The area and quality of farmland declared under agri-environment schemes promote birds and butterflies at the landscape scale

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The area and quality of farmland declared under agri-environment schemes promote birds and butterflies at the landscape scale

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Summary

1. The intensification of agricultural practices experienced by Western countries since World War II has triggered a collapse in farmland biodiversity. This prompted the deployment of agri-environment schemes (AES) from the 1990s onwards throughout Europe. Swiss farmers are required by the national AES prescriptions to manage at least 7% of their land as so-called biodiversity promotion areas (BPA). BPA are wildlife-friendly managed habitats that mostly include extensively managed meadows, high-stem orchards or wildflower strips. Despite the high financial inputs into EU and Swiss AES, their effectiveness has long been questioned as most assessments have demonstrated only limited benefits for biodiversity.

2. We investigated the effect of 9 types of BPA on bird and butterfly species richness and abundance in 46 1 km^2 farmed landscape quadrats distributed across the Swiss Lowlands (Plateau). Specifically, we analysed the effects of BPA size, area proportion of all types of BPA within a landscape, area proportion of those BPA achieving ecological quality (i.e. BPA with high botanical or structural diversity), diversity of BPA types and mean distance between BPA within a landscape. Other land uses, such as proportion of settlements and woodland area were also included in the analysis.

3. Results show that both birds and butterflies respond positively to the presence of BPA, but are affected by different BPA properties. Butterfly species, both generalists and specialists, were boosted by an increased proportion of BPA in the farmed matrix. Bird species richness and abundance increased with the diversity of BPA types and the proportion of BPA with high ecological quality within a landscape. The ecological quality of the latter BPA was particularly important for typical farmland birds, bird species with conservation priority in rehabilitation programmes and/or listed on the Swiss Red List. Birds also benefitted from the presence of hedges and water bodies in the agricultural landscape.

4. This landscape-scale study is one of the few demonstrating a positive role of AES for wildlife preservation among high-intensity farmland. It shows that bird and butterfly biodiversity can be promoted by increasing the area and ecological quality of AES, and by diversifying the types of AES. Further research is needed about ways of improving the ecological quality of AES.

Keywords: Agriculture, connectivity, conservation, landscape composition, Lepidoptera, habitat quality, restoration

1. Introduction

Since the second half of the 20th century, agricultural practices have been considerably intensified, particularly in Western European lowland systems (Robinson & Sutherland 2002). Agricultural intensification interventions include not only increase of fertilisers and agrochemicals input, but also the removal of structural landscape elements like hedges and implementation of monoculture systems (Stoate *et al.* 2001). As a consequence, the amount of semi-natural habitats decreased and a wide range of species that were adapted to the former extensively managed farmland matrix are nowadays facing dramatic population decline (Donald, Green & Heath 2001; Stoate *et al.* 2001; Albrecht *et al.* 2007; Voříšek *et al.* 2010; Duflot *et al.* 2015). This negative consequence of agricultural intensification is highlighted by the fact that bird species relying on farmland as primary breeding habitat are declining more rapidly than other assemblages such as forest species (Donald *et al.* 2006; Voříšek *et al.* 2010). This is not only the case for rare species, like the Little Owl *Athene noctua,* but also for those which used to be widespread some years ago, like the Skylark *Alauda arvensis* or the Yellowhammer *Emberiza citrinella* (Spiess, Marfurt & Birrer 2002). Butterfly and moth populations living in agricultural landscapes show similar trends (Weibull, Bengtsson & Nohlgren 2000; Botham *et al.* 2015). Most butterflies depend strongly on grassland habitats and are therefore particularly negatively impacted by grassland intensification and conversion to cropland (Weibull, Bengtsson & Nohlgren 2000; Aviron *et al.* 2007). In this context, the European Union has implemented agri-environment schemes (AES) to reverse the decline of farmland biodiversity, mainly by financially supporting the restoration and conservation of semi-natural farmland habitats, like extensively managed grasslands, wider field margins and hedgerows. In 2010, the amount of money the European Union spent for ecological direct payments reached 5,1 billion EUR (European Union ed. 2011). Similar to the European AES, biodiversity promotion areas (BPA) have been implemented in the early 1990s by the Swiss government. The expenses for BPA in Switzerland reached 364 million CHF in 2016 (http://www.agrarbericht.ch/de/politik/direktzahlungen/biodiversitaet, August 2016). Despite these high financial inputs, farmland biodiversity, including birds and butterflies, is still declining in Switzerland and throughout Western Europe (Donald *et al.* 2006; Voříšek *et al.* 2010; Wermeille, Chittaro & Gonseth 2014). There are several non-exclusive explanations for the low success of European and Swiss AES on the promotion of biodiversity. They include lack of connectivity between land under AES (Birrer *et al.* 2007; Dalang & Hersperger 2012; Arponen *et al.* 2013), too small ecological contrast between AES and conventionally managed land (Kleijn *et al.* 2011) and insufficient proportion of farmland under AES (Kleijn *et al.* 2006; Birrer *et al.* 2007). The effects of these schemes on wildlife species occurrence are often evaluated at the field scale (Kleijn *et al.* 2006; Knop *et al.* 2006; Roth *et al.* 2008; Voříšek *et al.* 2010), though, more recently, it was argued that the effects of AES need to be investigated at the landscape-scale to find distinct solutions for various landscape compositions and large-scale population restorations (Aviron *et al.* 2009; Siriwardena 2010;

Voříšek *et al.* 2010; Batáry *et al.* 2011; Princé, Moussus & Jiguet 2012; Duflot *et al.* 2015). This was rarely done, as precise digitalized maps of the location of those are required, but rarely available, to perform landscape-scale analyses. In Switzerland, digitalisation of BPA exists for large parts of the country, which allows such analyses. The main goal of this study was to investigate the relationship between the mentioned BPA properties and bird and butterfly biodiversity at the landscape-scale, i.e. 1 km^2. In this context our study is novel and of high importance for the allocation and prioritisation of financial resources and the development of a more wildlife friendly European Common Agricultural Policy (Pe'er *et al.* 2014).

Different habitat types like wildflower strips, hedges, traditional orchards and extensively managed meadows, can be set as BPA in Switzerland (BLW ed. 2016). These areas have to be managed according to specific guidelines, generally for a minimum of eight consecutive years. For example, the application of fertilizers and pesticides are prohibited in extensively managed meadows, the use of a hay conditioner is not allowed and the first cut cannot occur before 15 June (BLW ed. 2016). Farmers receive input-based financial contributions for land registered and managed as BPA. In addition to that, farmers can get output-based payments if the BPA reaches a certain level of "ecological" quality. The quality of the BPA is measured according to environmental quality guidelines (Schweizerischer Bundesrat 2001) which consider botanical diversity and structural properties of the BPA, however bird and butterfly diversity are not part of the quality measurement (Table 1).

