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Effects of local and landscape scale and cattle grazing intensity on Orthoptera assemblages of the Hungarian Great Plain

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Grass height

Summary

The aims of this study were to test the influence of grazing intensity, effects of local and landscape parameters, and regional effects on orthopteran assemblages. We made our investigations on extensively and intensively grazed cattle pastures in three regions of the Hungarian Great Plain. The regions differed in landscape complexity; one region was situated in a structurally simple landscape with large landscape units, one in a structurally complex landscape with marshy patches and trees in the grasslands and one in a landscape with intermediate structural complexity. In each region we had seven pairs of differently managed grasslands, which differed in grazing intensity. Grasshoppers were recorded once in July 2003 using sweepnet catches and visual and acoustic observations in two 95 m long transects at each site (84 transects in total). Botanical surveys and measurements of other local factors were also made for each transect. After samplings, we digitised the most important land-use types using aerial photographs to produce landscape scale parameters within 100 and 500 m circles around every site. Analysing the management, regional, landscape and local effects on species richness with linear mixed models, we showed only strong significant regional differences. Linear mixed models for Orthoptera abundance yielded significant regional effects and marginal management effects. However, after including local and landscape parameters in a separate model a marginal local effect was found instead of a management effect in

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addition to the significant regional effect. Logistic regression models of 15 species also revealed the importance of local factors, particularly the importance of grass height, which is highly dependent on grazing intensity. We conclude that management intensity has indirect effects on Orthoptera species richness and abundance. Landscape scale parameters are also important, at least for some species.

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Zusammenfassung

Das Ziel dieser Untersuchung war es, den Einfluss der Beweidungsintensität, die Effekte lokaler bzw. Landschaftsparameter sowie regionale Effekte auf die Vergesellschaftungen von Orthoptera zu testen. Wir führten unsere Untersuchung auf extensiv und intensiv beweideten Rinderweiden in drei Regionen der großen ungarischen Ebene durch. Die Regionen unterschieden sich in der Komplexität der Landschaft: eine Region lag in einer strukturell einfachen Landschaft mit großen Landschaftseinheiten, eine in einer strukturell komplexen Landschaft mit sumpfigen Flecken sowie Bäumen in den Grünländern und eine in einer Landschaft mit einer mittleren strukturellen Komplexität.

In jeder Region befanden sich sieben Paare von unterschiedlich bewirtschafteten Grünländern, die sich in der Beweidungsintensität unterschieden. Die Grashüpfer wurden einmal im Juli 2003 erfasst, indem Streifnetzfänge sowie visuelle und akustische Beobachtungen auf zwei 95 m langen Transekten in jedem Gebiet durchgeführt wurden (insgesamt 84 Transekte). Es wurden darüber hinaus für jedes Transekt botanische Erfassungen und Messungen anderer lokaler Faktoren durchgeführt. Nach der Beprobung wurden die wichtigsten Landnutzungstypen mithilfe von Luftbildern digitalisiert um Parameter der Landschaftsskalen innerhalb eines Radius von 100 und 500 m um jedes Gebiet zu schaffen. Durch die Analyse der Effekte der Bewirtschaftung, regionaler und lokaler Effekte sowie von Landschaftseffekten auf den Artenreichtum mithilfe von linearen gemischten Modellen zeigten wir nur einen stark signifikanten regionalen Unterschied. Lineare gemischte Modelle für die Orthoptera-Abundanz zeigten signifikante regionale Effekte und geringfügige Bewirtschaftungseffekte. Wurden jedoch lokale und Landschaftsparameter in einem separaten Modell mit einbezogen, wurde ein geringfügiger lokaler Effekt anstelle eines Bewirtschaftungseffekts zusätzlich zum signifikanten regionalen Effekt gefunden. Logistische Regressionsmodelle von 15 Arten offenbarten auch die Wichtigkeit lokaler Faktoren, besonders der Grashöhe, die stark von der Beweidungsintensität abhängt. Wir schlossen daraus, dass die Bewirtschaftungsintensität indirekte Effekte auf den Artenreichtum und –abundanz der Orthoptera hat. Parameter der Landschaftsskala sind zumindest für einige Arten ebenfalls wichtig.

