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ORIGINAL PAPER

The conservation value of restored landfill sites in the East Midlands, UK for supporting bird communities

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Abstract There has been a rapid decline of grassland bird species in the UK over the last four decades. In order to stem declines in biodiversity such as this, mitigation in the form of newly created habitat and restoration of degraded habitats is advocated in the UK biodiversity action plan. One potential restored habitat that could support a number of bird species is re-created grassland on restored landfill sites. However, this potential largely remains unexplored. In this study, birds were counted using point sampling on nine restored landfill sites in the East Midlands region of the UK during 2007 and 2008. The effects of restoration were investigated by examining bird species composition, richness, and abundance in relation to habitat and landscape structure on the landfill sites in comparison to paired reference sites of existing wildlife value. Twelve bird species were found in total and species richness and abundance on restored landfill sites was found to be higher than that of reference sites. Restored landfill sites support both common grassland bird species and also UK Red List bird species such as skylark *Alauda arvensis*, grey partridge *Perdix perdix*, lapwing *Vanellus vanellus*, tree sparrow, *Passer montanus*, and starling *Sturnus vulgaris*. Size of the site, percentage of bare soil and amount of adjacent hedgerow were found to be the most influential habitat quality factors for the distribution of most bird species. Presence of open habitat and crop land in the surrounding landscape were also found to have an effect on bird species composition. Management of restored landfill sites should be targeted towards UK Red List bird species since such sites could potentially play a significant role in biodiversity action planning.

Keywords Biodiversity · Birds · Restoration · Conservation · Grassland · Landfill · UK

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Abbreviations
LF Landfill
RF Reference

Introduction

Grassland accounts for over 65% of the agricultural land in Britain on which a range of birds depend exclusively or partly (Vickery et al. 2001; Atkinson et al. 2004; Morris and Gilroy 2008). Destruction of natural habitat, fragmentation, intensive agricultural practices and extensive changes in landscape structure are key factors in the recent decline of many bird species (Fuller et al. 1995; Atkinson et al. 2004). In Britain, most declines date back to at least the 1970s, a period when several fundamental changes were taking place in British agriculture through simplification of crop rotations, increased use of chemical pesticides, more intensive grassland management and a shift from spring to autumn sown cereals (Browne et al. 2000; Gregory et al. 2004). Such changes reflect broad-scale transformation across Western Europe as EU support for agriculture has resulted in range contractions and population declines in many farmland bird species (Donald et al. 2001; Vořišek et al. 2010).

Compensatory measures are recommended in the UK biodiversity action plan to offset the impact of habitat loss (Anon 1994; Parker 1995; Morris et al. 2006). Habitat creation or re-creation have been used in conjunction with habitat protection legislation in the UK to conserve extant biodiversity and habitat (Wheater et al. 2000; Morris et al. 2006). Restoration and reclamation of land once used for landfilling has generated great interest as landfill operators are obligated by planning legislation to restore such areas by creating grassland or planting trees (Davis 1988; Dobson and Moffat 1993; Handel et al. 1997; Wheater and Cullen 1997; White et al. 2003; Davies 2006). There are approximately 2,200 working landfill sites in England and Wales covering 28,000 ha and they are closing at a rate of about 100 per year (DETR 2001; EA 2006). These sites therefore represent a significant stock of land with conservation potential.

Species richness of an area is affected by local factors such as size, shape and habitat quality, and also by landscape level factors such as the spatial configuration of different land use (Wiens 1995; Mazerolle and Villard 1999). For example, grassland vegetation structure includes vertical and horizontal distribution of the vegetation which can affect feeding efficiency of birds, which in turn can influence foraging site selection by a range of grassland bird species, many of which are of current conservation concern (Tucker 1992; Butler et al. 2005). Habitats with a more heterogeneous vegetation structure suit the foraging requirements and predator escape strategies of a broad range of species and thus support a higher species richness (Butler et al. 2005).

At a larger scale the composition of habitat types in a landscape and the spatial structure of those habitats can influence species assemblages and help maintain viable populations (Dunning et al. 1992; Söderström et al. 2001). There is a growing recognition of the importance of landscape context on bird assemblages and the type of landscape matrix in which a patch is embedded can potentially mitigate the negative effect of habitat isolation for a given species (Wiens 1997; Bennett et al. 2004). The field margin, and in particular the hedgerow, is also a key factor for bird species richness with the height of the hedgerow being important (Parish et al. 1994; Hinsley and Bellamy 2000). At the landscape-scale, some species tend to use open grassland at specific times, e.g., in winter lapwing *Vanellus vanellus*, goldfinch *Carduelis carduelis* and robin *Erithacus rubecula* tend to shift more to landscapes with a greater pastoral component (Atkinson et al. 2002).

There have been few studies on the role that restored landfill sites can have for bird species conservation. The aim of the present research was to determine the role of newly created grassland and associated edge habitat (e.g., hedgerows) on landfill sites in providing habitat for bird species. Accordingly, we outline the abundance patterns and spatial distribution of birds in relation to local habitat and landscape variables in restored landfill sites, and make comparisons to nearby designated conservation sites.

