

Grassland versus non-grassland bird abundance and diversity in managed grasslands: local, landscape and regional scale effects

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Abstract Declines of West European farmland birds have been associated with intensive agricultural practices, while in Central and Eastern European countries grasslands still harbour a diverse and unique bird community. However, in these countries comparative studies on the effects of agricultural intensity on biodiversity are virtually missing. We compared bird communities of paired extensively and intensively grazed cattle pastures in three different regions of the Hungarian Great Plain. The influence of grazing intensity, landscape and regional effects were tested on the abundance and species richness of two ecological groups of bird species (grassland and non-grassland birds), as well as on the abundance of the three commonest grassland bird species (Skylark, Yellow wagtail, Corn bunting) in linear mixed models. We found significant effects of grazing intensity on the abundance of grassland birds, which were more abundant on the extensive sites, whereas no effects were found on non-grassland birds. This could be explained by a closer dependence of grassland birds on grasslands for nesting and foraging, whereas non-grassland birds only used grasslands opportunistically for foraging. Landscape effect was shown on grassland bird abundance, but not on non-grassland birds. The regions did affect only the species richness of grassland birds. At species level, the effect of management was significant for the three commonest grassland species, which were more abundant on the extensive fields in all regions. Additionally, on Skylark abundance landscape and regional effects were also shown. These findings suggest that conservation of biodiversity in agricultural systems requires the consideration of landscape perspective to apply the most adequate management.

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Introduction

In central Europe, natural ecosystems are almost absent and most nature reserves require management, which is probably the most important local factor influencing their natural values (Martin and van der Straaten 2004; Tschardtke et al. 2005). These man-made reserves include large proportions of grassland, which are among the most threatened habitats by agricultural intensification (Donald et al. 2002; Tschardtke et al. 2005). Low-intensity grassland systems have developed a characteristic and diverse fauna and flora, but their substitution by high input, simplified systems has been associated with a decline in biodiversity (Stoate et al. 2001). In recent decades, major declines and range contractions of European and North American farmland birds have been reported in relation to changes in agricultural practices (e.g. Tucker and Heath 1994; Siriwardena et al. 1998; Hole et al. 2002; Murphy 2003; Burfield and van Bommel 2004; Gregory et al. 2005).

Agri-environmental schemes of the European Common Agricultural Policy are considered an essential tool for stopping the decline of biodiversity in farmland areas. However, the review of Kleijn and Sutherland (2003) gave contrasting results in the case of birds. Out of 19 studies examining the response of birds, four showed significant increases in species richness or abundance, two showed decreases and nine showed both increases and decreases as compared to controls. In the Central and Eastern European (CEE) countries, which recently joined the EU, the agri-environmental schemes have just been introduced; nevertheless, well-designed studies now can serve to provide baseline data to assess effectiveness in the future (Kleijn and Sutherland 2003). Although the schemes perhaps could help in conservation of biodiversity of agricultural areas, but the larger part of subsidies of the Common Policy of the EU is spent on area based intensive agriculture, which probably will extend the homogenisation process of agricultural landscapes to CEE countries (Donald et al. 2002). These all call the attention of researchers on the need of comparative studies of agricultural intensification in Eastern and Central Europe as well.

Agricultural intensification has led to decline in biodiversity not only due to increased and widespread use of pesticides and machinery, but also due to the loss of non-crop habitats and habitat fragmentation. Semi-natural grasslands, which are important bird habitats especially in Hungary, can be easily transformed to arable lands (Pywell et al. 2002; Lundstrom-Gillieron and Schlaepfer 2003). Habitat fragmentation has serious effects on avian nesting success at several spatial scales, from edges to patches and landscapes (reviews in Paton 1994; Wiens 1995; Bender et al. 1998; Stephens et al. 2003; Batáry and Báldi 2004). However, there is little knowledge about biodiversity-driven agroecosystem functioning and the relative importance of local and landscape management for agricultural landscapes (Tschardtke et al. 2005). Furthermore, because of strong and widespread effects of habitat fragmentation, there is increasing need for multi-scale studies, where local and landscape scale effects are studied together. However, simultaneous studies of the effects of local-scale management and landscape structure are comparatively rare. Brotons et al. (2005) investigated the effect of adjacent agricultural habitat on

the distribution of passerines in natural grasslands. Based on their results, they suggest that the management of the context in which steppe habitat is imbedded will significantly affect the distribution and abundance of this group of passerines and determine both habitat quality and conservation value at a landscape scale.