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Introduction

Modern agriculture is one of the main anthropogenic threats to biodiversity (Donald, Pisano, Rayment, & Pain, 2002). The decline of farmland species diversity due to management intensity has been shown for several taxa, e.g. for birds (Murphy, 2003), for mammals (Pena et al., 2003) and for insects (Duelli, Obrist, & Schmatz, 1999). Many arthropod species inhabit semi-natural grasslands, which are important agricultural habitats. But these are among the most threatened habitats as well, because they can be easily transformed into arable lands (Kisbenedek & Báldi, 2000; Lundstrom-Gillieron & Schlaepfer, 2003; Pywell et al., 2002). The maintenance of grasslands in most European landscapes depends on regular management, usually through grazing or mowing, but their species diversity is known to decline with increasing management intensity (Cole et al., 2002; Kruess & Tscharntke, 2002a; Verhulst, Báldi, & Kleijn, 2004; Wilson et al., 2003). Based on earlier studies it seems that both species richness and abundance of Orthoptera may benefit from extensive grassland management in historically grazed grasslands, as shown by studies in Colorado (Capinera & Sechrist, 1982) and Germany (Kruess & Tscharntke, 2002b), but not in Montana (O'Neill et al., 2003).

Arthropods are the most significant contributors to biodiversity of grasslands in the Hungarian Great Plain (Báldi, 1999; Korsós & Mészáros, 1998). Both local and landscape scale parameters influence herbivorous insects, but while local variables have generally a strong impact, landscape scale parameters seem to be less important (Stoner & Joern, 2004). However, at the landscape scale, area of suitable habitat (Steffan-Dewenter, Münzenberg, Bürger, Thies, & Tscharntke, 2002) and structural connectivity (With & Crist, 1995) influence presence and abundance of insects. Further, there may be an interaction between the influence of landscape parameters and the complexity of the given landscape (Tscharntke, Steffan-Dewenter, Kruess, & Thies, 2002). A more interesting question is, however, the relative importance of local versus landscape scale parameters in shaping grassland insect assemblages. Mazerolle and Villard (1999) found that landscape scale parameters were less important for the majority of invertebrates than factors at the local (or patch) scale. In the Orthoptera, local factors, like vegetation structure (Varga, 1997, Wettstein & Schmid, 1999), vegetation composition (Gebeyehu & Samways, 2002) and vegetation heterogeneity (Kruess & Tscharntke, 2002b) are important determinants of diversity. Stoner and Joern (2004) showed that orthopteran communities responded directly and strongly to changes in plant community composition. They also found that the plant species communities were strongly influenced by management and less by regional aspects, such as area reduction, edge effects and proximity of neighbouring fragments.

We selected extensively and intensively grazed pastures in three regions of the Hungarian Great Plain. The three regions differed in landscape structure (from simple through intermediate to complex), with similarly high percent (ca. 75%) of semi-natural habitats. The structural complexity is determined by patch density and diversity of land-use types. In this sense, we considered a region as simple, if it consisted of large but few habitats with low diversity of land-use types. While complex landscape consisted of smaller but many habitat patches with high diversity of land-use types. Our aims were to test the influence of grazing intensity on orthopteran assemblages of the Hungarian Great Plain and to investigate the effects of local (grass height, plant species richness, ground and cow faeces cover) and landscape parameters (e.g., percent, area size and patch density of important land-use types in a radius of 100 and 500 m around sample sites) and regional effects on orthopteran assemblages.

Methods

Study areas

Our first study region was situated in the Heves Landscape Protection Area in Eastern Hungary. This region ('Simple' region) was dominated by a mosaic of dry and wet alkali grasslands and marshes on solonetz soil and had the most simple landscape structure with the largest, least fragmented grassland patches. The second region was in the Kiskunság National Park, which had an intermediate landscape structure, and contained secondary Pannonic alkali steppe vegetation on solonchak soils ('Intermediate' region). This 'Intermediate' region was situated in Central Hungary between the river Danube and the third, the 'Complex' region. The latter region (also in the Kiskunság National Park) was more heterogeneous with several marshy patches and woodlots in the grasslands, so it had the most complex landscape structure (Table 1). The main vegetation of this region was a mosaic of swamp meadows, calcareous purple moorgrass meadows, salt steppes and Pannonic sand steppe grasslands, with scattered small forests. For detailed area description see Báldi, Batáry, and Erdős (2005). In Table 1 four important landscape parameters are given for the three regions.

