

BREEDING HABITAT MODELLING OF THE LITTLE BUSTARD *TETRIX TETRIX* IN THE SITE OF COMMUNITY IMPORTANCE OF CABRELA (PORTUGAL)

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SUMMARY.—*Breeding habitat modelling of the Little Bustard Tetrax tetrax in the site of community importance of Cabrela (Portugal)*

Aims: The Little Bustard often occurs in fragmented open landscapes in southwest Portugal, where agricultural fields are spaced with forest stands and shrublands. In these areas species abundances and distribution patterns are poorly known, and there is almost no information about the effects of human activities on the species. In this study we present the first results on the distribution and abundances, as well as macro-habitat modelling for Little Bustard displaying males.

Location: Site of Community Importance of Cabrela, an area included in the national list of sites 'Natura 2000'. Alto Alentejo, southwest Portugal.

Methods: Combining field data (displaying males distribution), GIS techniques and spatial analysis such as Ordinary Kriging, predictive models were computed for the occurrence of the Little Bustard during the breeding season.

Results: Results indicate a total of 72 displaying males and an average breeding density of 0.7 displaying males' km⁻². Logistic regressions suggest a slight tendency for the selection of the inner part of the larger patches of potential habitat. Variables related with soil constraints are likely to be important. The interpolated Ordinary Kriging models indicate a good agreement with the field data.

Conclusions: Ordinary Kriging models can be very helpful for modelling distributions in highly fragmented landscapes and as a tool for the management of the species habitat by potentially predicting the impacts derived from human actions at landscape level.

Key words: Little Bustard, *Tetrax tetrax*, macro-habitat modelling, kriging, Portugal.

RESUMEN.—*Modelización del hábitat reproductor en el Sisón Común Tetrax tetrax en el lugar de interés comunitario de Cabrela (Portugal)*

Objetivos: El Sisón Común frecuentemente aparece en paisajes abiertos y fragmentados en el suroeste de Portugal, donde los campos de cultivo están espaciados e intercalados con bosquetes y manchas de matorral. En el área de estudio, la abundancia y los patrones de distribución de la especie no son conocidos, y además falta información sobre el efecto de la actividad del hombre sobre la especie. El estudio presente nos ofrece los primeros resultados de patrones de distribución y abundancia de la especie en esta área, así como una modelización a gran escala del hábitat seleccionado por los machos para realizar el «display» de cortejo hacia las hembras.

Localidad: El Lugar de Interés Comunitario (LIC) de Cabrela, un área incluida en la lista nacional de sitios 'Natura 2000'. Alto Alentejo, suroeste de Portugal.

Métodos: Combinando datos de campo (distribución de machos en cortejo), técnicas de GIS y análisis espaciales (Kriging), computamos modelos predictivos de la aparición de Sisones durante el periodo reproductor.

Resultados: Los resultados indican un total de 72 machos realizando el «display» de cortejo y una densidad reproductiva media de 0,7 machos por kilómetro cuadrado. El análisis de regresión logista sugiere una cierta tendencia por la selección de las partes internas de las grandes parcelas con un hábitat potencial. Las variables relacionadas con la limitación de suelo son probablemente importantes. El modelo de interpolación (Ordinary Kriging) indica un buen acople de los datos con las observaciones en el campo.

Conclusiones: Los modelos ordinarios de Kriging puede ser útil para modelizar la distribución de especies en paisajes altamente fragmentados. Estos modelos pueden ser una herramienta de manejo del hábitat de ciertas especies por potencialmente predecir el impacto derivado de la actividad del hombre a escala del paisaje.

Palabras clave: Sisón Común, *Tetrax tetrax*, modelación del macro-hábitat, kriging, Portugal.

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INTRODUCTION

The man-maintained balance between natural and agricultural systems is a special trait of the Mediterranean region and has contributed through past centuries to create the high levels of biological diversity detected in Mediterranean landscapes (e.g. Blondel & Vigne, 1993; Blondel & Aronson, 1999; Makhzoumi & Pungetti, 1999). In Portugal and Spain the traditional extensive cereal crops system supports several bird species of high conservation value, namely two globally threatened species, the Great Bustard *Otis tarda* and the Lesser Kestrel *Falco naumanni*, and one near-threatened, the Little Bustard *Tetrax tetrax* (e.g. Suárez *et al.*, 1997).

The Little Bustard is a Palearctic ground-nesting medium sized bird inhabiting dry grasslands and other open habitats with low intensity farming (Cramp & Simmons, 1980). From the 19th century onwards and particularly during the last century, the species has suffered a dramatic decline both in range and numbers, resulting in several local extinctions namely in central and eastern European countries (Schulz, 1985). Its present breeding distribution consists in two well separated sub-areas: an eastern one, in southern Russia and Kazakhstan and a western one mainly concentrated in the Iberian Peninsula, but reaching southern France, Sardinia and southeast Italy (Cramp & Simmons, 1980; Del Hoyo *et al.*, 1996). Reasons for this decline appear to be connected with habitat loss through changes in land-use and agricultural intensification (Tucker & Heath, 1994; Wolff *et al.*, 2001). Within the European Union (EU), the Little Bustard is presently one of the most endangered species with a conservation status of *Vulnerable* and classified as SPEC 2 - a species with an unfavourable conservation status concentrated in Europe (Tucker & Heath, 1994; De Juana & Martínez, 1996, 1999).

