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Are butterflies and moths suitable ecological indicator systems for restoration measures of semi-natural calcareous grassland habitats?

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ABSTRACT

The selection of suitable ecological indicator groups is of great importance for environmental assessments. To test and compare two such groups, we performed transect walks of butterflies and light traps of moths at eight sample localities in the Carinthian Alps. All of them were conducted with identical methods in the years 2002 and 2004 allowing the evaluation of the response on the conservation measures performed on five of the eight sites in late 2002. We recorded a total of 2346 butterflies (including Zygaenidae and Sesiidae) representing 83 species and 7025 moths of 534 species. 150 of these species were listed in the Red Data Book of Carinthia. In general, butterflies increased from 2002 to 2004 while moths declined. The highest increase rates of butterflies were obtained for the numbers of individuals of calcareous grassland specialists at the conservation sites, while their numbers were unchanged at the control sites. Similar trend differences between conservation and control sites were obtained for the Red Data Book butterfly species. On the contrary, the development of moth individuals was more positive at the control than the conservation sites for calcareous grassland specialists (only macro-moths) and species of the Red Data Book. However, change rates of species numbers were positively correlated between butterflies and moths. Principal Component Analysis revealed strong differences between the different sites, but mostly consistent results for butterflies and moths; however, stronger differences between years were only detected for some of the conservation sites for the butterfly communities. Our results show that butterflies as well as moths are suitable ecological indicator groups, but they do not yield identical results. Thus, butterflies are more suitable for the analysis of open habitats, whereas moths are suitable for open and forested habitats as well. Furthermore, butterflies might be a more sensitive indicator group than moths for the short-term detection of conservation measures, especially for the restoration of open habitat types.

1. Introduction

Biodiversity has become broadly recognised by the public since the Rio Conference in 1992, and the necessity of its worldwide conservation is widely accepted. However, the respective conservation focus has to differ considerably all over the world. In most regions, main conservation efforts have to be paid on the preservation of natural ecosystems like tropical rainforests, boreal forests, savannahs etc. (e.g. Groombridge, 1992; Lawton et al., 1998). However, the European perspective is rather different because most of the natural habitats have been displaced by cultivated areas based on Europe's history of long lasting land-use. Over longer time periods, many of these traditional agricultural landscapes have developed into species-rich habitats of high conservation value (Cremene et al., 2005; Schmitt and Rákosy, 2007).

Among these man-made landscapes, semi-natural calcareous grasslands belong to the most species-rich habitat types of Europe (WallisDeVries et al., 2002; Van Swaay, 2002; Ulrich, 2003; Varga and Rakosy, 2008). Their conservation and restoration is required in the Habitat Directive of the European Union, and calcareous grasslands therefore are in the focus of governmental and non-governmental nature conservation (Dolek and Geyer, 2002). However, the best biodiversity conservation strategies for these habitats are still debated due to the diverging ecological requirements of the different taxonomic groups (Baur et al., 1997; Zschokke et al., 2000). The restoration of such habitats therefore is still controversially discussed. Especially the time necessary for the successful transformation of degraded habitats into species-rich calcareous grasslands is under current discussion (Weidemann, 1986; SBN, 1987; Ebert and Rennwald, 1991; Cremene et al., 2005). Further, the question of the best suited taxonomic

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groups for monitoring of habitat quality and restoration is still unresolved.

Lepidopterans in general are accepted as sensitive indicators of environmental quality and changes (Erhardt, 1985; Kudrna, 1986; Kiser, 1987; Porter et al., 1992; Thomas, 2005; Wirooks, 2005), but the diurnal butterflies and the nocturnal moths are strongly different, especially as field methodologies for their recording are strongly diverging. It is therefore widely unknown whether results obtained in both groups have similar indicator functions and values (Collins and Thomas, 1991; Ebert, 1994). We therefore present comparative analyses of butterfly transect walks and moth light trapping in this article. As a case study, we monitored the process of calcareous grassland restoration in Carinthia, southeastern Austria. The five analysed restoration sites were heavily overgrown and partly afforested calcareous grasslands representing the gradient from wet to dry. Restoration measures took place in late autumn 2002. As a control, we also studied three not restored sites. We tested the short-term conservation effects by making semi-quantitative inventories of day-active butterflies (transect walks combined with pheromone exposure) on the one hand and automated light trapping for moths on the other. At one side, a light tower was operated beside the automated light trap for means of comparison between these two methodological approaches. Burnet and clearwing moths as day-active Lepidopterans were included in the group of butterflies sensu lato, whereas all other micro- and macro-lepidoptera were considered in the group of moths. We compared the differences between conservation and control sites, butterflies and moths as well as calcareous grassland specialists and non-specialists.

These data sets and analyses allow us to address several questions: Are butterflies and moths equally sensitive and applicable as ecological indicator groups? Do restoration measures have significant short-turn effects on these two groups? Are the desired effects of increases, in number and in population density, of calcareous grassland specialists (which are often listed in Red Data Books) achieved in such a short time period?

2. Materials and methods

2.1. Study sites

We selected eight sampling sites located at the southern slope of the Dobratsch massive (Central Carinthia, SE Austria). The minimum distance between these sites was 400 m between sites 1 and 2, but more than 4 km in all other cases. At five sites (1–5), restoration measures were performed in autumn 2002; the other three sites (C6–C8) served as control sites. In the following, the characteristics of these eight sites and the respective restoration activities are described.

