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EDITORIAL

A ideia da realização desta "expedição Castro Verde" surgiu no âmbito do projecto "*STEPPEBIRD – using multi-scale remote sensing to study habitat selection by cereal steppe birds in Portugal*", uma iniciativa conjunta do Instituto Superior de Agronomia e da Universidade de Southampton ao abrigo do programa EUFAR (European Fleet for Airborne Research). O objectivo geral deste projecto é relacionar os padrões de distribuição e abundância de aves estepárias na região de Castro Verde com variáveis ambientais e de habitat medidas a partir de dados obtidos por detecção remota. Neste contexto, em Maio de 2006, um avião do NERC (Natural Environment Research Council, UK) sobrevoou Castro Verde e recolheu uma grande quantidade de informação a partir de vários tipos de sensores. Os autores deste trabalho decidiram aproveitar esta oportunidade para, simultaneamente, realizar uma amostragem em larga escala dos padrões de distribuição e abundância das principais espécies de aves estepárias na região. Os primeiros resultados são agora publicados neste número do Airo.

Este não é um Atlas de distribuição das espécies de aves estepárias em Castro Verde. É antes uma "fotografia" dos padrões de distribuição e abundância, durante a Primavera de 2006, das espécies abrangidas por este estudo. A sua principal utilidade é poder servir de situação de referência para a monitorização de alterações futuras destes parâmetros.

Desde já fica lançado o desafio para a repetição desta aventura em 2011, como preconizado neste trabalho.

This study was carried out within the scope of the EUFAR (European Fleet for Airborne Research) research project STEPPEBIRD – using multi-scale remote sensing to study habitat selection by cereal steppe birds in Portugal, carried out by the Institute of Agronomy (Portugal) and the University of Southampton (UK). The general aim of this project is to link distribution patterns of bird species breeding in the grasslands of southern Portugal with environmental and habitat features derived from remote sensing data (such as CASI, ATM and LIDAR). In May 2006, a NERC (Natural Environment Research Council, UK) aeroplane flew over Castro Verde and collected data needed for this project. We took this opportunity to simultaneously carry out a large-scale census of steppe birds whose first results are presented in this issue of Airo.

In terms of the STEPPEBIRD project, these results constitute a first step to start exploring the links between remotely-derived data and the measured distribution patterns of the several species.

This is not an Atlas of steppe birds in Castro Verde. Rather, it is a "photograph" of the distribution and abundance patterns of selected species during spring 2006.

Its main utility is that it consists of a baseline situation against which the results of future monitoring can be compared. According to the suggested methodology, a similar characterization of species distribution patterns should be repeated in 2011, so this challenge is now launched!

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Spatial distribution patterns, habitat correlates and population estimates of steppe birds in Castro Verde

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SUMMARY – *Castro Verde is the main area of cereal steppes in Portugal (ca. 80,000 ha), having international importance for several steppe bird species with unfavourable conservation status. In spring 2006, a large-scale assessment of bird populations in the region was carried out using a simple methodological procedure. The occurrence and abundance of 16 species of steppe birds was estimated in 391 squares (1x1 km) in order to describe the spatial distribution patterns, explore the habitat variables explaining the observed patterns and estimate population sizes. The more frequent steppe species in the region were Corn Bunting* Miliaria calandra *(present in 78% of the sampling points), Calandra Lark* Melanocorypha calandra *(29%), Crested/Thekla larks* Galerida *spp. (29%) and Little Bustard* Tetrax tetrax *(28%). In terms of estimated population sizes, we confirmed the national importance of Castro Verde for several species, most noticeably Great Bustard* Otis tarda*, Little Bustard, Calandra Lark and Montagu's Harrier* Circus pygargus. *Regarding species-habitats associations, four groups of species could be identified: a) those associated with fallow land and grasslands, e.g. calandra lark; b) species associated with cereal fields, e.g. Zitting Cisticola* Cisticola juncidis; *c) species associated with ploughed fields, e.g. Black-eared Wheatear* Oenanthe hispanica*; and d) species associated with habitat mosaics, e.g.* Galerida *larks. Although simple, the methodology used permitted the characterization of the present distribution and abundance patterns, and established a baseline for the monitoring of changes in the future.*

Padrões de distribuição espacial, relação com o habitat, e estimativas populacionais de aves estepárias em Castro Verde. *Castro Verde é a principal área de estepe cerealífera em Portugal (ca. 80.000 ha) e possui importância internacional para várias espécies de aves estepárias com estatuto de conservação desfavorável. Durante a Primavera de 2006 foi efectuado um censo das populações de aves em toda a região, utilizando uma abordagem metodológica simples e expedita. A ocorrência e abundância de 16 espécies de aves estepárias foram estimadas em 391 quadrículas (1 x 1 km) com o objectivo de descrever os padrões de distribuição espacial, identificar as variáveis do habitat que melhor explicavam os padrões observados, e estimar as dimensões das populações. As espécies mais abundantes na região foram o Trigueirão* Miliaria calandra *(presente em 78% dos pontos de amostragem), Calhandra* Melanocorypha calandra *(29%), Cotovia-de-poupa /Cotovia-escura* Galerida *spp. (29%) e Sisão* Tetrax tetrax *(28%). Em termos de dimensão das*

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populações, foi confirmada a importância de Castro Verde para várias espécies, em particular a Abetarda Otis tarda*, Sisão, Calhandra e Tartaranhão-caçador* Circus pygargus. *Relativamente às preferências de habitat, puderam ser identificados 4 grupos de espécies: a) as associadas a pousios e pastagens, e.g. Calhandra; b) as associadas a campos de cereal, e.g. Fuínha-dos-juncos* Cisticola juncidis*; c) as associadas a terrenos lavrados, e.g. Chasco-ruivo* Oenanthe hispanica*; e d) as associadas a mosaicos de habitats, e.g. as cotovias do género* Galerida. *Apesar de simples, a metodologia usada permitiu a caracterização dos padrões de distribuição e abundâncias actuais das espécies na região, e constituiu uma caracterização da situação de referência, com vista à monitorização de alterações no futuro.*

The pseudosteppes of the Iberian Peninsula are one of the farmland habitat types holding a larger number of bird species with unfavourable conservation status (Suárez *et al.* 1997). Pseudosteppes occupy an area over 4,5 million hectares (Suárez *et al.* 1997) representing an important part of the Natura 2000 network in the region. There are several types of pseudosteppes, including semi-deserts, páramos and cereal steppes (e.g. Telleria *et al.* 1988, Martínez & Purroy 1993), but the latter is more common in western Spain and Portugal, and holds populations of many endangered birds including globally threatened species such as the Great Bustard (*Otis tarda*) and the Lesser Kestrel (*Falco naumanni*) (Tucker & Heath 1994, Tucker 1997).

Cereal steppes result mostly from the cultivation of dry cereal crops and extensive pastures. Thus, they are economically marginal farming systems threatened by agricultural intensification in the more productive soils, agricultural abandonment, often with afforestation of agricultural land, in poorer soils and, more generally, changes in management practices according to agricultural policy trends (e.g. Suárez *et al.* 1997).

Castro Verde is the main area of cereal steppes in Portugal (Costa *et al.* 2003). It has national and international importance for populations of several steppe bird species including Great Bustard, Little Bustard (*Tetrax tetrax*), Calandra Lark (*Melanocorypha calandra*), Lesser Kestrel, Stone Curlew (*Burhinus oedicnemus*), Roller (*Coracias garrulus*) and Black-Bellied Sandgrouse (*Pterocles orientalis*) (Costa *et al.* 2003). It is the most important area in the country for Great Bustard and Lesser Kestrel (Costa *et al.* 2003, Pinto *et al.* 2005) and it holds high densities of breeding Little Bustards (the highest in Europe) and Calandra Lark (Moreira 1999). As other steppe regions, Castro Verde is threatened by changes in farming practices and agricultural abandonment. Owing to its ornithological importance, three LIFE projects on steppe bird conservation have been carried out in the region. Moreover, a specific agri-environmental programme for farmers in the area (Castro Verde Zonal Plan) allows the existence of subsidies to carry out agricultural practices compatible with bird conservation.

Scientific research in Castro Verde was scarce until the 1990's, although the monitoring of some species such as the Great Bustard (e.g. Pinto *et al.* 2005), Lesser Kestrel (e.g. Rocha *et al.* 1996) and Crane *Grus grus* (e.g. Almeida 1992) had started since the 1980's. The beginning of the first LIFE project carried out by the Portuguese League for Nature Conservation (LIFE92 NAT/P/013900 - First phase of the conservation of steppic birds in Castro Verde) boosted scientific research in the area in the late 1990's, either on bird communities (e.g. Moreira & Leitão 1996a, 1996b, Leitão & Moreira 1996) or single-species studies (e.g. Franco *et al.* 1996, Morgado & Moreira 2000). Since then, there have been a growing number of scientific publications on Castro Verde's birds. In spite of this wealth of information there has been no large-scale detailed assessment of distribution patterns, or population estimates, for most species in the region. This is a drawback that hinders an effective characterization of the current situation (or system state) and the monitoring of likely changes in the near future (e.g. Yoccoz *et al.* 2001, Martin *et al.* 2007).

As part of a EUFAR (European Fleet for Airborne Research) research project (STEPPEBIRD), the Natural Environment Research Council (UK)

NERC undertook flights over Castro Verde in spring 2006 to collect detailed remotely-sensed data on habitat type and vegetation structure. These data are still being processed and will be used in further scientific studies, including bird-habitat relationships and vegetation structure. The opportunity was also taken to carry out a large-scale census of bird populations in the region using point counts to : a) describe the spatial distribution patterns of ground-nesting steppe birds in the region; b) explore the habitat variables explaining the observed patterns; c) obtain population estimates for the more common species. The final aim was to provide a baseline characterisation against which the results of future bird monitoring, using a similar approach, could be compared.

