (2021). Simplicity or complexity? Important aspects of high nature value grassland management in nature conservation. *Biodiversity and Conservation*, 30, 3563-3583.
- Leyer, I., & Wesche, K. (2007). *Multivariate Statistik in der Ökologie: Eine Einführung*. Springer-Verlag.
- Maas, B., Brandl, M., Hussain, R. I., Frank, T., Zulka, K. P., Rabl, D., ... & Moser, D. (2021). Functional traits driving pollinator and predator responses to newly established grassland strips in agricultural landscapes. *Journal of Applied Ecology*, 1-10.
- Marselle, M. R., Irvine, K. N., Lorenzo-Arribas, A., & Warber, S. L. (2016). Does perceived restorativeness mediate the effects of perceived biodiversity and perceived

- naturalness on emotional well-being following group walks in nature?. *Journal of Environmental Psychology*, 46, 217-232.
- Mayring, Philipp: *Qualitative Content Analysis*. *Forum Qualitative Sozialforschung / Forum:Qualitative Social Research*, 1(2).
- Meyer, B., Jauker, F., & Steffan-Dewenter, I. (2009). Contrasting resource-dependent responses of hoverfly richness and density to landscape structure. *Basic and Applied Ecology*, 10, 178-186.
- Meyer-GrandBastien, A., Burel, F., Hellier, E., & Bergerot, B. (2021). Characterization of Visitors' Perception of Landscape Heterogeneity in Urban Green Spaces. *Urban Science*, 5, 86.
- Milberg, P., Bergman, K. O., Cronvall, E., Eriksson, Å. I., Glimskär, A., Islamovic, A., ... & Westerberg, L. (2016). Flower abundance and vegetation height as predictors for nectar-feeding insect occurrence in Swedish semi-natural grasslands. *Agriculture, Ecosystems & Environment*, 230, 47-54.
- Newing, Helen; Eagle, C.M; Puri, R.K., Watson C.W. (2011): *Conducting research in conservation. A social science perspective*. Oxon: Routledge.
- Nickel, H., & Hildebrandt, J. (2003). Auchenorrhyncha communities as indicators of disturbance in grasslands (Insecta, Hemiptera)—a case study from the Elbe flood plains (northern Germany). *Agriculture, Ecosystems & Environment*, 98, 183-199.
- Nicholls, C. I., Parrella, M., & Altieri, M. A. (2001). The effects of a vegetational corridor on the abundance and dispersal of insect biodiversity within a northern California organic vineyard. *Landscape Ecology*, 16, 133-146.
- Ouvrard, P., Transon, J., & Jacquemart, A. L. (2018). Flower-strip agri-environment schemes provide diverse and valuable summer flower resources for pollinating insects. *Biodiversity and Conservation*, 1-24.
- Öckinger, E., & Smith, H. G. (2006). Landscape composition and habitat area affects butterfly species richness in semi-natural grasslands. *Oecologia*, 149, 526-534.
- Pfister, S. C., Sutter, L., Albrecht, M., Marini, S., Schirmel, J., & Entling, M. H. (2017). Positive effects of local and landscape features on predatory flies in European agricultural landscapes. *Agriculture, Ecosystems & Environment*, 239, 283-292.
- Plantureux, S., Peeters, A., & McCracken, D. (2005). Biodiversity in intensive grasslands: Effect of management, improvement and challenges. *Agronomy Research*, 3, 153-164.
- Potts, S. G., Woodcock, B. A., Roberts, S. P. M., Tscheulin, T., Pilgrim, E. S., Brown, V. K., & Tallowin, J. R. (2009). Enhancing pollinator biodiversity in intensive grasslands. *Journal of Applied Ecology*, 46, 369-379.
- R Core Team., 2018. *R: A Language and Environment for Statistical Computing (Ver. v3.1.1)*. [URL:http://www.R-project.org](http://www.R-project.org).
- Reyes-García, V., Aceituno-Mata, L., Calvet-Mir, L., Garnatje, T., Gómez-Baggethun, E., Lastra, J. J., ... & Pardo-de-Santayana, M. (2014). Resilience of traditional knowledge systems: The case of agricultural knowledge in home gardens of the Iberian Peninsula. *Global Environmental Change*, 24, 223-231.

