Bird Study (2010) **57**, 289–300

Identifying set-aside features for bird conservation and management in northeast Iberian pseudo-steppes

BARRY J. MCMAHON[1], DAVID GIRALT[2]*, MONTSE RAURELL[2], LLUÍS BROTONS[2] and GERARD BOTA[2]

[1]UCD School of Agriculture, Food Science and Veterinary Medicine, University College Dublin, Ireland and [2]Centre Tecnologic Forestal de Catalunya, Àrea de Biodiversitat, Crta. Sant Llorenç, km 2, 25280 Solsona, Catalonia, Spain

Capsule Set-aside (land temporally removed from agricultural production) features and their regional locations influence steppe-bird species of conservation concern in Catalonia.

Aims To identify set-aside features important to the ecology of four ground nesting species, namely Little Bustard *Tetrax tetrax*, Stone-curlew *Burhinus oedicnemus*, Greater Short-toed Lark *Calandrella brachydactyla* and Calandra Lark *Melanocorypha calandra*.

Methods Set-aside fields were surveyed in four regions of Catalonia (northeast of Spain) for the selected species during the 2004 and 2005 breeding seasons. Set-aside habitat descriptors (e.g. size, vegetation structure) were collected. Ordination plots and information theoretic methods were used to assess the relationship between the selected bird species, set-aside features and the regions.

Results The region where the set-aside was located had a strong effect on the abundance of the selected species. In addition, vegetation coverage, field shape of set-aside and surrounding natural habitats were critical features, but with contrasting effects on the different species.

Conclusion Populations of the selected species of conservation concern could be improved by effective management of set-aside. As selected species responded differently, we recommend that management at local level should take into account the conservation value at a regional level of the protected area for each of the selected species.

INTRODUCTION

The proportion of steppe-land birds with unfavourable conservation status is the highest compared to any other bird group in Europe (83% of species) (Tucker & Evans 1997, Burfield 2005). The Iberian Peninsula is the most important region for steppe birds within the EU (Santos & Suárez 2005). Therefore the conservation of steppe-land habitats within this region is vital in order to maintain the integrity of the bird populations found within these habitats in Spain and in Europe. In addition, many steppe-land bird species are associated with traditional agricultural practices. It is important to appreciate that many of these species appear to have highly specialized habitat requirements compared with other birds that exploit farmland habitats (Burfield 2005). In order to address the declines of these species it is vital to understand the ecosystem requirements of these birds and the main factors that are driving the declines. Agricultural intensification and specialization (e.g. irrigation projects and consequent crop shift, non-crop habitats removal, pesticide use, etc.) has been labelled as the main general causal factor for the decline of many steppe-land and farmland birds (Tucker & Evans 1997, Aebischer *et al.* 2000, Donald, Green *et al.* 2001). The reduction of steppe habitats in Spain in recent decades is primarily because of the increase of irrigated land (Suárez *et al.* 1997, Brotons *et al.* 2004). Therefore, the remaining pseudo-steppes need to be effectively protected and managed to support viable bird populations.

In a dynamic system such as the traditional winter cereal-based farmland, which dominates the Iberian Peninsula, semi-permanent habitat patches such as set-aside or fallow land (which is land normally

*Correspondence author. Email: david.giralt@ctfc.cat

removed from agricultural production in order to reduce overproduction and surpluses within the EU) are regarded as a vital component of non-intensive agriculture benefiting bird conservation and biodiversity (Donald, Green *et al.* 2001, Buskirk & Willi 2004, Giralt *et al.* 2008). This is because set-aside provides foraging habitats (Henderson *et al.* 2000, Vickery *et al.* 2002) and breeding sites (Wilson *et al.* 1997, Chamberlain *et al.* 1999, Wolff *et al.* 2002) for many farmland and steppe-land birds. Informed management of set-aside land is required to assist in the conservation of the bird species associated with these areas. This is especially true in the areas that have been recently included in the Natura 2000 network, even though formal support for compulsory set-aside was removed by the EU in 2008 (BirdLife International 2008).

Although bird communities respond to changes both at landscape and field scale (Moreira *et al.* 2005, Brotons *et al.* 2004, Brotons *et al.* 2005), it is often more effective for conservationists and managers to implement strategies for individual species at local level (Kleijn *et al.* 2006). With this in mind, the objectives of this study were to identify the most important ecological features of set-aside in Catalonian pseudo-steppes (northeast Spain) for four species of conservation concern namely Little Bustard *Tetrax tetrax*, Stone-curlew *Burhinus oedicnemus*, Greater Short-toed Lark *Calandrella brachydactyla* and Calandra Lark *Melanocorypha calandra*. All of these species depend on set-aside to a greater or a lesser extent during the breeding period (Martínez 1994, Tucker & Evans 1997, Moreira 1999, Delgado & Moreira 2000). The results of this study should provide valuable information to inform the effective management of set-aside and enhance the value of extensive cereal systems in Catalonia and Spain for the selected species of conservation concern.

METHODS

Study areas and species

A total of four separate study regions dominated by farmland in Catalonia, northeast Spain, were selected as study areas (Fig. 1). These regions were Alfés (5800 ha), Belianes (2500 ha), Balaguer (1350 ha) and Granja d'Escarp (1800 ha) and were selected owing to the homogeneous nature of the dominant farmland (i.e. pseudo-steppe habitats surrounded by irrigated land). Furthermore, these regions have the majority or the entire populations of the selected species in Catalonia (Estrada *et al.* 2004, Brotons *et al.* 2004). In addition, they have recently been included in the Natura 2000 network with the aim of conserving steppe-land bird species and their habitats. All regions belong to the easternmost edge of the Ebro basin characterized by low annual rainfall (between 300 and 450 mm) and a contrasted continental climate. Main land-uses are winter cereals (barley and wheat) and minor land-uses include set-aside, almond and olive orchards (mainly