As a final remark, one must notice that this study was carried out in the spring of 2006, the year following the worst drought of the last 60 years in Portugal. In fact, during 2005 rainfall in the region was just 40% of an average year (INAG 2005), which resulted in a poor agricultural year, particularly for dry crops (cereal yield was very low). This drought probably had important impacts on bird populations, mainly for resident species, which are likely reflected in the current results. This should be born in mind when discussing the present results and comparing them with future surveys.

METHODS

Study area

The Castro Verde special protection area (SPA) (Figure 1) is a plain (100–300 m) of about 80,000 ha, having a Mediterranean climate including hot summers (30–35ºC on average in July), fairly cold winters (averaging 5-8ºC in January) and over 75% of annual rainfall (500–600 mm) concentrated in October–March (Delgado & Moreira 2000, Moreira *et al.* 2005). It is mainly occupied with pseudosteppe habitats (ca. 55,000 ha; Figure 2) created by farming activities. The traditional agricultural system used in this region is as follows: each farm is divided into parcels, each lying under cereal cultivation for two years, after which the land is left fallow, normally for 2–3 years. The parcel is then ploughed to re-initiate the rotation cycle. Fallow land is generally used as pasture for sheep and, more rarely, cattle. In the north and south of the region there are holm oak

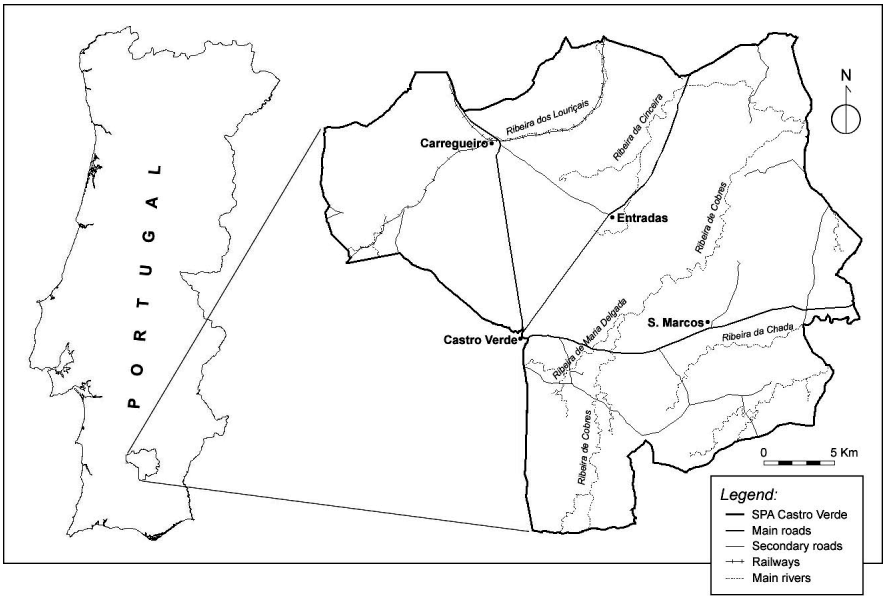

Figura 1. Location of the Castro Verde Special Protection Area for birds, and location of main roads, rivers and villages / ***Figure 1.*** *Localização da Zona de Protecção Especial de Castro Verde, e localização das principais estradas, rios e povoações.*

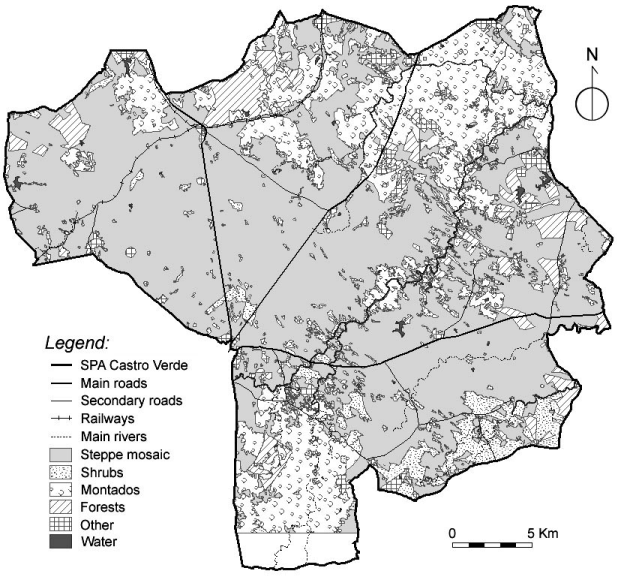

Figura 2. Land use map of the Castro Verde Special Protection Area. Adapted from Project LIFE2002/NAT/P8481 "Recuperação do Peneireiro-das-torres (*Falco naumanni*) em Portugal" / ***Figure 2.*** *Mapa de coberto do solo na Zona de Protecção Especial de Castro Verde. Adaptado do Projecto LIFE2002/NAT/P8481 "Recuperação do Peneireiro-das-torres (*Falco naumanni*) em Portugal"*

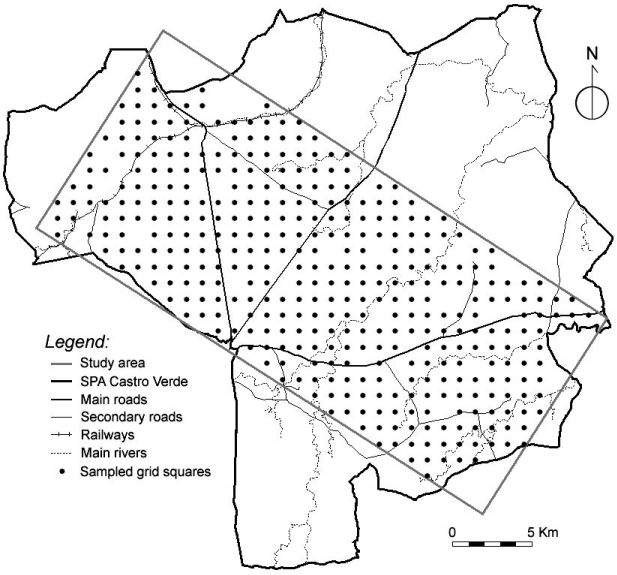

Figura 3. Study area (rectangle) and location of survey points for bird counts and habitat measurements. / ***Figure 3.*** *Área de estudo (rectângulo) e localização dos pontos de amostragem de aves e variáveis de habitat.*

Quercus rotundifolia woodlands (montados) of scarce tree cover, frequently with a grassy understorey grazed by livestock. Other forested areas are more rare and include olive groves, old Eucalyptus plantations and recent (<10 years) afforestations with eucalyptus *Eucalyptus* spp., umbrella pines *Pinus pinea* and holm and cork oak *Quercus suber* (Figure 2). Areas of shrubland occur mainly in association with river valleys and in the southeastern part of the region, as a mosaic of shrubland interspersed with old fallows resulting from agricultural abandonment and scrub encroachment (Moreira *et al.* 2005). Three main roads cross the area, the Castro Verde – São Marcos road, the Castro Verde – Entradas road, and the Castro Verde – Carregueiro road. A railway also crosses the western part of the area. Main rivers

include the Ribeira de Cobres and Ribeira de Maria Delgada (Figure 1).

Sampling scheme

The sampling area corresponded to the core of the SPA, a rectangle with 44,860 ha where pseudosteppe habitat prevailed (Figure 3). Our sampling scheme consisted in a grid of 391 sampling points placed throughout the study area in a systematic manner, by assigning one sampling point to each GAUSS 1x1km grid square (Hayford Gauss projection, International Ellipsoid, Datum Lisboa IGeoE) (Figure 3). The sampling points were located over dirt tracks (for accessibility) and as close as possible to the square's centre. A 125 m circular buffer was defined around each point, and it was also required that this buffer fell completely on pseudo-steppe habitat (based on Figure 2) and within a single grid square. In cases where these conditions did not apply, the grid square was not surveyed.

Bird counts

Bird censuses were carried out at the selected sampling points using 5-minute point counts with a distance limit of 125 m (Fuller & Langslow 1984, Bibby *et al.* 2000). All observations within the buffer were registered and, whenever possible, the sex and age group (juvenile or adult) of the birds was recorded. Most of the bird counts (about 75%) were carried out between the 29th of April and the 8th of May of 2006 by 9 teams comprising a total of 19 observers. The remaining counts were carried out in a larger time span (between the 20th of March and the 12th of May) by two observers (PL and RM) of the former group. All counts were carried out in the first 4 hours after sunrise and in the last 2 hours before sunset. Categorisation to the genus level was made for the crested and thekla larks (*Galerida cristata* and *Galerida theklae*) due to difficulties in reliably identifying all individuals of these two species in the field. All observers were experienced, thus we believe inter-observer differences did not significantly affect the results. A joint session with all observers to improve the team accuracy in estimating the distance limit for bird counts was carried out prior to the surveys.

Habitat measurements

Land-use information was collected in each sampling point by dividing the 125m-radius buffer into 8 quadrants and visually estimating the dominant habitat in each one of them. The following seven habitat categories were considered: a) fallow land and grasslands; b) fallow land and grasslands with scattered shrubs; c) cereal fields; d) ploughed fields; e) shrublands; f) afforestations; g) holm oak montados.