In Portugal, the Little Bustard is a protected species since 1992, although not included in the Portuguese Red Data Book (Cabral *et al.*, 1990). The species is resident and rather common in the southern part of the country. Pinto (1998) reports an average density during the breeding season of 4 displaying males km⁻² for the Baixo Alentejo region (M. Pinto *in* De Juana & Martínez, 1996) and Moreira & Leitão (1996) recorded an average of 26 displaying

males km⁻² in cereal fallows located in the Special Protected Area of Castro Verde. Rufino (1989) suggested that the total Portuguese population was 10,000-20,000 birds, but population estimates in Hagemeyer & Blair (1997) indicated total numbers to be 13,000-18,000 birds (M. Pinto, *pers. com.*). However, recent population estimates suggest some decline in species' numbers (De Juana & Martínez, 1999). Moreover, there is a general lack of information about the effects of human activities on the species' distribution and abundances in farmed landscapes (see, however Martínez, 1994). The increase in road density and landscape dissection, and changes in agricultural systems, namely through the irrigation of dry crops, are a present picture of several Portuguese landscapes.

Considering the scale and rate of these changes there is an urgent need for more data on the ecology of the Little Bustard, namely on (1) the identification of specific habitat requirements both in breeding and non-breeding seasons, (2) the assessment of spatial and temporal land use patterns and (3) the inventory of major areas of wintering concentrations (see De Juana & Martínez, 1999). As Salamolard & Moreau (1999) pointed out, the fulfilment of these targets may enable prediction of the species response to environmental changes and will help in the design of ecological sound management measures. Intensive field studies will often be required in order to improve current knowledge. However, intensive field studies are likely to involve great amount of human and financial resources and are strongly affected by the rate of land-use changes. Taking into account these limitations, new methods such as macrohabitat modelling based on spatial analysis techniques might be a valuable tool for predicting a species distribution at a regional scale (Palma *et al.*, 1999; Osborne *et al.*, 2001), allowing a more rational use of available resources for ecological studies and species management.

In this paper, the first data on the breeding densities of the Little Bustard in the SCI of Cabrela is given and the species macro habitat studied using GIS techniques. Finally, this information is used to create potential models in order to predict the species distribution and discuss possible impacts derived from landscape changes.

MATERIAL AND METHODS

Study area

The study was carried out at the Site of Community Importance (SCI) of Cabrela, a gently undulating plain located in southern Portugal east of the Sado estuary (Fig. 1). The area is included in the national list of sites 'Natura 2000' under de EU Habitats Directive (92/43/EEC). The area occupies a surface of about 55000 ha and comprises a complex mosaic of habitats, including cereal crops, pastures, shrublands, forested areas of cork and holm oaks (*Quercus suber*, *Q. rotundifolia*), umbrella pine *Pinus pinea* and eucalyptus *Eucalyptus globulus* plantations. The Alcáçovas and the São Martinho rivers are the most important watercourses of the area, both with several stretches of well-developed riparian forests. In several places agricultural abandonment is pronounced thus resulting in the development

of shrubs. Grazing is locally intensive, and the dominant livestock in the area is cattle; sheep grazing also occurs and is mostly extensive. The average rainfall varies from 650 to 800 mm/year (INAG, 2003) and the average annual temperature range from 15°C to 17.5°C (IA, 2003).

Sampling procedures

Digital aerial photographs (scale 1:5000; Flight year - 1995) covering the total surface of the SCI of Cabrela were analysed in order to select areas of potential habitat for the Little Bustard. When necessary, the information of digital aerial photographs was adjusted with field information. Based on previous knowledge of the species habitat requirements (e.g. Cramp & Simmons, 1980; Schulz, 1985; Martínez, 1994; Campos & López, 1996; Martínez & De Juana, 1996; Moreira & Leitão, 1996;

