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A Swiss agri-environment scheme effectively enhances species richness for some taxa over time

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Abstract

The effectiveness of agri-environment schemes (AESs) in promoting biodiversity was recently debated. One reason for limited effectiveness of AESs may be their application to small and scattered patches of land. This study presents the evaluation of a scheme adopted by the canton of Aargau, Switzerland, which seems to be unique in its consequent focus on entire farms, aiming at increasing quality and quantity of ecological compensated areas (ECAs). In vascular plants and snails, the species richness increased during a period of 5 years on plots with AES, but not on control plots without AES. In butterflies and birds, no significant differences were found between AES plots and control plots in the change of species richness over time. While butterfly species numbers generally decreased, bird species numbers increased on both AES plots and control plots. It appears that agri-environment schemes can be effective in protecting and promoting biodiversity, but the effect may depend on the group of organisms.

Keywords: Agri-environment scheme; Policy evaluation; Species diversity; Ecological compensated area; Aargau; Switzerland

1. Introduction

Most European countries have launched agri-environment schemes (AESs) more than one decade ago (Kleijn and Sutherland, 2003), and schemes currently cover more than 25% of all farmland in the EU15 countries (EU, 2005). The total average annual expenditure on agri-environment payments is estimated at € 3.7 billions for 2003 in the European Union (EEA, 2002). In the United States, for the period between 2000 and 2003, the expenditures averaged US$ 2.0 billions annually (Herzog, 2005). In the OECD (Organisation for Economic Cooperation and Development) countries, the expenses for AES sum up to about 8% of the total budget for agriculture (OECD, 2003).

Kleijn and Sutherland (2003) reviewed 62 studies evaluating European AES and pointed out that the majority of studies were inadequate to assess reliably the effectiveness of the AES because no baseline data were collected to examine trends in biodiversity over time (Kleijn and Sutherland, 2003; Herzog, 2005). The few studies that compared the change of species richness in AES fields and control plots included only few species groups (mainly plants and birds) or were located within or in the direct vicinity of nature reserves that were protected for a long time (Peter and Walter, 2001; Brereton et al., 2002). A particularly comprehensive study of several species groups in five European countries compared current species richness in AES plots with control plots, but did not include trends over time (Kleijn et al., 2006).

AES are often applied to small patches of land, which are referred to as ecological compensated areas (ECAs). Frequently, ECAs are scattered and unconnected, with negative influence on the effectiveness of AES in promoting

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biodiversity (Whittingham, 2007). In 1994, the canton of Aargau, Switzerland, started to establish an AES that was aimed to take this shortcoming of AES into account. The scheme was based on special contracts with farmers (Kanton Aargau, 2005). In addition to high standards concerning the quality of the ECA, the quantity and distribution of the ECA within the farm were evaluated and improved before a farmer could get a contract and additional payments. New ECAs were placed in a way to supplement and link existing ECAs or nature reserves in the area. If a farmer implemented a minimum proportion (currently 12%) of his farmland, he received an additional bonus.

Generally, ECA categories may differ in the way they affect species richness spatially or temporally, which often renders evaluating the success of the entire AES difficult. So far, AES evaluations mainly investigated the effect of single categories of ECA on species richness (Kleijn and Sutherland, 2003; Kleijn et al., 2006). However, it is often the general aim of an AES that all ECA categories taken together successfully increase species richness in the entire agricultural landscape.

Here, we present a long-term study evaluating the effects of the Aargau AES on the biodiversity of several trophic levels (primary producers: vascular plants; pollinators: butterflies; first level consumers: snails; top level consumers: birds). Sampling plots based on a regular grid were selected from the entire surface of the Aargau agricultural landscape, and species richness per study plot at an initial phase of the AES was compared with the species richness 5 years later. The effects of the AES were then tested against the change of species richness in conventionally used agricultural areas.