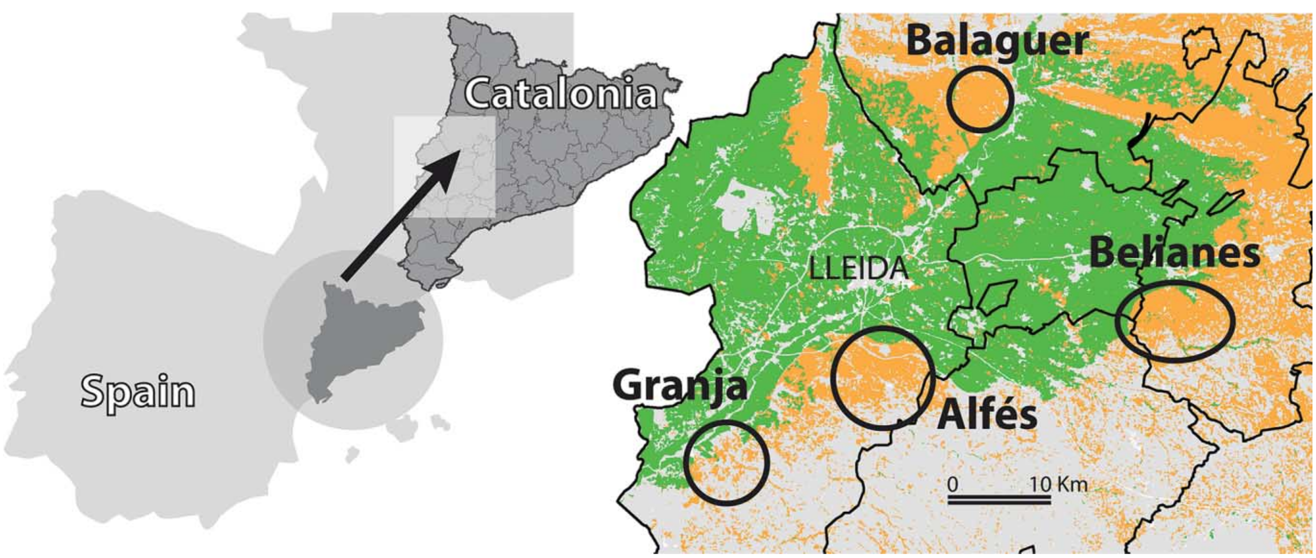

Figure 1. Location of the four study sites (circles) in Spain within the region of Catalonia. Orange areas (right side of the map) represent arid cereal crops, green areas represent irrigated crops and grey areas represent other land uses.

in Alfés and Belianes area) and patches of sparse scrubland (mainly in Alfés and Granja d'Escarp). Each year an area of arable land is devoted to set-aside or fallow, owing to an obligatory measure of the Common Agricultural Policy (CAP) for cereal crops. The area of set-aside available each year fluctuates, but usually represents around 3–15% of the studied regions. There was a substantial variation in the area of set-aside between each of the selected landscapes: Alfés, 14.0% (2004) and 14.9% (2005); Granja d'Escarp, 4.8% (2004) and 5.3% (2005); Balaguer, 3.2% (2004) and 4.0% (2005); Belianes, 2.2% (2004) and 3.8% (2005); all regions, 6.0 % ± 5.4 (2004) and 7.0 % ± 5.3 (2005). Most fields remain as set-aside for one year (some of them for two or three years) and they are periodically ploughed to control weeds, approximately once or twice per year.

The overall study area has the largest populations of Little Bustard, Stone-curlew, Short-toed Lark and Calandra Lark in Catalonia (Estrada *et al.* 2004). All species are present in the area during the spring and summer (March–July), although Stone-curlew, Calandra Lark and Little Bustard can also be found in the winter. In the case of Little Bustard, only adult males were documented during the field work as females are very secretive and difficult to detect.

Sampling methods

The four regions were surveyed for set-aside fields before the bird surveys to obtain information on set-aside distribution and abundance. To reduce variability only fields that had been left fallow for less than three years were considered. This represented the majority of the available set-aside in the different regions. Minimum distance between surveyed fields was set at 400 m to ensure independence between set-aside. Every effort was made to survey a representative distribution of set-aside sizes within the regions and to standardize the number of fields surveyed in each region. As a result, a total of 93 and 117 set-aside fields were surveyed in 2004 and 2005 respectively. The breakdown for the regions and the years was as follows: 2004: Alfés, n = 25; Belianes, n = 22; Balaguer, n = 22; Granja d'Escarp, n = 24; and 2005: Alfés, n = 33; Belianes, n = 30; Balaguer, n = 23; Granja d'Escarp, n = 31. Mean size of the surveyed fields was 2.5 ± 1.5 ha (range: 0.5–13.0 ha; n = 210).

Bird data were collected during the breeding season (mid-April to late May) in 2004 and 2005, using a variation of the transect method (Bibby *et al.* 2000). This involved walking and searching the whole set-aside field and noting all the birds seen or heard. Two visits to each field were carried out within a ten-day period. The maximum number of individuals of each species recorded on either of the two visits was used as an estimate of species abundance per set-aside field. Every day a different region was sampled to avoid seasonal biases i.e. in species and habitat data. Time of day was standardized so all surveys were carried out within three hours after sunrise. The habitat sampling was carried out immediately after the second bird survey. The time that each bird survey took was recorded and included in the analysis to control for sampling effort.

Set-aside habitat descriptors including field size (area), shape (edge length/area), vegetation structure (height, cover and volume) and vegetation richness (number of species) were measured. Vegetation height was obtained throughout the set-aside field by averaging five measures of maximum height taken. Vegetation cover was visually estimated using a cover estimation template (Prodon & Lebreton 1981). Volume was estimated as the average height at which the maximum vegetation cover occurred, reflecting the dominant structure of the vegetation (herbaceous or woody shrub). Therefore at each field we obtained one categorical value for each variable (cover: 0, 0–10%; 1, 11–25%; 2, 26%–50%; 3, 51–75%; 4, 76–100%; height and volume: 0, 0 cm; 1, 1–5 cm; 2, 6–10 cm; 3, 11–15 cm; 4, 16–25 cm; 5, 26–35 cm; 6, 36–50 cm; 7, >50 cm). Vegetation richness was recorded as the number of plant species identified in a 10 × 10-m square located in the centre of the field. Given that vegetation structure and composition variables were highly correlated, they were transformed to principal components through factor analysis (Table 1). Three independent factors explaining 96% of the variability of the original variables were calculated. The first factor was related to vegetation volume, the second factor to vegetation richness and the third factor to vegetation cover, while vegetation

Table 1. Factor analysis for the set-aside vegetation structure and composition variables. Figures in bold indicate the variable for which each factor explained the most variability.

Variable	Factor 1	Factor 2	Factor 3
Cover	0.31	0.28	**0.89**
Volume	**0.94**	0.07	0.29
Height	0.65	0.15	0.68
Vegetation richness	0.08	**0.97**	0.21
Proportion of total variance	0.35	0.26	0.34

Table 2. Description and classification of the final set-aside habitat predictor variables.

Variable code	Variable type	Description
Time	Continuous	Census time (min)
Year	Categorical	2004 and 2005
Region	Categorical	Alfés, Belianes, Balaguer and Granja d'Escarp
Area	Continuous	Field area (ha)
Edge/area	Continuous	Ratio of edge (m) and area (m^2) of set-aside
Natural buffer	Continuous	% of area around set-aside with natural vegetation (200-m radius)
Volume	PCA component	Height stratum of the maximum cover
Vegetation richness	PCA component	Number of plant species
Cover	PCA component	Vegetation cover in the set-aside

PCA, principle component analysis.

height was partitioned among Factors 1 and 3. In addition to set-aside features, the percentage of a 200-m buffer area around each set-aside that was occupied by natural habitats (natural buffer) was calculated (Table 2). Natural habitats were identified as all non-cropped land uses and included neighbouring set-aside and scrub. This variable provided quantified information regarding the habitats surrounding each set-aside field.

