Managing landscapes for the little bustard *Tetrax tetrax*: lessons from the study of winter habitat selection

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Abstract

More than half of the world’s population of the little bastard *Tetrax tetrax* lives in the Iberian Peninsula, where it is mostly dependent for survival on extensive agricultural areas. The species has declined dramatically, chiefly due to changes in agricultural practices, and is now globally ‘Near Threatened’. Knowledge of its habitat requirements is crucial to reverse the trend of habitat deterioration. Winter habitat preferences were studied in a region dominated by extensive cereal farming in Southern Portugal, comparing the characteristics of sites used by 54 flocks with those of randomly selected sites within the study area. The birds preferred recent fallows and grassy vegetation of mid-size (about 11–20 cm) and mid-density (about 11–50% cover). They tended to concentrate on the tops of hills and to avoid disturbed areas near roads and houses. Overall, the observed preferences suggest that predator avoidance is a significant factor in habitat selection. To improve habitat suitability for little bustard, managers of key wintering areas should minimize permanent sources of human disturbance, encourage rotations with frequent fallows, and favour moderate levels of grazing to manipulate vegetation height and cover. Particular attention should be given to the upper parts of the hills.

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1. Introduction

The little bustard *Tetrax tetrax* is considered a globally Near Threatened species (Hilton-Taylor, 2000). This medium-sized grassland bird has suffered a major decline in most of its Palearctic range, mainly due to agricultural intensification (De Juana et al., 1993; Goriup, 1994). The Iberian Peninsula harbours more than half of the world’s population of the species (Schulz, 1985a; Goriup, 1994; De Juana and Martínez, 1996, 2001). The Portuguese population is estimated in 10,000–20,000 individuals (Tucker and Heath, 1994), mostly concentrated in the southern part of the country, particularly in the province of Alentejo (Schulz, 1985a; Rufino, 1989, de Juana and Martínez, 1996). Since the little bustard is a priority species under the European Bird Directive (79/409/CEE), large areas are being designated for its protection in Portugal and Spain. The directive requires that these areas be managed to reach a favourable conservation status for the species.

In contrast with the northern and eastern breeding populations of the little bustard, which are fully migratory, the Iberian populations of the species tend to be sedentary or, at most, partially migratory (Cramp and Simmons, 1980). Individuals start to gather in flocks at the end of the mating season (mid-June) and remain gregarious until the beginning of the following breeding season (end of March) when the males start establishing their territories (Schulz, 1985b). In winter, the little bustard is vegetarian, feeding mostly on *Leguminosae* and *Cruciferae* (Cramp and Simmons, 1980; Martínez, 1994).

Since the little bustard is mostly dependent on open agricultural ecosystems, its survival is highly dependent on how these are managed within its range. Knowledge of the factors that determine how the species uses these ecosystems throughout its yearly cycle is essential to plan sound management practices. This issue can be particularly relevant in the winter season during which the little bustard can congregate in large flocks (Cramp and Simmons, 1980; Schulz, 1985b). However, although its habitat selection during the breeding season has been studied (Martínez, 1994, 1998; Campos and Lopez, 1996; Moreira, 1999; Salamolard and Moreau, 1999; Wolff et al., 2001, 2002), little information is available.
on the winter habitat requirements (but see Leitão and Costa, 2001 for a preliminary study). According to the Action Plan for the little bustard, this topic is a research priority (de Juana and Martínez, 2001).

The overall objective of this project is to contribute to the management of important winter sites for the species by providing information about habitat selection by the little bustard in extensive cereal systems. In particular, we checked the relevance of vegetation type, vegetation structure, disturbance, and topography for wintering little bustards. In addition, we evaluated the potential gains of manipulating some of these parameters to benefit the species.

2. Methods

2.1. Study area

The 1800 ha study area is situated in the province of Alentejo, Southern Portugal, between the town of Campo Maior and the Spanish border (Fig. 1). It is included in the Special Protection Area of Campo Maior, which is particularly important for the conservation of steppe birds, namely the little bustard and the great bustard Otis tarda. The area harbours far more little bustards during the winter than in the breeding season; in 1998, 650 individuals were counted in January, but in May an average of only 79 calling males were located.