1. *Napoleonwiese I*: This site represented fallow grassland with developing *Betula pendula*, *Populus tremula* and *Quercus robur* bushes. The understorey was built by grasses and high-growing herbs. In autumn 2002, the *B. pendula* and *P. tremula* plants were removed to conserve and restore semi-natural calcareous grasslands. At this site, an automated light trap and a manually collected light tower were run in parallel.
2. *Napoleonwiese II*: A *Picea abies* monoculture (age 30 and more years) with some few individuals of *B. pendula* and *Q. robur* and almost no herbaceous understorey has been changed into a mosaic of deciduous trees and calcareous grassland areas by removing the coniferous trees in autumn 2002. The restoration of flower-rich grasslands was initiated by sowing seed mixtures composed of typical calcareous grassland species.

Table 1
Means (±sd) of the individuals and species numbers of butterflies and moths in the years 2002 prior and 2004 after conservation measures. Five of the eight sites in the Carinthian Alps were conservation sites, three controls. Specialists of calcareous grassland habitats were considered as target species. Micro-moths were not included in the distinction between target and non-target species.

	All			Conservation sites			Controls		
	2002	2004	Change (%)	2002	2004	Change (%)	2002	2004	Change (%)
Individuals all	530 ± 254	471 ± 324	−11.1**	628 ± 260	555 ± 380	−11.6**	365 ± 158	331 ± 175	−9.3
Species all	148.8 ± 56.1	135.9 ± 59.9	−8.7***	160.6 ± 64.6	144.0 ± 69.9	−10.3***	126.3 ± 39.9	122.3 ± 48.6	−3.2
Individuals butterflies	129 ± 145	164 ± 144	+27.5***	168 ± 170	215 ± 155	+28.1**	64 ± 71	80 ± 81	+25.0(*)
Species butterflies	23.8 ± 19.5	29.5 ± 16.5	+23.9(*)	27.8 ± 23.6	34.2 ± 17.9	+23.0	17.0 ± 10.8	21.7 ± 13.1	+27.6
Individuals moths	401 ± 191	308 ± 194	−23.2***	461 ± 215	342 ± 236	−25.9***	301 ± 103	251 ± 109	−16.4
Species moths	124.1 ± 39.4	106.6 ± 45.7	−14.1***	133.0 ± 44.2	110.0 ± 53.8	−17.3***	109.3 ± 31.5	100.7 ± 38.0	−7.9(*)
Individuals target	42.5 ± 38.6	65.0 ± 91.1	+51.9*	49.4 ± 44.8	82.4 ± 113.1	+66.8(*)	31.0 ± 30.0	36.0 ± 38.0	+16.1
Species target	16.5 ± 12.0	14.9 ± 11.2	−9.7	19.2 ± 13.6	16.2 ± 12.9	−15.6	12.0 ± 9.5	12.7 ± 9.7	+5.8
Individuals non-target	353 ± 169	297 ± 196	−15.9(*)	418 ± 172	345 ± 227	−17.5*	243 ± 110	218 ± 128	−10.3
Species non-target	86.6 ± 31.1	85.1 ± 38.2	−1.7**	93.0 ± 36.5	89.0 ± 46.2	−4.3***	76.0 ± 22.3	78.7 ± 27.0	+3.6
Individuals butterflies target	20.3 ± 23.7	38.6 ± 60.1	+90.1**	23.6 ± 25.4	52.8 ± 73.8	+123.7**	14.7 ± 24.5	15.0 ± 20.2	+2.0
Species butterflies target	5.63 ± 6.35	6.25 ± 5.55	+11.0	7.20 ± 7.26	7.40 ± 6.02	+2.8	3.00 ± 4.36	4.33 ± 5.13	+44.3
Individuals butterflies non-target	109 ± 125	126 ± 91	+15.6*	144 ± 148	162 ± 90	+12.5(*)	49.3 ± 46.9	65.0 ± 64.2	+31.8(*)
Species butterflies non-target	18.1 ± 13.4	23.3 ± 28.7	+28.7	20.6 ± 16.4	26.8 ± 12.2	+30.1	14.0 ± 6.6	17.3 ± 9.0	+23.6
Individuals macro-moths target	22.3 ± 22.1	26.4 ± 31.8	+18.4	25.8 ± 26.6	29.6 ± 39.5	+14.7	16.3 ± 14.6	21.0 ± 18.5	+28.8
Species macro-moths target	10.88 ± 7.41	8.63 ± 6.02	−20.7	12.00 ± 7.97	8.80 ± 6.94	−26.7	9.00 ± 7.55	8.33 ± 5.51	−7.4
Individuals macro-moths non-target	244 ± 126	172 ± 121	−29.5***	274 ± 149	183 ± 151	−33.2***	194 ± 70	153 ± 70	−19.6
Species macro-moths non-target	68.5 ± 20.4	61.9 ± 28.7	−9.6***	72.4 ± 23.5	62.2 ± 35.7	−14.1***	62.0 ± 16.1	61.3 ± 18.2	−1.1

(*)$0.1 < p < 0.05$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ (Wilcoxon tests for individuals; sign tests for species).