It should be stated that the rainfall conditions during the two study years was markedly different. While 2004 was an average or slightly wet year in the whole study area (annual rainfall of 400–500 mm), 2005 was significantly drier (annual rainfall of 100–200 mm) (Meteorological Service of Catalonia, www.meteo.cat).

Statistical analysis

To investigate how the selected bird species interacted with set-aside attributes, ordination techniques were applied using CANOCO 4.5 (ter Braak & Šmilauer 2002). Detrended correspondence analysis (DCA) is an indirect gradient analysis technique i.e. it searches for major gradients in the species data irrespective of any environmental variables (ter Braak & Prentice 1988). DCA determines the gradient length in the response variable (i.e. bird data) and corresponds to the length of the theoretical explanatory variable along an ordination axis. It is expressed in sd units of species turnover. If the gradients are short (<3 sd) linear methods of analysis, e.g. redundancy analysis (RDA), are more appropriate (ter Braak & Šmilauer 2002). Analysis of these data was carried out using RDA with the four regions, Alfés, Belianes, Balaguer and Granja d'Escarp, as covariables. Variables that were not significant were removed from the analysis. The Monte Carlo test (499 unrestricted permutations) for significance was used to test whether the community was related to each predictor variable. For RDA, only continuous predictor variables were used in the analysis as there were a large number of categorical variables recorded during the habitat surveys.

The distribution of the selected species in relation to set-aside characteristics was modelled using GLM assuming a Poisson distribution and log-link. For each of the species, models were fitted to assess the set-aside variables likely to be significant predictor variables of bird abundance. The time taken to carry out a survey on each set-aside field was the first predictor variable to be entered into the model as an indication of survey effort. Both continuous and categorical predictor variables were considered for this section of the analysis. A basic model was selected that included predictor variables that were deemed integral to understanding the ecology of the selected species in the study. These variables included survey time, area, year and region. The significance of these variables was tested for using F-tests. Information theoretic methods were used to select a small subset of models, although initially a total of 26 models were analysed with five different predictor variables included in conjunction with the basic model. The fit of the model to the data was assessed by the ratio of residual deviance divided by degrees of freedom (Crawley 2007). Ratios close to 1.0 suggest that the model provides a good fit to the data (Crawley 2007). Only Calandra Lark showed some overdispersion (residual deviance/df = 2.04) and standard errors for estimates were appropriately inflated (standard error × square root (residual deviance/df)).

The relative importance of the multiple predictor variables (Table 2) were assessed using AIC (Akaike 1974), corrected to account for the potential bias introduced by a data/parameter ratio lower than 40 (a second parameter-based penalty was introduced: AICC = AIC + k/n–1–k [Burnham & Anderson 2002]). The model with the lowest AICC was considered the 'best-fitting' model, and models were compared using differences to this minimum AICC value. Akaike weights were calculated for each model (w_i). For the set of models considered (n = 26) the w_i summed to 1.0 and had probabilistic interpretation. Having ranked the models from best to least fitting, a 95% confidence set was selected by summing w_i until the sum exceeded 0.95. This represents the set of models within which is included the best approximating model to the true model with 95% certainty. Instead of estimating effects based on a single 'best-fitting' model, we took weighted averages of the estimated coefficients from each of the models in the 95% confidence set (weighed by their w_i). Further, summing the w_i for models which included each coefficient gave an indication of the probability of selecting a given predictor variable. Finally, we calculated parameter bias by comparing the weighted averages to the parameters estimated from the full model. A detailed description of the modelling methods used is provided in Whittingham *et al.* (2005). All analyses were performed in R (R Development Core Team 2009).

RESULTS

The four species studied showed strong differences in the overall occurrence rates between the four study regions (Table 3). Little Bustard was recorded in Alfés, Belianes and Balaguer and Short-toed Lark was only found in Alfés and Granja d'Escarp. Both Stone-curlew and Calandra Lark were recorded in set-aside fields in all four regions. We detected important changes in the relative dominance of species within the set-aside fields, where Stone-curlew and Little Bustard were recorded in greater numbers in 2004 (52% and 50% respectively), and Stone-curlew and Short-toed Lark were dominant in 2005 (43% and 28% respectively) (Table 3). The most abundant species in set-aside was Little Bustard (males) in 2004 and Stone-curlew and Calandra Lark in 2005. Bird abundance decreased between 2004 and 2005 for all four species, although the greatest decline (more than 50%) was in Little Bustard.

Ordination

The DCA for 2004 and 2005 resulted in a gradient length of 2.293 and 2.654 units respectively and, therefore, further analysis was carried out using RDA. The variables used in the RDA were the continuous predictors presented in Table 2. Area and the edge/area ratio of the set-aside were shown to be significant predictors of the distribution of the species in the sampled fields in 2004 (area, F= 8.37, P= 0.002; edge/area, F = 4.39, P = 0.002). Together these variables explained relatively little of the variation in the selected species data (6.6%). Fig. 2a illustrates the relationship between the selected species in the breeding in 2004 and the selected habitat variables. All species were positively associated with area and negatively with set-aside shape. The results for 2005 show a pattern of response similar to 2004 with positive effects of area (F = 9.16, P = 0.002) and negative for field shape (F = 7.05, P = 0.008). Together these variables explained 7.2% of the variation in the selected 2005 species data (see Fig. 2b).

Models for the selected species

The model selection process indicated that there were a number of plausible models for each species and the details are presented in Tables 4–7. All of the models included time, area, year and region. Region was very highly significant (P < 0.0001) in all the models for all species. The abundance of Little Bustard was greatest in the Belianes region followed by Alfés and Balaguer (Table 3). It was also more abundant in 2004 than in 2005 (Table 4). In addition, the number of Little Bustards was positively associated with increased area and vegetation cover (Fig. 3) within the set-aside field

Table 3. Percentages of occurrence, mean, and maximum bird densities in set-aside across years. Sample size corresponds to the number of surveyed fields.