Methods

Study sites

The study area covered mainly Northamptonshire and parts of Bedfordshire, Buckinghamshire and Warwickshire, ranging from 51°58′44.74″ N to 52°26′42.18″ N and 0°27′49.94″ W to 1°19′57.67″ W (Fig. 1). This region has countryside of low, undulating hills separated by valleys and lies entirely within the great belt of scarplands formed by rocks of Jurassic age which stretch across England from Yorkshire to Dorset (Beaver 1943; Sutherland 1995; Wilson 1995). Nine restored landfill (LF) sites were selected from the pool of 42 based on minimum size of the site and sites which have been restored for at least 4 years. The mean size (±standard deviation) of restored landfill sites was 13.98 ± 10.45 ha. The landfill sites, all between 4 and 15 years old, were selected to provide a spread of ages of recently restored grassland communities. Grassland on most of the restored landfill sites was managed by mowing during summer whereas all reference sites were managed by either mowing or grazing. In order to provide a comparison, the closest grassland sites of recognised conservation value (being designated as either local nature reserves (LNRs) or sites of special scientific interest (SSSI)) to the restored landfill sites were selected (Fig. 1). Such sites were close enough to the landfill sites so that they experience similar local climates, have the same regional pool of species, and have comparable landscape contexts (mean distance = 4.46 ± 3.47 km, range = 1.31–11.75 km). The landfill sites were representative of restored landfill sites within the region and thus probably fairly typical of restored landfill sites in lowland UK.

Bird sampling

Bird numbers were assessed in spring, summer and autumn by means of point counts with infinite counting range from April 2007 to October 2008. They involved counting birds from fixed points during a specified time interval (Baillie 1991). This method is ideal for bird sampling within grassland habitat and is a reliable estimator of bird density for a range of different species. Birds were counted from a centre point of each site with a 5 min duration, in line with European monitoring schemes (Baillie 1991) and identified by acoustic and morphological characteristics with the aid of 10 × 40 binoculars (Bibby et al. 1992). All birds foraging or nesting in particular study sites were counted, whilst species flying overhead but not using sites were not counted. Double counting was minimised by taking into account the area to which birds had moved. The rationale of this approach was to provide broad coverage over a number of paired sites with a view to standardising surveys. The data are therefore not intended to be a complete list of species and it is likely

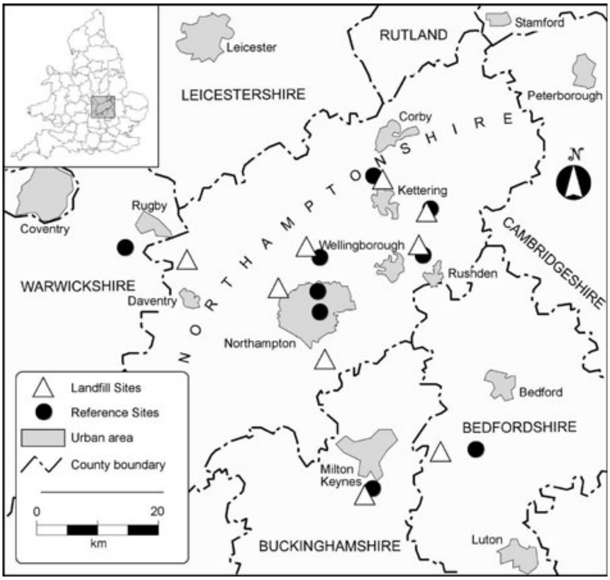

Fig. 1 Location of selected landfill sites and reference sites used in the present study in Northamptonshire and its surrounding counties

that this approach may have missed some of the more localised species. Nomenclature follows that of Hagemeijer and Blair (1997). Each landfill site and its corresponding reference site were sampled on the same day with no censuses conducted in high winds or heavy rain as in such weather conditions bird activity tends to be reduced (Wilson et al. 1997).

Local and landscape variables

Local habitat quality factors which are considered to have an effect on the distribution of birds include: size of the sites, shape index, total surrounding hedgerow $\geq$2 m in height and total surrounding hedgerow <2 m in height, mean vegetation height, vegetation height diversity, percentage of bare soil (Wilson et al. 1997; Bennett et al. 2004). The Shape Index, Shpindx, was calculated by comparing the perimeter of the patch to that of a circle of the same size:

$$\text{Shpindx} = P/2(\pi A)$$

where A is size of the site and P is boundary length (Faeth and Kane 1978; Forman 1995). The total length of hedgerow <2 and $\geq$2 m in height surrounding each site were estimated from Google Maps© combined with field surveys. Landscape parameters for each site were calculated within arcs of 500 and 1000 m radius around each site using a GIS (ESRI 1999). In each circle, the proportion of the total area covered by open habitat, grassland, cropland, built-up land, scrubland, and woodland were measured (Refer to Fig. 3 legend for abbreviations of variables used in analyses). Note that whole fields did not have to be within 500 or 1000 m radius to be included in the analysis. For example, if a field was dissected by the arc, the whole of that field was included in the estimate of cover. Measures of vegetation height and percentage bare soil were taken from the stem nearest the four corners and centre of each quadrat, respectively, in 10 random 1 $\times$ 1 m quadrats on each site.

Data analysis

Mean number of birds from multiple visits were used for data analysis. To analyse the data generalized linear models (GLMs) were constructed to compare local habitat and landscape parameters affecting different species, and to establish which habitat and landscape characteristics explained significant changes in the frequency of occurrence for each species. To ensure analyses focussed on resident species, habitat associations were modelled for those seven bird species which were recorded at least three times in the surveys. The analysis was carried out with the software R (R Development Core Team 2003). Non-significant predictors (independent variables) were removed in a stepwise manner (least significant factor first). For distribution pattern of bird species, data were initially analysed using detrended correspondence analysis. Redundancy analysis (RDA) was performed on the same data using CANOCO for Windows version 4.0 (ter Braak and Smilauer 2002).