This open agricultural area is formed by a mosaic of habitats dominated by cereal crops (46%), followed by first year fallows (18%), old fallows (over 1-year—8%), recently ploughed lands (14%) and various other habitats (14%). It has an undulating topography, with gentle slopes and an altitude between 190 and 240 metres. It is located in the Meso-Mediterranean bioclimatic stage (Rivas-Martínez, 1981), with annual averages for temperature and rainfall of 15–17 °C and 500–600 mm, respectively (H/COBA/HP, 1998).

2.2. Data collection

We marked 100 random points on 1:25,000 topographic maps. These points were then linked in five zigzagging sampling transects, with a total combined length of 40 km (Fig. 2). Every transect which criss-crossed the study area was sampled on foot during daytime (8:00 am–6:30 pm GMT), once in February and again in the first half of March 1998. The location of little bustard flocks was registered with the aid of a GPS and topographic maps. Two or more isolated birds were considered to be a flock. Only three isolated animals were located, and they were not included in the analyses.

Habitat sampling stations were established at each of the 100 random points and at the centre of the sites from which flocks took off during the transect surveys (Table 1). This central point was identified based on the presence of droppings, feathers and footprints.

The structure of the vegetation (height and% cover) of each sampling station was characterized by averaging the results obtained in nine 50×50 cm quadrates, located at the centre and at 10 and 20 m from it in the north, south, east, and west directions. Modal height of the vegetation (vegetation height) was measured with a ruler; percentage of vegetation cover was estimated visually and perpendicular to the ground. All measurements were made by the same observer.

Each station was assigned to one of the following cover classes: new fallow (cereal and sunflower stubble), older fallow (more than 1-year old), recently ploughed...
land, cereal, and other (olive groves, beetroot, and waterways). All the older fallows were grazed.

Potential disturbance level was estimated using the distance to the closest inhabited house (distance to house) and to the closest road (distance to road). Both were measured on field-checked topographic maps.

Hills were divided into four, vertical slope classes (position on the hill: top, upper slope, lower slope, and bottom. Since preliminary observations suggested that topography strongly influenced the location of flocks, this factor was studied closely. Ten hills located in new fallow fields were randomly chosen, and three, roughly parallel, 1-m wide transects running from the top to the bottom of each hill were established. Each transect was divided in four sectors, corresponding to the slope classes (above). Droppings were counted at every meter of the transect. This process resulted in 30 samples of dropping density for each of the four slope classes.

Since some hills were more emergent in the landscape than others, and this factor could influence their use by the birds, we also included in the analyses the variable, Altitude.

2.3. Data analysis

The relationship between each environmental variable and the occurrence of little bustards was analysed independently but also in combination with all the other variables by using multiple logistic regression. The potential roles of land use, vegetation height, vegetation cover, position on the hill, and altitude, were assessed using chi-square tests. Expected frequency values were calculated, using the information collected at the 100 random points. Multiple comparisons between individual observed and expected values were carried out with Bailey’s confidence intervals calculated for \( P < 0.05 \) (Cherry, 1996). Median distance of the observed flocks to roads and inhabited houses were compared to the equivalent values obtained for the random points using Mann–Whitney U-tests (Sokal and Rohlf, 1995; Zar, 1996).

Two multivariate logistic models (Hosmer and Lemeshow, 2000) were carried out to identify the combination of factors that had influenced the habitat selection by little bustard’s flocks in the winter. The objective of the first model was to identify the habitat factors that most influenced the little bustard’s use of a site, and this analysis included all the measured variables. The second model aimed at identifying habitat management practices that can have a significant impact on the species; this analysis excluded the variables that cannot be manipulated in a management program. A Spearman correlation matrix was generated to check for collinearity between variables, but all the correlation values were below 0.7 (Tabachnick and Fidell, 1996).

Our regression analyses contrast the characteristics of the points where the little bustard was found with the overall habitat availability. Among the 100 sites used to characterize availability in the univariate analyses, 70 were randomly selected to be used in the regressions. This site reduction was carried out to avoid prevalence problems, which could affect the performance of the models (Manel et al., 2001).