We selected extensively and intensively grazed pastures in three regions of Hungarian Great Plain (those can be categorised as solonchak alkali steppes, solonetz alkali steppes and wet meadows). In the year of the study, in 2003 were the first supports by National Agri-Environment Schemes given to farmers. None of our extensively grazed fields were supported, however all of them met the requirements of the National Agri-Environment Schemes (Ángyán et al. 1999). The three regions differ in landscape structure (from simple through intermediate to complex). Our aims were to test the influence of a local factor (grazing intensity), landscape and regional effects on two ecological groups of bird species (grassland and non-grassland birds) and on the most frequent species (Skylark *Alauda arvensis*, Yellow wagtail *Motacilla flava*, and Corn bunting *Miliaria calandra*) of the Hungarian Great Plain.

Methods

Twenty-one pairs of bird census sites were selected on grasslands with high and low grazing pressure in three distinct biogeographic regions of the Hungarian Great Plain. The three regions differ in their landscape structure, although grasslands are the most extensive land-use type (over 60%) in all regions. One of our study areas is situated in the Heves Landscape Protection Area in Eastern Hungary. This region ('Simple' region) has the most simple landscape structure with the largest, least fragmented grassland patches and is dominated by mosaic-complex of dry and wet alkali grasslands and marshes on solonetz soil. An other region is situated parallel to the river Danube, in the Kiskunság National Park (KNP), has an intermediate landscape structure, and contains secondary Pannonic alkali steppe vegetation on solonchak soils ('Intermediate' region). The third region (also in the KNP) is more heterogeneous, has several marshy patches and woodlots in the grasslands, so it has the most complex landscape structure ('Complex' region). For detailed area description see Báldi et al. (2005).

We established seven pairs of 12.5 ha plots, usually square in shape, in the extensively and intensively grazed grasslands in all regions (altogether 21 pairs of fields). The extensive field and intensive field in a pair had the same soil type and groundwater level and were situated in similarly structured landscapes, therefore the effects of confounding environmental variables were diminished. Cattle density was about 0.5 cows/ha on extensive and >1 cow/ha on intensive fields. None of the fields were fertilised, cut or re-seeded. Some of the study fields were not exactly 12.5 ha. In these cases we cut down the hang out piece on a randomly chose side of the larger field, because of the paired study design. This made possible to compare equally sized parts of a pair.

Breeding birds were surveyed using the territory mapping approach (Bibby et al. 1992). Altogether we made four censuses, two in April and two in May of 2003. Censuses were carried out under good weather conditions (no wind and rain), from sunrise to 9–10 a.m. The extensive and intensive fields of each pair were censused in the same morning by the same observer. The order in which sites were sampled was changed in the consecutive censuses. All observations registered by sight or sound

were plotted on maps of the fields. Birds just flying through and not foraging in flight were excluded from the analysis. Territories were then drawn around complementary observations made during the four visits. Nest sites were allocated to the site where the observation most indicative of a territory was made (e.g. singing or displaying male, actual nests). To draw a territory in the case of breeding birds, we took two observations within about 10–20 m, with exception of late migrants (e.g. Grasshopper Warbler *Locustella naevia*, where observations occurred only in May). In the case of territories located along the borders of study plots, we counted them, if we got at least one contact within the plot. Species whose territories are larger than the target plots (e.g. great bustard *Otis tarda*, raptors) or that use the plots for feeding and clearly nested outside them (e.g. some small passerines such as tree sparrow *Passer montanus*, white stork *Ciconia ciconia* and corvids) were also mapped. Two occurrences of them meant one territory independently of the number of individuals and of their places on the map.