Results

Bird species richness and abundance

A total of 12 species of birds were recorded in point counts both in restored landfill sites and their corresponding reference sites in all three different seasons during 2007 and 2008. All 12 species occurred on restored landfill sites whereas only five species were found on reference sites (Table 1). Greater mean species richness was found in restored landfill sites compared to reference sites (Fig. 2a). There were also significant differences in the abundance of birds counted between the restored landfill sites and reference sites (Fig. 2b). The ranking of species by their proportional abundances indicated that the most abundant in the restored landfill sites were skylark *Alauda arvensis* and carrion crow *Corvus corone,* whereas in reference sites the most abundant species were *C. corone* followed by magpie *Pica pica* (Table 1). Within restored landfill sites, there was no significant difference in mean species richness (ANOVA: $F_{1,8} = 0.77$, $P = 0.40$) or abundance (ANOVA: $F_{1,8} = 0.07$, $P = 0.79$) whether management (mowing) was applied or not. Further, there were neither significant correlations between bird species richness nor abundance with age of the restored landfill sites (bird abundance vs. age, $r = -0.37$, $P = 0.32$; bird species richness vs. age, $r = -0.38$, $P = 0.11$, $n = 9$).

Ordination of bird species with local habitat and landscape parameters

Ordination using multivariate analysis displayed the major variation in bird community composition across the restored landfill sites and reference sites with their environmental variables. DCA was carried out on the total species data set and the resulting gradient lengths were fairly short (less than 3.0), suggesting that linear analytical techniques were more appropriate. RDA was used to examine the influence of local habitat and surrounding landscape composition on community structure of bird species.

Figure 3a represents the RDA ordination plots of the variation in bird species composition with respect to local habitat parameters. The first two axes explained 69.5% of the

Table 1 Bird species recorded in restored landfill sites and their corresponding reference sites, the number of sites occupied and their status as grassland species and woodland/edge species

Scientific name	Species	No. of sites ($n = 18$)		Ecological groups[a]	
		Landfill	Reference	Grassland	Woodland/Edge
Alauda arvensis	Skylark	9	1	*	
Columba palumbus	Woodpigeon	4	2		*
Corvus corone	Carrion crow	9	9	*	
Passer montanus	Tree sparrow	6	0		*
Perdix perdix	Grey partridge	3	0	*	
Phasianus colchicus	Pheasant	4	0		*
Pica pica	Magpie	1	6		*
Prunella modularis	Dunnock	3	0		*
Streptopelia decaocto	Collared dove	3	1		*
Sturnus vulgaris	Starling	1	0	*	
Turdus merula	Blackbird	1	0		*
Vanellus vanellus	Lapwing	1	0	*	

[a] *Sources*: Bennett et al. (2004), Golley (2004) and Batary et al. (2007)

variability in species data with size of the sites, amount of hedgerow <2 m height, and percentage of bare soil all on the positive part of axis-1 and associated with most of the bird species in terms of distribution and abundance.

Within the 500 m and 1000 m radius zones, the first two axes of RDA explained 31.4 and 24.7% of the variability in species data, respectively (Fig. 3b, c). Open habitat and cropland were found to have the greatest power to explain the abundance and distribution of bird species in these analyses.

Exploratory GLM analysis for diversity, richness and abundance of bird species

Of the 12 bird species recorded, seven species which occurred on more than three sites in 2007 and 2008 were further analysed using GLM. Among the habitat quality variables, percentage bare soil, size of sites, and shape index were found to be significant explanatory variables for bird abundance. The size of the site was a highly significant variable explaining diversity and richness of bird species. Mean vegetation height and percentage bare soil were also found to be significant variables for bird species diversity (Table 2). Among the landscape variables, the percentage of open habitat surrounding each of the studied sites explained the largest amount of variation in diversity and richness of bird species. Bird abundance was found to be negatively influenced by the percentage of scrubland and woodland in the surrounding habitat but positively related to open habitat and built-up land, cropland and grassland (Table 2).

Bird species responded individually to the habitat and landscape variables. The size of the site was found to be the most common variable explaining the abundance of most bird species, except for pheasant *Phasianus colchicus*. This species tended to occur most often in sites surrounded by woodland patches. The presence of hedgerow surrounding the sites was found to significantly influence the abundance of skylark *A. arvensis*, woodpigeon *Columba palumbus*, tree sparrow *Passer montanus*, and magpie *P. pica*. The abundance of collared dove *Streptopelia decaocto* was mostly explained by the presence of open habitat