Data analysis

In total, ca. 3000 birds from 62 different species were observed. For the purposes of this study, we selected only 16 species (Table 1) including mostly ground-nesters, but also non-obligate ground-nesters that, although not exclusive of steppe-like habitats, were fairly common in the study area. The abundance of each species in each point was expressed as: (a) the number of pairs for songbirds (Passeriformes) and Quail (*Coturnix coturnix*). The number of pairs was determined using only the number of singing males, unless twice that number

Table 1. List of the 16 species studied, ordered by decreasing frequency of occurrence in the 391 sampled points. / ***Tabela 1.*** *Lista das 16 espécies estudadas, ordenadas por frequência de ocorrência decrescente nos 391 pontos de amostragem.*

Scientific name	*Common name*	*Proportion of points*
Miliaria calandra	Corn Bunting	0.783
Melanocorypha calandra	Calandra Lark	0.294
Galerida sp.	Galerida larks	0.289
Tetrax tetrax	Little Bustard	0.276
Saxicola torquatus	Stonechat	0.148
Cisticola juncidis	Zitting Cisticola	0.113
Alectoris rufa	Red-legged Partridge	0.100
Calandrella brachydactyla	Short-toed Lark	0.097
Circus pygargus	Montagu's Harrier	0.066
Coturnix coturnix	Quail	0.066
Burhinus oedicnemus	Stone Curlew	0.064
Upupa epops	Hoopoe	0.061
Anthus campestris	Tawny Pipit	0.054
Oenanthe hispanica	Black-eared Wheatear	0.051
Otis tarda	Great Bustard	0.041
Pterocles orientalis	Black-bellied Sandgrouse	0.020

was less than the number of singing males plus the number of all other observations. In the latter case, the number of pairs was determined from half the sum of the number of singing males plus the number of all other observations (DeSante 1981); (b) number of males for Little Bustard (*Tetrax tetrax*). In this species with a polygynous mating systems, females are quite inconspicuous and male density is usually assessed for population monitoring (e.g. Faria & Rabaça 2004); and (c) as number of individuals for the remaining species, in which difficulties in separating males from females occurred, or total population is usually assessed without discriminating gender. Population estimates were derived simply by using the mean and 95% confidence intervals of bird density in each point, for each species, to extrapolate to the total steppe area in the region (55,490 ha). Without correction for detectability, the obtained values are probably underestimates, and should be used only to compare time variations within-species; between-species comparisons should not be made. The average population size was compared with the estimates given by BirdLife International (2004) for Portugal, in order to assess the national importance of Castro Verde.

For each species, we produced a map showing all the points where the species occurred (presence/abundance). For visualisation purposes and interpretation of the spatial pattern of the four most frequent species, we interpolated the presence data points using Ordinary Kriging, a geostatistical technique capable of producing probability contour maps, derived from point data (Rossi *et al.* 1992, Burroughs 1995). For the more common species (Corn Bunting), an interpolated map of abundance (pairs/point) was also produced, using the same technique. All the geostatistical analyses were carried out in ArcGIS version 9.0 software package (ESRI 2004).

From the seven initial habitat variables describing habitat availability (number of quadrants where the habitat was dominant, ranging from zero to eight), other variables were derived: presence of habitat (binary variable stating if the habitat was present in any of the eight quadrants), habitat dominance (binary variable stating if the habitat was dominant on four-or-more quadrants), and habitat richness (total number of habitat classes in the buffer). Habitat dominance variables were only extracted in cases where, through empirical inspection of the bird and habitat data (by using scatter plots), we found some significant pattern that could explain the bird's probability of occurrence.

In order to explain the species-habitat associations, we applied a Generalized Linear Model (GLM) with a logit link function (logistic regression) using species presence-absence data (derived from the field data) and the habitat variables described above. In order to reduce the number of variables to enter in the models, we first used a Mann-Whitney U test (univariate non-parametric test for independent samples) to screen the variables excluding those that showed a weak association with the bird presence-absence data ($p>0.1$). In the multivariate GLMs, we used a forward stepwise (likelihood ratio) variable selection method as an exploratory approach. Based on the chosen model (by the stepwise procedure), we included and excluded variables considered important to describe the bird's probability of occurrence, based on ecological knowledge of the species, and compared the several models obtained. We used an Information Theoretic approach based on the AIC values to chose the best model for each species (Akaike 1974, Burnham & Anderson 2002, 2004).

RESULTS AND DISCUSSION

The frequency of occurrence of the species studied is shown in Table 1. Results are detailed below, ordered by decreasing species frequency.

Corn Bunting (*Miliaria calandra*)

The Corn Bunting was by far the most frequent species in the study area, occurring in 78.3% of the sampling points, with an average abundance of 1425 pairs per point (range=0-6; S.E.=0,060), which yielded an estimate of 16185 (95% CI=14852-17519) pairs for the total pseudo-steppe area of the Castro Verde SPA. The national population of this species has been roughly estimated as 100,000 to 1,000,000 pairs (BirdLife International 2004), so it is difficult to evaluate the significance of the Castro Verde population, as it could range from 2 to 16% of the national population.

The species was very common and widespread in the region, although more likely to be found west of

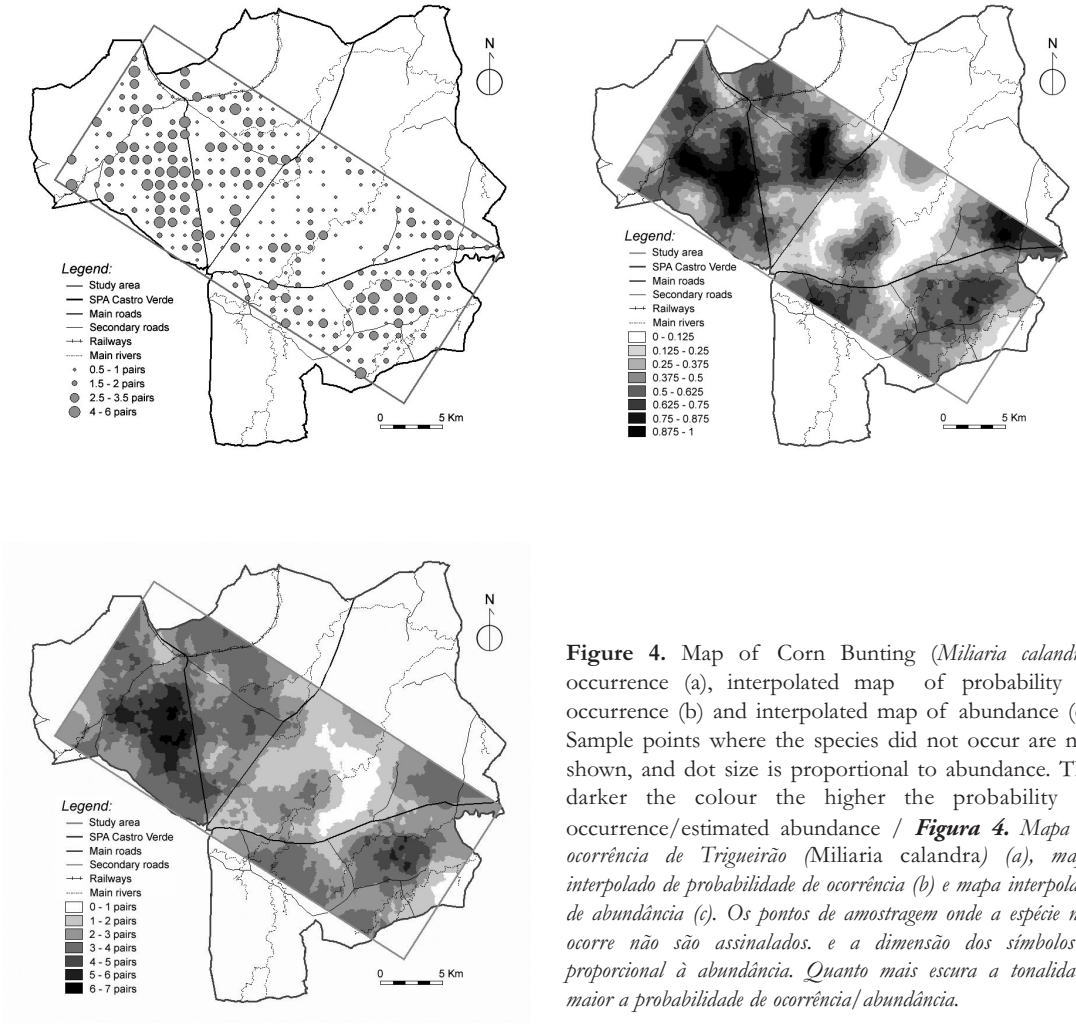

Figure 4. Map of Corn Bunting (*Miliaria calandra*) occurrence (a), interpolated map of probability of occurrence (b) and interpolated map of abundance (c). Sample points where the species did not occur are not shown, and dot size is proportional to abundance. The darker the colour the higher the probability of occurrence/estimated abundance / ***Figura 4.*** *Mapa de ocorrência de Trigueirão (*Miliaria calandra*) (a), mapa interpolado de probabilidade de ocorrência (b) e mapa interpolado de abundância (c). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância. Quanto mais escura a tonalidade, maior a probabilidade de ocorrência/abundância.*

the Castro Verde-Entradas road (Figure 4). Two hotspots with higher population densities were identified: west of the Castro Verde-Carregueiro road and in the southeast, south of Ribeira da Chada (Figure 4).

The existence of cereal fields was the main factor increasing Corn Bunting probability of occurrence (Table 2). The species was also more likely to be found near montados. The association of the species with cereal fields during the breeding season has already been reported (e.g. Delgado & Moreira 2000, Stoate *et al.* 2000) and is probably related to the availability of food (mainly arthropods) combined with appropriate nest cover provided by tall and dense vegetation. The presence of scattered holm/cork oak trees in the montados probably increases breeding habitat suitability, as these are intensively used as perches by singing males. Furthermore, many montados have an understorey of cereal crops.