In all regions, grasslands were the most abundant land-use type (Table 1). Most of the intensively grazed sites were not fenced (86%), while none of the extensively grazed pastures were fenced. All sites had been grazed by cattle for at least 5 yr from early spring until late autumn, and with the

Table 1. Mean of important landscape parameters

	Region			*F* value	Significance
	Simple	Intermediate	Complex		
Grassland (%)	71.82	61.72	62.70	1.627	0.210
Total patch density	16.71	20.71	30.86	6.458	0.004
Total land-use diversity (H')	0.49	0.58	0.77	5.910	0.006
Total length of all boundaries (km)	4.82	6.74	8.75	8.536	0.001

Each variable was measured within a circle with 500 m radius. d.f. is 41 for each one-way ANOVA. For details see "Methods" section.

exception of the fenced sites cattle were driven by a herdsman. Cattle density was about 0.5 cows/ha on extensive, and >1 cow/ha on intensive fields. None of the fields were fertilised.

Sampling method

We selected seven pairs of fields in extensively and intensively grazed grasslands in all regions (altogether 21 pairs of fields). On each field two 95 m long transects were located (84 transects in total), one at the field edge (e.g., along a channel or road) and the other 50 m towards the centre of the grassland and parallel to the edge. The landscape structure of each pair of extensively and intensively grazed fields was as similar as possible.

Orthoptera were surveyed by sweepnetting once in mid-July 2003. Sampling was done along the 95 m long transects, both in the edge and in the centre of each field. One sweepnet sampling was made per transect and each consisted of 3 × 20 sweeps with a heavy duty sweep net (38 cm internal diameter, 7215HS, BioQuip). The orthopteran individuals caught were identified to species in the laboratory. At the same time, we also made a visual and acoustic search for orthopteran species along the transects to obtain a species list as complete as possible.

Measure of local and landscape parameters

The local factors were measured along the same edge and field centre transects in June 2003. In each transect we established 10 1 × 5 m plots (840 plots in total). The plots were 5 m apart, so the 10 plots covered the whole transect. We estimated the cover of each plant species (%), bare ground (%), cow faeces (%), plant litter (%) and grass height (cm). We calculated the grass/forb cover-ratio. This could be interesting, because gomphocerine grasshoppers, which were the most frequent and abundant species in our samples, consume mainly grasses, while ensiferan species, which are generally omnivorous, consume mainly forbs (e.g., Harz, 1957; Isernvallverdu, Cuartas, & Pedrocchi, 1995).

We used aerial photographs (Institute of Geodesy, Cartography and Remote Sensing; Air Project 2000; 0.5 m/pixel resolution) of the study fields to digitise land-use types. First we drew the transects (start and end points of the transects were measured with GPS) and then located the midpoint of the rectangle formed by the two transects in a field. Around this point we considered two circles of 100 and 500 m radius, respectively. We digitised the following land-use types: (1) grasslands, (2) arable fields, (3) forests, (4) built-up area and infrastructure (paved road), (5) marshes, reeds and bogs, and (6) ditches, streams and lakes. Percentages of area and patch densities were measured for all the six land-use types within the circle. Patch density means the number of a given land-use type within the circle considered (100 or 500 m radius). Areas of patches were measured for grasslands, arable fields, forests and marshes, thereby including fields that were only in part situated within the 500 m radius. We also measured the total length of boundaries within circles. Boundaries were classified into five types according to their width and potential importance as corridors for dispersal: (1) simple boundary – between different land uses or between fields of the same land use, 0 m wide (e.g., crop–grassland, crop–forest or crop–crop contacts); (2) strip – boundaries with a strip of natural vegetation; mostly contacts between fields with the same land use but with some ground left undisturbed (e.g., vegetation below a fence), or the reverse of this, a strip of disturbed vegetation between fields (e.g., a small ditch without water or a trail), 0–2 m wide; (3) boundaries involving additional structures, including natural boundary, such as streams and hedgerows, >2 m wide; (4) man-made boundary (e.g., channels, roads, paths, ditches), >2 m wide and (5) the combination of the latter two, the combined boundary (e.g., channels with reed belt, or road with hedgerows), >2 m wide.