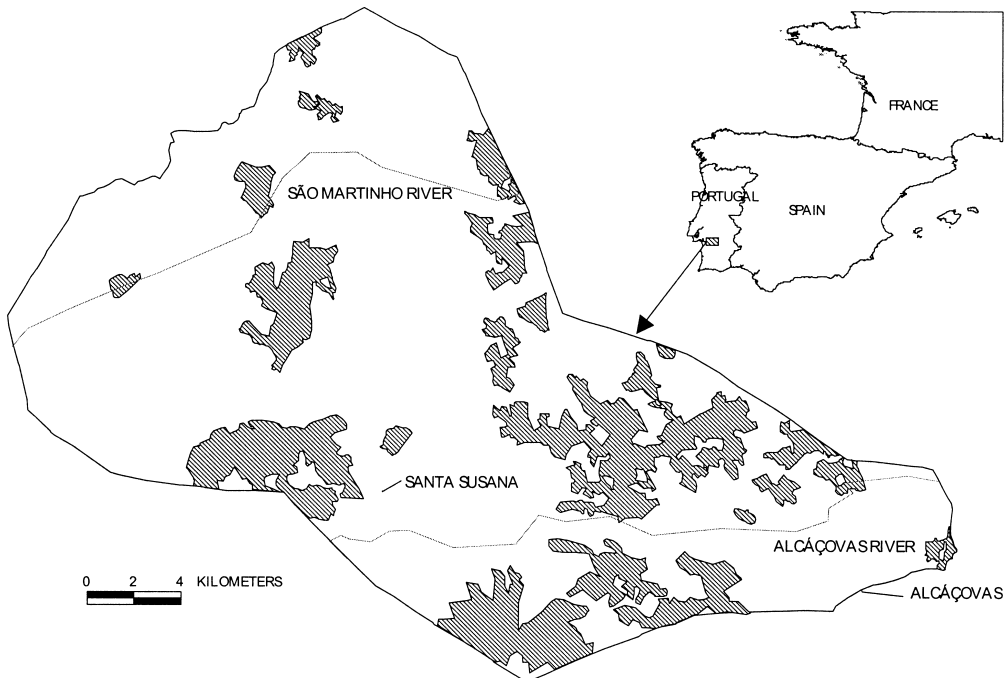


FIG. 1.—Geographical location of the Site of Community Importance (SCI) of Cabrela. Potential habitats for Little Bustard are represented in striped pattern.

[Localización geográfica de los Lugares de Interés Comunitario (LIC) de Cabrela. Los hábitats potenciales para el Sisón Común están marcados con una trama rayada]

De Juana & Martínez, 1999; Leitão & Costa, 2001; Silva *et al.*, 2001; Wolff *et al.*, 2001), we have delimited on a Geographic Information System (GIS) all patches of pasture and fallow lands, cereal fields, ploughed lands and irrigated crops that meet the following criteria: less than 30% of tree cover and a surface larger than 30 ha. In all, 21 patches of potential habitat occupying a total surface of about 10.600 ha were selected (Table 1). The most dominant habitat patches were of fallow (more than 50% of the total area) followed by cereal fields and ploughed lands. Irrigated crops such as sunflower and corn were scarce.

Fieldwork was carried out from 23 March to 11 April (first field session) and from 8 May to 5 June 2001 (second field session) and in each survey the number of displaying males observed was recorded. Each patch of potential habitat was visited once per field session and surveys were conducted by one of us (N.F.). Field procedure was based on the methods described in Leitão & Costa (2001), Silva *et al.* (2001) and Wolff *et al.* (2001): the selected areas were sampled by car and surveys were complemented by foot transects in places with hard tracks. Stops were made at each 500 meters and/or at the top of hills to search for displaying males with binoculars (8x40). The location of observed displaying male was registered on paper copies of aerial photographs and military maps (1:25000). Later, at the laboratory, all the information was incorporated into a Geographical Information System GIS.

Statistical analyses

Using GIS, 20 macro-habitat variables were extracted (28 continuous variables by considering the categories of the categorical variables; see Table 2 for each variable description). These variables consisted in (1) distance variables (distances between the displaying sites and human structures), (2) physical variables and (3) variables related to size, degree of isolation and shape of each patch of potential habitat.

In order to evaluate the importance of each variable in the distribution of Little Bustard displaying males a Forward Stepwise Logistic Regression procedure was used (Pearce & Ferrier, 2000; Bagley *et al.*, 2001). Habitat modelling was based on the results derived from the second field session, which was the census period with the largest number of calling males. Presence/absence data were used for modelling; in addition to Little Bustard points (presence data) 98 random points (absence data) were used, the smallest number of random points which allowed us to obtain at least one point per patch of potential habitat, a condition that was assumed as essential given the strong heterogeneity of the study area. In all, the minimum distance between random points was 800 m and the minimum distance between random and Little Bustard points was 100 m. Moreover, in order to minimise the effects of collinearity between the independent variables and spatial autocorrelation, correlation tables were computed and all variables presenting correlation values smaller than 0.7 were included in

TABLE 1

Summary statistics for the patches of potential habitat.
[Datos básicos de las parcelas con hábitat potencial.]

Classes [Categorías]	N. of patches [N.º de parcelas]	Total surface (ha) [Superficie total (ha)]	% of total area [% del total del área]
Less than 500 ha [menos de 500 ha]	15	2600	24
500-1000 ha	2	1213	12
1000-1500 ha	2	2514	24
1500-2000ha	1	1741	16
More than 2000 ha [más de 2000 ha]	1	2555	24

TABLE 2

Variables used for macro-habitat modelling of Little Bustard distribution in the study area.

[Variables utilizadas en la modelización de macrohábitat de la distribución de Sisones Comunes en el área de estudio.]