2. Material and methods

The canton of Aargau is a 1403 km^2 sized county in the north of Switzerland with relatively large areas of intense farming. More than half of the farmlands are meadows or pastures (53%), and most of the rest is arable land (44%; mainly maize, wheat, barley, potatoes, sugar beets, and rape). Farmland size of an average farm in the canton of Aargau is 20.8 ha (all figures from Swiss Statistics, www.bfs.admin.ch). The focus of the Aargau AES was on entire farms, aiming at increasing the quality and quantity of ECA (Kanton Aargau, 2005; Schmid et al., 1990). To implement an efficient strategy, farmers that joined the AES in Aargau were advised by persons with ecological and agricultural education. The ecological potential of the entire land of a farm was assessed with a particularly close look at the grassland, on which a plant inventory was taken. Farmer and adviser collaborated in devising how to realise an environmentally and biodiversity friendly farming practice and a target-oriented management of the ECA. On each farm, ECAs were established on the most promising areas (in terms of maximum biodiversity gain and not in terms of the economic perspective of the farmer). Care was taken that ECAs were grouped close together and that the surrounding farmland of the farm under contract was less intensively farmed (mainly by reducing the use of fertilizers). Making a contract secured additional payments, and farmers committed themselves to strict ecological measures for at least 6 years. General payments were made for the entire surface of a farm to compensate for the generally environmental friendly farming practice, and additional payments were made for each ECA depending on the category of the ECA. The average year (±S.D.) of contract starts of the ECA situated within our study plots (see below) was in July 1995 (±3.2 years). At the end of 2006, more than 530 farmers had agreed on such a contract, and the surface of those farms was about 20% of the Aargau agricultural landscape. The average area of ECA of the farms under contract amounted to 23% of their land and to 2565 ha in total.

In 1996, a long-term research project was started to monitor biodiversity in the whole canton of Aargau (Stapfer, 1999). We used the data from this biodiversity monitoring program to investigate the impact of the Aargau AES on biodiversity. The sampling scheme was based on a regular grid that covered the entire canton. Based on the national coordinate system, 516 grid points were selected by taking every second grid point of a grid with 1 km grid length. On each study plot at such a grid point, vascular plant, snail, butterfly and bird species were counted twice, the first time between 1996 and 2000 (1998 and 2000 for butterflies) and the second time between 2001 and 2005 (2003 and 2005 for butterflies). For each study plot, there were exactly 5 years between the first and the second census period. The sampling protocol was adapted to the different species groups, and sampling was done at two different spatial scales: On the small scale, vascular plants and snails were surveyed. Plants species were counted in a circle of 10 m^2, and on the outer line of the circle in which plant species were counted, eight soil samples were taken during the plant surveys and the number of snail species was estimated from these soil samples. On the larger scale, bird species were estimated from five surveys in a circle with 100 m radius, and for butterflies, 11 surveys were made along a transect of 250 m length (butterflies were recorded within 5 m to each side of the transect line). If possible, all individuals within the study plots of the four species groups were identified to the species level. The few individuals not identified to the species level were excluded from the data. Land use information for each study plot was collected during the first visit. For the present study, only plots with at least 75% agricultural land use were included into the analyses. A few surveys not fulfilling the criteria of the sampling protocol were excluded from the analyses (see Table 1 for the sizes of each data set).

For the analysis, the study plots were divided into two groups: if there was ECA within a plot, independently of the category and the size of ECA, the plot was included into the treatment group (AES plot). If there was no ECA within the plot, the plot was included into the control group. Because the plot size depended on the study group, the study plots were divided into treatment and control groups for each species group separately: The study plots of plants and snails were included into the treatment group if there was ECA

Table 1
Sample sizes and mean species numbers (±S.D.) of all study plots at the initial survey (number of species A) and at the second survey 5 years later (number of species B)

Species group	Number of treatment plots	Number of control plots	Number of species A	Number of species B
Vascular plants	33	211	15.3 (±8.7)	16.2 (±9.8)
Snails	33	209	4.1 (±4.3)	3.9 (±4.9)
Butterflies	52	35	6.7 (±3.7)	5.6 (±3.4)
Birds	120	61	9.0 (±4.3)	11.5 (±4.4)

within the study circle of 10 m^2. Similarly, the study plots of birds were included into the treatment group if there was ECA within the 100 m circle. For the butterflies, a study plot was included into the treatment group if there was ECA within 50 m of the transect. This approach using two spatial scales implies that the proportion of study plots that were included into the treatment groups differed among taxa: for plants and snails, 14% of the study plots were included into the treatment group, while for birds and butterflies, 60 and 66%, respectively, were included into the treatment group (Table 1). Furthermore, the mean proportion of a study plot area covered by ECA differed among species groups. For vascular plants and snails, the mean (±S.D.) proportional area of ECA within a study plot was 89.9% (±26.4), for butterflies 13.3% (±15.6), and for birds 16.7% (±18.5) (reference date: 31-12-2005). Differences in species numbers per plot between the two groups (treatment and control) were tested using Wilcoxon rank sum tests.

