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Butterfly diversity in Swiss grasslands: respective impacts of low-input management, landscape features and region

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Abstract
In order to enhance agro-biodiversity, Swiss farmers have to convert 7% of the arable land into low-input habitats, namely ecological compensation areas (ECA). This agri-environmental programme is of high scientific interest as it permits to assess and quantify the effects of farming practices at the local and landscape scales. This study aimed at testing the effects of low-input management of grassland on butterfly diversity at the local and the landscape scale in three Swiss farming regions. Low input grasslands did not have a higher butterfly diversity than intensive grasslands, despite a higher species richness in one year. However, butterfly assemblages varied according to the landscape pattern, namely the amount of low-input habitats, intensive grasslands, crops and forest in the surrounding landscape, and to the regional localisation. Regional differences can be explained by the type and intensity of agricultural production and by landscape features at the regional scale. Recommendations for the further development and regionalization of the Swiss ECA scheme are derived.

Key-words: low-input grasslands, agri-environmental scheme, butterfly diversity, landscape features.

Introduction

Butterflies are good indicators for biodiversity in agricultural landscapes. They require a combination of different types of habitats (Ouin *et al*, 2004) and some butterflies can be considered as 'flagship species' as they are perceived by the wider public. Butterflies are one of the species groups which suffered from agriculture intensification. They are affected by intensive or badly-timed farming practices (pesticides, mowing, fertilisation) (Oates, 1995) and by the reduction and spatial isolation of habitats at the landscape scale (Wettstein and Schmid, 1999). In Switzerland, 7% of farmland is converted into ecological compensation areas (ECA), low-input grasslands making up the major part of ECA. In order to halt the loss of agro-biodiversity, ECA are submitted to restricted fertilisation and pesticide use, and to late mowing. This agri-environmental programme can be regarded as a real landscape restoration experiment at a large scale and permits to assess the effects of farming practices at both local and landscape scales. Identifying the scales at which species respond to low-input management is crucial as it will determine the appropriate scales for establishing management schemes. This study aimed at assessing the effect of low-input grasslands on butterflies in three regions of the Swiss Plateau. The questions we wanted to answer were: Does low-input grasslands have higher butterfly diversity than intensive ones? Does the amount of low-input grasslands at the landscape scale affect butterfly diversity? What are the respective impacts of low-input management at local scale, landscape characteristics and regional localisation?

Material and methods

The study was conducted in three 7-8km² regions of the Swiss Plateau. Farming systems consist in mixed cattle-crop production in region 1, milk-cattle production in region 2 and cash-crop production in region 3. The three regions also have different landscape pattern (table 1): region 1 is characterised by a mixture of crops and grasslands (4% of low-input grasslands), region 2 is characterised by many crops and a few grasslands (1% of low-input grasslands), whereas region 3 has more grasslands (3% of low-input grasslands) and traditional orchards.

Table 1. Proportion of area covered by grasslands, orchards, crops, forest and other land-uses in the three studied regions.

Land-use	Region 1	Region 2	Region 3
Grasslands (%)	26.5	7.3	48.9
Traditional orchards (%)	1.5	0.0	8.4
Crops (%)	38.4	52.4	18.1
Forest (%)	27.3	25.1	18.5
Others (%)	6.4	15.2	6.0