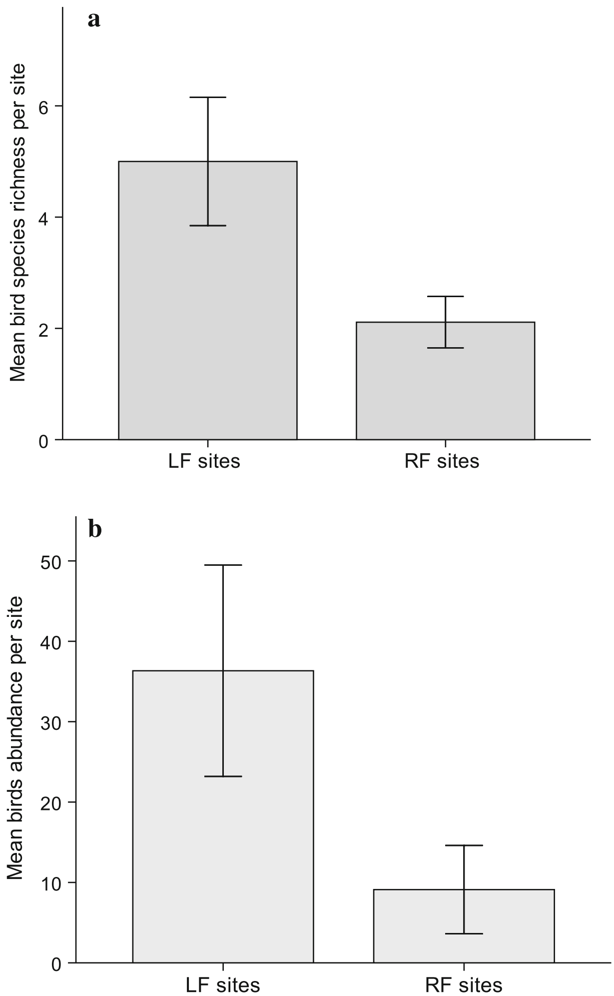

Fig. 2 **a** Differences in the numbers of bird species between landfill (LF) sites and reference (RF) sites (paired *t*-test, $t = 4.56$, df = 8, $P = 0.002$), and **b** Differences in the total abundance of birds between LF sites and RF sites (Paired *t*-test, $t = 3.74$, df = 8, $P = 0.006$) (both means ± 95% Confidence Limits)

in the surrounding landscape. However, the results from the GLM suggested that species diversity, abundance and richness of the restored landfill sites and reference sites were highly related to habitat quality and landscape variables (Table 2).

Discussion

General grassland bird species richness and abundance

Bird data from the 2007 and 2008 surveys showed that restored landfill sites appear to differ from their corresponding reference sites with respect to bird species richness and abundance (Fig. 2a, b). A comparison of the abundance of birds showed that re-created grassland on restored landfill sites contained numbers of species equal to or above that of equivalent habitats of nature conservation value. Most bird species were found on the restored grassland on landfill sites and such sites hosted the highest number of bird species

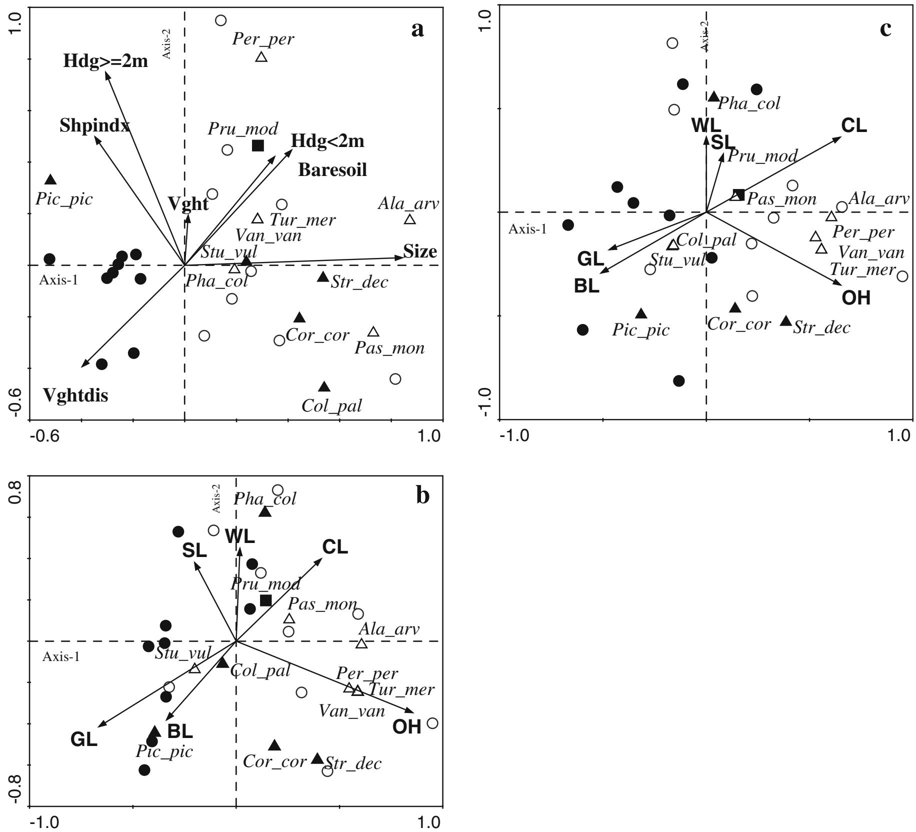

Fig. 3 Biplot ordination diagram of axis one and axis two of RDA analysis showing the effects of **a** local habitat parameters and **b** landscape variables within 500 m and **c** landscape within 1000 m, on bird community structure. All species are referred to by the *first three letters* of the genus name followed by the *first three letters* of the species name. *Alauda arvensis = Ala_arv, Columba palumbus = Col_pal, Corvus corone = Cor_cor, Passer montanus = Pas_mon, Perdix perdix = Per_per, Pica pica = Pic_pic, Phasianus colchicus = Pha_col, Prunella modularis = Pru_mod, Streptopelia decaocto = Str_dec, Sturnus vulgaris = Stu_vul, Turdus merula = Tur_mer and Vanellus vanellus = Van_van.* In the diagram, continuous local habitat quality and landscape variables are shown as vectors. Bare soil on site (%) = Baresoil, Length of hedgerow ≥2 m in height (m) = Hdg ≥2 m, Length of the hedgerow <2 m in height (m) = Hdg <2 m, Shape index of the sites = Shpindx, Size of the sites (ha) = Size, Mean vegetation height (cm) = Vght, Vegetation height diversity = Vghtdis, built-up land (%) = BL, cropland (%) = CL, grassland (%) = GL, open habitats (%) = OH, scrubland (%) = SL and woodland (%) = WL. *Black circle* RF sites, *white circle* LF sites, *white triangle* UK Red List species, *black square* UK Amber List species, *black triangle* Common species

