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Effectiveness of the Swiss agri-environment scheme in promoting biodiversity

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Summary

1. Increasing concern over the loss of biodiversity in agricultural landscapes was one of the reasons for the introduction of agri-environment schemes in Europe. These schemes compensate farmers financially for any loss of income associated with measures aimed to benefit biodiversity. Nevertheless, more than a decade after the introduction of the schemes, only a limited number of studies evaluating their ecological effects have been published. We assessed the effect of the Swiss agri-environment scheme that was designed to maintain and increase species richness in hay meadows. In Switzerland, hay meadows under this agri-environment scheme (ECA hay meadows) are the most widely adopted environmental measure to conserve biodiversity.

2. We tested whether meadows under the agri-environment scheme had higher species richness and species evenness than control meadows, whether species richness and species evenness were higher in the centre than at the edge of meadows, and whether these effects differed between geographical regions.

3. Biodiversity was sampled in 42 hay meadows in three different regions, using a pairwise comparison of ECA hay meadows with conventionally managed hay meadows. Biodiversity was estimated by assessing species richness and species evenness of four taxonomic groups representing different trophic levels: vascular plants, grasshoppers, wild bees and spiders.

4. Species richness of vascular plants, grasshoppers and wild bees was significantly higher on ECA hay meadows than on control meadows, but species richness of spiders did not differ. These results were consistent across the three study sites, except for the species richness of grasshoppers, which showed no difference between the ECA meadows and the control meadows in one region.

5. Species evenness was significantly higher on ECA hay meadows than on control meadows for plants and bees but not for spiders and grasshoppers. These results were consistent across the three study regions for bees and spider species only.

6. The species richness of vascular plants and spiders was higher at the edge than in the centre of both ECA and control meadows, suggesting a more extensive management in the meadow edges and a high species exchange between adjacent habitats for these two groups.

7. *Synthesis and applications*. We conclude that the Swiss agri-environment scheme for hay meadows positively affects biodiversity. The scheme should be maintained and farmers should be encouraged to engage in long-term extensive management. For spiders, the current management restrictions are not sufficient, most probably because of inappropriate vegetation structure. Therefore, organisms that particularly depend on vegetation structure should be targeted with additional restrictions: not only the time of the first cut but also the frequency of subsequent cuts and the mowing technique may have to be adjusted.

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Introduction

Agricultural intensification in the second half of the 20th century caused a dramatic loss of biodiversity in Europe and was one of the reasons for the introduction of agri-environment schemes in the early 1990s (European Communities 1985). Agri-environment schemes are payments to farmers and other landholders to address environmental problems or to promote the provision of environmental amenities (OECD 2003). Hence they compensate farmers financially for any loss of income associated with measures that aim to benefit the environment or biodiversity. Nevertheless, more than a decade after the introduction of agri-environment schemes, only a limited number of studies evaluating the ecological effectiveness of these schemes have been published (Kleijn & Sutherland 2003). These studies present contrasting results (Kleijn & Sutherland 2003): some report positive effects of agri-environment schemes on biodiversity (Herzog *et al*. 2005), others show no or even negative effects (Kleijn *et al*. 2001). However, the study design of the majority of these evaluation studies is inadequate to assess reliably the effectiveness of the schemes, and most of them are not found in the readily available scientific literature. Furthermore, most of the evaluation studies have measured biodiversity by focusing on only one group of organisms (Kleijn & Sutherland 2003).

Although Switzerland is not part of the European Union (EU), its agri-environmental policy has evolved in a similar way. Farmers have benefited from direct payments for ecological measures since the reform of agricultural policy in 1992 (Bundesrat 1992). In addition, since 1999 farmers can manage at least 7% of the farmland as so-called ecological compensation areas (ECA) in order to obtain a basic direct payment (Bundesrat 1998). As a consequence, in 2001 almost 9% of the total agricultural land in Switzerland was managed as ECA (Bundesamt für Landwirtschaft 2002). ECA consist of a variety of habitats, including traditional orchards, hedges and field margin strips. However, by far the most important ECA habitat is extensively managed hay meadows (ECA hay meadows). Two important management requirements on ECA hay meadows specify that the vegetation must be cut and removed at least once every year, but not before 15 June (or later depending on altitude and agricultural zone), and fertilizer applications are prohibited.