We divided the species for habitat specialist and generalist, because specialist species usually react in a different way to factors than generalist species (e.g. Siriwardena et al. 1998; Magura et al. 2000; Imbeau et al. 2003; Virkkala et al. 2004). We considered those species as habitat specialists (i.e. grassland birds), which breed on the ground of grasslands, whereas the remaining was considered as habitat generalist (non-grassland birds) (Table 1). Our previous analysis on the effect of grazing intensity on birds showed that species richness might increase due to increasing grazing pressure—a rather unexpected result (Báldi et al. 2005). However, this result was based solely on the local scale (grazing effect), and we explained it with the changing landscape structure of study fields. This paper in contrast to the earlier one is based on territories of grassland and non-grassland bird species and not on occurrences of all bird species, uses a pair-wise statistical design and a multi-scale approach, thus more comprehensive.

We used aerial photographs (Institute of Geodesy, Cartography and Remote Sensing; Air project 2000; 0.5 m/pixel resolution) from the study fields to digitise land-use types. First we searched the middle point of the 12.5 ha field and around this centre we used a buffer of 500 m radius. We digitised the following land-use types: (1) grasslands; (2) arable fields; (3) forests; (4) built-up areas; (5) marshes, reeds and bogs and (6) ditches, streams and lakes. Area percentages, mean areas and patch densities were measured for land-use types within the buffer. Further we also measured the total length of boundaries within buffers. All fields were situated only on grasslands and did not contain boundaries inside at all.

We analysed the local effect (extensive or intensive grazing regime), the effect of landscape and region and the interaction between management and landscape on the species number and on the abundance of grassland and non-grassland bird species in linear mixed models with the Restricted Maximum Likelihood method. To control for confounding effects of region on landscape influences (regions were selected based on their landscape structure, but differed also in soil type and vegetation structure), we built models with and without landscape factors. As landscape variable the total length of all boundaries was used, which reflects well the landscape complexity of the three regions (mean of total length of all boundaries within 500 m buffer areas in ‘Simple’ region: 4.74 km; in ‘Intermediate’ region: 6.25 km; in ‘Complex’ region: 8.53 km). The cause, why this variable was used is that the amount of boundaries or edges is one of the most important factors determining the nest success of ground nesting birds (Batáry and Báldi 2004). This landscape variable

Table 1 List of grassland and non-grassland species

Grassland species	Non-grassland species
Black-tailed godwit <i>Limosa limosa</i>	Barn swallow <i>Hirundo rustica</i>
Corn bunting <i>Miliaria calandra</i>	Bee-eater <i>Merops apiaster</i>
Curlew <i>Numenius arquata</i>	Common black-headed gull <i>Larus ridibundus</i>
Grasshopper warbler <i>Locustella naevia</i>	Common buzzard <i>Buteo buteo</i>
Great bustard <i>Otis tarda</i>	Cuckoo <i>Cuculus canorus</i>
Lapwing <i>Vanellus vanellus</i>	Great white egret <i>Casmerodius albus</i>
Montagu's harrier <i>Circus pygargus</i>	Greylag goose <i>Anser anser</i>
Partridge <i>Perdix perdix</i>	Hooded crow <i>Corvus corone cornix</i>
Pheasant <i>Phasianus colchicus</i>	Hoopoe <i>Upupa epops</i>
Quail <i>Coturnix coturnix</i>	Kestrel <i>Falco tinnunculus</i>
Redshank <i>Tringa tetanus</i>	Lesser grey shrike <i>Lanius minor</i>
Skylark <i>Alauda arvensis</i>	Magpie <i>Pica pica</i>
Stone curlew <i>Burhinus oedicnemus</i>	Mallard <i>Anas platyrhynchos</i>
Stonechat <i>Saxicola torquata</i>	Marsh harrier <i>Circus aeruginosus</i>
Tawny pipit <i>Anthus campestris</i>	Nightingale <i>Luscinia megarhynchos</i>
Whinchat <i>Saxicola rubetra</i>	Red-backed shrike <i>Lanius collurio</i>
Yellow wagtail <i>Motacilla flava</i>	Red-footed falcon <i>Falco vespertinus</i>
	Roller <i>Coracias garrulus</i>
	Rook <i>Corvus frugilegus</i>
	Sand Martin <i>Riparia riparia</i>
	Savi's warbler <i>Locustella luscinioides</i>
	Sedge warbler <i>Acrocephalus schoenobaenus</i>
	Starling <i>Sturnus vulgaris</i>
	Tree sparrow <i>Passer montanus</i>
	White stork <i>Ciconia ciconia</i>
	Wood pigeon <i>Columba palumbus</i>