Calandra Lark (*Melanocorypha calandra*)

Calandra Lark was the second most frequent species, being present in 29,4% of the sampled points, with an average abundance of 0.542 pairs per

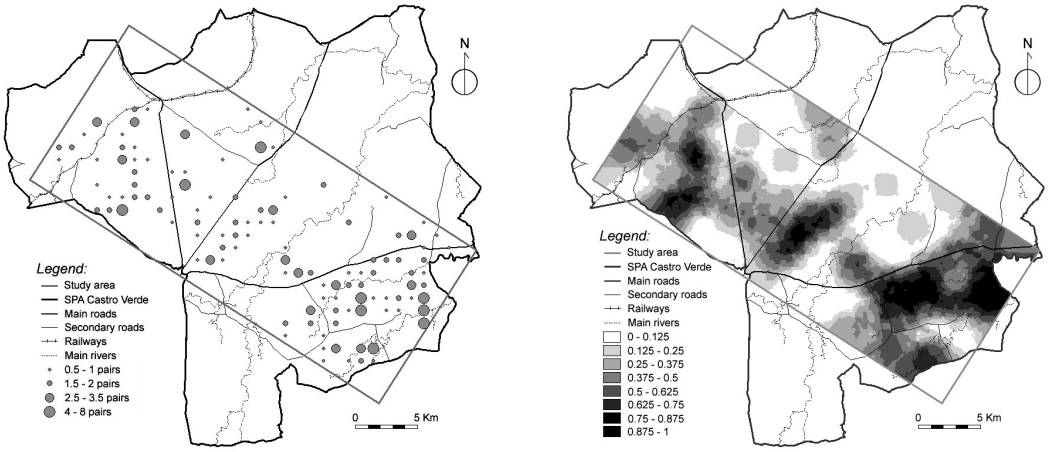

Figure 5. Map of Calandra Lark (*Melanocorypha calandra*) occurrence (left) and interpolated map of probability of occurrence (right). Sample points where the species did not occur are not shown, and dot size is proportional to abundance. The darker the colour the higher the probability of occurrence/estimated abundance / ***Figura 5.*** *Mapa de ocorrência de Calhandra (*Melanocorypha calandra*) (à esquerda) e mapa interpolado de probabilidade de ocorrência (à direita). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância. Quanto mais escura a tonalidade, maior a probabilidade de ocorrência/abundância.*

Tabela 2. Summary of logistic regression models, indicating for each species, the habitat variables selected, their slope (positive or negative), and significance values (* p<0.05; ** p<0.01; and *** p<0.001). Model performance is indicated by the Nagerkelke r2 and the area under the ROC curve. Species codes: Milcal (*Miliaria calandra*); Melcal (*Melanocorypha calandra*); Galsp (*Galerida* spp.); Tettet (*Tetrax tetrax*); Cisjun (*Cisticola juncidis*); Aleruf (*Alectoris rufa*); Calbra (*Calandrella brachydactyla*); Cirpyg (*Circus pygargus*); Cotcot (*Coturnix coturnix*); Upoepo (*Upupa epops*), Oenhis (*Oenanthe hispanica*); Pteori (*Pterocles orientalis*). Variable codes: F (amount of fallow land and grasslands); F+S (amount of fallow land and grasslands with scattered shrubs); C (amount of cereal fields); P (amount of ploughed fields); Md (amount of holm oak montados); PresF (presence of fallow land and grasslands); PresC (presence of cereal fields); PresP (presence of ploughed fields); PresMd (presence of holm oak montados); PresAf (presence of afforestations); PresF (presence of shrublands); Po50 (ploughed fields dominate more than half of the sampling point). / **Tabela 2.** *Sumário dos resultados dos modelos regressão logística, indicando para cada espécie as variáveis de habitat seleccionadas, a sua direcção de influência na ocorrência da espécie (positiva ou negativa), e os valores de significância (* p<0.05; ** p<0.01; e *** p<0.001). A performance do modelo é indicada pelo valor r2 de Nagerkelke e pela área debaixo da curva ROC.*

	Milcal	*Melcal*	*Galsp*	*Tettet*	*Cisjun*	*Aleruf*	*Calbra*	*Cirpyg*	*Cotcot*	*Upoepo*	*Oenhis*	*Pteori*
Variables												
F		+ , ***		+ , ***			+ , **					
F+S								+ , **				
C								+ , **	+ , ***		– , *	
P							+ , **					
Md				– , *								
PresF			+ , ***									
PresC	+ , ***				+ , ***							
PresP											+ , ***	
PresMd	+ , *	– , **				+ , **						
PresAf			+ , **									
PresS			+ , ***			+ , *						
Po50												+ , *
Richness										+ , *		
Model performance												
r2	*0.109*	*0.208*	*0.179*	*0.122*	*0.200*	*0.059*	*0.108*	*0.080*	*0.114*	*0.031*	*0.147*	*0.043*
ROC AUC	*0.669*	*0.731*	*0.696*	*0.676*	*0.743*	*0.628*	*0.671*	*0.694*	*0.728*	*0.624*	*0.701*	*0.557*

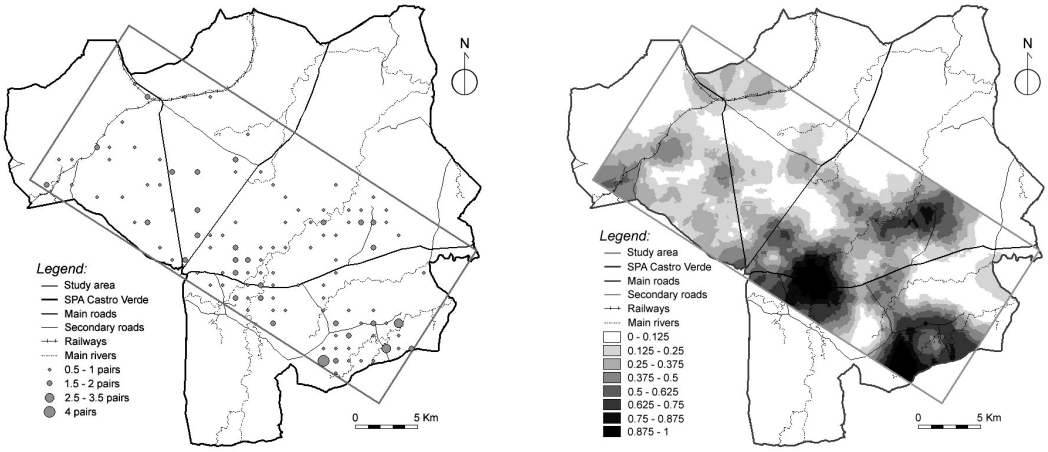

Figure 6. Map of Crested/Thekla Larks (*Galerida* spp) occurrence (left) and interpolated map of probability of occurrence (right). Sample points where the species did not occur are not shown, and dot size is proportional to abundance. The darker the colour the higher the probability of occurrence/estimated abundance / ***Figura 6.*** *Mapa de ocorrência de Cotovia-de-poupa/Cotovia-escura (*Galerida *spp) (à esquerda) e mapa interpolado de probabilidade de ocorrência (à direita). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância. Quanto mais escura a tonalidade, maior a probabilidade de ocorrência/abundância.*

point (range=0-8; S.E.=0.056), which yielded an estimate of 6160 (95% CI=4910-7410) pairs for the total pseudo-steppe area of the Castro Verde SPA. When compared with the previous population estimate for this region (400-8500 pairs, Costa *et al.* 2003), this new estimate adds extra precision, particularly in the lower range limit, and according to national population estimates (BirdLife International 2004), represents at least 60% of the total Portuguese population, showing how important this area is for the conservation of the species.

The Calandra Lark occurred all over the region, although three main nuclei of occurrence could be identified. The largest one was in the southeast (south of the Castro Verde-São Marcos road). A second was found between the Castro Verde-Entradas road and the Cobres river, and the third was located west of the Castro Verde-Carregueiro road (Figure 5).

Calandra Larks were more likely to be seen in points having a higher proportion of fallow fields and in areas without montados (Table 2). The association of the species with fallow fields during the breeding season in this region is in agreement with the results of previous studies (e.g. Moreira & Leitão 1996, Moreira 1999, Delgado & Moreira 2000), and could be related to the characteristic vegetation structure and diversity of fallow fields, which seems to suit better the breeding ecological requirements this lark species (e.g. nest cover, food availability and accessibility, predation risk perceiving) in comparison to alternative breeding habitats (e.g. cereal fields, ploughed fields). The species' avoidance of forested areas, including montados, had already been recognized (e.g. Cramp 1988).

Crested/Thekla Larks (*Galerida* spp.)

Crested/Thekla Larks were present in 28.9% of the sampling points, with an average abundance of 0.329 pairs per point (range=0-4; S.E.=0,031), which yielded an estimate of 3734 (95% CI=3031-4437) pairs for the total pseudo-steppe area of the Castro Verde SPA. Although these two species were not separated in the field due to their morphological similarities, most observations should correspond to Thekla Larks as they are more abundant in eastern