All the independent variables were considered categorical, and the classes presenting a frequency of zero were pooled with adjacent classes to avoid numerical problems (Hosmer and Lemeshow, 2000; Manel et al., 2001). These variables were selected for the models using Pearson’s chi-square test; those with a \( P > 0.25 \) were excluded (Hosmer and Lemeshow, 2000). Backward stepwise selection was used to build the logistics models based on the likelihood criteria, removing all variables with \( P > 0.05 \) and testing the null hypothesis that the coefficient of the variable is zero. The probability cut-off point used to predict presence/absence was 0.5.

The results of the contrast between the observations and the predictions of the regression models were organized in a 2×2 contingency table. The degree of association between predictions and observations was quantified with the phi coefficient \( (\phi^2 = \chi^2/n) \), the significance of which was tested with a chi-square (Daniel, 1990). The performance of the models was assessed using the percentage of correctly classified locations and by calculating the area under the receiver operating characteristics curve (AUC) (Pearce and Ferrier, 2000).

The logistic regression model that considered all variables was validated using a Jack-knife procedure (North and Reynolds, 1996; Manel et al., 1999). One location at a time was removed from the input table and a logistic model built to predict the presence or absence at the removed location (with a probability cut-off point of 0.5); this procedure was repeated once for each location.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Independent variables measured to analyse the habitat preferences of the little bustard, indicating the source of the data</th>
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</thead>
<tbody>
<tr>
<td>Name of variable</td>
<td>Source of data</td>
</tr>
<tr>
<td>Land use</td>
<td></td>
</tr>
<tr>
<td>New fallow</td>
<td>Field work</td>
</tr>
<tr>
<td>Old fallow</td>
<td>Field work</td>
</tr>
<tr>
<td>Ploughed land</td>
<td>Field work</td>
</tr>
<tr>
<td>Cereal crops</td>
<td>Field work</td>
</tr>
<tr>
<td>Others</td>
<td>Field work</td>
</tr>
<tr>
<td>Vegetation structure</td>
<td></td>
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<tr>
<td>Vegetation height</td>
<td>Field work</td>
</tr>
<tr>
<td>Vegetation coverage</td>
<td>Field work</td>
</tr>
<tr>
<td>Topography</td>
<td>Field work</td>
</tr>
<tr>
<td>Position on the hill</td>
<td></td>
</tr>
<tr>
<td>Altitude</td>
<td>Topographic map</td>
</tr>
<tr>
<td>Disturbance factors</td>
<td></td>
</tr>
<tr>
<td>Distance to road</td>
<td>Topographic map</td>
</tr>
<tr>
<td>Distance to house</td>
<td>Topographic map</td>
</tr>
</tbody>
</table>

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included in the analysis. These predictions were then used to calculate the AUC. A new 2×2 table contrasting predictions and observations was made; the percentage of correctly classified locations and the phi coefficient were calculated, and the latter was tested with a chi-square.

Median sizes of flocks observed at different altitude classes were compared using a Kruskal–Wallis test. A multiple comparison z-value test with a Bonferroni adjustment was used to compare the group medians in every possible combination of altitude classes. Medians are significantly different if z-value > 2.39. In order to evaluate how altitude was related to all other variables, Spearman correlations were calculated. The relationship between the densities of droppings and different slope classes was also analysed with Spearman correlations.

3. Results

A total of 54 flocks were sighted in the transects. Eighteen flocks totalling 521 individuals were observed during the month of February, and 36 flocks with 594 individuals were observed in March. The number of individuals in the flocks varied from two to 110 (median = 15). Three observations of single individuals were made during this time, but they were not included in the analyses.

3.1. Univariate analysis

All chi-square tests evaluating the potential influence of individual environmental variables on the occurrence of the little bustard (Fig. 3) were highly significant (land use $\chi^2 = 48.36$, $P < 0.001$; vegetation height $\chi^2 = 26.66$, $P < 0.001$; vegetation cover $\chi^2 = 29.78$, $P < 0.001$; position on the hill $\chi^2 = 88.05$, $P < 0.001$; altitude $\chi^2 = 17.61$, $P < 0.001$). The tests compared the numbers of flocks, but the numbers of birds followed similar patterns in all variables (Fig. 3).