Statistical analysis

First, we analysed possible effects of management (extensive or intensive grazing regime), region and interaction between management and region (fixed factors) on both species number and abundance of Orthoptera in linear mixed models with the restricted maximum likelihood method (pair was treated as random factor).

In a second model, we included two landscape parameters and a local factor as covariates in the original model to test how these variables explain the differences in the species number and abundance of Orthoptera. The landscape parameters used were total patch density within 100 and 500 m distance, which closely reflect the landscape complexity of the three regions (Table 1). Further these landscape parameters correlated with most other landscape parameters (e.g., positively with total length of boundaries, negatively with area and percent of grassland). The local factor included was grass height, which is particularly important, because it is a structural index, which can strongly affect occurrence of Orthoptera (Cuningham & Sampson, 2000).

To analyse the local and landscape effects on the presence of different Orthoptera species, we conducted logistic regression analyses with backward elimination of variables (F to remove $P \geqslant 0.1$). All local parameters (bare ground cover, faeces cover, plant species number, grass height, grass/forb cover-ratio and litter cover) were tested for normality and all landscape percentage data were *arcsin*-transformed, other landscape parameters (patch density, area size and boundary length) were square-root-transformed (Sokal & Rohlf, 1981). First we had to make a data reduction for landscape parameters because we had more independent variables (21 landscape parameters) than cases (14 fields per region). To reduce the number of independent variables, we performed a factor analysis using the varimax rotation method. We used separate analyses for the 100 and 500 m circles to reduce the chance of multicollinearity. We pooled the presence–absence data from all three regions to get enough data for this analysis. We excluded those species, which occurred in fewer than 9 or more than 34 of the total 42 fields. For the remaining 15 species we made three logistic regressions with backward elimination, one for the local parameters, one for the reduced 100 m circles parameters and one for the reduced 500 m circles parameters. Removal testing was based on the probability of the likelihood-ratio statistic based on the maximum partial likelihood estimates. SPSS 12.0 was used for analyses (SPSS, 2003).

Results

Altogether we caught 3309 Orthoptera individuals which belonged to 33 species. The acoustic and visual searching resulted in a total of 41 species. The dataset of abundant ($\geqslant$35 individuals) species represents 3170 observations of 10 species. All abundant Orthoptera species belonged to the suborder Caelifera and showed great, sometimes contrasting variations across regions and management regimes (Fig. 1). We evaluated whether the preference for extensive or intensive pastures was consistent across regions. Half of the abundant species (*Acrida hungarica*, *Chortippus mollis*, *Euchorthippus declivus*, *Omocestus haemorrhoidalis* and *Stenobothrus crassipes*) showed mixed preferences regarding management across regions. The other five species showed clear regional or management preferences. *Aiolopus thalassinus*, *Dociostaurus brevicollis* and *Omocestus petraeus* occurred more frequently on intensively grazed grassland and in the 'Simple' region, while *Chorthippus oschei* preferred extensively grazed grasslands and was also more abundant in the 'Simple' region. *Chorthippus parallelus* was most abundant on extensive grasslands and in the 'Complex' region. With the exception of the latter species the densities of abundant species were always higher in the 'Simple' region than at the other regions.

The linear mixed model of species richness showed only significant regional differences and no management or management by region interaction effect (Table 2; Fig. 2). In model 2, when local factors and landscape parameters were included as covariates, the result did not change. Considering the abundance of grasshoppers, the original model revealed strong regional differences, a significant interaction between management and region and a marginal but significant management effect (Table 2). In the latter case, there were more individuals on the extensive fields than on the intensive ones. When the above-mentioned factors were included, we found a strong regional effect again and a marginal but significant effect of grass height (Table 2, Fig. 3). In all regions, the grass was higher on the extensively than on the intensively grazed fields.