The aspects that were investigated, in this study, were the proportion of land registered as BPA (relative to total utilised agricultural area), the mean minimal distance between individual BPA and the mean size of BPA. The proportion of BPA with ecological quality relative to the amount of utilised agricultural area and the diversity of BPA types were as well

included in the analyses. In addition to these BPA-linked variables, the matrix between BPA patches consists of land-use types like forest, water bodies and human settlements and is known to strongly influence species occurrence (Ricketts 2001; Burel & Baudry 2005), thus these factors were also included in the statistical models (Table 2).
By focusing the study on the Swiss Lowland Plateau, we investigated the effect of BPA in a region where conflicts between biodiversity conservation and agricultural production are strong. Our results are therefore relevant for intensively managed agricultural regions across wide ranges of Europe and add to recent discussions about sustainable agriculture. Birds and butterflies were selected as model taxa because both have been shown to react to landscape-scale land-use changes (Siriwardena, Cooke & Sutherland 2012) and include species which depend on extensively managed farmland habitats (Donald *et al.* 2006; Botham *et al.* 2015). As the sampling grid of the Swiss Biodiversity Monitoring was used, the size of the investigated landscape plots was predefined to 1 km^2. Nevertheless, it has been shown that 1 km^2 is an adequate scale for such studies (Dover & Settele 2009; Siriwardena, Cooke & Sutherland 2012).

Previous studies showed positive effects of BPA in terms of species richness and abundance of various taxa. Semi-natural habitats like BPA increase environmental heterogeneity (Kleijn *et al.* 2006) and areas under BPA provide more territories, breeding sites and essential host and feeding plants for birds and butterflies (Aviron *et al.* 2007; Siriwardena 2010). The ecological quality standards of BPA are measured by means of indicator plant species and hence represent botanical diversity. Based on the reported findings we expect that landscapes with large, diverse and connected BPA harvest the highest biodiversity among our study landscapes. We hypothesise a positive influence of proportion of BPA per utilised agricultural area (UAA) on bird and butterfly diversity. Further, both species groups are predicted to increase with higher amount of BPA with quality (Birrer *et al.* 2007; Bailey *et al.* 2010; Aviron *et al.* 2011). As mentioned before, both species groups have the potential to move through the landscape, with birds generally moving over longer distances than butterflies. Consequently, we expected distance between BPA to be particularly relevant to the butterfly community (Krauss, Steffan-Dewenter & Tscharntke 2003). Beside the direct effect of BPA, we expected as well an influence of the surrounding landscape on species diversity. Naturally managed forest area, hedges and water bodies are thought to promote bird and butterfly diversity, since they grant sheltered corridors and provide nesting and foraging possibilities for many species (Robinson & Sutherland 2002; Herzog *et al.* 2005; Birrer *et al.* 2007; Bailey *et al.* 2010; Rey Benayas & Bullock 2015).

2. Material and Methods

2.1 Study site and landscape selection

The study was conducted on the Swiss Lowland Plateau, which lies between the Alps and the Jura mountain ranges. The Swiss Plateau can be characterised as an intensively used agricultural landscape where non-farmland semi-natural habitats (e.g. hedges and forest patches) are still present, but constitute usually only 1–20% of the matrix. It is also densely populated, with an average of 220 inhabitants per km^2. Following a systematic sampling method, the Biodiversity Monitoring Switzerland (BDM) programme conducts repeated monitoring in 520 landscapes of 1 km^2 across the country (BDM Coordiantion Office 2014). Among these 520 landscapes, we selected all located on the Swiss Plateau and where BPA data were digitally available for GIS (Geographic Information System) analyses (see subsection *2.3 Landscape data* below). In addition, selected landscapes had to have a minimum of 40 ha of utilised agricultural area (UAA). 46 study landscapes of 1 km^2 fulfilling the selection criteria were included in the study (Fig. 1).

2.2 Biodiversity data

The data on birds and butterflies was provided by the BDM. In each 1 km^2 study landscape, butterfly species richness was recorded once between 2009 and 2014 by repeated transect sampling, up to seven times during the corresponding sampling-year (Z7 indicator; BDM Coordination Office 2014). As species number of butterflies did not change on the Swiss Plateau during the last 10 years (Martinez 2014) we merged data from different sampling years for this study. Field experts identified butterflies to species level or attributed them to species-complexes. Note, that butterfly abundance was not precisely recorded for very numerous species (> 20 individuals), but classified into categories of 21-40, 41-100 and > 100 individuals, respectively. Butterfly abundance was therefore not included in this study. Bird species richness and abundance (defined as number of breeding pairs) were as well recorded between 2010 and 2014 (three transect counts per sampling year) by a cooperative monitoring project between the BDM and the Swiss Ornithological Institute (SOI; http://www.vogelwarte.ch/en/projects/monitoring/monitoring-common-breeding-birds.html, August 2016). In most study landscapes (33 out of 46), the bird counts were conducted in 2014. The other 13 landscapes were previously sampled (5 in 2010, 2 in 2011, 4 in 2012 and 2 in 2013).

Butterfly species were classified into four main groups: total, farmland, priority and Red List species, unless they were recorded as species-complex and therefore no habitat or Red List status was attributed (Appendix 1). Priority species were determined by the federal office of environment and are the focus of national farmland conservation program. These species are often endangered and characteristic of a given region (Walter *et al.* 2013). Species listed as near threatened, vulnerable or critically endangered were defined as Red List species (Keller *et al.* 2010; Wermeille, Chittaro & Gonseth 2014). Based on several life-history traits, butterflies were further classified into specialists or generalists (Settele, Feldmann & Reinhardt 1999). Species that are polyphagous, sedentary and multivoltine were defined as generalists, all others as specialists. Likewise, birds were classified in four main groups (total, farmland, priority and Red List species). Farmland bird species include all species that are strongly related to farmland as habitat (see Appendix 2). Bird species were then grouped into guilds according to their foraging and nesting priorities. We considered four feeding guilds: carnivorous (meat eating, mainly raptors), granivorous (seed eating), insectivorous (insect/arthropod eating) and omnivorous (varying diet composition). Further five nesting guilds were defined: building breeder (nesting on houses), cavity breeder (nesting in artificial or natural cavities), ground breeder (building nests on the ground), hedge/tree breeder (nesting aboveground in wooden structures) and reed breeder (breeding in reed beds). All classifications were done according to the SOI (http://www.vogelwarte.ch/en/birds/birds-of-switzerland/, August 2016).

2.3 Landscape data

Digitalised maps of the Swiss cadastral survey (Swisstopo 2011) were used to calculate areas, in m^2, of the different types of land-use per study landscape (Table 2 and Fig. 2). In addition to the land-use types listed in Table 2, six different BPA properties were calculated for every study landscape, using Geographic Information System (ArcGIS 10.2.2, Table 3); 1) total area of BPA [m^2]; 2) proportion of BPA per UAA [%]; 3) mean BPA size [m^2]; 4) mean minimal distance between BPA [m]; 5) proportion of BPA with ecological quality per UAA [%]; and

6) BPA diversity (Shannon diversity index). Data on BPA were collected in 2013/2014 and provided as digitalised maps by the respective cantonal authorities in 2015. We assume that fluctuations in BPA locations were relatively low, as most BPA generally remain on the same location (e.g. extensively managed meadows, hedges or orchards), at least for the contract duration of eight years. However, BPA on arable land (e.g. wildflower strips or fallow land) can change location from one year to another. To account for the effects of BPA that lie directly at the edge of the study landscapes, we set a 50 m buffer zone around each 1 km^2 and all analyses were performed with values calculated for this area (1.1025 km^2).