- Scharnhorst, V. S., Fiedler, K., Frank, T., Moser, D., Rabl, D., Brandl, M., ... & Maas, B. (2021). Ant community composition and functional traits in new grassland strips within agricultural landscapes. *Ecology and Evolution*, 1-13.
- Schirmel, J., Albrecht, M., Bauer, P. M., Sutter, L., Pfister, S. C., & Entling, M. H. (2018). Landscape complexity promotes hoverflies across different types of semi-natural habitats in farmland. *Journal of Applied Ecology*, 55, 1747-1758.
- Schwaiger, E., Berthold, A., Gaugitsch, H., Götzl, M., Milota, E., Mirtl, M., ... & Stix, S. (2015). *Wirtschaftliche Bedeutung von Ökosystemleistungen*.
- Sławska, M., Bruckner, A., & Sławski, M. (2017). Edaphic Collembola assemblages of European temperate primeval forests gradually change along a forest-type gradient. *European Journal of Soil Biology*, 80, 92-101.
- Smith, R. S., Shiel, R. S., Millward, D., Corkhill, P., & Sanderson, R. A. (2002). Soil seed banks and the effects of meadow management on vegetation change in a 10-year meadow field trial. *Journal of Applied Ecology*, 39, 279-293.
- Southon, G. E., Jorgensen, A., Dunnett, N., Hoyle, H., & Evans, K. L. (2018). Perceived species-richness in urban green spaces: Cues, accuracy and well-being impacts. *Landscape and Urban Planning*, 172, 1-10.
- Strauss G (2010) CORISA Wanzenabbildungen. Biberach. [www.corisa.de](http://www.corisa.de).
- Sutherland, J. P., Sullivan, M. S., & Poppy, G. M. (2001). Distribution and abundance of aphidophagous hoverflies (Diptera: Syrphidae) in wildflower patches and field margin habitats. *Agricultural and Forest Entomology*, 3, 57-64.
- Tiefenbach, M., Rabitsch W., & Brandl K. (2014). Fifth National Report of Austria: Convention on Biological Diversity. Retrieved from website: <https://www.cbd.int/doc/world/at/at-nr-05-en.pdf>.
- Tscharntke, T., Klein, A. M., Kruess, A., Steffan-Dewenter, I., & Thies, C. (2005). Landscape perspectives on agricultural intensification and biodiversity–ecosystem service management. *Ecology Letters*, 8, 857-874.
- van de Poel, D., & Zehm, A. (2014). Die Wirkung des Mähens auf die Fauna der Wiesen–Eine Literaturlauswertung für den Naturschutz. *Handbuch Naturschutz und Landschaftspflege*, 1-19.
- Veen, P., Jefferson, R., De Smidt, J., & Van der Straaten, J. (2009). *Grasslands in Europe: of high nature value*. BRILL.
- Wade, M. R., Gurr, G. M., & Wratten, S. D. (2007). Ecological restoration of farmland: progress and prospects. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363, 831-847.
- Wagner E (1967) *Die Tierwelt Deutschlands und der angrenzenden Meeresteile nach ihren Merkmalen und nach ihrer Lebensweise*, vol 55. Wanzen oder Heteroptera II. Cimicomorpha, Fischer, Jena.
- Walcher, R., Karrer, J., Sachslehner, L., Bohner, A., Pachinger, B., Brandl, D., ... & Frank, T. (2017). Diversity of bumblebees, heteropteran bugs and grasshoppers maintained by both: abandonment and extensive management of mountain meadows in three regions across the Austrian and Swiss Alps. *Landscape Ecology*, 32, 1937-1951.

- Walcher, R., Hussain, R. I., Sachslehner, L., Bohner, A., Jernej, I., Zaller, J. G., ... & Frank, T. (2019). Long-term abandonment of mountain meadows affects bumblebees, true bugs and grasshoppers: a case study in the Austrian Alps. *Applied Ecology and Environmental Research*, 17, 5887-5908.
- Waldén, E., & Lindborg, R. (2018). Facing the future for grassland restoration—What about the farmers?. *Journal of Environmental Management*, 227, 305-312.
- Walker, K. J., Stevens, P. A., Stevens, D. P., Mountford, J. O., Manchester, S. J., & Pywell, R. F. (2004). The restoration and re-creation of species-rich lowland grassland on land formerly managed for intensive agriculture in the UK. *Biological Conservation*, 119, 1-18.
- Warzecha, D., Diekötter, T., Wolters, V., & Jauker, F. (2018). Attractiveness of wildflower mixtures for wild bees and hoverflies depends on some key plant species. *Insect Conservation and Diversity*, 11, 32-41.
- Westphal, C., Steffan-Dewenter, I., & Tschardt, T. (2003). Mass flowering crops enhance pollinator densities at a landscape scale. *Ecology Letters*, 6, 961-965.
- Woodcock, B. A., Potts, S. G., Westbury, D. B., Ramsay, A. J., Lambert, M., Harris, S. J., & Brown, V. K. (2007). The importance of sward architectural complexity in structuring predatory and phytophagous invertebrate assemblages. *Ecological Entomology*, 32, 302-311.
- Woodcock, B. A., Bullock, J. M., Mortimer, S. R., Brereton, T., Redhead, J. W., Thomas, J. A., & Pywell, R. F. (2012). Identifying time lags in the restoration of grassland butterfly communities: A multi-site assessment. *Biological Conservation*, 155, 50-58.
- Zechmeister, H. G., Schmitzberger, I., Steurer, B., Peterseil, J., & Wrba, T. (2003). The influence of land-use practices and economics on plant species richness in meadows. *Biological Conservation*, 114, 165-177.
- Zurbrugg, C., & Frank, T. (2006). Factors influencing bug diversity (Insecta: Heteroptera) in semi-natural habitats. *Biodiversity & Conservation*, 15, 275-294.