Within or in the surroundings of the study plots, defined as a circle of 500 m radius around the centre of the sample plot, ECA had been established in 129 (53%) of the 244 study plots (reference date: 31-12-2005) and the overall surface of the ECA per circle ranged from 0.07 to 29.9 ha. The total area of the ECA within the 500 m circles was 592.0 ha, of which 308.8 ha (52.2%) were low intensity hay or litter meadows, 186.8 ha (31.6%) hedges, traditional orchards or trees, 43.6 ha (7.3%) pastures, and the remaining 52.8 ha (8.9%) of other categories such as wild flower strips, arable fallows or ruderal areas.

To examine the change of single species, the number of study plots in which a particular species was not observed during the first study period but was observed during the second study period (increase) were compared with the number of study plots in which the species was observed during the first but not during the second study period (decrease). This was done for all observed species, and numbers of increase and decrease were evaluated using McNemar tests (Zar, 1999). All analyses for this study were done using the software R 2.4.0 (R Development Core Team, 2006).

3. Results

During the first study period, three of the four species groups (plants, butterflies and birds) showed significantly higher species richness in study plots with ECA compared to control plots (all numbers mean (±S.D.), p-values from Wilcoxon rank sum tests; vascular plants: ECA = 19.2 (±9.9), control = 14.6 (±7.9), $p = 0.007$; snails: ECA = 5.0 (±4.3), control = 4.0 (±4.3), $p = 0.097$; butterflies: ECA = 7.3 (±3.8), control = 5.6 (±3.1), $p = 0.014$; birds: ECA = 9.7 (±4.0), control = 7.7 (±4.4), $p = 0.004$). Between the first and the second study period, the species richness of vascular plants and snails increased on plots with ECA, but not on control plots without ECA (Fig. 1). In study plots with ECA, the increase in species numbers of plants and snails per study plot was on average 5.1 species (relative increase: 26.9%) and 1.4 species (27.2%), respectively. The number of bird species per study plot increased significantly in the agricultural landscape of Aargau (mean increase of all study plots between 1996–2000 and 2001–2005: 2.05 species, $n = 181$, Wilcoxon signed rank test: $p < 0.001$). However, the increase in bird species numbers in plots with ECA was not different from control plots (Fig. 1). The number of butterfly species generally decreased in the agricultural landscape of Aargau, irrespective of whether the study plots included ECA or not (mean decrease of all study plots between 1998–2000 and 2003–2005: −1.13 species, $n = 87$, Wilcoxon signed rank test: $p < 0.001$). The decrease in butterfly species numbers in plots with ECA was not different from control plots (Fig. 1). In the agricultural landscape of Aargau, 16 species increased significantly (5 plant species, 3 butterfly species, 8 bird species), while 18 species decreased significantly (12 plant species, 1 snail species, 5 butterfly species; for tests and details, see Appendix A).

4. Discussion

During the first study period, which corresponded to an early state of the AES, three of the four species groups (plants, butterflies and birds) showed significantly higher species richness in study plots with ECA compared to control plots. Thus, the study plots with ECA could have profited from the AES already at this early stage of the contracts. Alternatively, the higher initial species richness could reflect the fact that ECAs were established mainly in ecologically more valuable agricultural areas. In the present study, the initial dissimilarity among plots was controlled for by comparing the temporal change of species richness on both the AES and control plots (Kleijn and Sutherland,