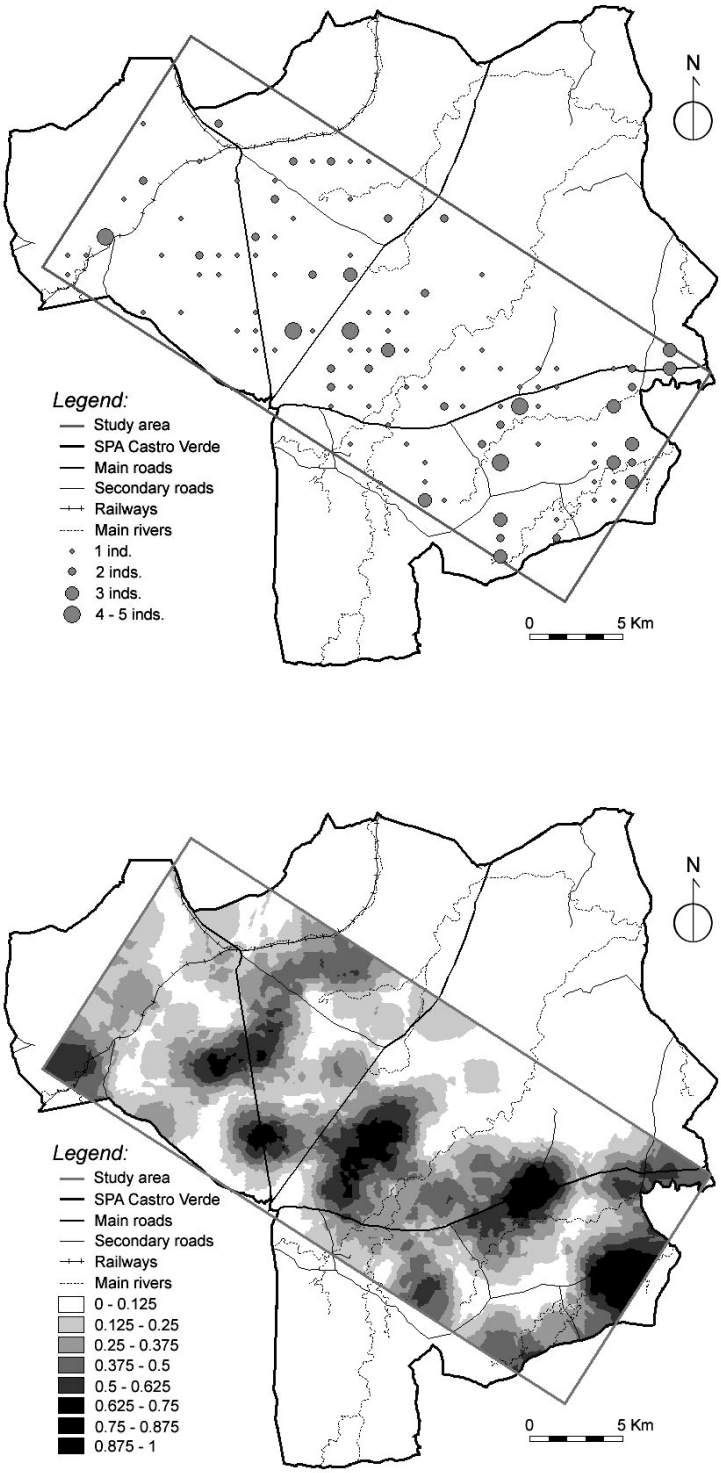

Figure 7. Map of Little Bustard (*Tetrax tetrax*) occurrence (left) and interpolated map of probability of occurrence (right). Sample points where the species did not occur are not shown, and dot size is proportional to abundance. The darker the colour the higher the probability of occurrence/ estimated abundance / ***Figura 7.*** *Mapa de ocorrência de Sisão (*Tetrax tetrax*) (à esquerda) e mapa interpolado de probabilidade de ocorrência (à direita). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância. Quanto mais escura a tonalidade, maior a probabilidade de ocorrência/abundância.*

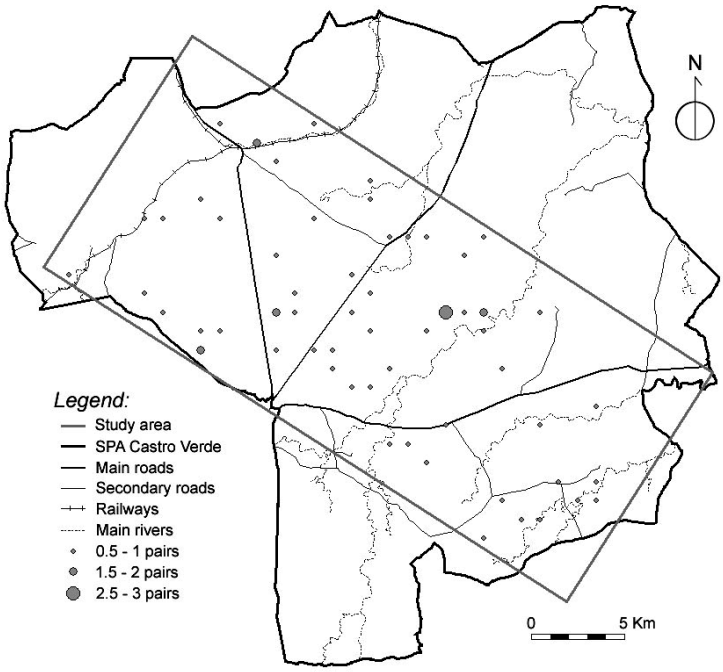

Figure 8. Map of Stonechat (*Saxicola torquatus*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 8.*** *Mapa de ocorrên+cia de Cartaxo (*Saxicola torquata*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

Alentejo than Crested Larks (Rufino 1989). The Portuguese population has been roughly estimated as 50,000 to 500,000 pairs for Thekla Lark and 10,000 to 100,000 pairs for Crested Lark (BirdLife International 2004). These species occurred across the region but were more frequent in the area where the Cobres and Maria Delgada rivers meet, and in the southeast (Figure 6).

The obtained model showed that the probability of finding these larks increased where shrublands, fallow fields and afforestations occurred (Table 2). These results are in general accordance with those obtained elsewhere, and reflect the association of these species to heterogeneous environments and to the presence of shrub-like cover. Manrique & Yanes (1994) for example, describe optimum habitat for Thekla Larks as open scrub of low to medium height in arid or semi-arid terrain. Rufino (1989) reports that in agricultural habitats, Thekla Larks occupy fallow land with scattered shrubs and trees, and sparse holm oak montados. In Castro Verde, Delgado & Moreira (2000) did not find a clear association of *Galerida* larks with specific habitat types, but other studies on fallow land showed that they prefer grasslands with scattered shrubs or trees (Moreira 1999, Santos 2000, Moreira *et al.* 2005).

Little Bustard (*Tetrax tetrax*)

The Little Bustard occurred in 27.6% of the sampling points, with an average abundance of 0.371 males per point (range=0-4; S.E.=0,036), which yielded an estimate of 4213 (95% CI=3402-5025) male Little Bustards for the total pseudo-steppe area of the Castro Verde SPA. These figures represent roughly 24% of the most recent estimate for the Alentejo region (17551 displaying males; Silva *et al.* 2006). Considering that the Alentejo holds 85% of the distribution area of Little Bustard in Portugal (Silva *et al.* 2006, Rufino 1989), we can say that the study area supports around 20% of the national population of this species. The estimate presented here is higher than the most recent estimate for Castro Verde (3340 displaying males, Silva *et al.* 2006).

The species occurred in the whole study area, although four to five scattered nuclei with higher prevalence could be identified (Figure 7). The main

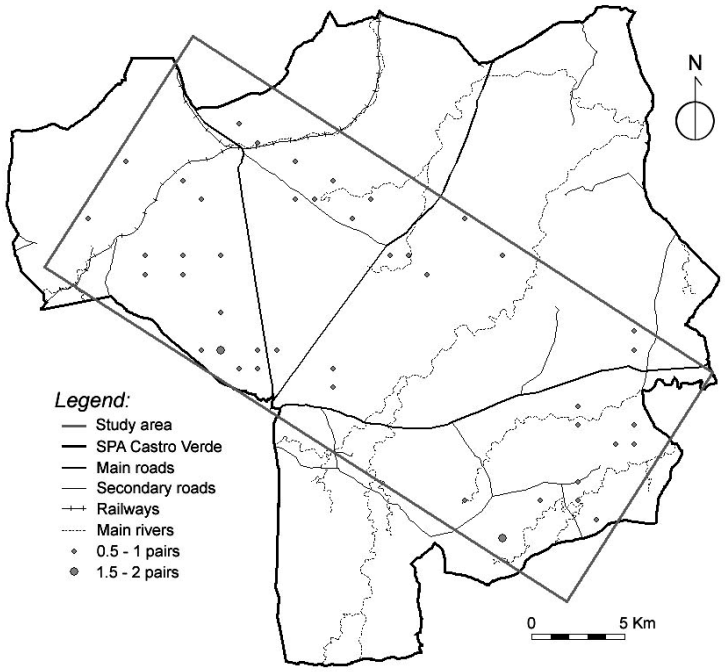

Figure 9. Map of Zitting Cisticola (*Cisticola juncidis*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 9.*** *Mapa de ocorrência de Fuinha-dos-juncos (*Cisticola juncidis*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

factor influencing (positively) the probability of occurrence was the availability of fallow fields. In contrast, a higher availability of montados decreased the probability of Little Bustard occurrence (Table 2). This agrees with the patterns found in other studies conducted in Castro Verde and in other areas of Alentejo (Moreira & Leitão 2006a,b, Moreira 1999, Faria & Rabaça 2004). These studies clearly showed that the Little Bustard is strongly associated with the grass layer of large fallow fields, both for displaying and laying the eggs, and that this species avoids overgrazed and recently ploughed fields and forested areas.

Stonechat (*Saxicola torquatus*)

The Stonechat occurred in 14.8% of the sampling points, with an average abundance of 0.136 pairs per point (range=0-3; S.E.=0,019), which yielded an estimate of 1540 (95% CI=1122-1958) pairs for the total pseudo-steppe area of the Castro Verde SPA. Recent studies carried out in the area did not provide information on either abundance or population estimates (e.g., Moreira & Leitão, 1996a,b, Delgado & Moreira, 2000), thus the current estimates are the first available for the region. Rufino (1989) suggested that this species is more abundant in the Alentejo region and Beira Interior than in the rest of the country. In any case, the Castro Verde population is not a significant proportion (at most ca. 5%) of the national population (25,000-250,000 pairs; BirdLife International 2004).

In the study area this species occurred locally, but it was scattered in the region (Figure 8). None of the studied variables significantly influenced its probability of occurrence (Table 2). Stonechats are known to be associated with a great variety of habitats in Baixo Alentejo, including not only agricultural land but also, hedges, bushes and saltmarsh, open oak woods, riverine vegetation and even sand dunes with bushes (Soares 1999). It is likely that other local and landscape variables that were not measured in this study, such as the amount of edges, fragmentation variables or vegetation structure, influence the Stonechat's distribution.