Variable <i>[Variable]</i>	Description of the variable <i>[Descripción de la variable]</i>	Scale <i>[Escala]</i>	Year of the Information <i>[Año de la información]</i>	Source <i>[Fuente]</i>
Altitude <i>[Altitud]</i>	Mean altitude of the sampling point <i>[Altitud media del punto de muestreo]</i>	1:25000	1984	Military Maps (IGEOE)*
Aspect <i>[Orientación]</i>	Exposition of the hillside <i>[Exposición de la ladera]</i>	1:25000	1984	Military Maps (IGEOE)
Density of tracks <i>[Densidad de pistas]</i>	Density of tracks within a 100 m radius buffer <i>[Densidad de pistas en un radio de 100 m]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to good asphalt roads <i>[Distancia a carretera asfaltada]</i>	Distance to nearest good asphalted road <i>[Distancia a la carretera más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to inhabited houses <i>[Distancia a casas habitadas]</i>	Distance to the nearest inhabited houses <i>[Distancia a la casa habitada más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to nearest patch <i>[Distancia a la parcela más cercana]</i>	Distance to nearest patch of potential habitat <i>[Distancia a la parcela más cercana con hábitat potencial]</i>	1:25000	2001	GIS
Distance to patch edge <i>[Distancia al borde de parcela]</i>	Distance to nearest patch edge <i>[Distancia al borde más cercano de la parcela]</i>	1:25000	2001	GIS
Distance to primary roads <i>[Distancia a la carretera principal]</i>	Distance to nearest primary road <i>[Distancia a la carretera principal más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to roads <i>[Distancia a carretera]</i>	Distance to nearest road <i>[Distancia a la carretera más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to rivers <i>[Distancia a rios]</i>	Distance to nearest river <i>[Distancia al rio más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to rough asphalt roads <i>[Distancia a la carretera asfaltada y bacheada]</i>	Distance to nearest rough asphalted road <i>[Distancia a la carretera asfaltada y bacheada más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to secondary roads <i>[Distancia a carretera secundaria]</i>	Distance to nearest secondary road <i>[Distancia a la carretera secundaria más cercana]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to tracks <i>[Distancia a caminos]</i>	Distance to nearest track <i>[Distancia al camino más cercano]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to villages <i>[Distancia a pueblos]</i>	Distance to nearest village <i>[Distancia al pueblo más cercano]</i>	1:25000	2001	Military Maps (IGEOE)
Distance to waterlines <i>[Distancia a curso de agua]</i>	Distance to nearest small waterline <i>[Distancia al curso de agua más cercano]</i>	1:25000	2001	Military Maps (IGEOE)
Lithology (5 substrates) <i>[Litología (5 sustratos)]</i>	Percent of each of type lithological substrates within a 100 m radius buffer <i>[Porcentaje de cada tipo de sustrato litológico en un radio de 100 m]</i>	1:100000	1982	I A (2003)
Size of the patch <i>[Tamaño de la parcela]</i>	Surface of the patch in ha <i>[Superficie de la parcela en ha]</i>	1:25000	2001	GIS
Slope <i>[Pendiente]</i>	Mean slope of hill <i>[Pendiente media del monte]</i>	1:25000	1984	Military Maps (IGEOE)
Soil Fertility (4 classes) <i>[Fertilidad del suelo (4 clases)]</i>	Percent of each class of capability of use of soil within a 100 meter radius buffer. From class I (poorest soils) to class V (very best soils) <i>[Porcentaje de cada clase de capacidad de uso del suelo en un radio de 100 m. Desde clase I (suelo pobre) a V (el suelo mejor)]</i>	1:50000	1978	IDRHa**
Soil Type (2 types) <i>[Tipo de suelo (2 clases)]</i>	Percent of each type of soil within a 100-meter radius buffer <i>[Porcentaje de cada tipo de suelo en un radio de 100 m]</i>	1:100000	1978	I A (2003)

* IGEOE - Geographic Institute of Army; ** IDRHa -Institute of Rural Development and Hydraulic

the analyses (Luck, 2002; Bouwknecht *et al.*, 2004). This criterion was chosen instead of other data reduction techniques such as PCA, because it allows a direct interpretation of the results and therefore an easier application to habitat management, one of the goals of the study.

Only variables presenting univariate logistic regression results with $P < 0.25$ were entered in the multivariate logistic regression analysis (Hosmer & Lemeshow, 2000; Palma *et al.*, 1999). The significance of the coefficients of each variable was calculated using Likelihood ratio test (Hosmer & Lemeshow, 2000). The goodness-of-fit of the final model was assessed using both the classification accuracy (*i.e.* percent of Little Bustard/random points correctly classified) and the AUC statistic (Area Under Curve) from Receiver Operating Characteristic - ROC plots (Hosmer & Lemeshow, 2000; Pearce & Ferrier, 2000). Classification accuracy was calculated by adjusting the probability cut-point in order to maximize simultaneously the number of Little Bustard and random points correctly classified (Franco *et al.*, 2000). The classification accuracy and the AUC statistic of the final model were validated using Jackknife analysis (Manel *et al.*, 2001; Bautista *et al.*, 1999). With the Jackknife analysis (also called Leave-One-Out technique), the logistic regression coefficients of the variables included in the final model, were recalculated leaving one observation out at a time; then the jackknifed probability of each observation was calculated using the logistic regression equation. For all calculations statistical significance was set to 0.05.