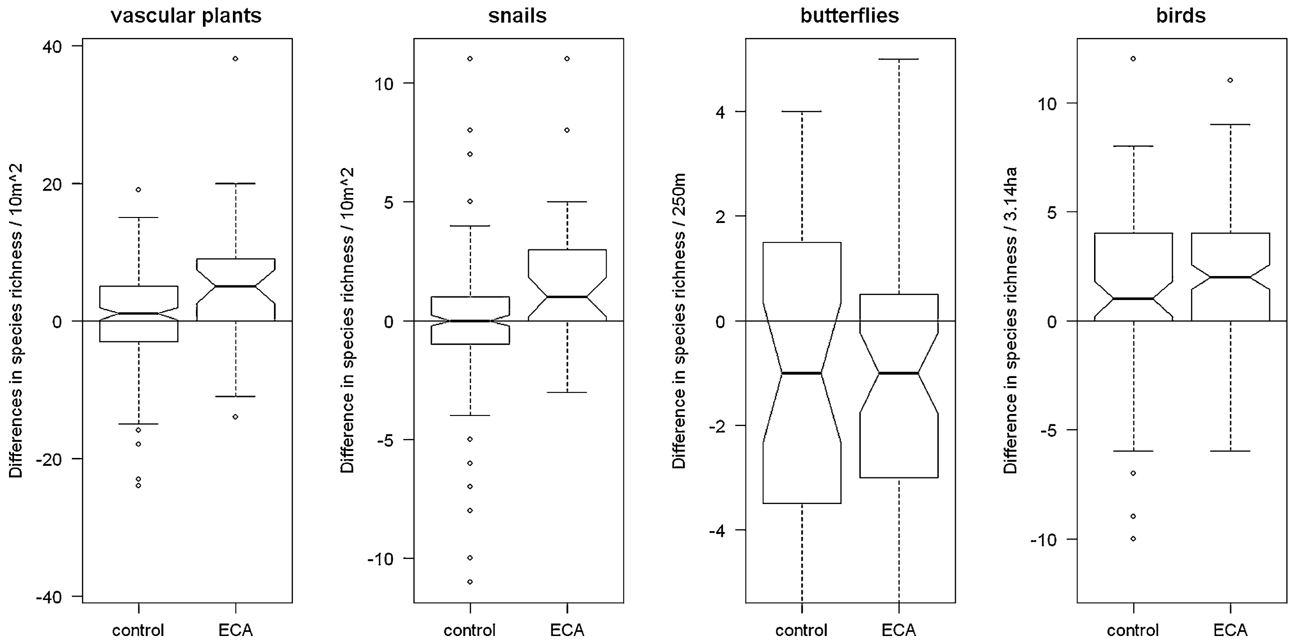

Fig. 1. Change of species richness over time. Notched box-plots show the differences of species richness per study plot between the two study periods (initial survey 1996–2000 and repeated survey 2001–2005 for vascular plants, snails and birds; 1998–2000 and 2003–2005 for butterflies). For each study plot, there were exactly 5 years between the first and the second census period. ECAs are study plots with ecological compensated area, and controls are study plots without ecological compensated area. For sample sizes, see Table 1. Boxes are median and 25th and 75th percentiles, whiskers are non-outlier ranges, dots are outliers, and non-overlapping notches indicate significant differences in central tendency (Wilcoxon rank sum tests: vascular plants: $p = 0.005$; snails: $p = 0.012$; butterflies: 0.607; birds: 0.429).

2003). Between the first and the second study period, the species richness of vascular plants and snails increased on plots with ECA, but not on control plots. Therefore, this study suggests that the AES in the canton of Aargau effectively enhanced species diversity for vascular plants and snails. Studies testing for an effect of AES on biodiversity have regularly investigated plant species numbers and often found that it is difficult to enhance plant species diversity in intensively used agricultural landscape (Kleijn and Sutherland, 2003). This conclusion is in contrast to our results and to the results from another study in Switzerland that confirmed higher species richness of vascular plants on ECA compared to conventionally managed fields (Knop et al., 2006).

Herzog et al. (2005) found almost no general benefits of ECA for grassland birds and orchard birds in the agricultural landscape of the entire Switzerland. In contrast, we found that in the agricultural landscape of the canton of Aargau, the bird species richness per study plot increased, and the negative trend in the number of bird species found on a larger scale may have been reversed (Zbinden et al., 2005; Donald et al., 2006). Three of the eight bird species for which a positive trend could be identified were proposed as indicator species for agriculture landscapes (*Columba palumbus*, *Passer montanus* and *Emberiza citrinella*; Gregory et al., 2005). The farms under contract covered around 20% of the Aargau agricultural landscape and provided resources that are most valuable for farmland birds (e.g. fallows, non-cropped habitats, or extensively managed grassland; Vickery et al., 2004).