Mean minimal distance between BPA was taken as proxy for connectivity within the study landscape and was calculated as the average distance to the nearest BPA. If two BPA were adjoining, a distance of 0 m was assigned. Mean minimal distances in study landscapes with < 2 BPA, which was the case in one study landscape, were not taken into account. To be considered as BPA ”with ecological quality”, the area needs to comply with the properties defined by the environmental quality ordinance (Schweizerischer Bundesrat 2001), which account for botanical and/or structural diversity on the areas (Table 1). Shannon diversity index (H) was used to define the the compositional heterogeneity of the BPA;

$$H = -\sum_{i=1}^{N} p_i \times \ln(p_i)$$

where N is the total number of different BPA types and p_i the proportion of the BPA type i in the study landscape.

2.4 Data analysis

Multiple linear models were used to analyse the effect of BPA and land-use variables on bird species richness and abundance, and butterfly species richness. First, the Pearson's correlation coefficient (r_s) was calculated for each pair of BPA properties and land-use variables, and one variable was removed if $|r_s| \geq 0.7$. A strong positive correlation between total BPA area and BPA per UAA was found, thus total BPA area was excluded from the analyses. Within the land-use variables paved (e.g. streets and settlements) was removed as it was strongly positively correlated with the variable vegetated (e.g. gardens, vegetated roadsides). After that, a three-step model approach following the example of Potts *et al*. (2009) was used: Model 1 included all explanatory variables related to BPA (BPA per UAA, mean BPA size, mean minimal distance, proportion of BPA with quality per UAA, BPA diversity); Model 2 comprised all the different land-use variables (forest, vegetated, non-vegetated, hedge, UAA, water bodies); and Model 3 included only the significant explanatory variables retained Model 1 and Model 2. The best model for all three steps was chosen applying the *dredge* function in the *MuMIn* package of R (Bartoń 2015), which uses the Akaike's Information Criterion (AICc) as relative metric of model parsimony. The same approach was applied to analyse bird and butterfly groups, i.e. total, farmland, priority and Red List, and butterfly generalist and specialists. Insectivorous and omnivorous birds (feeding guilds) as well as hedge/tree- and cavity breeders (nesting guilds) were analysed, since they included at last 20 species. All analyses were performed using R version 3.1.2 (R Development Core Team 2016).

3. Results

In the examined landscapes, the most abundant BPA types were extensively managed meadows (56%) and traditional orchards (19%). Low-intensity managed meadows (7%) and extensively managed pastures (6%) were common as well (Appendix 3). The average (± standard deviation) proportion of BPA per UAA was 11% (± 6). The mean BPA size was 3168 m^2 (± 1577), and BPA were on average 41 m (± 43) apart from each other. The proportion of BPA with ecological quality per UAA was on average 1% (± 4; Table 3). In all cases Model 3 had the lower AICc and was therefore appointed the best model.

Overall, 59 butterfly and 99 bird species were recorded within the 46 study landscapes. Average (± standard error) number of farmland butterfly and farmland bird species per study landscape was 15 (± 4) and 8 (± 2), respectively. Similarly, there were on average 13 (± 7) butterfly and 7 (± 3) bird priority species. The number of Red List species was on average 1 (± 1) per study landscape for the butterflies and 4 (± 2) for the birds. The complete lists of butterfly and bird species can be found in Appendices 1 and 2 respectively.

3.1 Butterflies

The number of total, farmland and priority butterfly species increased significantly with higher proportions of BPA per UAA (Table 4 and Fig. 3a). Red List butterflies were very rare in our study landscapes. Consequently, we are not able to provide evidence for any effect of BPA or other land-use types for this particular species group. The only significant effect of land-use variables was observed for total butterfly species richness, which reacted positively to amount of forest area. The analyses of butterfly guilds showed positive effects of BPA per UAA on generalists and specialists species richness. Generalists also responded positively to the amount of forest in the study landscape and negatively to mean size of BPA (Appendix 4).

3.2 Birds

Total bird species richness showed a significant positive response to the proportion of BPA per UAA (Table 5 and Fig. 3b). Farmland, priority and Red List bird species richness increased significantly in study landscapes with higher proportion of BPA with ecological quality (Table 5 and Fig. 3c). Farmland and priority bird species reacted likewise positively to BPA with ecological quality in terms of abundance. Beside the effect of BPA, hedges, forests and water bodies influenced bird species richness and abundance significantly positive (Table 5).

Two, out of the 46 study landscapes, had comparatively high proportions of BPA with ecological quality (65 and 81%, while on average there were only 1% of BPA with ecological quality per UAA per landscape), which gave them disproportionately high weight in the analyses. If these two study landscapes were excluded from the analyses (n = 44), the results changed in a way that the diversity of BPA became the most crucial factor for all bird species groups (Table 6).

Bird guilds were only represented if they included at least 20 species, consequently insectivorous, omnivorous, hedge/tree and cavity breeders were analysed. Detailed results of bird guild analyses are presented in Appendix 5. In short, species richness of insectivorous birds significantly increased in study landscapes with higher proportion of BPA with high ecological quality and larger area of covered by hedges and forests. Species richness of omnivorous birds significantly increased with larger mean BPA size and amount of forest area. Their abundance was positively affected by high amount of hedges. Birds nesting in hedges and trees showed no significant reaction to any of the BPA variables but their species richness and abundance increased significantly in study landscapes with more hedges and larger forested areas. Species richness of cavity breeders was significantly positively affected by the proportion of BPA per UAA and amount of forests. Their abundance increased in study landscapes with large proportions of vegetated areas.

4. Discussion

This study investigated the landscape-scale effects of agri-environment schemes (AES) on butterfly and bird species richness and abundance. The results prove that butterfly species richness benefit strongly from landscapes with higher proportion of land under AES per utilised agricultural area, and that bird species richness and abundance are higher in landscapes where AES are of higher ecological quality, expressed by botanical diversity and structural elements. In addition, landscapes with a higher diversity of AES types as well enhance bird species richness and abundance. Our study demonstrates the considerable importance of landscape-scale investigations of AES. In contrast to other surveys (e.g. Kleijn *et al.* 2006; Roth et al. 2008; but see Aviron et al. 2009), we observed significant positive effects of Swiss agri-environment schemes (BPA) on butterflies and birds. The outcome of this large-scale study provides recommendations for AES improvement and is relevant for European agricultural policy, which currently aims to make farming practices more sustainable (Pe'er *et al.* 2014). We shall now discuss in detail the influence of different AES parameters before drawing conclusions and management recommendations for efficient farmland conservation measures.

4.1 BPA proportion

Total, farmland and priority butterfly species were all positively influenced by increasing proportion of BPA per UAA. Priority species are focal species in national conservation programmes (Walter et al. 2013). These findings are in line with other studies that show a promotion of butterfly species richness with increasing amounts of semi-natural habitat in the landscape (Steffan-Dewenter & Tscharntke 2000; Krauss, Steffan-Dewenter & Tscharntke 2003; Hodgson *et al.* 2011). Biodiversity promotion areas like extensively managed meadows and wildflower strips represent important resources of host and nectar plants for many butterfly species (Haaland & Gyllin 2010; Aviron *et al.* 2011). Of remarkable interest is the finding that not only generalists but also specialist species reacted positively to BPA. This implies that BPA are useful measures to counteract the loss of specialist, due to land-use intensification (Börschig *et al.* 2013; Bruppacher *et al.* 2016). In accordance with our hypotheses, total bird species richness was significantly higher in study landscapes with more BPA. Particularly BPA with woody elements, such as hedges and orchards, are important structural components in the generally intensively used agricultural landscape and are beneficial for birds (Birrer *et al.* 2007; Bailey *et al.* 2010).