Species	Regions with presence	% occurrence in set-aside 2004	% occurrence in set-aside 2005	Mean ± se density (n = birds/ha) 2004	Mean ± se density (n = birds/ha) 2005	Region with maximum density in set-aside (n = birds/ha) (2004 & 2005)
Little Bustard	Belianes, Alfes & Balaguer	50 (n = 68)	23 (n = 86)	0.80 ± 0.24 (n = 68)	0.27 ± 0.15 (n = 86)	Belianes 1.43 ± 0.43 (n = 45)
Stone-curlew	All	52 (n = 93)	43 (n = 117)	0.60 ± 0.13 (n = 93)	0.41 ± 0.07 (n = 117)	Belianes 0.85 ± 0.22 (n = 45)
Short-toed Lark	Alfes & Granja d'Escarp	32 (n = 50)	28 (n = 64)	0.39 ± 0.12 (n = 50)	0.20 ± 0.05 (n = 64)	Granja 0.47 ± 0.12 (n = 56)
Calandra Lark	All	34 (n = 93)	27 (n = 117)	0.70 ± 0.16 (n = 93)	0.36 ± 0.08 (n = 117)	Balaguer 1.05 ± 0.21 (n = 51)

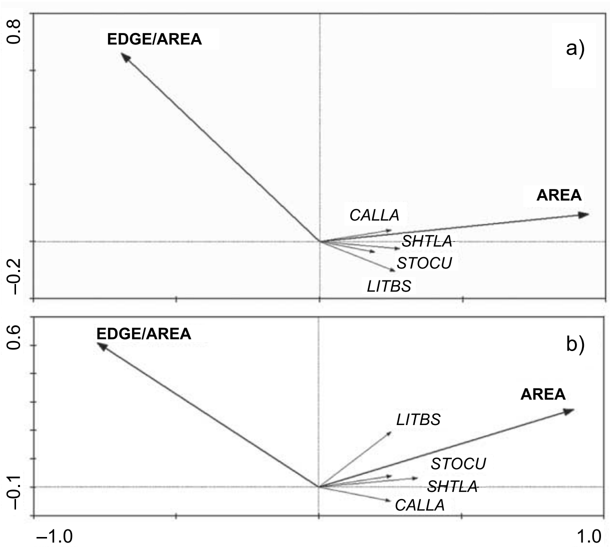

Figure 2. Redundancy analysis Axis 1 and Axis 2 species–environment biplot summarizing the effects the predictor habitat variables have on the selected species in the 2004 (a) and 2005 (b) breeding seasons. Only significant habitat variables (plot area and edge/area) were included in the ordinations graphs; LITBS, Little Bustard; STOCU, Stone-curlew; SHTLA, Short-toed Lark; CALLA, Calandra Lark.

but negatively related to the percentage of natural habitat surrounding the set-aside fields (Table 4). Stone-curlews were more abundant in Balaguer followed by Belianes, Alfés and Granja d'Escarp with more individuals of the species in 2004 compared to 2005. Stone-curlews were negatively influenced by set-aside shape and amount of vegetation cover (Table 5 and Fig. 3). The models for Short-toed Lark indicated that the species was more abundant in Granja d'Escarp compared to Alfés, although this abundance strongly depended upon a negative relationship with set-aside area, set-aside shape and vegetation cover (Table 6 and Fig. 3). Calandra Larks were more abundant in Balaguer followed by Belianes, Granja d'Escarp and Alfés with more individuals detected in 2004 compared to 2005. Set-aside area significantly increased Calandra Lark abundance, but less convoluted shapes tended to favour species presence within set-aside (Table 7). All of these ecological associations are based on the output from the 95% confidence model selection process, Akaike weights and selection probabilities.

DISCUSSION

The results of this study reinforce the opinion that set-aside is a highly attractive habitat for the four selected species of conservation concern: all of them had high breeding densities compared with those reported in other suitable areas surveyed in Europe and the Iberian Peninsula (Moreira 1999, Delgado & Moreira 2000, Green *et al.* 2000, Wolff *et al.* 2002, Suarez-Seoane *et al.* 2002). Furthermore, the role of set-aside may be critical for these bird populations when set-aside occupies a reduced area in the pseudo-steppe landscape (i.e. less than 15% in all of our study sites). However, it also should be noted that there was great variability in the relationship between bird abundance and set-aside features. Therefore, specific set-aside management action planning, involving accurate implementation of different strategies at the landscape scale, is required to manage effectively different steppe birds with contrasting habitat needs within the same region.

Set-aside features and surrounding habitats

Vegetation cover is a key set-aside feature given that it influenced the abundance of Little Bustards, Stone-curlews and Short-toed Larks (Fig. 3). While Short-toed Larks showed a marked density peak at 25–50% cover, Stone-curlew density decreased above 50% cover and male Little Bustards showed the opposite trend, increasing above 25% cover. Calandra Lark abundance positively increased with vegetation cover, although the model selection process provided weak evidence that this variable would be in the best model for this species (Table 7 and Fig. 3). Vegetation cover is a determining factor in the distribution and abundance of many farmland birds (Donald, Evans *et al.* 2001, Moorcroft *et al.* 2002, Whittingham *et al.* 2006) in addition to the specific species in the present study (Green *et al.* 2000, Moreira *et al.* 2005, Serrano & Astrain 2005). The availability of bare ground in vegetated areas give easier access to ground food for birds, allowing an increase of their intake rates (Whittingham & Markland 2002). Furthermore, low cover and height also provide good visibility, which allows early predator detection (Whittingham & Evans 2004). Both processes (foraging and anti-predator behaviour) are affected by vegetation cover and, therefore, both can explain the selection pattern for Short-toed Larks and Stone-curlews. In the case of Little Bustards, other studies have found that breeding males tend to select areas where the vegetation presents a certain type of spatial variation in structure that provides both areas for display (short vegetation) and areas for feeding (denser vegetation) (Moreira 1999, Wolff *et al.* 2002, Morales *et al.* 2008, Traba *et al.* 2008). In our study,

Table 4. Little Bustard model selection details. All predictors presented were included in the modelling process; time, area, year and region were included in all models; the additional variables included in the model, the AIC, delta weight and the model selection probability (w_i) are listed; the selection probabilities are also summed for each parameter across all models across 95% confidence for the data set by summing all the w_i scores for all models in which the predictor was included; the parameter estimates (β) presented are the averages across all models (weighted by selection probabilities); the models represent 95% confidence for the data set.