and the highest abundance of individuals (Fig. 4). Every species has specific habitat preferences, and these newly created grasslands can contribute greatly to conservation by providing additional habitat for common species but also for declining bird species such as skylark *A. arvensis*.

Intensive grassland management can have both positive and negative effects on bird species richness and diversity (Fuller and Gough 1999; Verhulst et al. 2004). Management can impact on bird populations through changes in vegetation structure, food resources,

Table 2 GLM of overall abundance, diversity, and richness in LF sites and RF sites combined

	Local habitat model				Landscape within 500 m buffer zone model				Landscape within 1 km buffer zone model			
	Variables	Estimate	Chi-square	Explained variance (%)	Variables	Estimate	Chi-square	Explained variance (%)	Variables	Estimate	Chi-square	Explained variance (%)
Abundance	Intercept	0.11			Intercept	3.11			Intercept	0.96		
	Bare soil	0.22	83.4***	32.51	Scrubland	−0.10	54.7***	21.36	Built-up land	0.02	30.2**	11.79
	Size	0.03	58.6***	22.85	Open habitat	0.03	30.4***	11.88	Scrubland	−0.14	21.1***	8.24
	Shpindx	−0.01	26.8***	10.44	Built-up land	0.01	8.5**	3.33	Open habitat	0.09	18.7***	7.28
									Cropland	0.02	8.8***	3.42
									Woodland	−0.03	7.5**	2.93
									Grassland	0.05	2.3***	0.89
Diversity	Intercept	0.11			Intercept	0.85						
	Size	0.02	1.2**	31.08	Open habitat	0.02	0.9*	24.05				
	Bare soil	0.11	0.7*	17.83								
	Veg ht	0.01	0.6*	16.75								
Richness	Intercept	0.95			Intercept	1.12						
	Size	0.02	9.12*	44.15	Open habitat	0.02	3.5*	21.49				
Skylark *A. arvensis*	Intercept	3.95			Intercept	0.42			Intercept	0.69		
	Bare soil	0.31	41.6***	17.75	Built-up land	0.05	28.7***	12.88	Cropland	0.02	34.7***	14.80
	Shpindx	−0.02	38.9***	16.62	Open habitat	0.05	22.1***	9.43	Woodland	−0.19	25.5***	10.89
	Size	0.04	24.9***	10.61	Cropland	0.02	17.7***	7.53	Open habitat	0.11	9.3***	3.98
	Hdg <2 m	0.001	17.1***	7.30	Scrubland	−0.09	7.0**	2.98	Scrubland	−0.19	7.3**	3.13
									Grassland	0.05	1.0**	0.40
Wood pigeon *C. palumbus*	Intercept	0.21										
	Hdg ≥2 m	−0.003	16.0**	47.00								
	Size	0.04	3.9*	11.38								

Table 2 continued

	Local habitat model				Landscape within 500 m buffer zone model				Landscape within 1 km buffer zone model			
	Variables	Estimate	Chi-square	Explained variance (%)	Variables	Estimate	Chi-square	Explained variance (%)	Variables	Estimate	Chi-square	Explained variance (%)
Carrion crow *C. corone*	Intercept	2.06			Intercept	2.10			Intercept	2.11		
	Size	0.03	9.1**	24.02	Scrubland	−0.11	16.4***	43.52	Scrubland	−0.13	7.7**	20.40
	Veg ht	−0.01	6.4*	16.93								
Tree sparrow *P. montanus*	Intercept	0.57			Intercept	−0.19						
	Bare soil	0.25	6.9*	24.09	Woodland	0.07	12.5***	12.54				
	Hdg >2 m	−0.002	18.1***	18.07	Scrubland	−0.10	2.0*	1.98				
	Size	0.04	24.1***	6.88	Open habitat	0.04	1.4*	1.35				
					Built-up land	0.04	1.3**	1.31				
Pheasant *P. colchicus*	Intercept	−3.83			Intercept	−2.46			Intercept	−2.45		
	Veg ht	0.04	16.7*	25.86	Woodland	0.12	11.8**	52.48	Woodland	0.18	11.7***	52.01
Magpie *P. pica*	Intercept	−0.70			Intercept	−0.98			Intercept	−2.51		
	Size	−1.04	34.4**	36.23	Grassland	0.05	35.6***	37.53	Woodland	−0.35	20.9***	22.01
	Hdg ≥2 m	0.006	25.5***	26.88	Built-up land	0.02	7.1*	7.44	Grassland	0.20	17.9***	18.93
	Hdg <2 m	0.007	3.2**	3.41	Scrubland	−0.11	5.5*	5.81	Scrubland	−0.30	13.0***	13.75
									Open habitat	0.17	0.5**	0.50
Collared dove *S. decaocto*	Intercept	−2.01			Intercept	−1.46			Intercept	−1.63		
	Size	0.11	18.7***	55.66	Open habitat	0.09	20.9***	49.72	Open habitat	0.15	22.3***	53.14