During summers 2000 and 2002, butterflies were recorded in 21 low-input grasslands (LIG) and 16 intensive grasslands (INTG) in region 1, in 14 LIG and 12 INTG in region 2 and in 21 LIG and 20 INTG in region 3. Landscape characteristics were described using Geographic Information Systems (GIS). Several landscape descriptors were calculated on land-use maps: (i) the percentage of the different ECA types (low-input grasslands, traditional orchards, flower strips, hedgerows), of crops and of forest in 200m buffers around sampled grasslands and (ii) the Euclidian distance from sampled grasslands to the nearest forest edge, as a measure of grassland isolation from (semi-)natural habitats. The effects of management intensity (low-input vs. intensive), landscape descriptors and region were tested on the species richness using analysis of covariance (ANCOVA). Redundancy analysis (RDA) and partial RDA were used to test the effects of environmental variables on butterfly species assemblages (Ter Braak, 1996). The length of the environmental gradient was short, suggesting a linear response of species to environmental variables. Redundancy analysis is a linear and constrained ordination method which is appropriate in this context. Selection of significant variables was first performed in RDA using Monte-Carlo permutations. A hierarchy of management, landscape and regional variables was then established with a partial RDA: the variance explained by each variable and its significance (Monte Carlo permutations) was obtained after eliminating the variance due to the other variables, which were used as covariables (partial variables).

Results and discussion

Forty one butterfly species corresponding to 7,314 individuals were observed in the three regions in 2000 and 2002. Butterfly species richness was influenced by management intensity in 2002 (ANCOVA, $P = 0.001$) but not in 2000 (ANCOVA, $P > 0.05$): low-input grasslands had higher numbers of butterfly species than intensive grasslands in 2002. None of the landscape descriptors did affect significantly the number of butterfly species, either in 2000 or 2002 (ANCOVA, 2000 and 2002: $P > 0.05$). Butterfly species richness was higher in region 1 than in region 2 and 3 (ANCOVA, 2000: $P < 0.001$, 2002: $P < 0.001$).

Environmental variables explained 40.2% and 48.6% of the variation in butterfly assemblages in 2000 and 2002 respectively (RDA, Mont-Carlo permutations, $P = 0.002$). After elimination of interactions between variables in partial RDA, the greatest part of variance of butterfly assemblages was explained by regional localisation (29.5% in 2000 and 2002; Monte-Carlo permutations, P = 0.002). Landscape characteristics explained a lower but significant part of variance (8.5% in 2000 and 7% in 2002; Monte-Carlo permutations, P = 0.002). Butterfly assemblages were not significantly influenced by grassland management (1.9% of variance in 2000 and 0.9% in 2002; Monte-Carlo permutations, P > 0.05).

Figure 1 illustrates the results of RDA performed with significant variables in 2000. The first RDA axis expressed the influences of region and landscape pattern around grasslands. Along this axis, grasslands were differentiated into three groups according to their regional localisation. Axis 1 also differentiated grasslands surrounded by low-input grasslands (200m radius) from grasslands surrounded by many orchards (200m radius). This effect of the landscape characteristics along first RDA axis reflects partly the differences between regions 1 and 3 in the amount of traditional orchards (higher in region 3) and low-input grasslands (higher in region 1).