4.2 BPA quality

Landscapes with higher proportion of BPA with ecological quality significantly promoted farmland, priority and Red List bird species. The promoting effect might be based on structural elements like stone/branch piles or nesting cavities, which are typical requirements for BPA orchards to qualify as "with ecological quality". In meadows and hedges, respectively, botanical diversity and the presence of thorny shrubs are required (Schweizerischer Bundesrat 2001). These factors increase the ecological quality of BPA and therefore the habitat suitability for birds and other taxa (Herzog *et al.* 2005; Meichtry-Stier *et al.* 2016). Our analyses showed that the observed positive effect of BPA with ecological quality was mainly driven by two study landscapes in the Canton of Argovia, which included large extensively managed meadows and wildflower strips with quality. Then again, the vast majority of our study landscapes had very low proportions of BPA with quality and a continuous gradient was lacking. This limits our ability to make conclusive statements about the importance of BPA with quality, especially for butterflies.

4.3 BPA diversity

The outcome of our study provides evidence that enhancing the diversity of habitat types within the landscape benefits farmland biodiversity. When the two landscapes with outstanding high proportion of BPA with ecological quality were excluded, all bird species reacted positively to higher BPA diversity. Adding different habitat types to a landscape increases its compositional diversity and thus benefits biodiversity in general (Benton, Vickery & Wilson 2004; Fahrig *et al.* 2011; Duflot *et al.* 2015; Perović *et al.* 2015). Increased diversity of semi-natural habitats, e.g. BPA in agricultural ecosystems benefits birds by increasing landscape complementation (Devictor & Jiguet 2007; Fahrig *et al.* 2011).

4.4 Distance between BPA

Our findings are in accordance with the hypothesis that distance between individual BPA has no influence on bird species richness at the investigated scale. That we did neither observe any influence of mean minimal distance on butterflies stands in contrast to our predictions. However, this may be explained, by the fact that the mean distances between BPA in our study landscapes were small (on average 41 meters) and therefore our investigated gradient might not be suitable to show an effect of distance on those two mobile taxa (Krauss, Steffan-Dewenter & Tscharntke 2003; Roth *et al.* 2008). However distances between BPA or other semi-natural habitats in other study systems might still be of importance (Krauss, Steffan-Dewenter & Tscharntke 2003).

4.5 Effects of other land-use types

The chosen three-step model approach allowed us to study the importance of BPA while accounting for the influence of the surrounding land-use types. Study landscapes with a lot of hedges were evidently beneficial for all investigated bird species groups. Woody elements, like hedges, promote many bird species, even if they are not declared and managed as biodiversity promotion areas. In addition to this, they represent vertical-structured corridors in agricultural regions which allow species to move under shelter over short and long distances without crossing the open cultivated area (Hinsley & Bellamy 2000). Water bodies promoted birds belonging to the priority and Red List group. Riparian ecosystems and shrubs surrounding water bodies promote biodiversity in general by creating structural heterogeneity and shelter possibilities (Vickery *et al.* 2004; Siriwardena, Cooke & Sutherland 2012; Rey Benayas& Bullock 2015).

5. Conclusions and management recommendations

Our results provide strong evidence on the beneficial effects of agri-environment schemes on farmland bird and butterfly biodiversity. At the scale of 1 km^2, the presence of BPA (Swiss AES) in agricultural landscapes enhanced species richness of both taxa and abundance of birds (butterfly abundance was not investigated). Landscapes with high amount of BPA of high ecological quality significantly enhanced farmland, priority and Red list bird species richness.

In order to improve the effectiveness of AES at the landscape-scale, it is recommended to increase the amount of land under AES in agricultural regions. Beside the area of AES, their diversity is essential for the maintenance of farmland biodiversity by increasing the compositional heterogeneity of the landscape and should therefore be promoted. This can be achieved by favouring rare or particularly valuable AES types, like wildflower strips or fallow areas. Principally AES with ecological quality play an important role, but are still rare in agricultural landscapes. Consequently the ecological quality of existing AES should be improved, by adding structural elements and raising botanical diversity. Moreover, the quality can be increased by implying adjusted management practices (e.g. Schmiede, Otte & Donath 2012; Buri, Arlettaz & Humbert 2013).

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8. Tables

Table 1. Criteria required for different the biodiversity promotion areas (BPA) to be qualified as “BPA with quality”. The minimum commitment period for BPA with quality is eight years.

BPA type	**Quality criteria**
Extensively managed meadows Low-intensity meadows Wildflower strips Litter meadow	Minimum of six required plant indicator species (indicator species list provided in Agridea ed. 2002)
Extensively managed pastures Vineyards	Minimum of six required plant indicator species and/or structural elements like stone plies, dead wood and ponds
Hedges Field and riverside woods	Native species, >2 m width, >5 tree or shrub species per 10 m length, >20% of thorny shrubs and/or one native tree every 30 m (stem perimeter >170 cm at 150 cm above ground)
Orchards	30-100 trees/ha, >0.2 ha with >10 trees, in combination with another BPA within 50 m distance

Table 2. Land-use types extracted for each study landscapes. UAA stands for utilised agricultural area and BPA for biodiversity promotion area.

Category	**Land-use description**
UAA	Arable fields, meadows, pastures, woodland pastures, vineyards, orchards, plantations
Forest	Closed forest
Water bodies	Lakes, ponds, rivers, streams, reed
Hedges	Hedges (not BPA), planted roadsides
Vegetated	House gardens, non-planted roadsides and other vegetated areas
Non-vegetated	Landfills, gravel, rocks, other non-vegetated areas and mixed surfaces of grass and rocks
Paved	Railway, settlements, roads, other paved; parking

Table 3. Biodiversity promotion areas (BPA) variables calculated for each study landscapes. UAA stands for utilised agricultural area, SD for standard deviation.

Parameter	**Unit**	**Minimum**	**Mean**	**Maximum**	**SD**
BPA per UAA	%	< 2	11	25	6
Quality per UAA	%	0	1	18	4
Mean BPA size	m^2	1529	3168	8285	1577
Mean minimal distance	m	4	41	229	43
BPA diversity	Index	0	0.82	1.8	0.3

Table 4. Effects of biodiversity promotion areas (BPA) and other land-use types on butterfly species richness. Estimate, standard error (SE) and the significance code (P) are given. Number of species per group: Total n = 59, Farmland n = 41, Priority n = 28, Red List n = 13. UAA stands for utilised agricultural area. Significance codes are indicated as follows: **.** $P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

	Butterfly species richness											
	Total			Farmland			Priority			Red List		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA	52.9	14	***	34.1	10.1	**	32.1	8.9	***			
Quality per UAA												
Mean BPA size	< 0.001	< 0.001	.				< 0.001	< 0.001	.			
Mean minimal distance												
BPA diversity												
Land-use variables												
UAA												
Forest	12.6	5.3	*									
Water bodies							< 0.001	< 0.001	ns			
Hedges												
Vegetated												
Non-vegetated										52.8	28.6	.

Table 5. Effects of biodiversity promotion areas (BPA) and other land-use variables on bird species richness and abundance. Estimate, standard error (SE) and the significance code (*P*) are given. For abbreviations and significance codes see legend Table 3.