Logistic regression analyses showed that a number of local habitat parameters and also some characteristics of the 100 and 500 m radius area have significant effects on the presence–absence pattern of some orthopteran species (Tables 3 and 4). Among the local habitat characters, grass height was correlated with the highest number of species. In the 100 and 500 m radius area, the factors correlating with human activities had the most prominent effect on the number of species.

Discussion

The orthopteran species that were recorded in the present study represent approximately one third of the Hungarian orthopteran fauna showing that cattle grazed pastures and meadows maintain a significant part of the species diversity of Orthoptera in Hungary (Nagy, 2003; Rácz, 1998).

Orthopteran species differ in their movement patterns, hiding and feeding behaviour, and therefore they often show well-defined habitat preferences and can be categorised into life forms. For example, geobiont species like *Calliptamus italicus* spend most of their time on the ground surface, while chortobiont grasshoppers such as *Chorthippus*

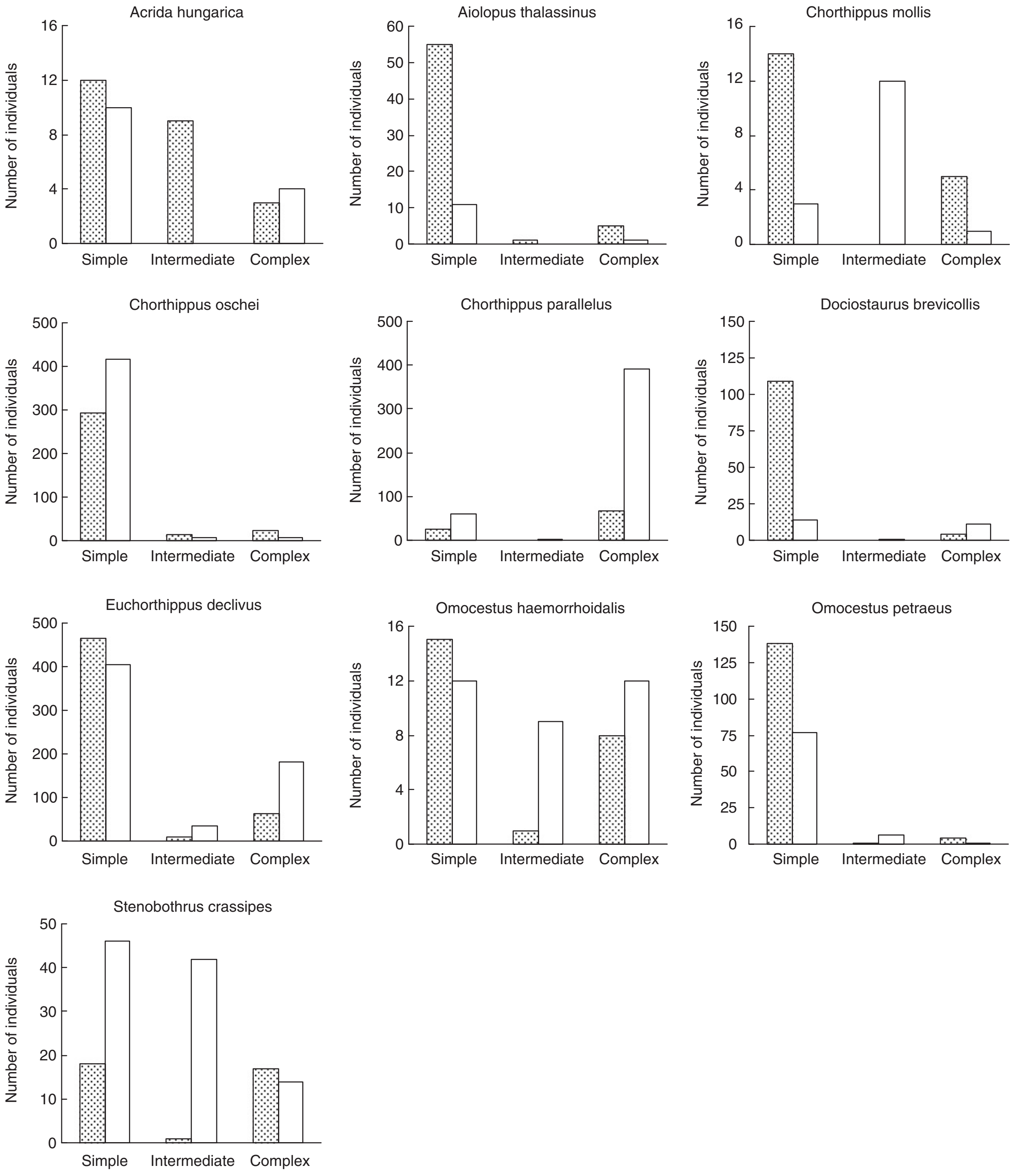

Figure 1. Total number of individuals of abundant orthopteran species. Landscape complexity increases from the 'Simple' region to 'Complex' region. Spotted bars indicate intensive grazing, open bars indicate extensive grazing.

parallelus live climbing on grasses and forbs (for a classification of the Hungarian fauna into life forms see Rácz, 1998). Hence, it is reasonable to expect specific and characteristic reactions to grazing. Holmes, Smith, and Johnston (1979) found that increased intensity of grazing decreased the numbers