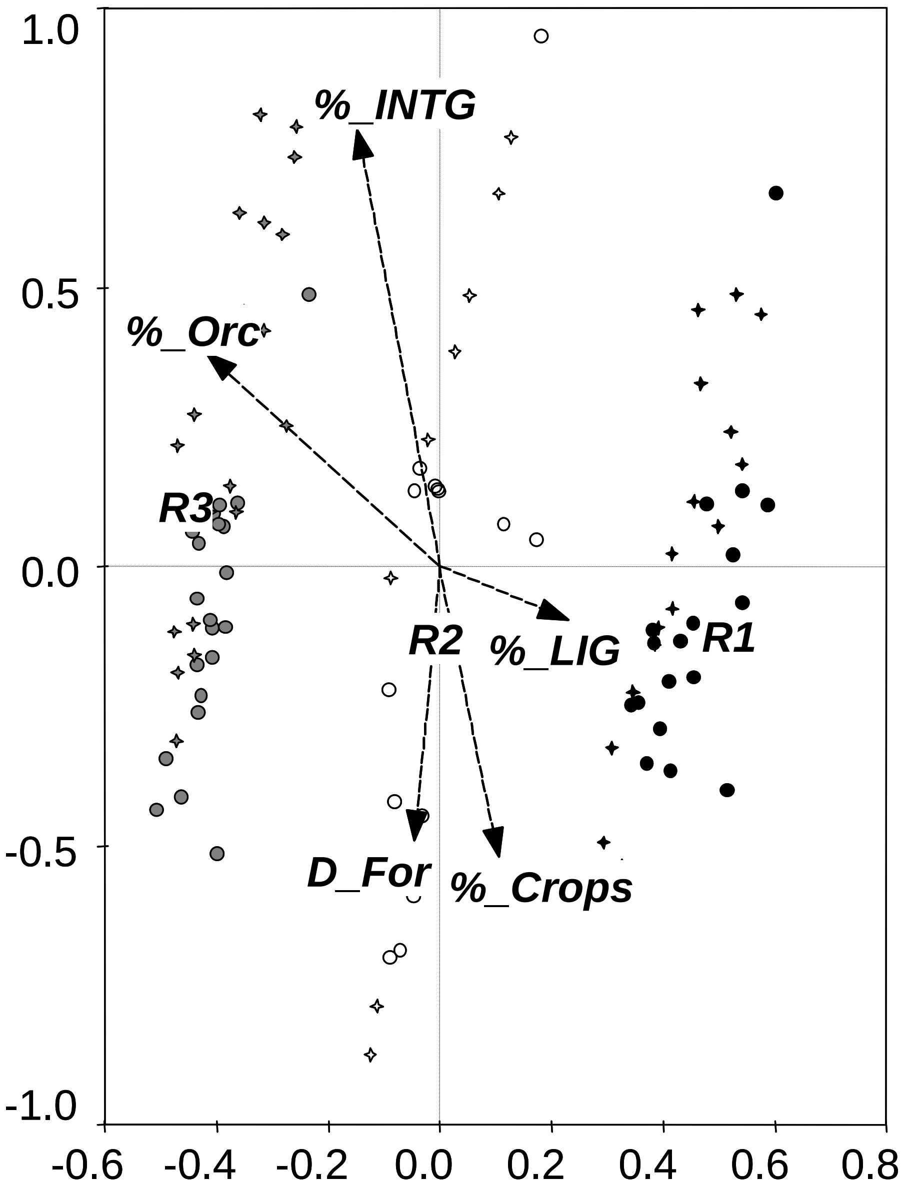

Figure 1. RDA ordination diagram of grasslands based on the butterfly assemblages in 2000 (axes 1 and 2). Significant environmental factors are represented by their centroid on the diagram: R1 = region 1, R2 = region 2, R3 = region 3, D_For = distance to the nearest forest, P_For = percentage of forest (200m), P_LIG = percentage of low-input grasslands (200m),

P_Orc = percentage of orchards (200m), P_INTG = percentage of intensive grasslands (200m), P_Crop = percentage of crops (200m). Sampled grasslands are represented according to their management and regional localisation: circles = low-input grasslands, stars = intensive grasslands; black symbols = region 1, empty symbols = region 2, grey symbols = region 3.

The second RDA axis was associated with an effect of the landscape characteristics: grasslands embedded in cropped areas and far from forest edges were opposed to grasslands surrounded by many intensive grasslands. The RDA diagram in 2002 showed similar results and is not presented.

Conclusion

Management intensity did not influence the composition of butterfly assemblages in grasslands, although the number of butterfly species was higher in low-input grasslands in one year. However, species assemblages were influenced by the amount of low-input grasslands at the landscape and regional scales. They were also dependant on the amount of crops vs. intensive grasslands in the surrounding landscape. The three regions had different sets of species. Regional differences can be explained by the type of agriculture production and by landscape characteristics at the regional scale, but might also be linked to regional differences in abiotic conditions . The results suggest that the ecological compensation programme should not only focus on low-input management at the local scale but should also promote a connected network of low-input habitats at the landscape and regional scale.

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