Higher biodiversity on ECA than on conventionally managed hay meadows has been taken for granted: first, because on ECA meadows reduced fertilization and late cutting dates generally lead to a higher plant species richness and evenness (Rajaniemi 2002; Jacquemyn, Brys & Hermy 2003; Zechmeister *et al*. 2003); secondly, because on conventionally managed meadows the steadily increasing management intensity decreases plant species diversity and simplifies vegetation structure, which may in turn lead to reduction in arthropod diversity (Hunter & Price 1992; Matson & Hunter 1992; Schläpfer & Schmid 1999). We do not know, however, whether the extensification measures prescribed by the ECA scheme are sufficient to bring back the species that have been lost during the years of intensification (Schmid 2002).

We were further interested in possible edge effects on species diversity. Edge effects may be created through a more extensive management in the meadow edge than in the meadow centre (Melman & Van Der Linden 1988). In addition, a positive edge effect on species diversity could be expected as a result of arthropods and plants spreading from species-rich meadow margins into the meadow (Dennis & Fry 1992; Marshall & Moonen 2002). Finally, we wanted to assess whether results about the effectiveness of the scheme can be extrapolated from one to several study sites. The overall aim of the study was to evaluate the effectiveness of the ECA scheme for the preservation of biodiversity on hay meadows. Specifically, we tested the following hypotheses: (i) biodiversity is higher on ECA hay meadows than on conventionally managed hay meadows; (ii) species richness is higher in the meadow edge compared with the meadow centre; (iii) agri-environment schemes have similar effects in different regions.

A paired sample approach of ECA and control hay meadows was used to decouple spatial environmental variation and between-treatment variation as much as possible. For example, spatial variation between fields in species richness may occur because of habitat heterogeneity (Benton, Vickery & Wilson 2003), species pool differences (Partel *et al*. 1996) and management history (Poschlod & Wallis De Vries 2002). Biodiversity was assessed by investigating the species richness and evenness of four different groups of organisms representing three distinct trophic levels: vascular plants, grasshoppers, wild bees and spiders. All four groups are potential indicators of grassland quality with regard to overall species diversity (Detzel 1998; Duelli & Obrist 1998; Tscharntke, Gathmann & Steffan-Dewenter 1998; Bell, Wheater & Cullen 2001; Jacquemyn, Brys & Hermy 2003; Jeanneret, Schüpbach & Luka 2003). If they demonstrate similar responses to ECA management, further assessments required by the new ECA quality-control regulations in Switzerland (Bundesrat 2001) could be restricted to only one or two groups.

Materials and methods

STUDY DESIGN

The field pairs were situated between 600 and 1100 m altitude and were located in three study regions, two in the Canton of Lucerne (Ruswil and Flühli) and one in the Canton of Zurich (Bauma), Switzerland. The regions Bauma and Flühli are characterized by widespread dairy farming, whereas in the region Ruswil there is also some arable farming.

Within each region we selected seven pairs of meadows. Each pair was close to one another, experienced similar abiotic conditions (e.g. soil type, water table, exposition, inclination and landscape structure) and was surrounded by the same habitat type but differed in terms of management. One meadow in each pair served as a control and thus was conventionally managed according to common agricultural practices in Switzerland. The other meadow in a pair represented the treatment and thus was under the ECA management prescribed by the Swiss agri-environment scheme for hay meadows (Bundesrat 1998). With the exception that the meadows must be at least 0·05 ha in size, farmers have no other prescribed criteria when selecting meadows for the scheme. Farmers must commit to manage an ECA meadow for at least 6 consecutive years under ECA regulations. Specific management practices on the control and treatment meadows, such as the exact amount of fertilizer application and mowing regime, were recorded through farmer interviews. On each meadow all investigated taxa were sampled on one transect along the edge of the meadow and on one in the centre. The meadow edge was 1 m wide and was measured from the transition from a road, forest or adjacent agricultural field.