	Bird species richness											
	Total			Farmland			Priority			Red List		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA	36.3	13.9	*									
Quality per UAA				18.2	5.6	**	27.6	8	**	16.6	6.7	*
Mean BPA size				< 0.001	< 0.001	ns	< 0.001	< 0.001	ns	< 0.001	< 0.001	ns
Mean minimal distance												
BPA diversity	3.5	2.3	ns									
Land-use variables												
UAA				5.2	1.5	**				3.8	1.7	*
Forest	18.2	5.5	**									
Water bodies	51.9	22.1	*				23.2	7.5	**	28.2	6.3	***
Hedges	342.5	114.4	**	72.7	32.2	*	99.6	44.4	*	143	38.1	***
Vegetated												
Non-vegetated				53.8	1.5	.						

	Bird abundance											
	Total			Farmland			Priority			Red List		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA												
Quality per UAA				160.2	79.2	*	192.1	53.5	***	78.8	48.3	ns
Mean BPA size							< 0.001	0.001	ns	0.002	0.001	ns
Mean minimal distance												
BPA diversity	75.6	38.8	.	12.4	7.8	ns	7.8	5.3	ns			
Land-use variables												
UAA	-400.6	103.6	***									
Forest												
Water bodies				56.5	74.7	ns				86.1	45.2	.
Hedges	4254.3	1970.2	*				798.1	307	*			
Vegetated							-47.3	28.7	ns			
Non-vegetated												

Table 6. Effects of biodiversity promotion areas (BPA) and other land-use variables on bird species richness and abundance after exclusion of two study landscapes with extremely high percentage of BPA with quality (thus no. of landscapes = 44). Estimate, standard error (SE) and the significance code (*P*) are given. For abbreviations and significance codes see legend Table 3.

	Bird species richness											
	Total			Farmland			Priority			Red List		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA												
Quality per UAA												
Mean BPA size	<0.001	< 0.001	ns	< 0.001	< 0.001	ns	< 0.001	< 0.001	ns	< 0.001	< 0.001	ns
Mean minimal distance												
BPA diversity	5.5	2.3	*	1.5	0.5	*	2.2	0.7	**	1.5	0.7	*
Land-use variables												
UAA				5.3	1.5	***	3.4	1.9	.	3.9	1.7	*
Forest	17.1	2.8	**									
Water bodies	32	23	ns				18.5	7.4	*	26.1	6.5	***
Hedges	309.6	125.6	*	54.4	31.5	.	91.8	41.8	*	126.8	37.2	**
Vegetated												
Non-vegetated				58.2	26.8	*						

	Bird abundance											
	Total			Farmland			Priority			Red List		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA												
Quality per UAA												
Mean BPA size										< 0.001	< 0.001	ns
Mean minimal distance												
BPA diversity	58.1	38.6	ns	14.2	6.9	*	7.4	4.9	ns			
Land-use variables												
UAA	-262.3	134.5	.									
Forest	197.6	125.6	ns	-32	16.7	.						
Water bodies												
Hedges	4947.7	2007.5	*				716.1	249	**	332.1	271.1	ns
Vegetated							-50	26.8	.			
Non-vegetated												

9. Figures

Fig. 1. Map of the 46 selected study landscapes in Lowland Switzerland.

Fig. 2. Satellite picture of one selected study landscape. Study landscape (1 km^2) and buffer borders are indicated by the black lines. BPA areas are colored according to their different types; wildflower strips: orange, extensively managed meadows: light-green, low-intensity meadows: yellow, hedges: purple.

Fig. 3. Effects of different BPA variables on farmland butterfly species richness (a), total (b) and farmland (c) bird species richness. Partial residuals of the most important BPA variable were extracted from the best model for each species group.

Figure 1

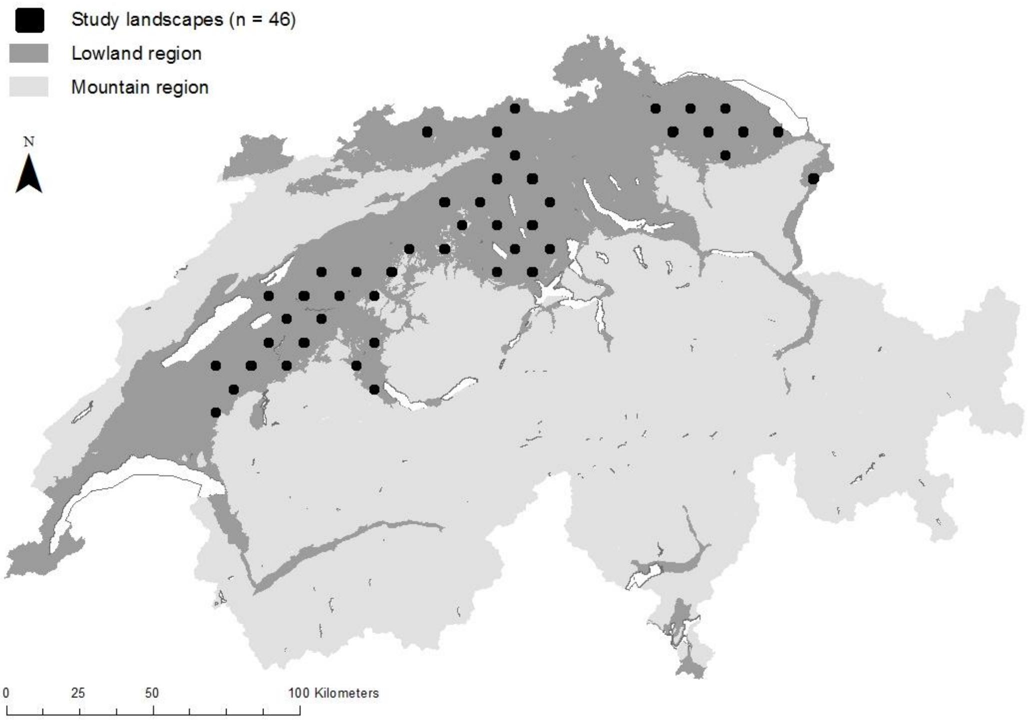
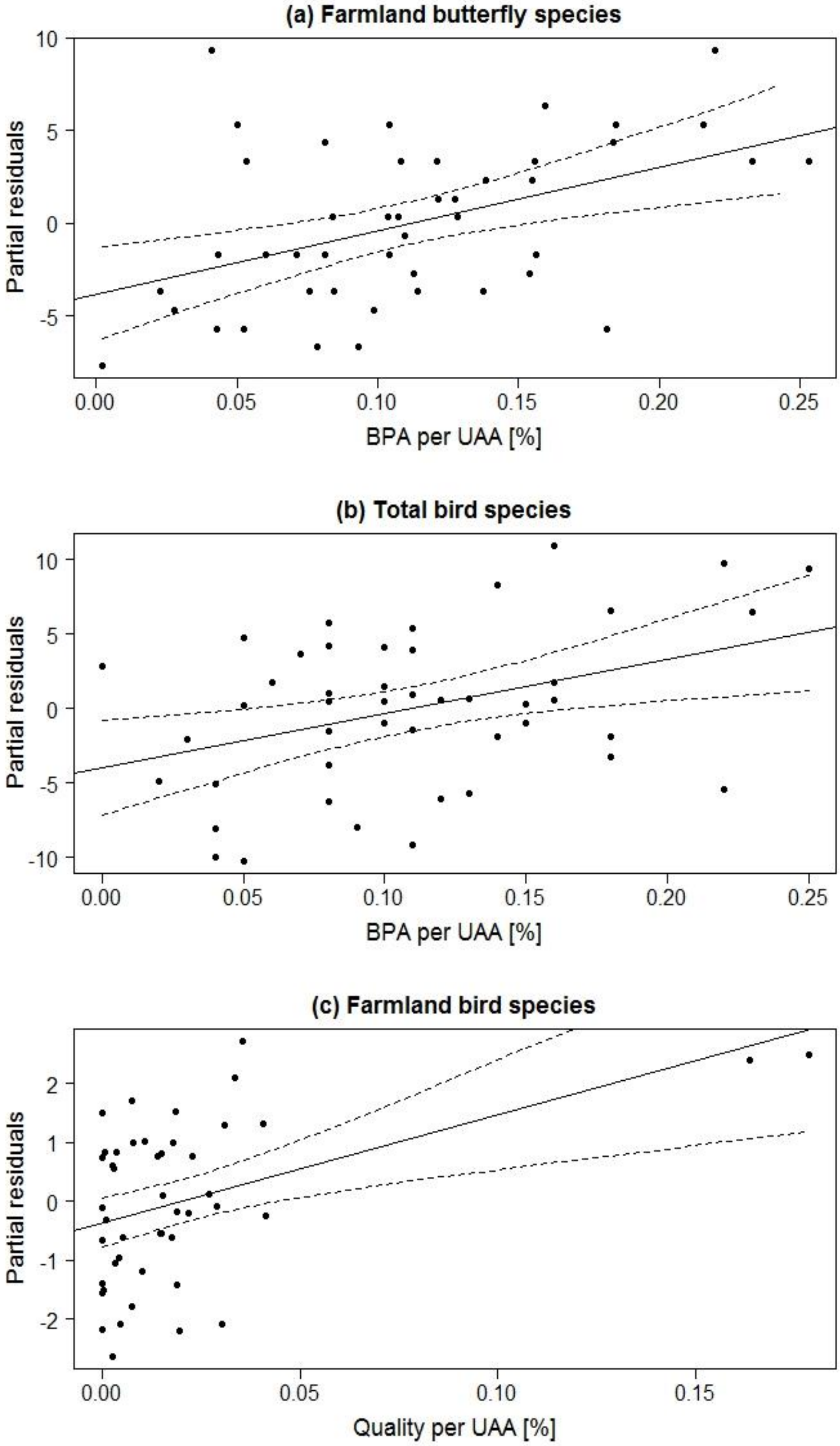