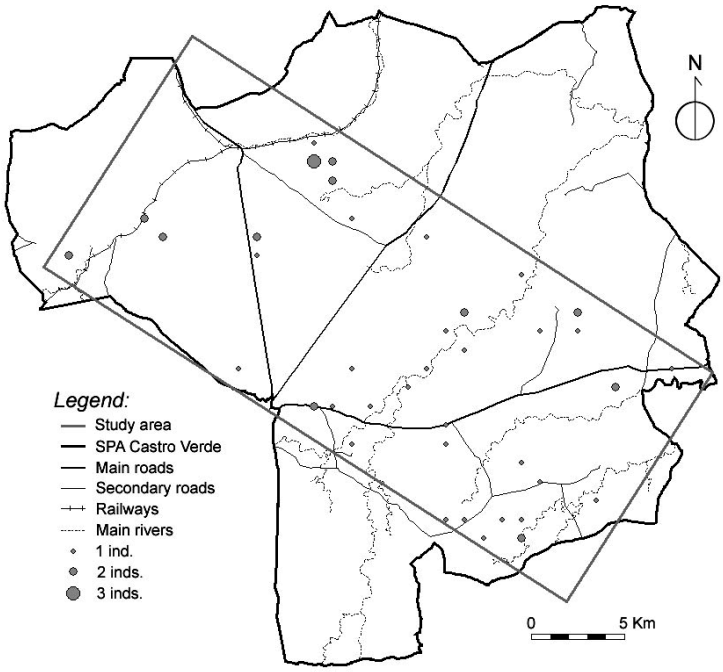

Figure 10. Map of Red-legged Partridge (*Alectoris rufa*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 10.*** *Mapa de ocorrência de Perdiz-vermelha (*Alectoris rufa*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

Zitting Cisticola (*Cisticola juncidis*)

The Zitting Cisticola was present in 11.3% of the sampling points, with an average abundance of 0.115 pairs per point (range=0-2; S.E.=0,017), which yielded an estimate of 1308 (95% CI=931-1684) pairs for the total pseudo-steppe area of the Castro Verde SPA. In comparison with the estimate for the national population (50,000-500,000 pairs; BirdLife International 2004), the population in Castro Verde is not significant at the national level.

This species could be found scattered in the area (Figure 9). It was more likely to occur in points where cereal fields were present (Table 2), which agrees with previous studies that have showed that the species is much more abundant in cereal fields than in other habitat types (Delgado & Moreira 2000). Delgado & Moreira (2002) also found a preference of Zitting Cisticola for wheat over barley and oat fields, suggesting that the incorporation in this analysis of variables describing cereal type structure would produce a more accurate prediction model of this species' occurrence.

Red-legged Partridge (*Alectoris rufa*)

The Red-legged Partridge was detected in 10.0% of the sampling points, with an average abundance of 0.133 birds per point (range=0-3; S.E.=0,022), which yielded an estimate of 1511 (95% CI=1022-2000) individuals for the total pseudo-steppe area of the Castro Verde SPA. This is equivalent to a density of ca. 0.02 partridges/ha, similar to the estimates of Borralho *et al.* (1997, 2000) in other areas without specific game management in Alentejo region. The Portuguese Red-legged Partridge population was estimated in 10,000-100,000 pairs (BirdLife International 2004), indicating a low importance of Castro Verde SPA population in a national context (less than 5%).

The species has a scattered distribution in the region (Figure 10), being more common where holm/cork oak trees (montados) and shrublands were present (Table 2). The positive association with scattered montados and shrubs may be related with the availability of shelter and breeding sites. This has been already reported in similar areas, with partridges showing a preference for boundaries and shrub

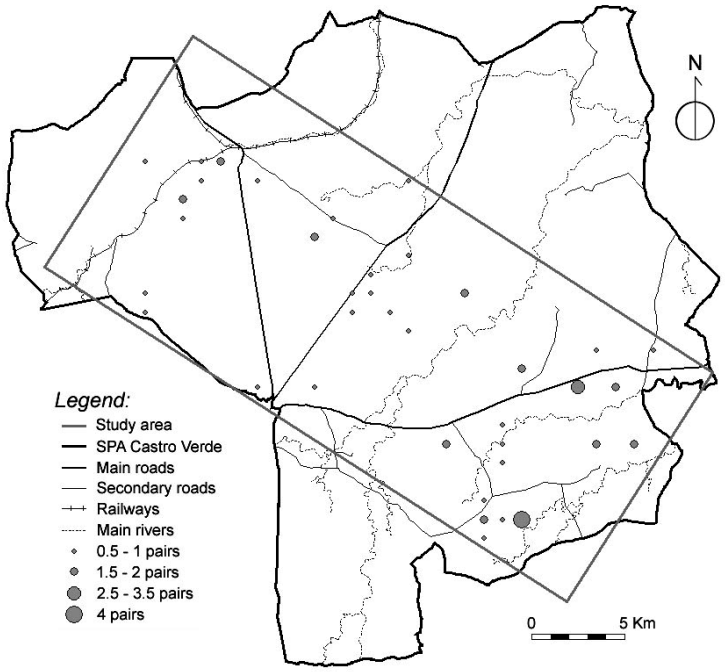

Figure 11. Map of Short-toed Lark (*Calandrella brachydactyla*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 11.*** *Mapa de ocorrência de Calhandrinha (*Calandrella brachydactyla*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

patches (Fortuna 2002). Although Borralho *et al.* (1999) found a positive association with fallows during the breeding season, in this study this association was not found, probably due to the sampling period (late for this species).

Short-toed Lark (*Calandrella brachydactyla*)

The Short-toed Lark occurred in 9.7% of the sampling points, with an average abundance of 0.128 birds per point (range=0-4; S.E.=0,023), which yielded an estimate of 1453 (95% CI=939-1966) pairs for the total pseudo-steppe area of the Castro Verde SPA. If compared with the population estimates of 2000-20,000 pairs for Portugal (BirdLife International 2004), this corresponds at least to 7% of the national population, but could be as high as 60% or more. There are no previous population estimates for the region, and usable density estimates to extrapolate population sizes are only available for fallow land (Moreira & Leitão 1996; Moreira 1999), which does not represent the habitat with the highest abundance (see below).

The species was uncommon, although it occurred all over the region (Figure 11). Increasing availability of fallow land and ploughed fields favoured its occurrence (Table 2). Previous studies have shown that this species prefers sparse vegetation including dunes, low density shrublands, fallow fields, and ploughed land (Rufino 1989, Diaz 1994, Suárez *et al.* 2002). In Castro Verde, Delgado & Moreira (2000) found that Short-toed Larks were most abundant in ploughed land, although they also occurred in fallow fields and pastures. Densities in fallow grasslands increased where fields had a higher proportion of bare ground (Moreira 1999).

Montagu's Harrier (*Circus pygargus*)

The Montagu's Harrier occurred in 6.6% of the sampling points, with an average abundance of 0.077 birds per point (range=0-3; S.E.=0,016), which yielded an estimate of 872 (95% CI=521-1223) birds for the total pseudo-steppe area of the Castro Verde SPA. Yet, the used methodology is not suitable for accurately censusing raptors, therefore results should be interpreted cautiously. In a previous study, Franco *et al.* (1996) estimated a population density of 45-50

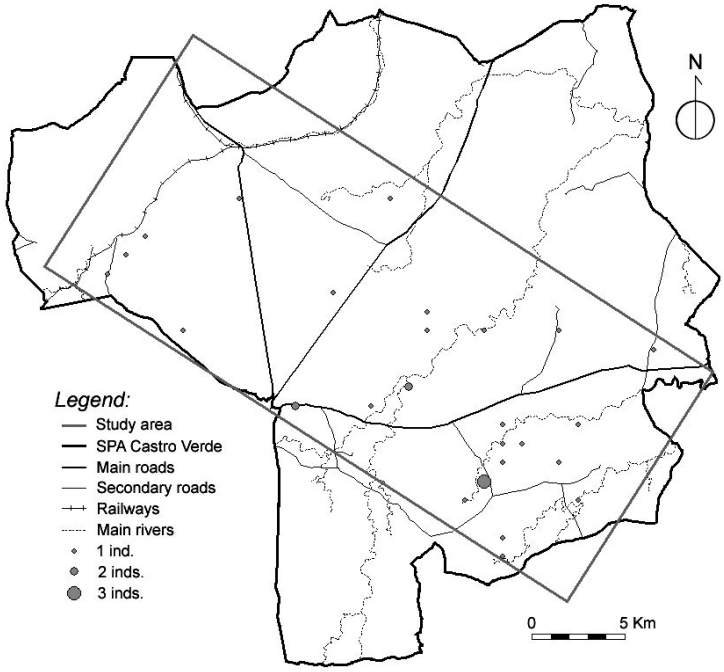

Figure 12. Map of Montagu's Harrier (*Circus pygargus*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 12.*** *Mapa de ocorrência de Tartaranhão-caçador (*Circus pygargus*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

pairs per 10,000 ha in the area of Castro Verde SPA, which would correspond to a population size of ca. 500 individuals. The Portuguese population is estimated as 900-1200 individuals (BirdLife International, 2004), which suggests that Castro Verde is one of the strongholds for this species in Portugal. This harrier occurred scattered in the region (Figure 12). It was more likely to be seen in points with higher availability of cereal fields and fallow land with scattered shrub patches (Table 2). These results confirm the preferred habitat types of Montagu's harrier for breeding and feeding (e.g. Hagemeijer & Blair 1997, Millon *et al.* 2002) in most of its distribution range. These habitats seem to be the most suitable since they are likely to contain large amounts of arthropods, microtine rodents, and birds, which represent the main prey taken by the species (e.g. Hiraldo *et al.* 1975, Arroyo 1998).

Quail (*Coturnix coturnix*)

The Quail was detected in 6.6% of the sampling points, with an average abundance of 0.082 birds per point (range=0-3; S.E.=0,017), which yielded an estimate of 930 (95% CI=553-1307) individuals for the total pseudo-steppe area of the Castro Verde SPA. BirdLife International (2004) roughly estimated a national population of 5,000 to 50,000 pairs (based on data from 2002) which suggests that the Castro Verde plains may represent from 1% to 9% of the total Portuguese population.