of some species of grasshoppers, and increased the abundance of others on a fescue rangeland. For the majority of species, the ratio of abundance between extensive and intensive fields varied inconsistently from region to region in the present study (Fig. 1). Therefore, our results do not allow for a characterisation of the species regarding their tolerance of grazing. Regional differences were

Table 2. Results of test statistics of the effects of management, local and landscape parameters and region on the species richness and abundance of Orthoptera in Hungarian grasslands

	Model 1			Model 2					
	M	R	M × R	M	R	M × R	Local	L 100 m	L 500 m
Species richness	0.33	7.29**	1.31	0.04	4.48**	1.16	1.52	0.01	0.25
Abundance	3.09*	23.08***	4.05**	0.08	24.60***	0.82	3.50*	0.01	0.03

*$P<0.1$; **$P<0.05$; ***$P<0.001$

Model 1 includes only management (M), region (R) and the management × region interaction (M × R) as fixed factors and pair as a random factor. In Model 2, one local factor (grass height) and two landscape parameters (L 100 m and L 500 m – total patch density within 100 and 500 m circles of the surveyed fields) have been included as covariates. Only test statistics of fixed factors are shown. The given values are *F* values of the restricted maximum likelihood statistic.

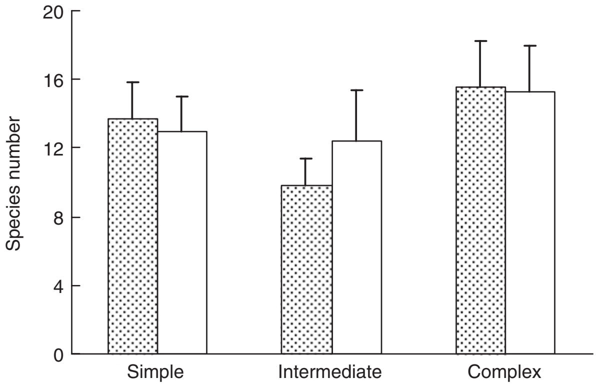

Figure 2. Mean species number of grasshoppers in regions of different landscape complexity in the Hungarian Great Plain. Landscape complexity increases from 'Simple' to 'Complex' region. Spotted bars indicate intensive grazing, open bars indicate extensive grazing. One column represent sampling from two transects of seven fields. Error bars represent SE.