Study landscapes (n = 46)
Lowland region
Mountain region
N
0
25
50
100 Kilometers

Figure 2

Biodiversity promotion areas (BPA)
Wildflower strips
Extensively managed meadows
Low-intensity meadows
BPA hedges
0
Kilometers
1.1

Figure 3


(a) Farmland butterfly species
Partial residuals
BPA per UAA [%]
10
5
0
-5
0.00
0.05
0.10
0.15
0.20
0.25
(b) Total bird species
Partial residuals
BPA per UAA [%]
10
5
0
-5
-10
0.00
0.05
0.10
0.15
0.20
0.25
(c) Farmland bird species
Partial residuals
Quality per UAA [%]
2
1
0
-1
-2
0.00
0.05
0.10
0.15

10. Appendix

Appendix 1

Butterfly species list: Generalists were defined as species which are polyphagous, sedentary and multivoltine, all others as specialists. Life-history traits derived from Settele, Feldmann & Reinhardt (1999).

Species		Specialist	Farmland	Priority	Red List
Adonis blue	*Polyommatus bellargus*	yes	yes	yes	no
Arctic skipper	*Carterocephalus palaemon*	no	yes	no	no
Brown argus	*Aricia agestis-Komplex*	no	X	yes	no
Brown hairstreak	*Thecla betulae*	no	no	yes	no
Chapamn's blue	*Polyommatus thersites*	no	yes	yes	yes
Clouded yellow	*Colias croceus*	no	yes	no	no
Comma	*Polygonia c-album*	no	no	yes	no
Common blue	*Polyommatus icarus*	yes	yes	yes	no
Common brimstone	*Gonepteryx rhamni*	yes	no	no	no
Common copper	*Lycaena phlaeas*	no	yes	yes	no
Dingy skipper	*Erynnis tages*	no	yes	no	no
Essex skipper	*Thymelicus lineola*	no	yes	yes	no
European peacock	*Inachis io*	no	no	no	no
False heath fritillary	*Melitaea diamina*	no	yes	yes	yes
Great banded grayling	*Brintesia circe*	no	yes	yes	yes
Green-veined white	*Pieris napi-Komplex*	no	X	yes	no
Grizzled skipper	*Pyrgus malvae-Komplex*	no	yes	yes	no
Heath fritillary	*Melitaea athalia*	no	yes	yes	no
High brown fritillary	*Argynnis adippe*	no	yes	no	no
Holly blue	*Celastrina argiolus*	yes	no	no	no
Large grizzled skipper	*Pyrgus alveus-Komplex*	yes	X	yes	no
Large skipper	*Ochlodes venata*	yes	yes	yes	no
Large tortoiseshell	*Nymphalis polychloros*	no	no	yes	no
Large wall brown	*Lasiommata maera*	no	yes	yes	no
Large white	*Pieris brassicae*	no	yes	yes	no
Lulworth skipper	*Thymelicus acteon*	no	yes	yes	yes
Mallow skipper	*Carcharodus alceae*	no	yes	yes	yes
Map	*Araschnia levana*	no	no	no	no
Marbled fritillary	*Brenthis daphne*	no	no	no	no
Marbled white	*Melanargia galathea*	no	yes	no	no
Mazarine blue	*Polyommatus semiargus*	yes	yes	yes	no
Meadow brown	*Maniola jurtina*	no	yes	no	no
Meadow fritillary	*Melitaea parthenoides*	no	yes	yes	yes
Oberthür's grizzled skipper	*Pyrgus armoricanus*	no	X	yes	yes
Old world swallowtail	*Papilio machaon*	no	yes	yes	no
Orange tip	*Anthocharis cardamines*	yes	yes	no	no
Painted lady	*Vanessa cardui*	yes	yes	yes	no

Species		**Specialist**	**Farmland**	**Priority**	**Red List**
Pale clouded yellow	*Colias hyale-Komplex*	no	X	no	no
Provencal short-tailed blue	Cupido alcetas	no	yes	no	yes
Purple emperor	*Apatura iris*	no	no	no	yes
Queen of Spain fritillary	*Issoria lathonia*	yes	yes	yes	no
Red admiral	*Vanessa atalanta*	no	yes	yes	no
Red-underwing skipper	*Spialia sertorius*	no	yes	yes	yes
Ringlet	*Aphantopus hyperantus*	no	yes	no	no
Short-tailed cupid	*Cupido argiades*	no	yes	no	yes
Silver-washed fritillary	*Argynnis paphia*	yes	no	no	no
Six-spot burnet	*Zygaena filipendulae*	yes	yes	yes	no
Small blue	*Cupido minimus*	no	yes	yes	no
Small heath	*Coenonympha pamphilus*	yes	yes	no	no
Small skipper	*Thymelicus sylvestris*	no	yes	yes	no
Small tortoiseshell	*Aglais urticae*	no	yes	no	no
Small white	*Pieris rapae-Komplex*	no	X	yes	no
Sooty cooper	*Lycaena tityrus*	no	yes	yes	no
Southern small white	*Pieris mannii*	no	yes	yes	yes
Speckled wood	*Pararge aegeria*	no	no	yes	no
Violet fritillary	*Boloria dia*	no	yes	yes	yes
Wall brown	*Lasiommata megera*	no	yes	yes	no
White admiral	*Limenitis camilla*	no	no	no	no
Wood white	*Leptidea sinapis-Komplex*	no	yes	no	no