Starting from each point probability obtained through the logistic model, the probability surface for the study area was interpolated using spatial analysis techniques. The variogram for the set of probabilities was computed first. The variogram represents the autocorrelation commonly observed in spatial data and is computed as half the average squared difference between the components of data pairs (Goovaerts, 1999). The best variogram was selected using the Akaike's Information Criterion - AIC (Oliver *et al.*, 2000; Reich *et al.*, 2000) according to which best-fitted model produces the lowest AIC value. In the next step, and using the selected variogram *Ordinary Kriging* was implemented to interpolate the probability of

occurrence of Little Bustards displaying males for all the area (Reich *et al.*, 2000; Wallace *et al.*, 2000). This method is based in the calculation of the weighted moving averages from the observed point values in a given neighbourhood according to the following equation:

$$\hat{Z}(B) = \sum_{i=1}^N \lambda_i z(x_i)$$

where $\hat{Z}(B)$ is the estimated value for the block and λ_i are the sampling point weights in the defined neighbourhood. The local error associated to the predictions is represented through the kriging variance plots. All calculations were conducted using Arcview 3.2 GIS software and the statistical package SPSS 10.0.

RESULTS

Species abundances

A total of 72 displaying males were recorded, most of them detected in fallow land (71 males). Birds were mainly detected at the central and southern part of the study area, where more than 60% of the total population occur (Fig. 2). Generally, densities were low and smaller than 1 displaying male km⁻² (average density = 0.7 displaying males km⁻², $n = 72$), except in the southern part of the area where densities were about 2 displaying males km⁻².

Macro-habitat modelling

From the 28 initial variables, only 17 accomplished the univariate logistic regression analyses and correlation criteria and were run in the multivariate approach (Table 3). The obtained multivariate logistic model led to the selection of three variables: distance-to-patch-edge, size-of-patch and soil fertility-Class II (Table 3). These results show that Little Bustard male's displaying grounds are located in middle areas of the larger patches of potential habitat and in soils with fertility of Class II. Classification accuracy indicated an overall classification of 77% of the samples for a Cut-Point of 0.4 (78% of absences and 77% of presences, Fig. 3). The AUC value for the final model was 0.85 (0.029, $P < 0.001$), which can

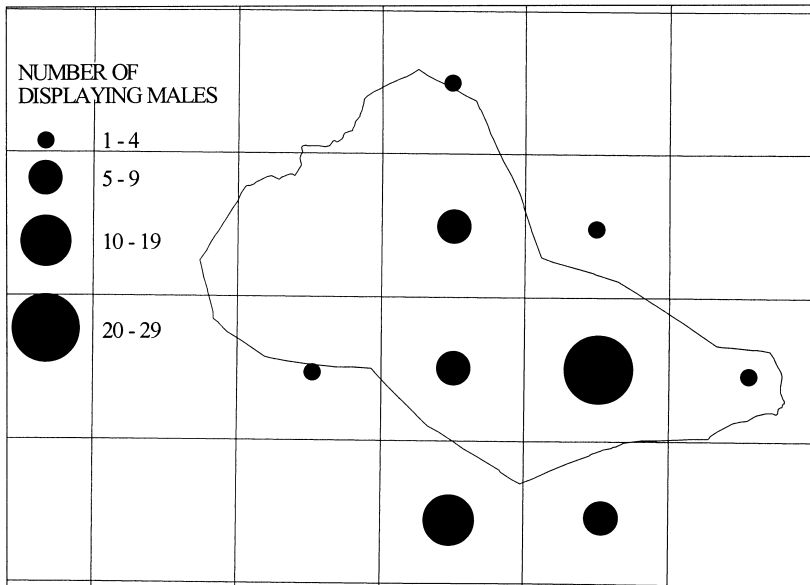


FIG. 2.—Distribution and abundance of the Little Bustard displaying males in the study area during the breeding season (UTM 10x10 km).
 [Distribución y abundancia de machos de *Sisón Común* en cortejo en el área de estudio durante la primavera (UTM 10x10 km).]

TABLE 3

Results from logistic regression analysis for the breeding season data ($n = 180$; 72 Little Bustard points and 98 random points).
 [Resultados del análisis de regresión logística para los datos obtenidos en la época reproductiva ($n = 180$; 72 puntos con *Sisón común* y 98 puntos al azar).]