However, the similarly mobile butterfly species decreased in the canton of Aargau irrespective of the AES. This is an alarming result, as butterfly diversity is at a very low level and generally decreases in the Central Plateau of Switzerland (Koordinationsstelle Biodiversitätsmonitoring Schweiz, 2006), and the AES was apparently not able to stop this decrease so far. Note, however, that the differences of the responses to the Aargau AES in the four species groups may be partly explained by differences in the plot sizes. ECA covered most of the area of the small sized study plots for plants and snails, but only a smaller fraction of the larger study plots for birds and butterflies. Therefore, the larger proportion of conventional land use within the study plots for birds and butterflies may have blurred the effect of AES.

In the majority of cases, the general goal of AES is to protect and increase overall species diversity (Kleijn and Sutherland, 2003) and not to protect a single species group (e.g. Ottvall and Smith, 2006) or a particular species (e.g. Peach et al., 1998; Aebischer et al., 2000). However, our study showed that the effect of AES on biodiversity may vary depending on the group of organisms. This was also found in other studies including more than one species group to investigate the effect of AES on biodiversity (Kleijn et al., 2001, 2006; Knop et al., 2006). Therefore, if the goal of AES is to protect general biodiversity, then the effectiveness of an AES can only be assessed adequately if several indicator species groups are included into the study.

Less mobile species groups are likely to benefit from an AES only if ECA plots are close to each other (Ockinger and

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Smith, 2007). In the canton of Aargau, the species richness per study plot increased among the less mobile species (plants and snails), which suggests that the aims of the Aargau AES to connect ECA were achieved. The effect of the Aargau AES was not tested against the effect of other conventional AES, and the average farm in the canton of Aargau is small compared to farm sizes in other parts of Europe. However, the Aargau AES with its contracts focussing on entire farms instead of single fields and its effort to connect ECA seem to have had positive effects at least on parts of biodiversity measures and may be regarded as a model for other regions and countries.

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Appendix A

Species for which a significant trend between the first study period and the second study period 5 years later could be detected (change) in the agricultural landscape of the canton of Aargau. Number of study plots in which a particular species was not observed during the first study period but was observed during the second study period (increase) were compared with the number of study plots in which the species was observed during the first but not during the second study period (decrease). The significance of the trends was tested using McNemar tests.

Species	Change	Increase	Decrease	χ^2	*p*-Value
Plants					
Bromus hordeaceus	+	22	8	5.63	0.018
Phleum pratense	+	28	10	7.61	0.006
Poa trivialis	+	75	35	13.83	<0.001
Veronica arvensis	+	36	1	31.24	<0.001
Veronica chamaedrys	+	27	8	9.26	0.002
Achillea millefolium	−	0	7	5.14	0.023
Cardamine pratensis	−	12	34	9.59	0.002
Galinsoga ciliata	−	0	7	5.14	0.023
Helictotrichon pubescens	−	6	18	5.04	0.025
Lolium multiflorum	−	34	59	6.19	0.013
Matricaria recutita	−	4	16	6.05	0.014
Poa annua	−	31	55	6.15	0.013
Poa pratensis	−	7	54	34.69	<0.001
Polygonum persicaria	−	11	27	5.92	0.015
Rumex obtusifolius	−	15	31	4.89	0.027
Taraxacum officinale	−	30	62	10.45	0.001
Veronica persica	−	12	91	59.07	<0.001
Snails					
Carychium tridentatum	−	16	35	6.35	0.012
Butterflies					
Cynthia cardui	+	19	7	4.65	0.031
Gonepterix rhamni	+	6	0	4.17	0.041
Lasiommata megera	+	9	0	7.11	0.008
Aphantopus hyperantus	−	4	21	10.24	0.001
Colias hyale/alfacariensis	−	5	20	7.84	0.005
Inachis io	−	4	22	11.12	0.001
Mellicta parthenoides	−	0	10	8.1	0.004
Pararge aegeria	−	1	27	22.32	<0.001
Birds					
Dendrocopos major	+	24	11	4.11	0.043
Passer montanus	+	30	13	5.95	0.015
Emberiza citrinella	+	27	11	5.92	0.015
Turdus viscivorus	+	28	12	5.63	0.018
Sylvia atricapilla	+	29	8	10.81	0.001
Columba palumbus	+	47	11	21.12	<0.001
Erithacus rubecula	+	21	8	4.97	0.026
Parus palustris	+	27	13	4.23	0.04

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