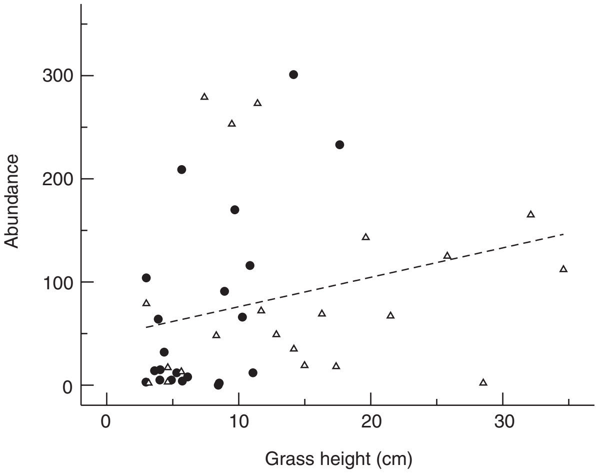

Figure 3. Correlation between grass height and Orthoptera abundance on differently grazed grasslands (● intensively grazed fields; △ extensively grazed fields). Dashed line indicates the marginal significant effect of grass height on Orthoptera abundance in the linear mixed model.

often more pronounced than differences between intensive and extensive fields. Our data suggest that grazing may have even differing effects on the abundance of a given species comparing different regions. For example, *Chorthippus mollis* was more abundant in the intensive fields of the 'Simple' region while it was more abundant in the extensive fields of the 'Intermediate' region.

Policy makers introduced agri-environmental schemes to stop the decline of biodiversity in farmland areas. In these schemes farmers are paid for nature friendly management, e.g. for organic farming, maintaining extensive systems, or for habitat management (Donald et al., 2002; Ovenden, Swash, & Smallshire, 1998). However, Kleijn and Sutherland (2003) conclude in their review (based mostly on Western European studies) that the effectiveness of agri-environment schemes cannot be evaluated, mainly because of a lack of sufficiently rigorous studies. They call attention to a particularly urgent need for studies evaluating the effects of management schemes in extensively farmed areas. This is especially true for Central and Eastern European countries, where well-designed comparative studies on the effects of agricultural intensity are virtually absent; exceptions are studies in maize stands and orchards (Mészáros et al., 1984; Szentkirályi & Kozár, 1991). However, in these countries the biodiversity is still quite high and the agricultural intensification is lower than in Western Europe (Donald et al., 2002; EEA, 2003). In our study, we found no significant difference in species richness and only marginally significant differences in abundance of Orthoptera between intensively and extensively grazed grasslands, which contradict former studies (Capinera & Sechrist, 1982; Kruess & Tscharntke, 2002b; Ludwig, Eager, Williams, & Lowe, 1999). There was nearly the same mean species number in all regions irrespective of management. The explanation for this could be that our intensive study sites were unfertilised, free of pesticide-use and

Table 3. Results of the logistic regressions with backward elimination using presence–absence data of orthopteran species as dependent variable, and local variables as independent variables

	Ground	Faeces	Plant speices no.	Grass height
Acrida hungarica	–	–	–	−0.124
Aiolopus thalassinus	–	–	–	−0.133
Calliptamus italicus	–	–	–	–
Chorthippus brunneus	–	–	–	–
Chorthippus mollis	−0.123	−1.218		−0.112
Decticus verrucivorus	–	–	–	0.089
Dociostaurus brevicollis	–	–	–	−0.128
Gampsocleis glabra	–	–	–	0.296
Metrioptera bicolor	−0.141	−1.722	–	–
Omocestus petraeus	0.150	–	−0.043	–
Omocestus ventralis	–	–	–	–
Platycleis affinis	–	–	−0.038	–
Stenobothrus crassipes	–	–	–	–
Stenobothrus nigromaculatus	–	–	0.061	–
Tesselana vittata	–	–	–	–

Only significant logistic regression coefficients are presented ($P<0.05$).

probably even less intensively grazed than sites studied in Western Europe. For example, in the study of Kruess and Tscharntke (2002b), the mean grazing pressure probably was higher on the extensively grazed German pastures (1.4 cattle/ha) than our intensively grazed grasslands (>1 cattle/ha). Further, this is in agreement with Tscharntke, Kleijn, Kruess, Steffan-Dewenter, and Thies (2005) who stated that in a landscape where the biodiversity is high (in this sense all of our regions) the effectiveness of agri-environment schemes or effects of management intensity are low. Therefore, even intensively grazed grasslands could preserve a rich Orthoptera fauna in Hungary.