The selected conventionally managed meadows were fertilized with 183 ± 22 kg ha^{-1} nitrogen (mean ± SE) and were cut $3{\cdot}8 \pm 0{\cdot}2$ times year^{-1}, the first cut mostly taking place in May. The selected ECA hay meadows were not fertilized at all, except for three meadows, which, in spite of the regulations, received a small amount of nitrogen. ECA hay meadows were cut $1{\cdot}8 \pm 0{\cdot}2$ times year^{-1}. All ECA hay meadows had been under the agri-environment scheme for between 4 and 10 years. Prior to the extensive management all meadows had been conventionally managed grassland. The mean area of conventionally managed meadows was $1{\cdot}3 \pm 0{\cdot}2$ ha and mean area of ECA hay meadows was $0{\cdot}6 \pm 0{\cdot}1$ ha.

DATA COLLECTION

From March to September 2003, we sampled species composition of four taxonomic groups in the edge and centre of each meadow: vascular plants, grasshoppers, wild bees and spiders.

Vascular plants were sampled in 10 plots of 5×1 m, spaced 5 m apart along transects, in both the centre and the edge of each meadow. In each plot, all plant species were identified (Lauber & Wagner 2001). The abundance of each species was assessed by estimating visually the percentage cover of each species. The vegetation was recorded before the meadows were cut for the first time; seven conventional meadows, however, were cut before the relevés were done. Therefore, these meadows were recorded when the vegetation had sufficiently grown again. Two people were involved in the relevés. A hierarchical analysis of variance (ANOVA) revealed that estimated species richness and cover did not differ significantly between investigators.

Wild bees were sampled by transect and sweep net surveys. A transect survey consisted of catching all individuals that were observed on a 1-m wide transect over a 15-min period, using a bioquip 7112NA student net (BioQuip Products, Rancho Dominguez, CA). For a detailed description of the method see Banaszak (1980). Subsequent to the transect survey, a sweep net sample was undertaken on each transect using a bioquip 7625HS heavy duty net (BioQuip Products). Sixty sweeps, each covering a half-circle of about 1 m radius, were made sequentially in one flowing motion. In total, three survey rounds were made, the first in May, the second in June and the third between July and August. Sampling was carried out on sunny days between 10:00 and 16:00. The two meadows of a pair were sampled on the same day by the same person. Species of wild bees were identified in the laboratory using the following literature: Amiet (1996), Amiet *et al*. (2001), Amiet, Müller & Neumeyer (1999), Scheuchl (1996), Scheuchl (2000) and Schmid-Egger & Scheuchl (1997).

Grasshoppers were sampled by the same sampling scheme as the bees, but only once during August. They were identified using Coray & Thorens (2001).

Spider sampling was undertaken using four pitfall funnel traps per meadow, two located in the central transect and two in the edge transect. The two traps in a pair of replicate samples were 10 m apart from each other and on either side of the fifth or sixth vegetation survey plots. The traps were filled with 70% alcohol. A small cover plate *c*. 2 cm above each trap prevented rain from entering the traps. The first sampling period of 4 weeks began 1 week after the start of the flowering of *Taraxacum officinale* Weber (Duelli, Obrist & Schmatz 1999). Subsequently, there was a 2-week period without sampling followed by a final 2-week sampling period. The traps were emptied every week and the samples were brought to the laboratory for identification. Of the two traps in each pair of replicate samples, only the one that contained most individuals was used for species identification. The spiders were identified using Heimer & Nentwig (1991).

STATISTICAL ANALYSIS

Species richness and species evenness were analysed with analysis of variance (ANOVA). Kendall's rank correlations were calculated to determine whether the diversity measures were correlated between the different trophic groups. All analyses were computed using the R software (R Development Core Team 2004).

Species richness

Species richness was described by the number of species per transect. We used a hierarchical ANOVA with the three fixed factors region (REG, the three study sites Bauma, Ruswil and Flühli), management (MANAG, ECA vs. conventionally managed hay meadows) and position (POS, edge vs. centre of meadows) and the blocking factor PAIR. In order to match the distributional assumption of ANOVA, we transformed the data with the box-cox transformation as necessary (Sokal & Rohlf 1997). When counts included zeros, 0·5 was added before transformation. The data for species richness of plants were log-transformed; those for species richness of bees and spiders were power-transformed (exponents 0·25 and 0·3, respectively). The data for the species richness of grasshoppers did not require transformation.