Variable	Intercept	Time	Area	Year (2005)	Region (Balaguer)	Region (Belianes)	Edge/ area	Natural buffer	Volume	Vegetation richness	Cover	AIC	ΔAIC	w_i
Best AIC	X	X	X	X	X	X		X			X	288.88	0.00	0.33
	X	X	X	X	X	X	X	X			X	290.34	1.47	0.16
	X	X	X	X	X	X		X	X		X	290.35	1.48	0.16
	X	X	X	X	X	X		X	X	X	X	291.35	2.48	0.10
	X	X	X	X	X	X	X	X	X		X	291.87	3.00	0.07
Full model	X	X	X	X	X	X	X	X	X	X	X	292.08	3.20	0.07
	X	X	X	X	X	X					X	293.84	4.97	0.03
	X	X	X	X	X	X				X	X	294.58	5.70	0.02
	X	X	X	X	X	X			X		X	295.71	6.83	0.01
	X	X	X	X	X	X	X				X	295.95	7.07	0.01
	X	X	X	X	X	X		X				296.00	7.12	0.01
	X	X	X	X	X	X		X	X			296.18	7.31	0.01
Selection probability	–	–	–	–	–	–	0.31	0.89	0.41	0.18	0.94			
β	0.169	0.023	0.203	−0.971	−0.753	0.860	−1.642	−2.564	−0.038	0.029	0.321			
Bias	−1.955	0.019	0.078	−0.013	−0.082	−0.077	−3.301	−0.176	−1.375	−5.676	0.005			

Table 5. Stone-curlew model selection details. All predictors presented were included in the modelling process; time, area, year and region were included in all models; the additional variables included in the model, the AIC, delta weight and the model selection probability (w_i) are listed; the selection probabilities are also summed for each parameter across all models across 95% confidence for the data set by summing all the w_i scores for all models in which the predictor was included; the parameter estimates (β) presented are the averages across all models (weighted by selection probabilities); the models represent 95% confidence for the data set.

Variable	Intercept	Time	Area	Year (2005)	Region (Balaguer)	Region (Belianes)	Region (Granja d'Escarp)	Edge/ area	Natural buffer	Volume	Vegetation richness	Cover	AIC	ΔAIC	w_i
Best AIC	X	X	X	X	X	X	X	X				X	527.54	0.00	0.20
	X	X	X	X	X	X	X			X		X	528.55	1.01	0.12
	X	X	X	X	X	X	X					X	528.68	1.14	0.11
	X	X	X	X	X	X	X			X	X	X	528.73	1.19	0.11
	X	X	X	X	X	X	X				X	X	528.97	1.43	0.10
Full model	X	X	X	X	X	X	X	X	X	X	X	X	529.29	1.75	0.08
	X	X	X	X	X	X	X	X	X			X	529.36	1.82	0.08
	X	X	X	X	X	X	X	X	X	X		X	529.42	1.88	0.08
	X	X	X	X	X	X	X		X	X		X	530.45	2.90	0.05
	X	X	X	X	X	X	X		X	X	X	X	530.58	3.04	0.04
Selection probability	–	–	–	–	–	–	–	0.43	0.33	0.47	0.33	0.95			
β	0.246	0.017	0.063	−0.396	0.157	0.119	−1.066	−4.994	−0.132	−0.054	0.039	−0.318			
Bias	−1.550	−0.093	0.421	−0.079	0.451	−0.240	−0.079	−1.291	−2.563	−1.117	−2.267	−0.023			

Table 6. Short-toed Lark model selection details. All predictors presented were included in the modelling process; time, area, year and region were included in all models; the additional variables included in the model, the AIC, delta weight and the model selection probability (w_i) are listed; the selection probabilities are also summed for each parameter across all models across 95% confidence for the data set by summing all the w_i scores for all models in which the predictor was included; the parameter estimates (β) presented are the averages across all models (weighted by selection probabilities); the models represent 95% confidence for the data set.

Variable	Intercept	Time	Area	Year (2005)	Region (Granja d'Escarp)	Edge/ area	Natural buffer	Volume	Vegetation richness	Cover	AIC	ΔAIC	w_i
Best AIC	X	X	X	X	X	X				X	245.46	0.00	0.38
	X	X	X	X	X	X	X			X	247.73	2.27	0.12
	X	X	X	X	X	X			X		247.74	2.28	0.12
Full model	X	X	X	X	X	X	X	X	X	X	247.98	2.52	0.11
	X	X	X	X	X	X	X	X		X	248.87	3.41	0.07
	X	X	X	X	X		X				249.62	4.16	0.05
	X	X	X	X	X	X		X			249.64	4.18	0.05
	X	X	X	X	X	X	X		X		250.01	4.56	0.04
	X	X	X	X	X	X	X	X	X		250.05	4.59	0.04
Selection probability	–	–	–	–	–	0.97	0.38	0.26	0.31	0.68			
β	1.363	0.043	−0.189	−0.057	1.213	−74.651	0.018	−0.053	−0.070	−0.211			
Bias	0.075	0.031	0.001	0.715	−0.164	−0.047	−7.228	−2.257	−2.068	−0.301			

Table 7. Calandra model selection details. All predictors presented were included in the modelling process; time, area, year and region were included in all models; the additional variables included in the model, the AIC, delta weight and the model selection probability (w_i) are listed; the selection probabilities are also summed for each parameter across all models across 95% confidence for the data set by summing all the w_i scores for all models in which the predictor was included; the parameter estimates (β) presented are the averages across all models (weighted by selection probabilities); the models represent 95% confidence for the data set.

Variable	Intercept	Time	Area	Year (2005)	Region (Balaguer)	Region (Belianes)	Region (Granja d'Escarp)	Edge/ area	Natural buffer	Volume	Vegetation richness	Cover	AIC	ΔAIC	w_i
Best AIC	X	X	X	X	X	X	X	X					0.29	616.20	0.00
	X	X	X	X	X	X	X	X			X		0.16	617.38	1.18
	X	X	X	X	X	X	X	X	X				0.13	617.89	1.69
	X	X	X	X	X	X	X	X				X	0.11	618.09	1.90
	X	X	X	X	X	X	X	X		X			0.10	618.36	2.16
	X	X	X	X	X	X	X	X	X		X		0.07	619.17	2.98
	X	X	X	X	X	X	X	X	X			X	0.05	619.83	3.63
	X	X	X	X	X	X	X	X	X	X			0.04	620.07	3.88
Selection probability	–	–	–	–	–	–	–	0.95	0.28	0.14	0.16	0.16			
β	−0.295	−0.013	0.075	−0.719	2.356	1.953	0.419	−23.605	0.111	0.000	0.017	0.006			
Bias	−0.399	−0.138	−0.153	−0.016	−0.052	−0.071	0.179	−0.005	−2.129	−114.289	−3.623	−6.787			

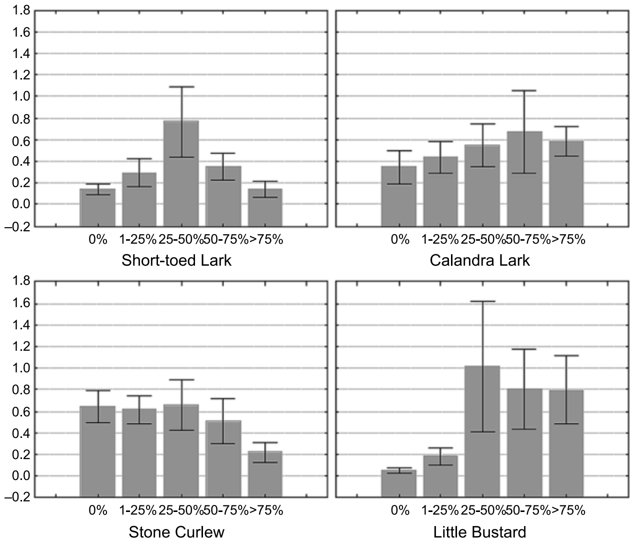

Figure 3. Observed density distribution of the selected species within set-aside across the different percentage vegetation cover categories. Data are presented as mean ± SEM.

male Little Bustard abundance increased over 25% cover, but tended to be higher in set-aside with coverage of 25–50%, which is an intermediate value that can probably offer both food (mainly plant material) and display resources.