Results show the explanatory variables selected at each of the three scales for the occurrence of selected bird species (see text for further explanation)

[a] Shpindx = Shape index, Veg ht = Mean vegetation height, Hdg <2 m = length of hedgerow less than 2 m height, Hdg ≥2 m = length of hedgerow greater than or equal to 2 m height. Significance: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$

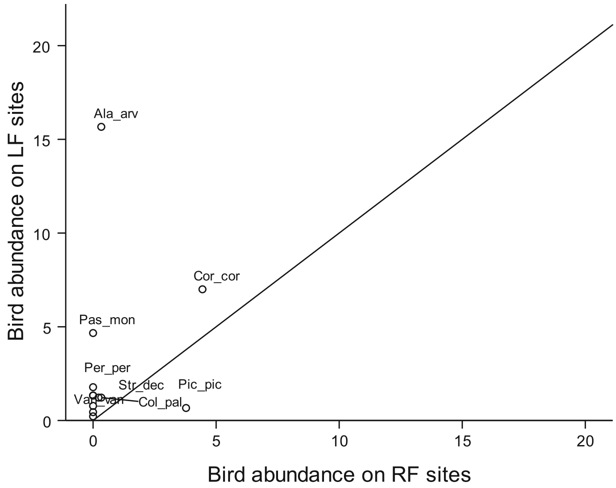

Fig. 4 Bird species abundance (individuals) on LF sites and their corresponding RF sites. (line = 1:1). All species are referred to by the first three letters of the genus name followed by the first three letters of the species name. Some species names omitted for clarity

and predation pressure (Vickery et al. 2001). Intensive management may increase nest losses due to predation and trampling (Wilson et al. 1999; Pavel 2004). However, in the present study any differences in management (i.e., mowing vs. grazing) produced no discernable impacts on species richness and abundance of birds on restored grasslands. This could be explained by the fact that sites harbour both grassland and non-grassland bird species, some of which only feed on sites and do not nest there, and that both types of management produce a fairly uniform sward with little variation in vegetation height which therefore have a lack of explanatory power when compared with other independent variables (Table 1).

Relationships between bird species, habitat quality and landscape features

Most of the bird species showed one or more significant correlations with habitat and landscape variables in the GLM analysis (Table 2). The size of the sites and the percentage bare earth on site were found to be significant factors explaining species abundance and diversity, possibly because such habitats help contribute towards the provision of sufficient foraging resources for a large number of individuals of different bird species. The abundance of birds was also found to be related to all six landscape variables. This result is consistent with other studies that found that the abundance of bird species within a patch was influenced by the surrounding habitat matrix (Robertson et al. 1990; Baillie et al. 2000).

Species richness and diversity were related to both the nature of the sites themselves and to that of the surrounding landscape within a 500 m radius. The site itself clearly had the strongest influence on the number of bird species (Fig. 5). Local habitat quality and landscape factors within 500 and 1000 m radius zones were significant factors explaining the abundance of bird species in the study sites. However, it should be noted that the RDA generated similar plots for these two scales and the overall explanatory power was marginally higher at the 500 m compared with the 1000 m scale (31.4 cf. 24.7%) (Fig. 3b, c).

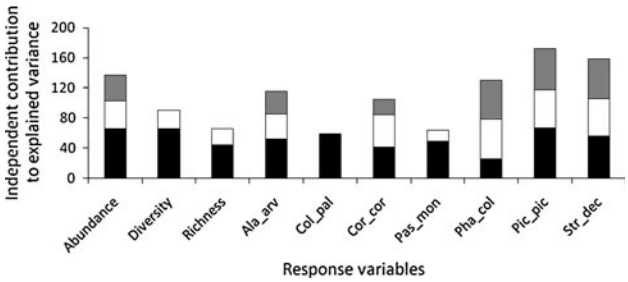

Fig. 5 Comparison of the total independent variance attributed to local habitat quality (*shaded*), landscape variables within 500 m radius zone (*clear*) and landscape variables within 1000 m radius zone (*grey*) for each response variables. All species are referred to by the first three letters of the genus name followed by the first three letters of the species name

Overall, the 500 m scale also had higher explanatory power in the GLM analysis with some models being significant at the 500 m scale but not the 1000 m scale (i.e., diversity, richness, and tree sparrow *P. montanus*) and, with the exception of woodpigeon *C. palumbus* which only generated significant models at the local habitat scale, greater overall explanatory power for the remaining variables except magpie *P. pica* and collared dove *S. decaocto*.

Overall, the Local Habitat Model accounted for higher variance in GLM analysis and it may be concluded, therefore, that the local scale plays a significant role in determining bird species richness and diversity in the restored landfill sites. A higher proportion of insect feeding birds (e.g. skylark *A. arvensis,* tree sparrow *P. montanus,* dunnock *Prunella modularis* and lapwing *V. vanellus*) were found on restored landfill sites compared to the reference sites. Such differences may come about due to differences in the availability of differing food resources on restored landfill sites compared to reference sites and in particular due to the availability of invertebrates. In contrast, generalists (e.g., magpie *P. pica*) were found in higher proportions within the reference sites than the restored landfill sites (Fig. 4).