Species evenness

Species evenness was described by the slopes of rank–abundance curves by pooling the data from the centre and edge of meadows. The rank-abundance curve was obtained by plotting the logarithm of the relative abundance of species against the logarithm of the species rank (Hayek & Buzas 1997; Magurran 2004).

To analyse the slopes, we used a hierarchical ANOVA with the two fixed factors region (REG, the three study regions Bauma, Ruswil and Flühli) and management (MANAG, ECA vs. conventionally managed meadows). In order to match the distributional assumption of ANOVA we transformed the data with the box-cox transformation as necessary (Sokal & Rohlf 1997). All slopes were negative and therefore they were multiplied by (–1) before box-cox transformation. The slopes for the evenness of plants, bees, grasshoppers and spiders were power-transformed (exponents –0·5, 0·2, 0·5 and 0·7, respectively).

Results

SPECIES RICHNESS

A total of 246 vascular plant species was recorded, with 159 species in Bauma, 173 species in Flühli and 109 species in Ruswil. The average number of species per meadow varied significantly between regions (Table 1). Significantly more plant species occurred in ECA than in conventionally managed meadows and significantly more also in the edge rather than in the centre of meadows (Table 1 and Fig. 1). This was mainly because of strongly positive edge effects in conventionally managed meadows, whereas the edge effects were smaller in ECA hay meadows (significant MANAG–POS interaction; Table 1 and Fig. 1). The effectiveness of the ECA treatment did not differ between the three study sites (no significant REG–MANAG interaction; Table 1 and Fig. 1).

In total, 18 species of grasshoppers were recorded, with 12 species in Bauma, 14 species in Flühli and six species in Ruswil. The average number of species per meadow varied significantly between regions (Table 1). Again, there were significantly more species found in ECA than in control meadows, but the number of species did not differ between meadow centre and edge (Table 1 and Fig. 1). The effectiveness of the ECA treatment was clearly visible in the two regions Bauma and Flühli but not in Ruswil (significant interaction REG × MANAG; Table 1 and Fig. 1).

A total of 49 species of wild bees was recorded, with 28 species in Bauma, 31 species in Flühli and 26 species in Ruswil. The average number of species per meadow did not vary significantly between regions (Table 1). For this group also, there were significantly more species in ECA than in conventionally managed meadows and the number of species did not differ between meadow centre and edge (Table 1, Fig. 1). There were no indications that edge effects differed between ECA and conventionally managed meadows.

A total of 103 species of spiders was identified, with 77 species in Bauma, 53 species in Flühli and 56 species

Table 1. Results of the analysis of variance (ANOVA) testing the effects of region (REG), ECA treatment (MANAG), and transect position (POS) on the species richness of vascular plants, grasshoppers, wild bees and spiders

		Vascular plants			Grasshoppers			Wild bees			Spiders		
	d.f.	MS	*F*	*P*	MS	*F*	*P*	MS	*F*	*P*	MS	*F*	*P*
REG	2	1·46	15·10	0·000	56·40	24·76	0·000	0·06	1·07	0·363	0·02	0·54	0·590
PAIR	18	0·10			2·28			0·05			0·04		
MANAG	1	1·73	29·11	0·000	19·05	42·11	0·000	0·17	4·78	0·042	2e-04	0·01	0·931
REG × MANAG	2	0·19	3·18	0·066	4·15	9·19	0·002	0·05	1·31	0·294	7e-04	0·04	0·966
PAIR(MANAG)	18	0·06			0·45			0·04			0·02		
POS	1	0·93	35·29	0·000	0·05	0·07	0·792	0·02	1·08	0·305	0·52	21·65	0·000
REG × POS	2	0·04	1·64	0·208	0·23	0·34	0·717	0·02	1·29	0·289	0·04	1·68	0·200
MANAG × POS	1	0·25	9·39	0·004	0·05	0·07	0·792	0·03	1·45	0·237	0·04	1·72	0·198
REG × MANAG × POS	2	0·02	0·69	0·506	0·08	0·12	0·884	0·01	0·65	0·530	0·02	0·96	0·392
Residuals	36	0·03			0·67			0·02			0·02		