In addition to vegetation cover, field shape was an important set-aside feature for our selected species, given that three out of these four species (both lark species and Stone-curlews) appeared to prefer regular set-aside fields. Regular set-asides tend to be circular or square shaped, where the perimeter is minimized in relation to the area. This shape tends to maximize the distance between any bird position inside the set-aside and the edge, which can be interpreted in terms of edge avoidance bird behaviour. Visibility is known to be a key aspect in relation to predation risk and has been demonstrated to affect habitat selection by birds feeding on the ground (Whittingham & Evans 2004; Whittingham *et al*. 2006). Henderson *et al.* (2000) also showed that Sky Larks *Alauda arvensis* tended to avoid field margin areas to feed. In addition, it is important to consider the predator avoidance strategy of each species to improve our understanding of patterns of habitat selection (Whittingham & Evans 2004). As with Sky Larks, Calandras and Short-toed Larks do not use the edges and hedgerows to hide from predators, but rather prefer to fly over the detected predator. Therefore, edges reduce visibility and do not offer any anti-predator advantage for these lark species. The same principal can be applied to the Stone-curlews, a species that relies on crypsis rather than on shelters (edges) to escape from predators. In fact, none of our selected species are considered to be typical edge species, unlike other farmland species (Bradbury *et al.* 2000, Vickery *et al.* 2002), but rather have a clear preference for open landscapes (Bota *et al.* 2005). We therefore hypothesize that regular fields could be preferred because of their greater visibility and reduced predation risk. Further studies should deal with this relationship between field shape and bird abundance given its widespread effect on our study species.

Habitats adjoining set-aside have an important role in determining the abundance of Little Bustards, but not the other three species. It appears that male Little Bustards were detected with higher abundances in isolated set-aside. This is expected in landscapes in which the preferred habitat (i.e. natural habitats with a more stable vegetation structure) is limited and where individuals congregate in available patches. In areas where natural habitats are more common, individuals may show less selective patterns and we would not expect to find a strong effect of habitat availability in the surroundings.

Landscape and inter-annual variability

Region had a stronger effect on the abundance of the selected species than specific set-aside features, which means that landscape and regional effects are more important than local features for bird abundance (Atauri & de Lucio 2001, Brotons *et al.* 2005). This is not surprising because although all four regions are typical cereal pseudo-steppes, they are also unique in terms of annual rainfall and availability of minority land-uses (i.e. almond trees, scrubland and set-aside). This information is useful to identify regions where each species should be given priority in terms of set-aside management and conservation.

The inter-annual difference in bird abundance between 2004 and 2005 is an expected effect derived from the overall weather differences in rainfall, with an exceptionally dry year in 2005 (Meteorological Service of Catalonia). Other studies have found strong relationships between annual rainfall or moisture and bird abundance and distribution of steppe-land and grassland birds (De Juana & García 2005, Niemuth *et al.* 2008, Delgado *et al.* 2009). Rainfall differences result in vegetation cover and height variation (De Juana & García 2005) and can lead to different primary production and thus different food availability for birds (insects and seeds) (Hawkins & Holyoak 1998). All four species decreased in abundance within set-aside from 2004 to 2005, but male Little Bustards showed the highest sensitivity to the year effect and, therefore, to drought (Table 3). This is expected as Little Bustards prefer set-aside with denser vegetation. Also, during 2005 many Little Bustard males were observed using cereal as displaying grounds (i.e. 55% of Little Bustard males in Belianes, unpubl. data), which would support a shift in habitat selection mediated by an increase in displaying habitat availability. Vegetation height is one of the main determining factors in Little Bustard habitat selection (Morales *et al.* 2008). In dry years cereal height is lower and more suitable for displaying owing to the vegetation structure. Delgado & Moreira (2000) also reported higher densities of Little Bustard males in cereal crops during dry years.

Conservation and management implications

The important role of set-aside in conservation needs to be emphasized given that the EU has recently removed it as an obligatory measure from CAP (BirdLife International 2008). This is likely to have a negative impact on many farmland and steppe-land bird species in the future in Europe. Alternatives to set-aside that provide food and nest resources as well as spatial heterogeneity in vegetation structure should be urgently considered to minimize the potential negative effect of their removal (Henderson *et al.* 2009). However, Firbank *et al.* (2003) suggested that it may be difficult to find alternatives to set-aside to manage and favour farmland birds over extensive areas after analysing the benefits and costs of set-aside from both an agronomic and ecological perspective. Many conservation measures included in agri-environment schemes (i.e. field margins or strips, low fertilizer input and crop diversification) are being applied in Europe in recent years (Kleijn *et al.* 2006, Henderson *et al.* 2009), but their positive effects on farmland biodiversity have yet to be quantified. Kleijn *et al.* (2006) found that the European schemes had limited usefulness for the conservation of endangered farmland species and, therefore, suggested that their conservation would require more elaborate measures than the ones currently applied. In addition to the uncertainties regarding the benefits of those measures, climatic conditions (aridity) in our study area, and in other pseudo-steppic areas, do not allow crop diversification or rotation and reduce the number of management alternatives to two herbaceous land-uses: winter cereal and set-aside. It is clear from our study, for example, that the abundance of two of the four species (Short-toed Lark and Stone-curlew) is much greater when vegetation cover does not exceed the 50% threshold. Because the dominant land-use in our study area was winter cereal, which always exceeds this cover threshold during the breeding season, it would be difficult to manage and favour those species at a landscape level without the presence of set-aside or non-cropped plots. An alternative could be to substitute set-aside fields with low cover non-cropped or grass strips between cereal crops. However, our results indicate that Little Bustards and Calandra Larks favour larger set-asides and that the two lark species, as well as Stone-curlews, prefer to avoid irregular fields with many boundaries or edges. We therefore suspect that these ecologic requirements would not be satisfied when managing small patches of set-aside (strips), even if the total area occupied by them was identical to the current area occupied by entire set-aside fields. Therefore, we staunchly suggest that in specific protected areas for steppe-land bird conservation at least, set-aside should be maintained as an area of uncropped habitat within the agricultural matrix, providing irreplaceable breeding sites and sources of food throughout the year (Henderson *et al.* 2000, Donald, Evans *et al.* 2001, Onrubia & Andrés 2005).