Flocks positively selected new fallow, and rejected ploughed land and others ($P < 0.05$). The use of cereal and old fallow was proportional to their availability in the study area. Little bustards showed preference for the vegetation height that varies between 11 and 20 cm in height and avoided the vegetation between 0 and 10 cm and over 30 cm height ($P < 0.05$). Vegetation between 21 and 30 cm in height was used according to its availability. Flocks selected the intermediate class of vegetation cover, varying between 11 and 20% and avoided the first and last class, between 0 and 10 and 71 and 90% respectively ($P < 0.05$). Vegetation with 11–30% of coverage was not significantly selected, although the number of observed flocks was superior to that expected. The classes above 51% showed expected figures below those observed, indicating that little bustards avoided very dense vegetation.

The flocks preferred hilltops ($P < 0.05$), and the great majority of the flocks were observed on the upper half of the elevations (96.3%), while the two classes corresponding to the lower half of the hill were negatively selected ($P < 0.05$). The upper slope (position number 3) was used nearly in proportion to availability. Dropping
The goodness-of-fit of the first logistic regression model, which considered all variables, was quite significant $\phi = 0.69$, $\chi^2 = 59.04$ ($P < 0.001$), classifying correctly 83.3% of the cases (88.3% of absences and 78.2% of presences) (Table 2). An AUC of 87.8% ($P < 0.001$) corroborates the good adjustment of the model to the data. The Jack-knife validation procedure classified correctly 76.6% of the cases, corresponding to $\phi = 0.54$, $\chi^2 = 36.16$ ($P < 0.001$) and presenting an AUC of 83.3% ($P < 0.001$). The final model included four variables (Table 2), with position on the hill the variable that most contributed to the model, followed by distance to house, vegetation height, and presence of new fallow.

The second logistic model, based only on manageable variables, selected the same variables, with the exception of position on the hill (Table 2), which was not included in this analysis because it cannot be subjected to management. Naturally, this model explains less variance, but it nevertheless shows a reasonable adjustment to the data by classifying correctly 71.8% of the locations, $\phi = 0.44$, $\chi^2 = 24.01$ ($P < 0.001$), and AUC=80.0% ($P < 0.001$). According to this model isolation, adequate vegetation height and the presence of new fallows resulted in a higher probability for the occurrence of the little bustard (Fig. 5). The coefficients of both models (Table 2) are in agreement with the results of the univariate analyses. In fact, the highest coefficients were associated with the tops of the hills, locations farthest from houses, vegetation 10–20 cm high, and the presence of new fallows.

### Table 2

<table>
<thead>
<tr>
<th>Variables that entered the models. $G$ tests indicate the significance of the contribution of each variable to the model. The first model considered the role of all measured variables, whereas the second was developed to analyse the contribution of the manageable variables alone.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
</tr>
<tr>
<td>All variables</td>
</tr>
<tr>
<td>$G = 27.52; \text{df}=2; P = 0.000$</td>
</tr>
<tr>
<td>Distance to house</td>
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<tr>
<td>$G = 12.77; \text{df}=3; P = 0.005$</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Vegetation height</td>
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<tr>
<td>$G = 9.73; \text{df}=2; P = 0.007$</td>
</tr>
<tr>
<td>New fallow</td>
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<tr>
<td>$G = 6.19; \text{df}=1; P = 0.013$</td>
</tr>
<tr>
<td>$G = 13.24; \text{df}=3; P = 0.004$</td>
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<tr>
<td></td>
</tr>
<tr>
<td>New fallow</td>
</tr>
<tr>
<td>$G = 11.28; \text{df}=1; P = 0.000$</td>
</tr>
<tr>
<td>$G = 10.71; \text{df}=2; P = 0.005$</td>
</tr>
</tbody>
</table>

### 4. Discussion

Twice as many flocks were observed in March ($n = 36$) than in February ($n = 18$), but the total number of birds counted was almost the same, suggesting that the sampling effort was similar in the two months. In March the animals may be split in smaller flocks because of the approach of the breeding season.

#### 4.1. Land cover

Although old fallows are favoured in the breeding season (Martínez, 1994; De Juana and Martínez, 2001),
in the winter the little bustards used this habitat according to availability, while showing a clear preference for new fallows. This result might be related to a higher abundance of dead plant in old fallows and more green plants regenerating at this time of the year in the new fallows, probably resulting in more food availability. Recent fallows with stubbles were also recorded as preferred by Leitão and Costa (2001) in the Tejo grasslands, and stubbles are also known to be important for other steppe birds (Suárez et al., 1997; Lane et al., 2001). Ploughed land was avoided, most likely because no vegetation suitable for cover or food is provided by this habitat. Although cereal was not selected, 40.7% of the flocks were found in this habitat. This is most likely due to an adequate cover provided by its vegetation. Flocks disturbed in alfalfa and broccoli fields were often seen flying for refuge in cereal fields, returning to the original field after the cessation of the disturbance.