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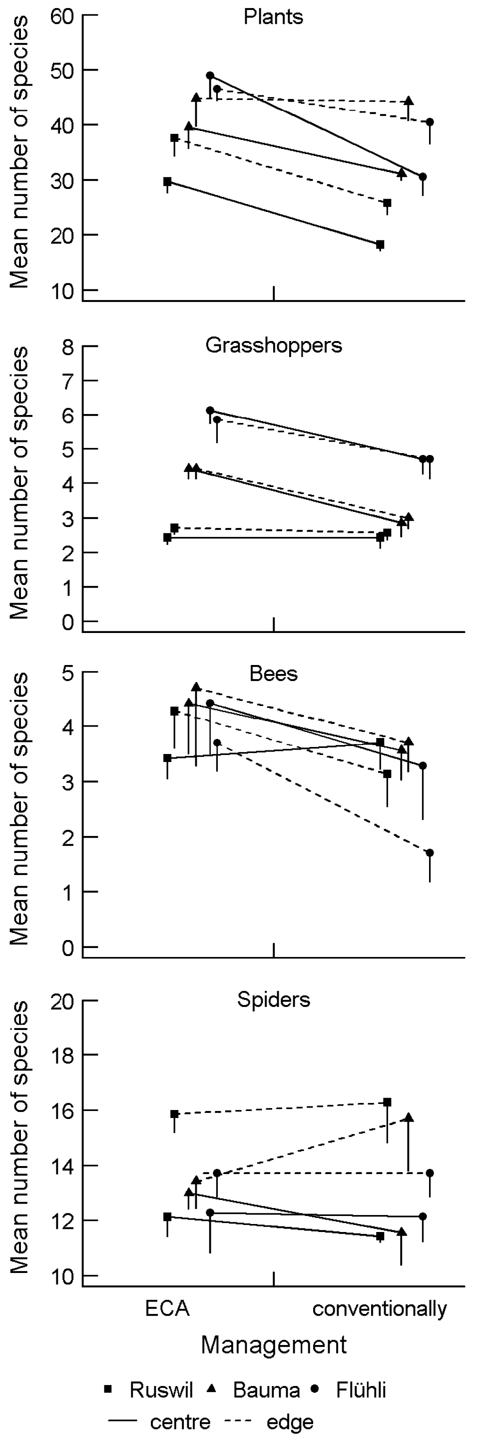

Fig. 1. Mean ± standard error of the number of species of vascular plants, grasshoppers, wild bees, and spiders per transect, for each of the three study sites, on ECA hay meadows (with agri-environment scheme) and on conventionally managed hay meadows (without agri-environment scheme) and in the centre or in the edge of the meadows ($n = 7$ for each mean). The lines are drawn to help the eye.

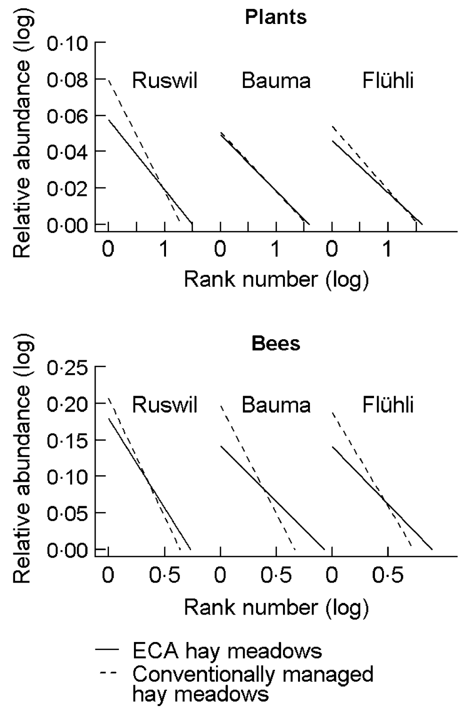

Fig. 2. The evenness (slope of the rank–abundance curve, $n = 7$ for each slope) of vascular plants and wild bees for each of the three study sites, on ECA hay meadows (within agri-environment scheme) and on conventionally managed hay meadows (without agri-environment scheme).

in Ruswil. The average number of species per meadow did not vary significantly between regions (Table 1). Only in this group did the number of species not differ between ECA and conventionally managed meadows (Table 1). Significantly more spider species were trapped in the edge than in the centre of the meadows, regardless of the type of management (Table 1 and Fig. 1).