Bird abundance responded to specific set-aside features. The ecological attributes that attract certain steppe birds to set-aside should be integrated in the future management and conservation plans for these species. Of all the relevant set-aside features found in this study, vegetation coverage is probably the easiest parameter to manage through accurately designed agrarian practices. Usually field size and shape cannot be directly designed by managers, but the information presented in this study can help to identify the optimal fields for set-aside in a specific region. In this case, the implementation of prioritized criterion in agri-environment schemes could be an effective tool to favour the 'best' fields to be retained as set-aside in particular years.

Our study shows that optimal specific management actions do not always coincide across species, since they may show specific or even opposite micro-habitat requirements. When the same management action can produce the opposite effect on different sympatric species, managers are forced to prioritize or keep different areas or regions for each of the selected species. Dominant landscape features could be an optimal indicator of which region to select for specific management of set-aside features for each of the studied species. The implementation of agri-environment schemes in Natura 2000 steppe-land sites and in special protection areas has to be tailored to the specific requirements of the endangered species to maximize the benefits of the measures (Kleijn *et al.* 2006). Therefore, our study is relevant for bird conservation and management and encourages the integration of approaches at different spatial scales: firstly, at the regional or landscape level, allowing the prioritizing of regions or Natura 2000 sites to manage specific species; secondly, at the set-aside or field level, identifying which micro-habitat or field scale features need to be managed to improve conditions for certain species of conservation concern.

ACKNOWLEDGEMENTS

We thank Cristina Torres and Juan Bécares for their help in the field work. Thank you to Tim Carnus and Mark J. Whittingham for providing comments on earlier versions of the manuscript. The study was financed by REGSEGA (Reg Sistema Segarra-Garrigues SA) and the Department of Environment and Housing of Catalonia. Barry J. McMahon was supported by The Ag-Biota Project, (Monitoring, Functional Significance and Management Tools for the Maintenance and Economic Utilisation of. Biodiversity in the Farmed Landscape) which is a capability development project (2001-CD/B1-M1) funded by the Irish Environmental Protection Agency, as part of the ERTDI programme under the Irish National Development Plan. Lluís Brotons benefited from a Ramon y Cajal contract from the Spanish government.

REFERENCES

Aebischer, N.J., Green, R.E. & Evans, A.D. 2000. From science to recovery: four case studies of how research has been translated into conservation action in the UK. In Aebischer, N.J., Evan, A.D., Grice, P.V. & Vickery, J.A. (eds) *Ecology and Conservation of Lowland Farmland Birds*: 43–54. British Ornithologists' Union, Tring, UK.

Akaike, H. 1974. A new look at the statistical model identification. *IEEE Trans. Autom. Control* **19:** 716–723.

Atauri, J.A. & de Lucio, J.V. 2001. The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. *Landscape Ecol.* **16:** 147–159.

Bibby, C.J., Burgess, N.D., Hill, D.A. & Mustoe, S.H. 2000. *Bird Census Techniques*, 2nd edn. Academic Press, London.

BirdLife International. 2008. Abolition of set-aside in Europe threatens farmland birds. In *State of the world's birds*, BirdLife International. Available at: http://www.biodiversityinfo.org/casestudy.php?r=pressure&id=115 (accessed 27 October 2009).

Bota, G., Morales, M.B., Mañosa, S. & Camprodon, J. 2005. *Ecology and Conservation of Steppe-land birds*. Lynx Editions, Centre Tecnològic Forestal de Catalunya, Barcelona.

Bradbury, R.B., Kyrkos, A., Morris, A.J., Clark, S.C., Perkins, A.J. & Wilson, J.D. 2000. Habitat associations and breeding success of yellowhammers on lowland farmland. *J. Appl. Ecol.* **37**(5): 789–805.

Brotons, L., Mañosa, S. & Estrada, J. 2004. Modeling the effects of irrigation schemes on the distribution of steppe birds in Mediterranean farmland. *Biodivers. Conserv.* **13:** 1039–1058.

Brotons, 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.J. 2005. The conservation status of steppic birds in Europe. In Bota, G., Morales, M.B., Mañosa, S. & Camprodon, J. (eds) *Ecology and Conservation of Steppe-land Birds*, 119–139. Lynx Editions, Centre Tecnològic Forestal de Catalunya, Barcelona.

Burnham, K.P. & Anderson, D.R. 2002. *Model Selection and Multimodel Inference*. Springer, New York.

Buskirk, J.V. & Willi, Y. 2004. Enhancement of farmland biodiversity within set-aside land. *Conserv. Biol.* **18:** 987–994.

Chamberlain, D.E., Wilson, A.M., Browne, S.J. & Vickery, J.A. 1999. Effects of habitat type and management on the abundance of Skylarks in the breeding season. *J. Appl. Ecol.* **36:** 856–870.

Crawley, M.J. 2007. *The R Book*. Wiley, Chichester, UK.

De Juana, E. & Garcia, A.M. 2005. Fluctuations related to rainfall in richness and abundance of birds of steppic Mediterranean habitats. *Ardeola* **52:** 53–66.

Delgado, A. & Moreira F. 2000. Bird assemblages of an Iberian cereal steppe. *Agric. Ecosyst. Environ.* **78:** 65–76.

Delgado, M.P., Morales, M.B., Traba, J. & García De La Morena E.L. 2009. Determining the effects of habitat management and climate on the population trends of a declining steppe bird. *Ibis* **151:** 440–451.

Donald, P.F., Green, R.E. & Heath, M.F. 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. *Proc. R. Soc. Lon. B* **268:** 25–29.

Donald, P.F., Evans, A.D., Buckingham, D.L., Muirhead, L.B. & Wilson, J.D. 2001. Factors affecting the territory distribution of Skylarks *Alauda arvensis* breeding on lowland farmland. *Bird Study* **48:** 271–278.

Estrada, J., Pedrocchi, V., Brotons, L. & Herrando, S. 2004. *Catalan Breeding Bird Atlas*. Catalan Ornithological Institute (ICO), Lynx Editions, Barcelona.

Firbank, L.G., Smart, S.M., Crabb, J., Critchley, C.N.R., Fowbert, J.W., Fuller, R.J., Gladders, P., Green, D.B., Henderson, I. & Hill, M.O. 2003. Agronomic and ecological costs and benefits of set-aside in England. *Agric. Ecosyst. Environ.* **35:** 73–85.