Variable	B	S.E.	P
Density of tracks [<i>Densidad de pistas</i>]	—	—	<i>n.s.</i> ($p < 0.1$)
Distance to inhabited houses [<i>Distancia a casas habitadas</i>]	—	—	<i>n.s.</i>
Distance to nearest patch [<i>Distancia a la parcela más cercana</i>]	—	—	<i>n.s.</i>
Distance to patch edge [<i>Distancia al borde de parcela</i>]	0.071	0.012	< 0.001
Distance to primary roads [<i>Distancia a la carretera principal</i>]	—	—	<i>n.s.</i>
Distance to roads [<i>Distancia a carreteras</i>]	—	—	<i>n.s.</i>
Distance to rivers [<i>Distancia a ríos</i>]	—	—	<i>n.s.</i>
Distance to tracks [<i>Distancia a caminos</i>]	—	—	<i>n.s.</i>
Lithology - Clayey Schist, Grauwagues, Sandstone	—	—	<i>n.s.</i>
Lithology - Sandstone, Calcareous Rocks, Gravel, Clays	—	—	<i>n.s.</i>
Lithology - Gravel, Arkose, Sandstone, Calcareous Rocks	—	—	<i>n.s.</i>
Size of the patch [<i>Tamaño de la parcela</i>]	0.008	0.003	0.001
Soil Fertility I [<i>Fertilidad del suelo I</i>]	—	—	—
Soil Fertility II [<i>Fertilidad del suelo II</i>]	0.007	0.003	0.002
Soil Type - Luvisols [<i>Tipo de suelo Luvisols</i>]	—	—	<i>n.s.</i>
Soil Type - Litosols [<i>Tipo de suelo Litosols</i>]	—	—	<i>n.s.</i>
Slope [<i>Pendiente</i>]	—	—	<i>n.s.</i>
Constant [<i>Constante</i>]	-3.528	0.590	< 0.001

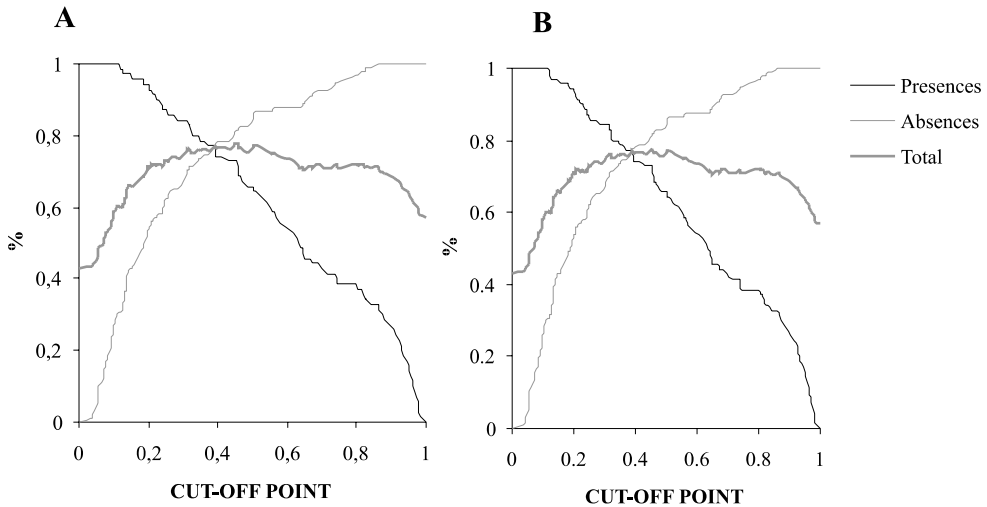


FIG. 3.—Correct classifications for the final model (A) and for the data validation through Jackknife analyses (B) considering all possible Cut-off points.

[Clasificaciones correctas para el modelo final (A) y para la validación de los datos a través de un análisis de Jackknife (B) considerando todos los posibles puntos de corte.]

be considered a good performance for the model (Hosmer & Lemeshow, 2000; Manel *et al.*, 2001). Validation through Jackknife Analysis correctly classified 77% of samples (78% of absences and 74% of presences, Fig. 3), whereas the jackknifed AUC was 0.83 (0.030, $P < 0.001$).

The best variogram for the breeding season probability of occurrence data set was produced by a spherical model (lag interval of 70 m) with an AIC of -462.49 and a range of 2030 meter (Fig. 4). The good quality of the fitted variogram can be confirmed by the low nugget effect (0.001), which indicates a very small random effect in the variogram variability (less than 2% of total variability). In Figure 5 it is represented the krigged continuous model for the probability of occurrence of Little Bustard displaying males for the patches of potential habitat for the SCI of Cabrela. The low values for the kriging variance (average kriging variance = 0.04 (0.02; maximal kriging variance = 0.11) indicates also a good robustness for the interpolated model.

DISCUSSION

Local people at the SCI of Cabrela often say that the Little Bustard was quite numerous in

the recent past. If this is true, considering the relatively steadiness in quality and area availability of used habitats, the species is probably experiencing some decline in the study area. The density of the species in the study area was low compared with values derived from other localities both in Portugal and Spain: 1.5 to 4.1 displaying males km^{-2} at Alqueva dam region (Pessoa, 2002), 26 displaying males km^{-2} at Castro Verde (Moreira & Leitão, 1996) and 3.8 displaying males km^{-2} at central Spain (de Juana & Martínez, 1996). However, density values are similar to the 0.79 displaying males km^{-2} recorded by J. P. Silva (*pers. obs.*) at Campo Maior (Alto Alentejo).