The species was more common in the western part of the study area (Figure 13), and the likelihood of occurrence increased proportionally with the availability of cereal fields (Table 2). The association of the species with this habitat is consistent with results from previous studies during the breeding season (e.g. Borralho *et al.* 1998, Carvalho *et al.* 1996, Delgado & Moreira 2000). In comparison with the Zitting Cisticola, this species responded positively not only to the presence of cereal fields, but to their abundance, suggesting that it may favour larger patches of cereal crops.

Stone Curlew (*Burhinus oedicnemus*)

The Stone Curlew was detected in 6.4% of the sampling points, with an average abundance of 0.087

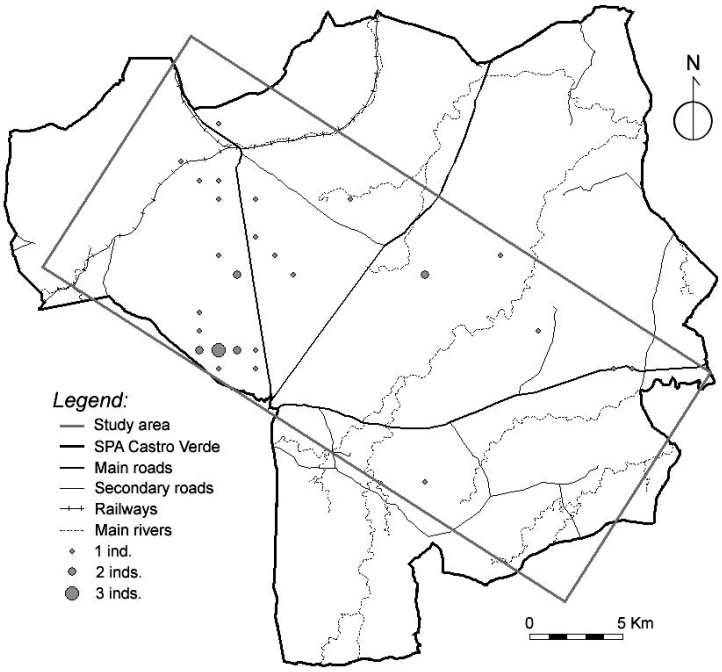

Figure 13. Map of Quail (*Coturnix coturnix*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 13.*** *Mapa de ocorrência de Codorniz (*Coturnix coturnix*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

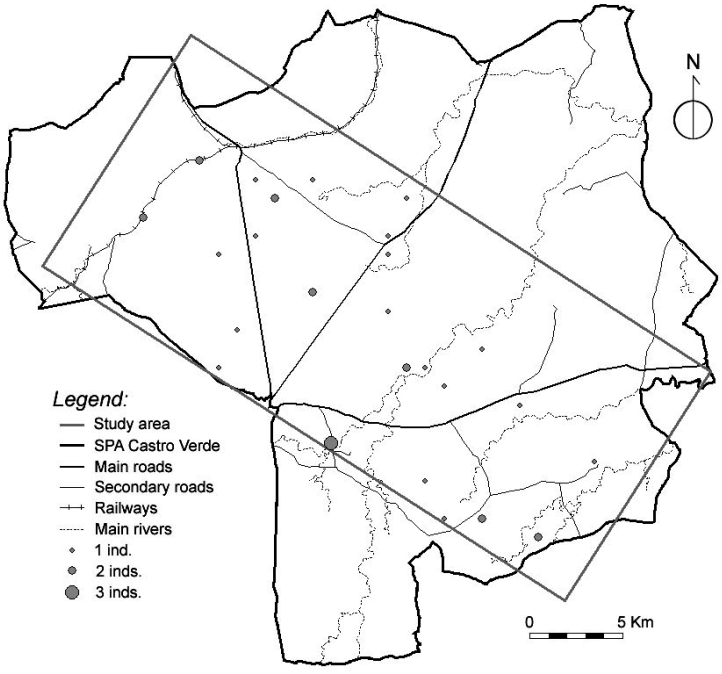

Figure 14. Map of Stone Curlew (*Burhinus oedicnemus*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 14.*** *Mapa de ocorrência de Alcaravão (*Burhinus oedicnemus*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

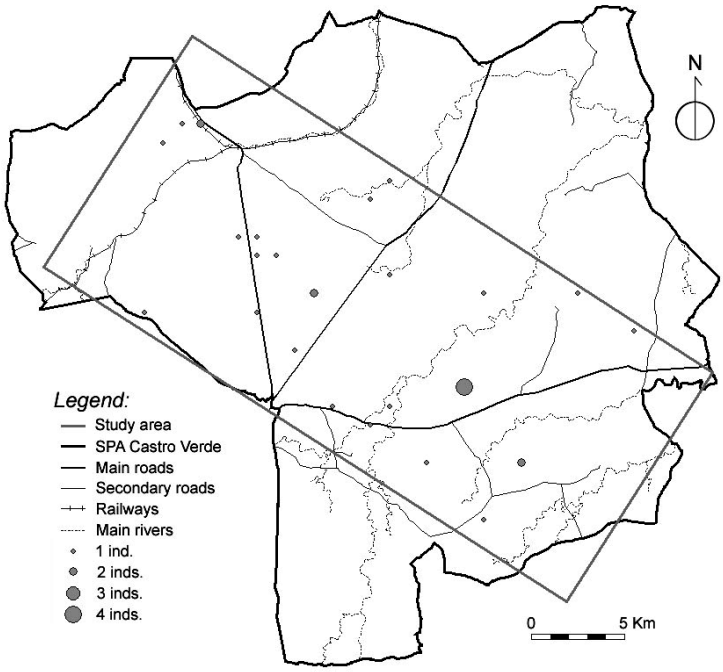

Figure 15. Map of Hoopoe (*Upupa epops*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 15.*** *Mapa de ocorrência de Poupa (*Upupa epops*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

birds per point (range=0-3; S.E.=0,018), which yielded an estimate of 988 (95% CI=579-1397) individuals for the total pseudo-steppe area of the Castro Verde SPA. The used methodology is not suitable for accurately censusing this species, so care should be taken when interpreting this result. Population estimates for Portugal range from 2500 to 10,000 birds (Cabral *et al.* 2006), thus Castro Verde could hold at least 10%, and up to 40% of the national population. For Castro Verde, the previous estimate of 100-150 pairs (Costa *et al.* 2003) is lower than the current one.

The species occurred scattered over the area (Figure 14), and none of the studied variables influenced its probability of occurrence (Table 2). Moreira (1999) found that the presence of the species in fallow land was associated with shrub occurrence, while Delgado & Moreira (2000) found relatively high densities in ploughed land when compared with other habitats. In the Alto Alentejo, Brito (1996) also found a significant selection of uncultivated fields with scattered scrubs and a large proportion of bare ground. These results suggest that habitat selection patterns of the Stone Curlew are determined by vegetation structure and soil ground-cover variables that were probably not addressed at the appropriate scale in the present analysis.

Hoopoe (*Upupa epops*)

The Hoopoe was present in 6.1% of the sampling points, with an average abundance of 0.077 birds per point (range=0-4; S.E.=0,017), which yielded an estimate of 872 (95% CI=485-1258) individuals for the total pseudo-steppe area of the Castro Verde SPA. The 10,000 to 100,000 pairs estimated by BirdLife International (2004) suggest that Castro Verde's plains are not very important for this species. This is not surprising if we consider that, in Iberia, the highest densities occur in open holm oak stands and juniper woodlands (Santos et al. 1981, Díaz *et al.* 1996, Muñoz & Altamirano 2003).

Hoopoes occurred in a scattered pattern all over the region (Figure 15). The likelihood of finding this species increased proportionally with habitat richness in the points (Table 2). The Hoopoe is basically a bird of warm, dry, level or gently

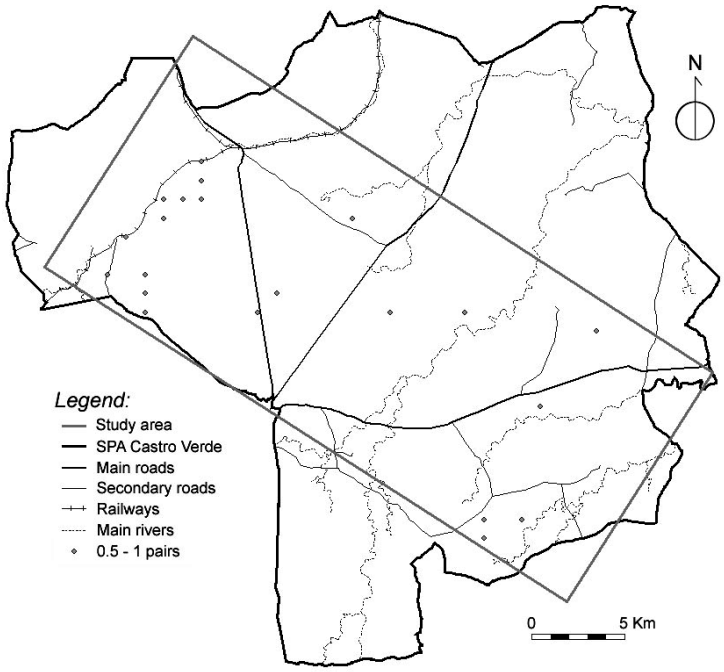

Figure 16. Map of Tawny Pipit (*Anthus campestris*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 16.*** *Mapa de ocorrência de Petinha-dos-campos (*Anthus campestris*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

undulating terrain with much exposed bare surface, but numerous upstanding features offering perches, shade and breeding cavities, thus avoiding extensive featureless open tracts, like some large irrigated cultivation and pasture fields (Snow & Perrins 1998). In southern Europe, it is common on farmland with walls and isolated trees, bare or sparsely vegetated soil being in every case essential for ground feeding (Bannerman 1955). Mixed landscapes where woods alternate with cultivation, fallow and pasture fields also appear to be its favourite habitat in Portugal (Rufino 1989), and agrees with our finding of preference for areas with higher habitat diversity. In the most featureless areas of Castro Verde plain pseudo-steppe, the Hoopoe breeds mostly on piles of stones removed from cultivation fields to make ploughs easier, a situation also noted in Spain (Muñoz & Altamirano 2003).