The observed differences in Orthoptera abundance between extensively and intensively grazed field pairs were largely explained by grass height. O'Neill et al. (2003) showed differences in plant cover, which were greatest immediately after grazing and found that Orthoptera microhabitats tended to be shadier, cooler, less windy and more humid in the ungrazed plots. Further, different soil types, vegetation and water balance could explain the significant regional differences in grasshopper abundance. Nevertheless we could not show any differences in these landscape parameters.

The results of logistic regression suggest that vegetation structure is a very important factor, which may have strong effects on the species composition of the local orthopteran assemblages (Table 3). The presence of the two large bush-cricket species *Decticus verrucivorus* and *Gampsocleis glabra* was positively correlated with grass height. It is likely that these species need tall vegetation to find sufficient shelter from bird predation, to which they are much more exposed than smaller species (Belovsky & Slade, 1993). Among the other species, *Aiolopus thalassinus* and *Dociostaurus brevicollis* perhaps need shorter vegetation, because visual elements are important in their communication (Harz, 1957). We agree with Fielding and Brusven (2000) that behavioural responses of certain grasshopper species to characteristics of grazed habitats (e.g., reduced plant height, increased bare ground, higher temperatures and lower relative humidity) may affect population responses to grazed habitats. For instance, grasshoppers that take refuge in vegetation may actively seek extensively grazed habitats, which provide a greater abundance of refuges. Grasshoppers that escape predators by blending in with bare ground may be indifferent to grazing. However, our analyses gave insignificant results for a number of habitat characteristics that were expected to have detectable effects on the examined Orthoptera assemblages.

Finally we think that to find the best protection for the species examined in this study, it is clear that further detailed research is required. This can only be achieved by co-ordinated planning of conservation measures for each region, because of the large differences observed between the regions. Based on the results of the present study cattle grazing intensity seems to have indirect effects on Orthoptera species richness and abundance. Landscape scale parameters could also be important, at least for certain species.

Table 4. Results of the logistic regressions with backward elimination using presence-absence data of orthopteran species as dependent variable, factors from the factor analysis (FA) of 100 m landscape scale and factors from the FA of 500 m landscape scale, respectively as independent variables in separate models

	Factor100/1	Factor100/3	Factor100/4	Factor500/1	Factor500/2	Factor500/3	Factor500/5
Acrida hungarica	–	–	–	–	–	1.085	–
Aiolopus thalassinus	–	–	–	–	−0.821	–	–
Calliptamus italicus	–	–	–	–	–	–	−0.968
Chorthippus brunneus	–	–	–	–	–	–	–
Chorthippus mollis	–	–	–	–	–	–	–
Decticus verrucivorus	–	1.445	–	–	–	–	–
Dociostaurus brevicollis	–	–	−1.118	–	−0.887	–	–
Gampsocleis glabra	–	−1.070	–	–	–	–	–
Metrioptera bicolor	–	–	0.751	–	0.843	–	–
Omocestus petraeus	−1.845	–	−0.923	−1.211	–	–	–
Omocestus ventralis	–	–	–	–	1.003	–	–
Platycleis affinis	–	–	–	–	–	–	–
Stenobothrus crassipes	–	–	–	–	–	–	–
Stenobothrus nigromaculatus	–	–	–	–	–	–	–
Tesselana vittata	–	–	–	–	–	–	–
Factors correlating strongly with landscape metrics[a]	+Ma %; +Ma density	+Ar %; +Ar density; +Ar size	+BUA %; +BUA density	+Ma %; +Ma density; +Ma size; +Simple	+BUA %; +BUA density; +Manmade	+Fo %; +Fo size; +Strip	+Ar %; −Gr %; +Ar density

Only significant logistic regression coefficients (factors from the FA; e.g. the first factor from FA of 100 m landscape scale – Factor100/1) are presented ($P<0.05$). The last row shows the strong correlative ($\geqslant 0.7$) variables of the factor analysis in the case of the two landscape scales.

[a] + means positive, −negative correlation; Ar, arable field; BUA, built-up area; Fo, forest; Gr, grassland; Ma, marsh; Simple, boundary between different land uses or between fields of the same land use, 0 m wide; Strip, boundary with a strip of natural vegetation, 0–2 m wide; Manmade, boundary involving additional structures, like channels or roads, >2 m wide.

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