correlates with most other important landscape metrics—e.g. positively with total patch density ($r_{42} = 0.895$, $P = 0.001$), negatively with area and percent of grassland ($r_{42} = -0.810$, $P = 0.001$ and $r_{42} = -0.475$, $P = 0.001$) and positively with habitat diversity ($r_{42} = 0.454$, $P = 0.003$). Models contained only management, landscape, region and interaction between management and landscape as fixed factors and pair as random factor. Further we used the same models for the most abundant species, namely for Skylark, Yellow wagtail and Corn bunting as well. In the case of two latter species, data of one region was not included in the models, because both species occurred nearly only in two regions (for Yellow wagtail the 'Intermediate' region, for Corn bunting the 'Simple' region was not included into the models).

Results

Overall 748 bird territories belonging to 43 species were recorded at the 42 study sites. Intensively and extensively grazed fields had nearly the same species richness (13 grassland and 22 non-grassland species on intensively grazed grasslands, while 14 grassland and 22 non-grassland species on extensively grazed grasslands).

Investigating management (extensive versus intensive grazing) and regional effects on species richness, we showed both effects on grassland birds, but no effect on non-grassland birds (Table 2). The species richness of grassland birds was significantly

higher on extensively grazed fields, and the ‘Intermediate’ region proved to be the most species rich. When we included landscape (total length of boundaries) in the models, no effect was found either on grassland or non-grassland birds (Table 2).

Abundance of grassland species was higher on extensive than on intensive fields (Table 2; Fig. 1), in contrast to the abundance of non-grassland species. In the case of grassland birds, management effect was shown in both models (with and without including landscape). Further, investigating the significant landscape effect, the abundance of grassland species was negatively related to total length of boundaries (Table 2; Fig. 2; intensive fields: $r_{21} = -0.328$, $P = 0.146$; extensive fields: $r_{21} = -0.462$, $P = 0.035$). No effect of region and no interaction effect were found on the abundance of grassland and non-grassland bird species.

At the species level, the effect of management was significant for the commonest species, the Skylark (in both models), which was more abundant on the extensive fields in all regions (Table 2; Fig. 3a). Additionally, Skylark abundance was also negatively related to total length of boundaries and occurred more frequently in the ‘Simple’ and ‘Intermediate’ region than in the ‘Complex’ region (Table 2; Figs. 3a and 4; intensive fields: $r_{21} = -0.456$, $P = 0.038$; extensive fields: $r_{21} = -0.713$, $P = 0.001$). The effect of management and landscape on Skylark abundance was also manifested by a significant interaction between management and landscape—Skylark abundance was more sensitive to boundary length on extensively grazed fields than intensive fields (Fig. 4). In the case of two other frequent species management effects were found, the abundance of these species tended to be higher on the extensive fields than on the intensive ones (Table 2; Fig. 3b, c). Further, no landscape effects were shown for the Yellow wagtail and the Corn bunting, but in the case of Corn bunting a significant management \times landscape effect was found (Table 2).

Table 2 Linear mixed models on the effects of management (intensive versus extensive grazing [M]), of landscape (total length of boundaries in surrounding landscape [L]) and of region [R] on bird communities and species of Hungarian grasslands. Model 1 contains management and region, while in model 2 landscape and management \times landscape interaction were included. Bold P -values indicate significant effects

	Model 1				Model 2							
	M		R		M		L		R		M \times L	
	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>	<i>F</i>	<i>P</i>
Species richness												
Grassland species	6.936	0.016	4.338	0.029	0.419	0.524	0.135	0.716	2.548	0.103	0.088	0.770
Non-grassland species	1.337	0.261	0.481	0.626	0.098	0.758	2.120	0.154	1.281	0.299	0.006	0.940
Territories												
Grassland species	40.030	0.001	1.492	0.251	7.613	0.012	4.671	0.038	0.492	0.619	0.215	0.647
Non-grassland species	1.333	0.262	0.119	0.888	0.001	0.984	1.427	0.240	0.557	0.581	0.189	0.667
Skylark	9.033	0.007	11.354	0.001	9.734	0.005	5.088	0.030	8.154	0.003	4.534	0.045
Yellow wagtail	11.039	0.003	1.616	0.510	0.913	0.350	2.402	0.132	2.306	0.157	0.346	0.562
Corn bunting	1.174	0.294	0.325	0.616	7.499	0.014	1.937	0.178	0.044	0.8401	0.470	0.005