SPECIES EVENNESS

The evenness of vascular plants did not vary between the three regions but was significantly higher in ECA than in conventionally managed meadows (Table 2 and Fig. 2). However, the nearly significant interaction between region and management indicated that the difference in evenness between ECA and conventionally managed hay meadows was larger in one area compared with others (Fig. 2).

In total, 791 individuals of grasshoppers were recorded in Bauma, 784 individuals in Flühli and 671 individuals in Ruswil. The evenness did not vary between regions or between the two management treatments (Table 2).

In total, 482 individuals of wild bees were recorded in Bauma, 212 individuals in Flühli and 896 individuals in Ruswil. Excluding *Apis mellifera* Linné, 184 individuals of wild bees were caught in Bauma, 89 individuals in Flühli and 134 in Ruswil. The evenness did not vary between the regions but evenness was significantly higher in ECA than in conventionally managed meadows (Table 2).

A total of 4118 individuals of spiders was caught in Bauma, 3225 individuals in Flühli and 6305 individuals in Ruswil. The evenness did not vary significantly between regions or management treatments (Table 2).

Table 2. Analysis of variance (ANOVA) testing the effects of region (REG) and ECA treatment (MANAG) on the slope of the rank-abundance curves of vascular plants, grasshoppers, wild bees and spiders

		Vascular plants			Wild bees			Grasshoppers			Spiders		
	d.f.	MS	*F*	*P*	MS	*F*	*P*	MS	*F*	*P*	MS	*F*	*P*
REG	2	4·75	11·75	0·081	0·01	0·66	0·755	0·09	6·93	0·133	1e-03	1·81	0·415
PAIR	18	0·4			0·01			0·01			6e-04		
MANAG	1	3·81	16·38	0·000	0·08	24·46	0·000	0·02	1·74	0·204	5e-04	1·06	0·317
REG × MANAG	2	0·81	3·47	0·053	0·01	3·24	0·063	0·05	4·37	0·028	1e-03	2·8	0·087
Residuals	18	0·23			3e-03			0·01			5e-04		

KENDALL'S RANK CORRELATIONS

Positive rank correlations in species richness were found between vascular plants and wild bees ($z_{1,84}$ = 2·13, P = 0·033) and between vascular plants and grasshoppers ($z_{1,84}$ = 5·13, P = 3E-07). With respect to species evenness, positive rank correlations were found between vascular plants and wild bees ($T_{1,42}$ = 580, P = 0·001) and between vascular plants and spiders ($T_{1,42}$ = 520, P = 0·033)

Discussion

The results confirm our first hypothesis, that species richness and evenness are generally higher on ECA hay meadows than on conventionally managed meadows. For plants this can be seen as an effect of lower fertilizer levels and later hay cutting on ECA hay meadows. The higher species richness of the two taxa at the second trophic level, bees and grasshoppers, can be interpreted as consequence of the greater diversity (richness and evenness) in plant food sources (Pfisterer, Diemer & Schmid 2003). The bottom-up effect of plant diversity on primary consumer diversity is further supported by the positive correlation of species richness between vascular plants and wild bees, and between vascular plants and grasshoppers, respectively. However, the ecological quality of the fields prior to the uptake of the scheme is unknown. It is possible that the less accessible and least productive sites, and therefore the most extensively managed, locations became ECA hay meadows. The more productive sites are likely to have remained conventionally managed (Kleijn & Sutherland 2003). Therefore, the positive effect of the agri-environment scheme on biodiversity might also be influenced by the baseline diversity prior to the ECA management.