Giralt, D., Brotons, L.L., Valera, F. & Kristin, A. 2008.The role of natural habitats in agricultural systems for bird conservation: the case of the threatened Lesser Grey Shrike. *Biodiv. Conserv.* **17:** 1997–2012.

Green, R.E., Tyler, G.A. & Bowden, C.G. 2000. Habitat selection, ranging behaviour and diet of the Stone Curlew (*Burhinus oedicnemus*) in Southern England. *J. Zool.* **250:** 161–183.

Hawkins, B.A. & Holyoak, M. 1998. Transcontinental crashes of insect population? *Am. Nat.* **152:** 480–484.

Henderson, I., Vickery, J.A. & Fuller, R.J. 2000. Summer bird abundance and distribution on set-aside fields on intensive arable farms in England. *Ecography* **23:** 50–59.

Henderson, I.G., Ravenscroft, N., Smith, G. & Holloway, S. 2009. Effects of crop diversification and low pesticide inputs on bird populations on arable land. *Agric. Ecosyst. Environ.* **129:** 149–156.

Kleijn, D., Baquero R.A., Clough, Y., Díaz, M., De Esteban, J., Fernández, F., Gabriel, D., Herzog, F., Holzschuh, A., Jöhl, R., Knop, E., Kruess, A., Marshall, E.J.P.,

Steffan-Dewenter, I., Tscharntke, T., Verhulst, J., West, T.M. & Yela, J.L. 2006. Mixed biodiversity benefits of agri-environment schemes in five European countries. *Ecol. Lett.* **9:** 243–254.

Martínez, C. 1994. Habitat selection by the Little Bustard *Tetrax tetrax* in cultivated areas of Central Spain. *Biol. Conserv.* **67:** 125–128.

Moorcroft, D., Whittingham, M.J., Bradbury, R.B. & Wilson, J.D. 2002. The selection of stubble fields by wintering granivorous birds reflects vegetation cover and food abundance. *J. Appl. Ecol.* **39:** 535–547.

Morales, M.B. Traba, J., Carriles, E., Delgado, M.P. & Garcia de la Morena, E.L. 2008. Sexual differences in microhabitat selection of breeding Little Bustards *Tetrax tetrax*: ecological segregation based on vegetation structure. *Acta Oecol.* **34:** 345–353.

Moreira, F. 1999. Relationships between vegetation structure and breeding bird densities in fallow cereal steppes in Castro Verde, Portugal. *Bird Study* **46:** 309–318.

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.

Niemuth, N.D., Solberg, J.W. and Shaffer, T.L. 2008. Influence of moisture on density and distribution of grassland birds in North Dakota. *Condor* **110:** 211–222.

Onrubia, A. & Andrés, T. 2005. Impact of human activities on steppic-land birds: a review in the context of the western paleartic. In Bota, G., Morales, M.B., Mañosa, S., Camprodon, J. (eds) *Ecology and Conservation of Steppe-land Birds*: 185–209. Lynx Editions, Centre Tecnològic Forestal de Catalunya, Barcelona.

Prodon, R. & Lebreton, J.D. 1981. Breeding avifauna of a Mediterranean succession: the Holm oak and Cork oak series in the eastern Pyrenees, 1. Analysis and modeling of the structure gradient. *Oikos* **37:** 21–38.

R Development Core Team 2009. *R: a language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org.

Santos, T., & Suárez, F. 2005. Biogeography and population trends of Iberian steppe birds. In Bota, G., Morales, M.B., Mañosa, S., Camprodon, J. (eds) *Ecology and Conservation of Steppe-land Birds*: 69–102. Lynx Editions, Centre Tecnològic Forestal de Catalunya, Barcelona.

Serrano, D. & Astrain, C. 2005. Microhabitat use and segregation of two sibling species of Calandrella Larks during the breeding season: conservation and management strategies. *Biol. Conserv.* **125:** 391–397.

Suárez, F., Naveso, M.A. & De Juana, E. 1997. Farming in the drylands of Spain: birds of the pseudo-steppes. In Pain, D.J. & Pienkowski, M.W. (eds) *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation*: 297–330. Academic Press, London.

Suarez-Seoane, S., Osborne, P.E. & Baudry, J. 2002. Responses of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in northern Spain. *Biol. Conserv.* **105:** 333–344.

ter Braak, C.J.F. & Prentice, I.C. 1988. A theory of gradient analysis. *Adv. Ecol. Res.* **18:** 271–317.

ter Braak, C.J.F. & Šmilauer, P. 2002. *CANOCO reference manual and user's guide to Canoco for Windows Software for Canonical Community Ordination* (version 4.5). Microcomputer Power, Ithaca, NY.

Traba, J., Morales, M.B., de la Morena, E.G., Delgado, M.P. & Kristin, A. 2008. Selection of breeding territory by Little Bustard (*Tetrax tetrax*) males in central Spain: the role of arthropod availability. *Ecol. Res.* **23:** 615–622.

Tucker, G.M. & Evans, M.I. 1997. *Habitats for birds in Europe: A Conservation Strategy for the Wider Environment.* BirdLife International, Cambridge, UK.

Vickery, J.A., Carter, N. & Fuller, R.J. 2002. The potential value of managed cereal field margins as foraging habitats for farmland birds in the UK. *Agric. Ecosyst. Environ.* **89:** 41–52.

Whittingham, M.J. & Evans, K.L. 2004. The effects of habitat structure on predation risk of birds in agricultural landscapes. *Ibis* **146:** 210–220.

Whittingham, M.J. & Markland, H.M. 2002. The influence of substrate on the functional response of an avian granivore and its implications for farmland bird conservation. *Oecologia* **130:** 637–644.

Whittingham, M.J., Swetnam, R.D., J.D. Wilson, Chamberlain, D.E. & Freckleton, R.P. 2005. Habitat selection by Yellowhammers *Emberiza citronella* on lowland farmland at two spatial scales: implications for conservation management. *J. Appl. Ecol.* **42:** 270–280.

Whittingham, M.J., Devereux, C.L., Evans, A.D. & Bradbury, R.B. 2006. Altering perceived predation risk and food availability: management prescriptions to benefit farmland birds on stubble fields. *J. Appl. Ecol.* **43:** 640–650.

Wilson, J.D., Evans, J., Browne, S.J. & King, J.R. 1997. Territory distribution and breeding success of Skylarks *Alauda arvensis* on organic and intensive farmland in southern England. *J. Appl. Ecol.* **34:** 1462–1478.

Wolff, A., Dieuleveut, T., Martin, J.L. & Bretagnolle, V. 2002. Landscape context and Little Bustard abundance in a fragmented steppe: implications for reserve management in mosaic landscapes. *Biol. Conserv.* **107:** 211–220.

(MS received 16 February 2010; revised MS accepted 4 March 2010)