Appendix 2

Bird species list: Feeding guilds: c = carnivorous; g = granivorous; i = insectivorous; o = omnivorous. Nesting guilds: a = above ground (hedge/tree); b = buildings; c = cavity; g = ground; r = reed

Species		Feeding	Nesting	Farmland	Priority	Red List
Barn Swallow	*Hirundo rustica*	i	b	yes	yes	no
Black Kite	*Milvus migrans*	c	a	no	no	no
Black Redstart	*Phoenicurus ochruros*	i	c	no	no	no
Black Woodpecker	*Dryocopus martius*	i	c	no	no	no
Blue Tit	*Parus caeruleus*	o	c	no	no	no
Coal Tit	*Parus ater*	o	c	no	no	no
Common Blackbird	*Turdus merula*	o	a	no	no	no
Common Buzzard	*Buteo buteo*	c	a	yes	no	no
Common Chaffinch	*Fringilla coelebs*	o	a	no	no	no
Common Chiffchaff	*Phylloscopus collybita*	i	g	no	no	no
Common Cuckoo	*Cuculus canorus*	i	a	no	yes	yes
Common House Martin	*Delichon urbicum*	i	c	no	no	yes
Common Kestrel	*Falco tinnunculus*	c	a	yes	yes	yes
Common Kingfisher	*Alcedo atthis*	c	c	no	no	yes
Common Linnet	*Carduelis cannabina*	g	a	yes	yes	yes
Common Moorhen	*Gallinula chloropus*	o	r	no	no	no
Common Nightingale	*Luscinia megarhynchos*	i	a	no	yes	yes
Common Pheasant	*Phasianus colchicus*	o	g	yes	no	no
Common Quail	*Coturnix coturnix*	o	g	yes	yes	no
Common Redstart	*Phoenicurus phoenicurus*	i	c	yes	yes	yes
Common Reed Bunting	*Emberiza schoeniclus*	o	r	no	no	yes
Common Swift	*Apus apus*	i	c	no	no	yes
Common Wood Pigeon	*Columba palumbus*	g	a	no	no	no
Common Starling	*Sturnus vulgaris*	o	c	yes	no	no
Dunnock	*Prunella modularis*	o	a	no	no	no
Eurasian Blackcap	*Sylvia atricapilla*	o	a	no	no	no
Eurasian Bullfinch	*Pyrrhula pyrrhula*	g	a	no	no	no
Eurasian Collared Dove	*Streptopelia decaocto*	o	b	no	no	no
Eurasian Coot	*Fulica atra*	o	r	no	no	no
Eurasian Golden Oriole	*Oriolus oriolus*	o	a	no	no	no
Eurasian Hobby	*Falco subbuteo*	i	a	no	no	yes
Eurasian Jay	*Garrulus glandarius*	o	a	no	no	no
Eurasian Magpie	*Pica pica*	o	a	no	no	no
Eurasian Nuthatch	*Sitta europaea*	o	c	no	no	no
Eurasian Reed Warbler	*Acrocephalus scirpaceus*	i	r	no	no	no
Eurasian Skylark	*Alauda arvensis*	o	g	yes	yes	yes
Eurasian Sparrowhawk	*Accipiter nisus*	c	a	no	no	no
Eurasian Stonechat	*Saxicola rubicola*	i	g	yes	yes	yes
Eurasian Tree Sparrow	*Passer montanus*	o	c	yes	no	no

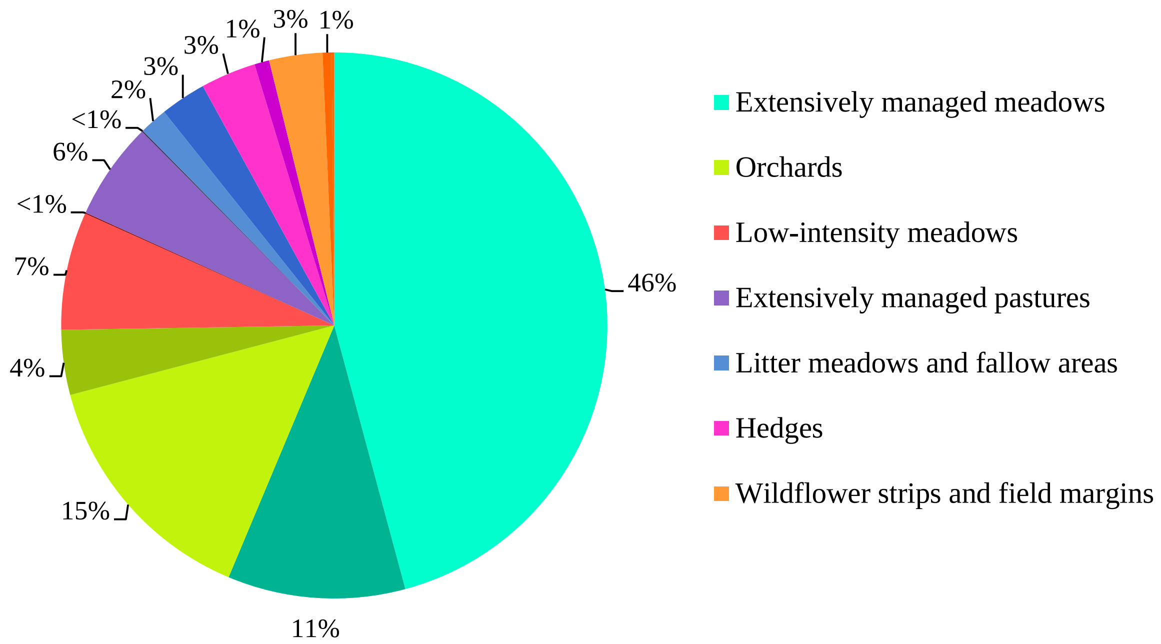
Species		Feeding	Nesting	Farmland	Priority	Red List
Eurasian Treecreeper	*Certhia familiaris*	i	a	no	no	no
European Crested Tit	*Parus cristatus*	o	a	no	no	no
European Goldfinch	*Carduelis carduelis*	g	a	no	yes	no
European Green Woodpecker	*Picus viridis*	i	c	no	yes	no
European Greenfinch	*Carduelis chloris*	g	a	no	no	no
European Honey Buzzard	*Pernis apivorus*	i	a	no	no	yes
European Pied Flycatcher	*Ficedula hypoleuca*	i	c	no	no	no
European Robin	*Erithacus rubecula*	o	g	no	no	no
European Serin	*Serinus serinus*	g	a	no	no	no
European Turtle Dove	*Streptopelia turtur*	g	a	yes	yes	yes
Feral Pigeon	*Columba livia domestica*	o	b	no	no	no
Fieldfare	*Turdus pilaris*	o	a	yes	yes	yes
Firecrest	*Regulus ignicapilla*	i	a	no	no	no
Garden Warbler	*Sylvia borin*	i	a	no	yes	yes
Goldcrest	*Regulus regulus*	i	a	no	no	no
Great Crested Grebe	*Podiceps cristatus*	c	r	no	no	no
Great Spotted Woodpecker	*Dendrocopos major*	o	c	no	no	no
Great Tit	*Parus major*	o	c	no	no	no
Grey Heron	*Ardea cinerea*	c	a	no	no	no
Grey Wagtail	*Motacilla cinerea*	i	c	no	no	no
Grey-headed Woodpecker	*Picus canus*	i	c	no	yes	yes
Greylag Goose	*Anser anser*	o	g	no	no	no
Hawfinch	*Coccothraustes coccothraustes*	o	a	no	no	no
Hooded Crow	*Corvus corone*	o	a	yes	no	no
House Sparrow	*Passer domesticus*	o	c	no	no	no
Icterine Warbler	*Hippolais icterina*	i	a	no	no	yes
Lesser Spotted Woodpecker	*Dendrocopos minor*	i	c	no	yes	no
Little Grebe	*Tachybaptus ruficollis*	c	r	no	no	yes
Long-eared Owl	*Asio otus*	c	a	yes	yes	yes
Long-tailed Bushtit	*Aegithalos caudatus*	i	a	no	no	no
Mallard	*Anas platyrhynchos*	o	g	no	no	no
Marsh Tit	*Parus palustris*	o	c	no	no	no
Marsh Warbler	*Acrocephalus palustris*	i	r	no	yes	no
Middle Spotted Woodpecker	*Dendrocopos medius*	i	c	no	no	yes
Mistle Thrush	*Turdus viscivorus*	o	a	no	no	no
Mute Swan	*Cygnus olor*	o	g	no	no	no
northern Goshawk	*Accipiter gentilis*	c	a	no	no	no
northern Lapwing	*Vanellus vanellus*	o	g	yes	yes	yes
northern Raven	*Corvus corax*	o	c	no	no	no
Red Crossbill	*Loxia curvirostra*	g	a	no	no	no
Red Kite	*Milvus milvus*	c	a	yes	yes	no
Red-backed Shrike	*Lanius collurio*	c	a	yes	yes	no
Savi's Warbler	*Locustella luscinioides*	i	r	no	no	yes
Short-toed Treecreeper	*Certhia brachydactyla*	i	c	no	yes	no
Song Thrush	*Turdus philomelos*	o	a	no	no	no
Spotted Flycatcher	*Muscicapa striata*	i	a	no	no	no
Stock Dove	*Columba oenas*	g	c	no	no	no
Tawny Owl	*Strix aluco*	c	c	no	no	no
Water Rail	*Rallus aquaticus*	c	r	no	no	no
Western Jackdaw	*Corvus monedula*	o	c	yes	yes	yes
Western Yellow Wagtail	*Motacilla flava*	i	g	yes	yes	yes
White Stork	*Ciconia ciconia*	c	b	yes	yes	yes
White Wagtail	*Motacilla alba*	i	b	no	no	no