Fig. 1 Mean territory number of grassland (breeds on the ground of grasslands) and non-grassland bird species of intensively and extensively grazed grasslands of Hungarian Great Plain ($n = 42$ fields); bars show 1 SE

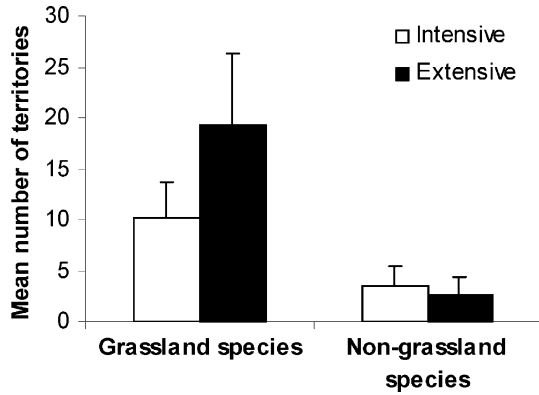


Fig. 2 Correlation between the total length of boundaries (km) and mean territories of grassland bird species on differently managed grasslands (Δ intensive fields, \bullet extensive fields). Dashed line indicates correlation for intensive fields, while continuous line indicates correlation for extensive fields

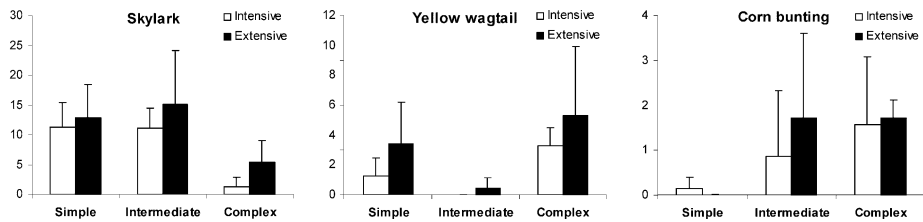
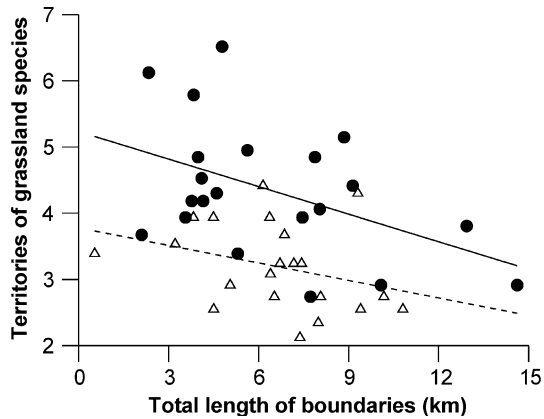
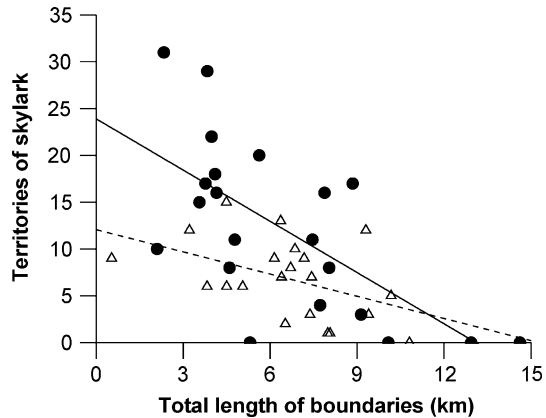


Fig. 3 Mean individual number of the most abundant grassland bird species on Hungarian grasslands. Landscape complexity increases from the ‘Simple’ region to ‘Complex’ region. Filled bars indicate extensive grazing, open bars indicate intensive grazing. (a) Skylark, (b) Yellow wagtail, (c) Corn bunting