Although these results do not focus on habitat selection, they show a good agreement with the real distribution of the species. Nonetheless, there are several areas with a high probability of species occurrence where no birds were detected. This fact suggests that those areas were probably occupied by the species in a recent past, which is consistent with information provided by the local people as mentioned above. So, from a macrohabitat perspective the settlement of Little Bustards in these areas seems to be a reasonable possibility provided that present land uses are maintained or even improved. Nonet-

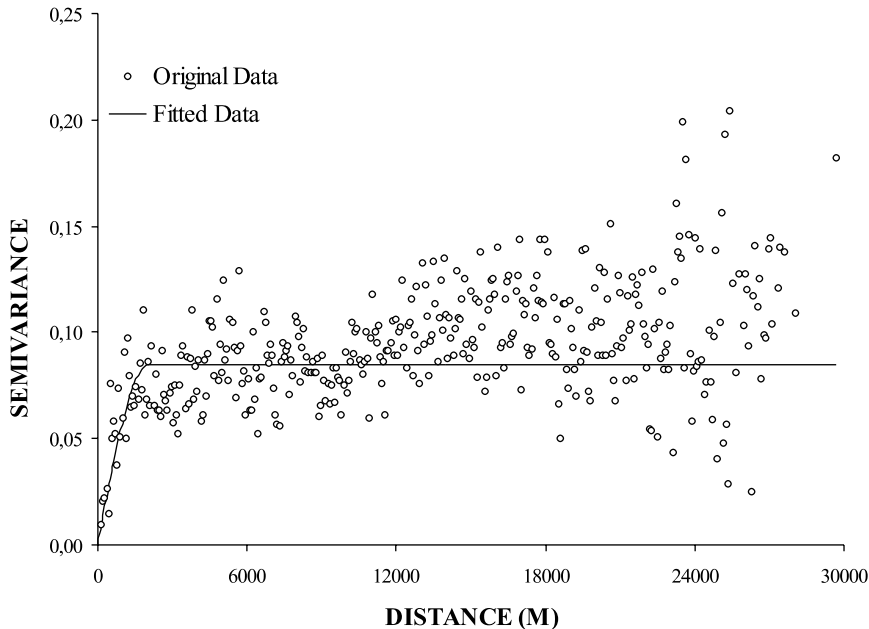


FIG. 4.—Variogram for the probability of occurrence of Little Bustard displaying males according to a spherical model.

[Variograma de las probabilidades de aparición de machos de Sisón Común en cortejo de acuerdo con el modelo esférico.]

heless, in some isolated areas presenting suitable habitat conditions, the species is close to extinction; remaining at very low and constant densities in recent years and throughout the year (*pers. obs.*) and no reoccupation seems to occur. This fact suggests that behavioural constraints such as site fidelity and/or conspecific attraction can limit this process, as has been described in other habitat-related species such as the Great Bustard *Otis tarda* and the Lesser Kestrel *Falco naummani* (Osborne *et al.*, 2001; Lane *et al.*, 2001; Serrano *et al.*, 2003).

The use of poor quality soils by the species is probably related with the fact that these soils are inadequate for crop growing purposes. They are long-time managed for extensive livestock grazing, with dry cereals often cultivated in a five-year rotation system and are the main habitat of occurrence of the Little Bustard in the area (*pers. obs.*). Moreover, the best soils (classes IV and V) are scarce in the study area and mostly occupied with intensive/irrigated crops (*e.g.* corn and rice), which are poorly attractive habitats for the species.

Despite latest studies that indicate that Little Bustard distribution is negatively correlated with human-built structures (Suárez-Seoane *et al.*, 2002), results here and as shown by Martínez (1994) did not show any particular response to roads, villages or inhabited houses. Only high densities of tracks seem to have a negative impact on the species, although the results for this variable were marginally not significant according to the final model (see Table 3). Nevertheless, it should be noted that most of the roads that cross the study area have a low traffic intensity and that the villages are relatively small and far away from the best areas of potential habitat, which on a small spatial scale, difficult considerably habitat modelling. However, if habitat fragmentation occurs as a result of the construction of roads, tracks and new buildings, the species will probably be mostly affected given that both the size-of-patch and distance-to-patch-edge seem to have a crucial role in the selection of the displaying grounds. Since new roads are projected for the SCI of Cabrela, it is thought that the models gi-