4.2. Vegetation structure and topography

The observed choice of mid-height vegetation may be explained by several factors related to predation avoidance. Very short vegetation would deprive the animals of the possibility of concealment, and high vegetation would not allow them to watch the surroundings effectively. Other authors have explained a similar choice of vegetation height in the breeding season with the needs for concealment for safety and visibility for vigilance (Martínez, 1994; Salamolard and Moreau, 1999).

Visibility may also play a relevant role in the observed selection of medium density vegetation, at the expense of the use of very sparse and very dense vegetation. The first does not provide much cover and the latter may hamper vigilance. In addition, sparse vegetation may provide less food, and exceptionally dense vegetation is likely to hinder the mobility required for foraging. Finally, the observed preference of little bustard flocks for hilltops is probably also related to visibility. In an undulating landscape, these locations offer both good visibility of potential approaching predators and cover from them. In fact, near the hilltops, birds can find concealment from a disturbance by simply moving a short distance to the side of the hill opposite the source of the disturbance. In similar terrain, undulating and open, sandgrouse also selects drinking sites that allow good visibility (Ferns and Hinsley, 1995).

Our results suggest that in the winter the little bustard tends to select sites in which the risk of predation is minimized. We often observed flocks fleeing at the approach of potential predators such as the hen harrier Circus cyaneus and the red fox Vulpes vulpes, which are common in the region. It has been suggested that cover provides protection by hiding birds from predators, but also obstructs visibility and, consequently, the capacity of the birds to detect approaching predators. These factors influence avian vigilance (Lazarus and Symonds, 1992). The choice of mid-height vegetation, mid-density vegetation, and hilltops suggests that the little bustard chooses locations that balance the two contrasting effects of protective and obstructive cover.

The choice of sites with good visibility also facilitates the formation and maintenance of large flocks. Larger flocks have the advantages of minimizing the individual risk of predation and sharing vigilance with a bigger number of birds (Lima, 1995).

4.3. Human disturbance

The univariate analyses demonstrated that both the proximity to roads and inhabited houses was avoided. Suárez-Seoane et al. (2002) found that in the breeding season they also avoid the proximity of roads. In the logistic regression models, distance to house significantly affected little bustard distribution. Distance to road did not enter either logistic regression model, but this was probably due to its correlation with distance to house.
4.4. Conservation and management implications

Proper habitat management for the little bustard should take into consideration its habitat preferences during the full annual cycle. The results of this winter study, when compared to studies carried out in the breeding season, suggest that the preferred habitat conditions vary throughout the year, with the animals favouring diverse stages of the rotational cereal system at different seasons. This underlines the need to maintain the habitat mosaics provided by extensive rotation cereal systems in Iberia. Many areas are used both during the winter and breeding seasons, and management should prioritise the preferences during the most limiting season, while not ignoring the needs during the other seasons.

In what concerns management to provide suitable winter habitat, three measures seem to be particularly important: (i) the planning of rotations should always incorporate substantial amounts of multi-year fallows; (ii) permanent sources of disturbance, such as houses and roads, should be minimized; and (iii) the height of the vegetation should be manipulated with extensive grazing in order to avoid very short or very tall vegetation. The results of the logistic regression in Fig. 4 demonstrate that such measurement practices should result in substantial gains in habitat suitability. Particular attention should be given to the upper parts of the hills, which have been shown to be particularly important for the little bustard.

The great majority of the European populations of the little bustard are presently dependent on agricultural systems, which can be subjected to significant changes driven by markets and agricultural policies. Such changes have been causing the decline of the little bustard, so it is essential that critical sites for the species should be actively managed. Promisingly, our results suggest that, in the context of extensive cereal farming, winter habitat suitability can be maintained and improved with relatively minor adjustments to the existing agricultural practices in many of the key sites for the species.

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