Discussion

The relative importance of local farming management (intensive versus extensive grazing), landscape context and region was analysed on grassland and non-grassland bird diversity. In the case of community analysis region had no confounding effects on landscape influences. In recent decades great attention have been paid to the

Fig. 4 Correlation between the total length of boundaries and territories of Skylark on differently managed grasslands (Δ intensive fields, \bullet extensive fields). Dashed line indicates correlation for intensive fields, while continuous line indicates correlation for extensive fields



population declines of farmland birds attributed to intensive agricultural management (Vickery et al. 2001). Grazing generally has negative effect on bird species richness or abundance (Dobkin et al. 1998; Fuller and Gough 1999; Verhulst et al. 2004; Maron and Lill 2005). In the present study we showed effect of management on species richness and abundance of true grassland birds with higher species richness and abundance on the extensive sites, while on non-grassland species no effect was found. This could be explained probably by that true grassland birds are more specialised on grassland habitats than non-grassland birds, which only feed and not nest there. Grazing can impact on bird populations through changes in vegetation structure, food resources and predation pressure (Vickery et al. 2001). Alteration of the vegetation structure will affect the suitability of the sward for nesting and feeding (Milsom et al. 1998). Intensive grazing may increase nest losses due to predation and trampling (Ammon and Stacey 1997; Wilson et al. 1999; Pavel 2004).

Tscharntke et al. (2005) concluded in their recent review that agri-environment schemes need to broaden their perspective and to take the different responses to schemes in simple (high impact) and complex (low impact) agricultural landscapes into account. Furthermore, Benton et al. (2003) reviewed that several studies have shown heterogeneity to be associated with diversity. In the present study we found landscape effect on grassland bird abundance, however with increasing heterogeneity (increasing total length of boundaries) the abundance of grassland birds declined. The conclusion of Benton et al. (2003) is probably valid only in highly managed regions. Here we have to emphasise that our study sites contained more than 60% grasslands in all regions and generally are less intensively managed (non-fertilised and pesticide free) than in Western Europe. This, and other studies warn that the understanding of biodiversity in agricultural landscapes need a more comprehensive approach (Kleijn and Báldi 2005; Tscharntke et al. 2005). In contrast to our results, the model of Virkkala et al. (2004) explained a moderate proportion of the variation in the total density of farmland birds in the landscape. Söderström et al. (2001) emphasised the importance of landscape composition for mobile organisms such as birds and found that species richness of grassland birds decreased with increasing proportion of urban elements and arable fields in a 1000 m landscape area centred on each pasture. In a similar multi-scale study, like ours, examining the farmland management on assemblages of grassland wintering birds in Portugal,

Moreira et al. (2005) found that species richness was primarily influenced by landscape context, whereas field management mostly determined abundance. Finally, we could separate regional and landscape effects with building models with and without a landscape metric. The results showed that the regional effect on species richness was not due to landscape complexity differences between regions, but probably differences in e.g. soil type and/or vegetation structure and composition.

At species level our analyses were limited to the most abundant birds (Skylark, Yellow wagtail and Corn bunting), which are important contributors of the Hungarian grassland bird assemblages. All three species underwent smaller or larger declines during the recent decades mostly in West Europe, but the key eastern populations remained stable (Siriwardena et al. 1998; Brickle et al. 2000; Burfield and van Bommel 2004; Newton 2004; Gregory et al. 2005). In our study significant management effect was shown for all species, while landscape effect was only found in the case of Skylark. For Skylark regional effect was not separable from landscape effect, which at species level is not surprisingly, because species react individually for landscape, management, vegetation, etc. (Bradbury et al. 2004). Our results confirm that Skylarks avoid smaller fields (Donald et al. 2001; Perkins et al. 2000; Moreira et al. 2005). This is consistent with the theory that abundant generalist species should be less affected by fragmentation than (habitat) specialist species (Braschler and Baur 2005). The significant interaction between management and landscape reflect that the increased Skylark density was confined to extensively grazed fields, of which surrounding landscapes contained less boundaries.