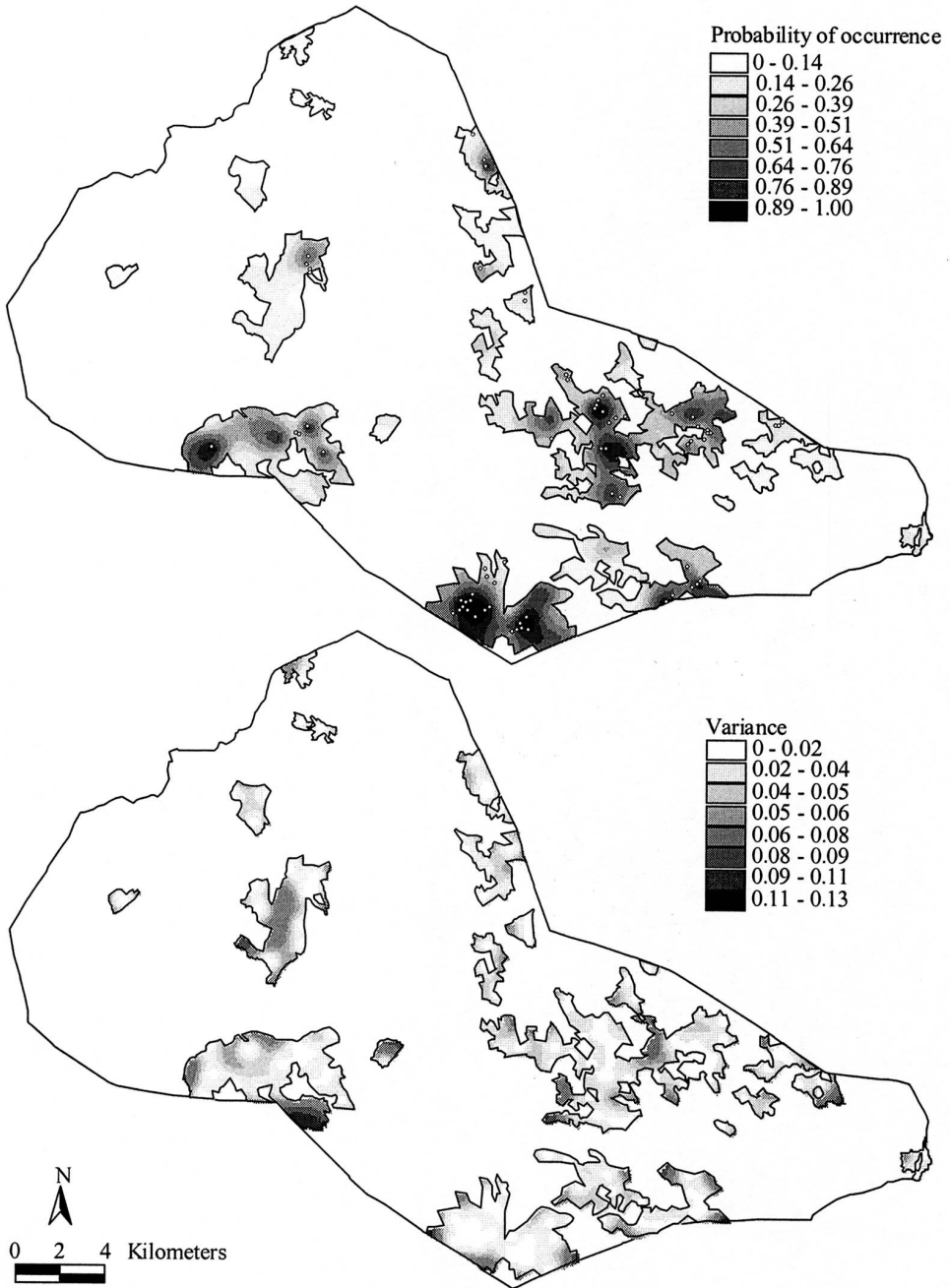


FIG. 5.—Probability of occurrence (top) and Kriging variance (bottom) overlaid with the recorded Little Bustard locations (open circles) for the interpolated Ordinary Kriging model of Little Bustard displaying males in the study area (pixel size = 50 m).

[Probabilidad de aparición (arriba) y de varianza Kriging (abajo) sobrepuesto con las localizaciones de Sisones Comunes (círculos) por el modelo de interpolación de Kriging de los machos en cortejo de Sison Común en el área de estudio (tamaño de pixel = 50 m).]

ven here should be regarded as useful tools for land managers in order to predict the impact of such structures at the landscape level.

The dynamic associated with the selection of larger patches and/or areas in the interior or centre of the patches (core areas) is particularly evident in the largest patch (2555 ha) located at central Cabrela (Fig. 5). In this patch, which shows a high degree of convolution (*e.g.* Forman, 1995), with major narrow lobes, the densities of Little Bustard are rather small, probably because the narrowing from lobe base to the tip reduces the habitat suitability for the species. Therefore, these two variables (size-of-patch and distance-to-patch-edge), although somewhat intercorrelated, can operate as predictors of the influence of habitat fragmentation and/or shape attributes of habitat patches on species distribution and abundances.

In addition, GIS data from other areas with similar landscape patterns can be used to predict the distribution of the species with a reasonable level of confidence. The presented models can be particularly important to new studies covering large areas with low species density, enabling the right choice of sampling areas and a correct management of sampling effort.

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