The absence of an effect of ECA management on spider diversity and the lack of a significant correlation between plant diversity and spider diversity may be the result of the trophic difference between secondary consumers and primary producers (Pfisterer *et al*. 2005). An alternative explanation is that prey abundance and vegetation structure may be more relevant to spiders than plant species richness and prey diversity (Baines *et al*. 1998; Bell, Wheater & Cullen 2001). Indeed, the higher spider diversity in the meadow edge than in the centre of both ECA and conventionally managed meadows indicates that greater spider diversities can spill over from adjacent habitats. This is particularly true for habitats with richer vegetation structure such as uncut field margins and forest margins. However, it seems that species richness of spiders should not be used as an indicator for the quality of hay meadows with regard to ecological compensation.

The second hypothesis, that species richness is higher in the meadow edges compared with the meadow centres, was only confirmed for vascular plants and spiders. These results might be explained by spiders and plants spreading from species-rich meadow margins into the meadows (Dennis & Fry 1992; Marshall & Moonen 2002). In addition, more extensive management in the meadow edges (Melman & Van Der Linden 1988) might lead to a more diverse vegetation structure, which in turn is known to increase spider diversity (Bell, Wheater & Cullen 2001). Thus, it could be that the potentially more diverse vegetation structure in the meadow edges promotes more spider diversity than the current management restriction of the scheme. However, in contrast to the spiders, plant species richness in the centre of ECA hay meadows was higher than plant species richness in the edge of conventionally managed hay meadows. This may indicate that, for plants, the ECA hay meadows contribute more to the preservation of species richness than species-rich edges of conventionally managed meadows. Against our expectations, grasshoppers and bees showed no edge effect. It could be that our sampling method was inappropriate to detect differences within a meadow for these two highly mobile groups.

The third hypothesis, that ECA hay meadows are similarly effective in promoting biodiversity across sites, was confirmed among the three selected study regions for the species richness of all indicator groups except the grasshoppers. The significant interaction between management and region for the species richness of grasshoppers is probably a result of the generally low diversity levels at one of the three study sites, Ruswil (Fig. 1). This finding should be taken as a cautionary note that regional factors such as site conditions (Benton, Vickery & Wilson 2003), species pool (Partel *et al*. 1996) and management history (Poschlod & Wallis De Vries 2002) can sometimes confound the measured effectiveness of agri-environment schemes. Therefore, it might be necessary to adjust the schemes to compensate for these factors. However, such adjustment possibilities are poorly incorporated in existing Swiss and European agri-environment schemes. We therefore suggest implementing regional aspects in agri-environment schemes. A first step has been undertaken in Switzerland with the introduction of the by-law for ecological quality (Bundesrat 2001). This provides extra bonus payments for hay meadows (and other ECA types) if they comply with certain ecological quality standards. These standards can be adapted to regional conditions by the local authorities.

We conclude that the Swiss agri-environment scheme targeted at hay meadow conservation preserves biodiversity. The results contribute to the assessment of the Swiss agri-environmental policy, which is presently being reviewed, and supports the justification of further payments for the preservation of ECA hay meadows (Herzog *et al*. 2005). We recommend that farmers should be encouraged to engage in long-term extensive management.

Obviously, not all groups of organisms can be targeted with the same efficiency by a single scheme or using a single habitat type, as was the case here for spiders. The higher spider diversity in the edge of the meadows suggests that the current management restrictions are not sufficient with respect to vegetation structure. Therefore, spider diversity may be targeted by including additional management restrictions. These could include regulating not only the time of the first cut but also the frequency of the subsequent cuts. In addition, the mowing technique might be adjusted to benefit groups of organisms that particularly depend on vegetation structure.

We still do not know, however, whether the simple extensification measures prescribed by the ECA scheme are indeed bringing back the species that have been lost during the years of intensification (Schmid 2002) or whether they simply preserve the still existing diversity. Therefore, the most important places for the protection of typical grassland species are probably species-rich meadows that have never been intensively cultivated in the first place. These old species-rich meadows might be particularly important to guarantee a large species pool for seeding the ECA hay meadows.

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