The ongoing changes in the agriculture threaten the rich eastern European ecosystems. However, the agri-environmental schemes open up new views to protect the biodiversity there. But as other researchers, we also have to emphasise that conservation of biodiversity and ecosystem services in agricultural systems requires a landscape perspective (Bengtsson et al. 2003; Tscharrntke et al. 2005). Finally, we conclude that both local management and landscape structure has significant effects on grassland bird abundance, but not on non-grassland abundance when analysed together, and that such effects depend on the ecology of each bird species.

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References

- Ammon EM, Stacey PB (1997) Avian nest success in relation to past grazing regimes in a montane riparian system. *Condor* 99:7–13
- Ángyán J, Fésűs I, Podmaniczky L, Tar F, Madarassy A (1999) Nemzeti Agrár-környezetvédelmi Program. Ministry of Agriculture and Rural Development, Budapest
- Báldi A, Batáry P, Erdős S (2005) Effects of grazing intensity on bird assemblages and populations of Hungarian grasslands. *Agric Ecosyst Environ* 108:251–263
- Batáry P, Báldi A (2004) Evidence of an edge effect on avian nest success: a meta-analysis. *Conserv Biol* 18:389–400

- Bender DJ, Contreras TA, Fahrig L (1998) Habitat loss and population decline: a meta-analysis of the patch size effect. *Ecology* 79:517–533
- Bengtsson J, Angelstam P, Elqvist T, Emanuelsson U, Folke C, Ihse M, Moberg F, Nystrom M (2003) Reserves, resilience and dynamic landscapes. *Ambio* 32:389–396
- Benton TG, Vickery JA, Wilson JD (2003) Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol Evol* 18:182–188
- Bibby CJ, Burgess ND, Hill DA (1992) *Bird Census Techniques*. Academic Press, London
- Bradbury RB, Browne SJ, Stevens DK, Aebischer NJ (2004) Five-year evaluation of the impact of the Arable Stewardship Pilot Scheme on birds. *Ibis* 146:171–180
- Braschler B, Baur B (2005) Experimental small-scale grassland fragmentation alters competitive interactions among ant species. *Oecologia* 143:291–300
- Brickle NW, Harper DGC, Aebischer NJ, Cockayne SH (2000) Effects of agricultural intensification on the breeding success of Corn buntings *Miliaria calandra*. *J Appl Ecol* 37:742–755
- Brotans L, Wolff A, Paulus G, Martin J-L (2005) Effect of adjacent agricultural habitat on the distribution of passerines in natural grasslands. *Biol Conserv* 124:407–414
- Burfield I, van Bommel F (2004) *Birds in Europe: population estimates, trends and conservation status*. BirdLife International, Cambridge
- Dobkin DS, Rich AC, Pyle WH (1998) Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the Northwestern Great Basin. *Conserv Biol* 12:209–221
- Donald PF, Green RE, Heath MF (2001) Agricultural intensification and the collapse of Europe's farmland bird populations. *Proc Roy Soc Lond B* 268:25–29
- Donald PF, Pisano G, Rayment MD, Pain DJ (2002) The Common Agricultural Policy, EU enlargements and the conservation of Europe's farmland birds. *Agric Ecosyst Environ* 89:167–182
- Fuller RJ, Gough SJ (1999) Changes in sheep numbers in Britain: implications for bird populations. *Biol Conserv* 91:73–89
- Gregory RD, van Strien A, Vorisek P, Meyling AWG, Noble DG, Foppen RPB, Gibbons DW (2005) Developing indicators for European birds. *Philos T Roy Soc B* 360:269–288
- Hole DG, Whittingham MJ, Bradbury RB, Anderson GQA, Lee PLM, Wilson JD, Krebs JR (2002) Widespread House Sparrow extinctions – Agricultural intensification is blamed for the plummeting populations of these birds. *Nature* 418:931–932
- Imbeau L, Drapeau P, Morkkonen M (2003) Are forest birds categorised as “edge species” strictly associated with edges? *Ecography* 26:514–520
- Kleijn D, Sutherland WJ (2003) How effective are European agri-environment schemes in conserving and promoting biodiversity? *J Appl Ecol* 40:947–969
- Kleijn D, Báldi A (2005) Effects of set-aside land on farmland biodiversity: comments on van Buskirk and Willi. *Conserv Biol* 19:963–966
- Lundstrom-Gillieron C, Schlaepfer R (2003) Hare abundance as an indicator for urbanisation and intensification of agriculture in Western Europe. *Ecol Model* 168:283–301
- Magura T, Tóthmérész B, Bordán Z (2000) Effects of nature management practice on carabid assemblages, Coleoptera: Carabidae, in a non-native plantation. *Biol Conserv* 93:95–102
- Maron M, Lill A (2005) The influence of livestock grazing and weed invasion on habitat use by birds in grassy woodland remnants. *Biol Conserv* 124:439–450
- Martin D, van der Straaten J (2004) *Cultural landscapes and land use*. Kluwer Academic Publishers, Dordrecht
- Milsom TP, Ennis DC, Haskell DJ, Langton SD, McKay HV (1998) Design of grassland feeding areas for waders during winter: the relative importance of sward, landscape factors and human disturbance. *Biol Conserv* 84:119–129
- Moreira F, Beja P, Morgado R, Reino L, Gordinho L, Delgado A, Borralho R (2005) Effects of field management and landscape context on grassland wintering birds in Southern Portugal. *Agric Ecosyst Environ* 109:59–74
- Murphy MT (2003) Avian population trends within the evolving agricultural landscape of eastern and central United States. *Auk* 120:20–34
- Newton I (2004) The recent declines of farmland bird populations in Britain: an appraisal of causal factors and conservation actions. *Ibis* 146:579–600
- Paton PWC (1994) The effect of edge on avian nest success: How strong is the evidence? *Conserv. Biol* 8:17–26
- Pavel V (2004) The impact of grazing animals on nesting success of grassland passerines in farmland and natural habitats: a field experiment. *Folia Zool* 53:171–178