In the present study, abundance of birds was found to be mostly determined by both local and landscape factors whereas bird species richness was mostly influenced by size of the sites (Fig. 5). Söderström et al. (2001) emphasised the importance of landscape composition for birds and found that grassland birds decreased with increasing proportions of urban elements and arable fields in a 1000 m landscape area. Likewise, Moreira et al. (2005) found that species richness was primarily influenced by landscape context, whereas local factors mostly determined abundance. McCollin (1993) found that bird distribution was mainly related to landscape structure represented by an underlying gradient of habitat fragmentation. There is therefore growing evidence that the nature of the surrounding landscape influences bird communities (Robinson et al. 2001; Atkinson et al. 2002).

In this study, both local and landscape variables were significant predictors of abundance for all species except woodpigeon. Thus it seems that the variation in abundance and frequency amongst species in different restored landfill and reference sites was determined by habitat quality features within the sites and in the surrounding landscape. Two factors that appear to distinguish LF from RF sites in the RDA are size of site (Fig. 3a) and the presence of open habitats (OH) (Figs. 3b, c). Grassland bird species of conservation concern associated with these areas include skylark, lapwing and grey partridge. Open habitats in this context contrasts with the vicinity of woodland (WL) and other scrubby vegetation (SL) or vertical habitats (BL) which could potentially provide perching or nesting sites for predators.

It is clear from these data that local characteristics and landscape measures should be taken into consideration when considering management of sites. Field boundary habitats are known to be extremely important in providing both foraging and nesting habitats for many species of farmland bird (Morris and Gilroy 2008). Moreover, habitat preferences and autoecological traits of an organism, together with landscape features must be considered in conservation and management planning for each restored landfill site.

Conclusions

In conclusion, it has been demonstrated that bird richness and abundance depends upon local and landscape variables in newly created grasslands on restored landfill sites. A number of UK Red List bird species recorded on restored landfill sites include skylark *A. arvensis,* tree sparrow *P. montanus*, grey partridge *P. perdix*, starling *S. vulgaris* and lapwing *V. vanellus,* and UK Amber List species included Dunnock *P. modularis*. The particular factor that led to inclusion in the UK Red List for these species was severe (at least 50%) decline in UK breeding populations over last 25 years, or declines over a longer-term period (Eaton et al. 2009). The degree to which restored landfill sites have the potential to play a role in the conservation effort for UK Red List bird species in the UK deserves further investigation to test the generality of our findings.

Notwithstanding the need for such research, developing broad plans for managing these restored sites sensitively for birds is unlikely to be difficult. The results of this study suggest that there are several ways of maximising the benefits of restored landfill sites to a number of bird species. It should be emphasised that conservation of bird species in restored landfill sites may require both local and a landscape perspectives. By increasing habitat heterogeneity within a landscape, restored landfill sites can enhance the diversity of a local area.

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References

Anon (1994) Biodiversity: the UK action plan. HMSO, London, UK

Atkinson PW, Fuller RJ, Vickery JA (2002) Large-scale patterns of summer and winter bird distribution in relation to farmland type in England and Wales. Ecography 25:466–480

Atkinson PW, Buckingham D, Morris AJ (2004) What factors determine where invertebrate-feeding birds forage in dry agricultural grasslands? Ibis 146:99–107

Baillie SR (1991) Monitoring terrestrial breeding bird populations. In: Goldsmith FB (ed) Monitoring for conservation and ecology. Chapman and Hall, New York, pp 112–132

Baillie SR, Sutherland WJ, Freeman SN, Gregory RD, Paradis E (2000) Consequences of large-scale processes for the conservation of bird populations. J Appl Ecol 37:88–102