Species		**Feeding**	**Nesting**	**Farmland**	**Priority**	**Red List**
White-throated Dipper	*Cinclus cinclus*	i	c	no	no	no
Willow Tit	*Parus montanus*	o	c	no	no	no
Willow Warbler	*Phylloscopus trochilus*	i	a	no	no	yes
Winter Wren	*Troglodytes troglodytes*	i	g	no	no	no
Wood Warbler	*Phylloscopus sibilatrix*	i	g	no	no	yes
Yellowhammer	*Emberiza citrinella*	o	a	yes	yes	no
Yellow-legged Gull	*Larus michahellis*	o	g	no	no	no

Appendix 3

Proportion of different BPA types: Average relative proportions of the different biodiversity promotion areas (BPA) types present in the study landscapes. Extensively managed meadows represent the majority of BPA (56%), followed by orchards (19%). The percentage of BPA with ecological quality is indicated with the same but darker colour. On average, 1% of the BPA had ecological quality.

BPA Types



Appendix 4

Butterfly guilds: Effects of biodiversity promotion areas (BPA) and other land-use variables, on butterfly specialists and generalists. Estimate, standard error (SE) and the significance code (*P*) are given. UAA stands for utilised agricultural area. Significance codes are indicated as follows: **.** $P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

	Butterfly species richness					
	Specialist			Generalist		
BPA variables	Estimate	SE	*P*	Estimate	SE	*P*
BPA per UAA	14.8	4.7	**	37.2	10.4	***
Quality per UAA						
Mean BPA size				< -0.001	< 0.001	*
Mean minimal distance						
BPA diversity						
Land-use variables						
UAA						
Forest	3.4	1.8	**.**	9.4	3.9	*
Water bodies						
Hedges						
Vegetated						
Non-vegetated						

Appendix 5

Bird guilds: Effects of biodiversity promotion areas (BPA) and other land-use types, on bird feeding (a) and nesting (b) guilds. Estimate, standard error (SE) and the significance code (*P*) are given. UAA stands for utilised agricultural area. Significance codes are indicated as follows: *P < 0.05, **P < 0.01, ***P < 0.001.

a) Feeding guilds	**Bird species richness**						**Bird abundance**					
	Insectivorous			Omnivorous			Insectivorous			Omnivorous		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA												
Quality per UAA	25.2	12.1	*						**			
Mean BPA size				< 0.001	< 0.001	*			ns			
Mean minimal distance												
BPA diversity	2.2	1.7	.	1.3	1.1	ns	11.7	12.1	ns	48.4	26.8	.
Land-use variables												
UAA										-296	71.6	***
Forest	8.8	2.9	**	10.1	2.6	***	108.6	29	***			
Water bodies	17.4	11.9	ns	15.9	10.1	ns	211.2	116.6	.			
Hedges	230	60	***				1349.1	598.1	*	2960.2	1362.7	*
Vegetated												
Non-vegetated												

b) Nesting guilds	**Bird species richness**						**Bird abundance**					
	Hedge/tree breeder			Cavity breeder			Hedge/tree breeder			Cavity breeder		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
BPA variables												
BPA per UAA				12.2	5.4	*				160.4	115.6	ns
Quality per UAA	24.8	12.8	.									
Mean BPA size	< 0.001	< 0.001	ns									
Mean minimal distance												
BPA diversity	2.1	1.3	.				33.7	20.2	ns			
Land-use variables												
UAA												
Forest	7.7	3.4	*	9.4	2.1	***	290.7	50	***			
Water bodies												
Hedges	194	73.5	*	56	44	ns	3102	1025.7	**			
Vegetated	-11.4	7.6	ns							331.6	101	**
Non-vegetated												

Erklärung

gemäss Art. 28 Abs. 2 RSL 05

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Studiengang: Master of Science in Ecology and Evolution

Bachelor ☐ Master ☑ Dissertation ☐

Titel der Arbeit: The area and quality of farmland declared under agri-environment schemes promote birds and butterflies at the landscape scale

LeiterIn der Arbeit: Prof. Dr Raphaël Arlettaz
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Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Stellen, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet. Mir ist bekannt, dass andernfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe r des Gesetzes vom 5. September 1996 über die Universität zum Entzug des auf Grund dieser Arbeit verliehenen Titels berechtigt ist. Ich gewähre hiermit Einsicht in diese Arbeit.

Bern, 24.08.2016

Ort/Datum

E. Ritschard

Unterschrift