- Perkins AJ, Whittingham MJ, Bradbury RB, Wilson JD, Morris AJ, Barnett PR (2000) Habitat characteristics affecting use of lowland agricultural grassland by birds in winter. *Biol Conserv* 95:279–294
- Pywell RF, Bullock JM, Hopkins A, Walker KJ, Sparks TH, Burke MJW, Peel S (2002) Restoration of species-rich grassland on arable land: assessing the limiting processes using a multi-site experiment. *J Appl Ecol* 39:294–309
- Siriwardena GM, Baillie SR, Buckland ST, Fewster RM, Marchant JH, Wilson JD (1998) Trends in the abundance of farmland birds: a quantitative comparison of smoothed common bird census indices. *J Appl Ecol* 35:24–43
- Söderström B, Svensson B, Vessby K, Glimskar A (2001) Plants, insects and birds in semi-natural pastures in relation to local habitat and landscape factors. *Biodiv Conserv* 10:1839–1863
- Stephens SE, Koons DN, Rotella JJ, Willey DW (2003) Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. *Biol Conserv* 115:101–110
- Stoate C, Boatman ND, Borralho RJ, Carvalho CR, de Snoo GR, Eden P (2001) Ecological impacts of arable intensification in Europe. *J Environ Manage* 63:337–365
- Tscharntke T, Klein AM, Kruess A, Steffan-Dewenter I, Thies C (2005) Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. *Ecol Lett* 8:857–874
- Tucker GM, Heath MF (1994) *Birds in Europe: Their Conservation Status*. BirdLife International, Cambridge
- Verhulst J, Báldi A, Kleijn D (2004) Relationship between land-use intensity and species richness and abundance of birds in Hungary. *Agric Ecosyst Environ* 104:465–473
- Vickery JA, Tallwin JR, Feber RE, Asteraki EJ, Atkinson PW, Fuller RJ, Brown VK (2001) The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. *J Appl Ecol* 38:647–664
- Virkkala R, Luoto M, Rainio K (2004) Effects of landscape composition on farmland and red-listed birds in boreal agricultural-forest mosaics. *Ecography* 27:273–284
- Wiens JA (1995) Habitat fragmentation – Island vs. landscape perspectives on bird conservation. *Ibis* 137:97–104
- Wilson JD, Morris AJ, Arroyo BE, Clark SC, Bradbury RB (1999) A review of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. *Agric Ecosyst Environ* 75:13–30