Batary P, Baldi A, Erdos S (2007) Grassland versus non-grassland bird abundance and diversity in managed grasslands: local, landscape and regional scale effects. Biodivers Conserv 16:871–881
Beaver SH (1943) The land of Britain. Geographical Publications Ltd, London
Bennett AF, Hinsley SA, Bellamy PE, Swetnam RD, Mac Nally R (2004) Do regional gradients in land-use influence richness, composition and turnover of bird assemblages in small woods? Biol Conserv 119:191–206
Bibby CJ, Burgess ND, Hill DA (1992) Bird census techniques. Academic Press, London
Browne S, Vickery J, Chamberlain D (2000) Densities and population estimates of breeding skylarks *Alauda arvensis* in Britain in 1997. Bird Study 47:52–65
Butler SJ, Bradbury RB, Whittingham MJ (2005) Stubble height affects the use of stubble fields by farmland birds. J Appl Ecol 42:469–476
Davies AM (2006) Nature after minerals: how mineral site restoration can benefit people and wildlife. RSPB report. Sandy, Beds, UK
Davis BNK (1988) Habitat creation on a landfill site. Mine Quarr Environ 2:25–29
DETR (2001) Towards a future renaissance. Urban Planning Policy Document, HMSO, London
Dobson MC, Moffat AJ (1993) The potential for woodland establishment on landfill sites. HMSO, London, UK
Donald PF, Green RE, Heath MF (2001) Agricultural intensification and the collapse of Europe's farmland bird populations. Proc R Soc Lond B 268:25–29
Dunning JB, Danielson BJ, Pulliam HR (1992) Ecological processes that affect populations in complex landscapes. Oikos 65:169–175
EA (2006) Landfill. http://www.environmentagency.gov.uk/yourenv/eff/1190084/resources–waste/213982/207743/?version=1&lang=e.EnvironmentAgency. Cited 08 Nov 2006
Eaton MA, Brown AF, Noble DG, Musgrove AJ, Hearn R, Aebischer NJ, Gibbons DW, Evans A, Gregory RD (2009) Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and the Isle of Man. Br Birds 102:296–341
ESRI (1999) ArcView GIS vers. 3.2. Environmental Systems Research Institute, Inc, Redlands, CA, USA
Faeth SH, Kane TC (1978) Urban biogeography. Oecol Berl 32:127–133
Forman RTT (1995) Land Mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, UK
Fuller RJ, Gough SJ (1999) Changes in sheep numbers in Britain: implications for bird populations. Biol Conserv 91:73–89
Fuller RJ, Gregory RD, Gibbons DW, Marchant JH, Wilson JD, Baillie SR, Carter N (1995) Population declines and range contractions among lowland farmland birds in Britain. Conserv Biol 9:1425–1441
Golley M (2004) A field guide to the birds of Britain and Ireland by habitat. New Holland Publishers (UK) Ltd, UK
Gregory RD, Noble DA, Custance J (2004) The state of play of farmland birds: population trends and conservation status of farmland birds in the United Kingdom. Ibis 146:1–13
Hagemeijer WJH, Blair MJ (eds) (1997) The EBCC atlas of European breeding birds-their distribution and abundance. T&AD Poyser, England
Handel SN, Robinson GR, Parsons WFJ, Mattei JH (1997) Restoration of woody plants to capped landfills: root dynamics in an engineered soil. Restor Ecol 5:178–186
Hinsley SA, Bellamy PE (2000) The influence of hedge structure, management and landscape context on the value of hedgerows to birds: a review. J Environ Manag 60:33–49
Mazerolle MJ, Villard MA (1999) Patch characteristics and landscape context as predictors of species presence and abundance: a review. Ecoscience 6:117–124
McCollin D (1993) Avian distribution patterns in a fragmented wooded landscape (North Humberside, UK): the role of between-patch and within-patch structure. Glob Ecol Biogeogr Lett 3:48–62
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
Morris AJ, Gilroy JJ (2008) Close to the edge: predation risks for two declining farmland passerines. Ibis 150:168–177
Morris RKA, Alonso I, Jefferson RG, Kirby KJ (2006) The creation of compensatory habitat—can it secure sustainable development? J Nat Conserv 14:106–116
Parish T, Lakhani KH, Sparks TH (1994) Modelling the relationship between bird population variables and hedgerow and other field margin attributes. Species richness of winter, summer and breeding birds. J Appl Ecol 31:764–775
Parker DM (1995) Habitat creation-a critical guide. English nature science, English Nature, Peterborough

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

R Development Core Team (2003) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria

Robertson JGM, Eknert B, Ihse M (1990) Habitat analysis from infra-red aerial photographs and the conservation of birds in Swedish agricultural landscapes. Ambio 19:195–203

Robinson RA, Wilson JD, Crick HQP (2001) The importance of arable habitat for farmland birds in grassland landscapes. J Appl Ecol 38:1059–1069

Söderström B, Svensson B, Vessby K, Glimskär A (2001) Plants, insects and birds in semi-natural pastures in relation to local habitat and landscape factors. Biodivers Conserv 10:1839–1863

Sutherland DS (1995) Geology and soils. In: Gent G, Wilson R (eds) The flora of Northamptonshire and the soke of Peterborough. Robert Wilson Designs, Northampton, pp 23–30

Ter Braak CJF, Smilauer P (2002) CANOCO reference manual and canoDraw for windows user's guide: software for canonical community ordination (version 4.5). Microcomputer Power, New York

Tucker GM (1992) Effects of agricultural practices on field use by invertebrate-feeding birds in winter. J Appl Ecol 29:779–790

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, Tallowin 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

Voříšek P, Jiguet F, van Strien A, Škorpilová J, Klvaňová A, Gregory RD (2010) Trends in abundance and biomass of widespread European farmlands birds: how much have we lost? In: BOU proceedings—Lowland Farmland Birds III. http://www.bou.org.uk/bouproc-net/lfb3/vorisek-etal.pdf

Wheater CP, Cullen WR (1997) The flora and invertebrate fauna of abandoned limestone quarries in Derbyshire, United Kingdom. Restor Ecol 5:77–84

Wheater CP, Cullen WR, Bell JR (2000) Spider communities as tools in monitoring reclaimed limestone quarry landforms. Landsc Ecol 15:401–406

White G, Gilbert J, Benstead P, Fasham M, Jose P (2003) Habitat creation handbook for the minerals industry. RSPB, Sandy, Beds

Wiens JA (1995) Habitat fragmentation: island versus landscape perspectives on bird conservation. Ibis 137:97–104

Wiens JA (1997) Metapopulation dynamics and landscape ecology. In: Hanski IA, Gilpin ME (eds) Metapopulation biology: ecology, genetics, and evolution. Academic Press, San Diego, pp 43–62

Wilson R (1995) The landscape. In: Gent G, Wilson R (eds) The flora of Northamptonshire and the soke of Peterborough. Robert Wilson Designs, Northampton, pp 31–32

Wilson JD, Evans J, Browne SJ, Jon RK (1997) Territory distribution and breeding success of skylarks *Alauda arvensis* on organic and intensive farmland in southern England. J Appl Ecol 34:1462–1478

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