Tawny Pipit (*Anthus campestris*)

The Tawny Pipit occurred in 5.4% of the sampling points, with an average abundance of 0.041 birds per point (range=0-1; S.E.=0,009), which yielded an estimate of 465 (95% CI=260-670) pairs for the total pseudo-steppe area of the Castro Verde SPA. The current estimate of the Portuguese population of this species is 1,000-10,000 pairs (BirdLife International 2004), which means that Castro Verde could hold 5 to 45% of the national population.

The species was scarce but occurred across the whole region. However, the data suggests that it was more prevalent in the western part (Figure 16). None of the studied variables influenced its probability of occurrence (Table 2). Rufino (1989) describes it as a species typical of mountain pastures and also fallow land. Previous studies in Castro Verde found highest densities in ploughed land (Delgado & Moreira 2000).

Black-eared Wheatear (*Oenanthe hispanica*)

The Black-eared Wheatear occurred in 5.1% of the sampling points, with an average abundance of 0.049 birds per point (range=0-2; S.E.=0,011), which yielded an estimate of 552 (95% CI=302-802) wheatear pairs for the total pseudo-steppe area of the Castro Verde SPA. The national breeding

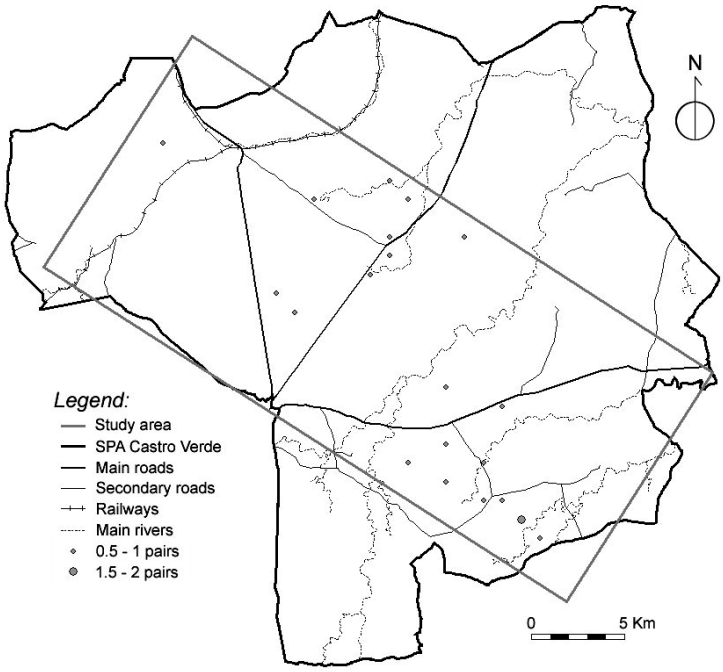

Figure 17. Map of Black-eared Wheatear (*Oenanthe hispanica*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 17.*** *Mapa de ocorrência de Chasco-ruivo (*Oenanthe hispanica*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

population has been estimated as 2,000-20,000 pairs (BirdLife International 2004), the species being more common and abundant in the south of the country (Rufino 1989). More recently, Almeida *et al.* (2005) reported that the Portuguese breeding population was probably less than 10,000 birds. Considering this estimate, the Castro Verde SPA could support at least 10% of the national breeding population.

The species was very scarce but occurred across the whole region (Figure 17). However, it seemed more prevalent in the eastern part. Its occurrence was positively related to the presence of ploughed fields, and negatively related to the availability of cereal fields (Table 2). In Portugal, this wheatear is strongly associated with very dry land with poor vegetation cover, as fallow land and a variety of habitats with poor or low vegetation cover and height (Rufino 1989). Delgado & Moreira (2000) reported higher densities on ploughed land for Castro Verde. The present distribution in Castro Verde SPA may partially be explained by both habitat and climatic features, as the eastern part of the study area is drier, probably with poor soils and less vegetation cover.

Great bustard (*Otis tarda*)

The Great Bustard was present in 4.1% of the sampling points, with an average abundance of 0.064 birds per point (range=0-4; S.E.=0.018), which yielded an estimate of 726 (95% CI=316-1137) individuals for the total pseudo-steppe area of the Castro Verde SPA. Pinto *et al.* (2005) estimated ca. 900 birds in this SPA, corresponding to 80% of the national population. Thus, although the methodology used was not suitable for accurately censusing this species (e.g. Alonso & Alonso 1996, Pinto *et al.* 2005), the population estimate reflects the real population size in the area.

The spatial distribution pattern across the region (Figure 18) partially reflects what is known on the main areas of occurrence during the breeding season (Rocha 1999, Morgado & Moreira 2000), with more observations occurring close to the main lekking grounds. Nevertheless, other known lekking areas were not detected by our sampling scheme.

None of the studied variables influenced the probability of occurrence of this species in the sampled points, probably because the spatial scale

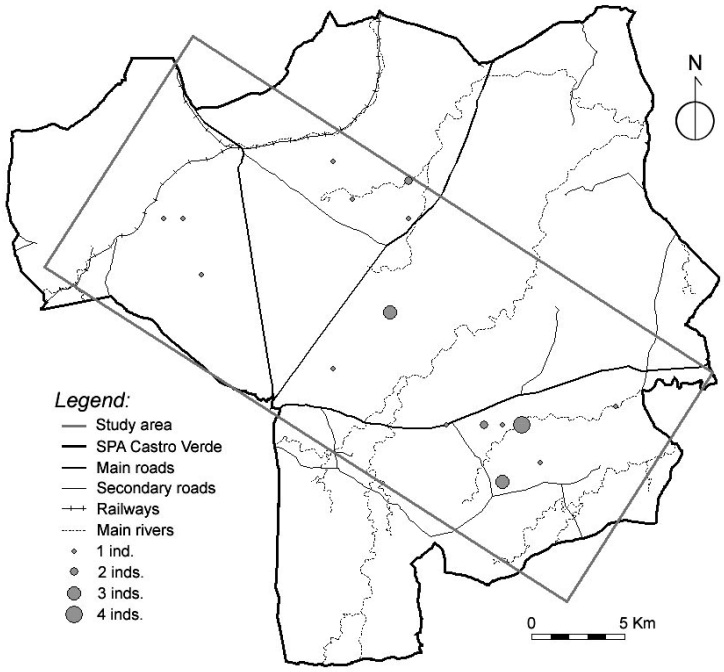

Figure 18. Map of Great Bustard (*Otis tarda*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 18.*** *Mapa de ocorrência de Abetarda (*Otis tarda*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

and methods were not suitable for describing habitat selection patterns in the Great Bustard. Previous studies in Castro Verde showed gender differences in habitat selection during the breeding season, with males showing stronger selection for fallows and females preferring cereal fields (Morgado & Moreira 2000, Moreira *et al.* 2004).

Black-bellied Sandgrouse (*Pterocles orientalis*)

The Black-bellied Sandgrouse was the scarcest of the studied species, being detected in just 2.0% of the sampling points, and with an average abundance of 0.046 birds per point (range=0-4; S.E.=0,018). This yielded an estimate of 523 (95% CI=122-924) individuals for the total pseudo-steppe area of the Castro Verde SPA, but the methodology used is not suitable for accurately censusing this species. This probably explains why the obtained estimate was higher than that given by Costa *et al.* (2003) for Castro Verde (20-120 birds). More recently, a Black-bellied Sandgrouse national census estimated that the Portuguese population is not larger than 300 individuals, and counted just 50 individuals in the Castro Verde region, during spring (Cardoso 2005).

The species occurred mainly in the eastern part of the region (Figure 19), a pattern also observed during the national census (Cardoso 2005). Although the area has suitable habitat further west, where observations had occurred in previous years, the present data suggest that the distribution area of Black-bellied Sandgrouse is contracting towards the east (Cardoso 2005).

The probability of finding Black-bellied Sandgrouse was higher in points with a large (over 50%) availability of ploughed land (Table 2). This finding is consistent with a previous study on habitat selection of this species in a nearby area, which found that it prefers areas with scarce vegetation cover (Poeiras 2003). The same study also reports an association with pastures and a high preference for dry leguminous crops.

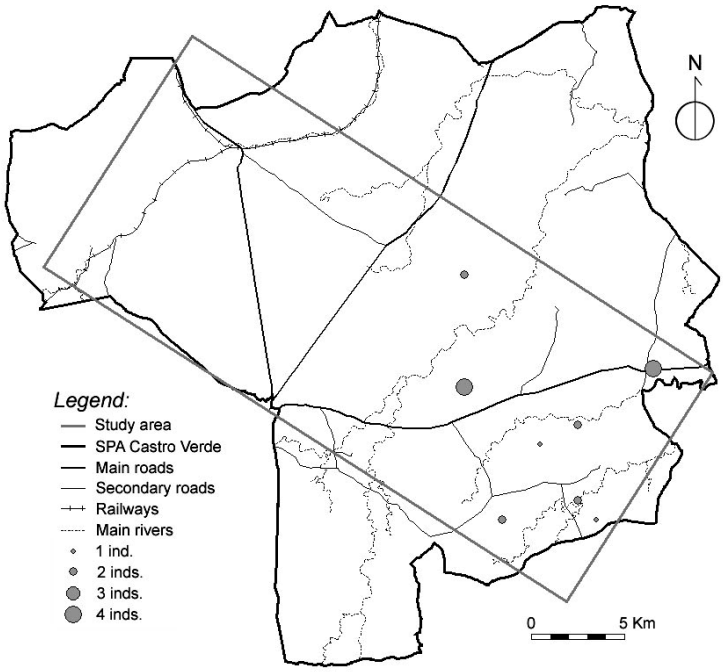

Figure 19. Map of Black-bellied Sandgrouse (*Pterocles orientalis*) occurrence. Sample points where the species did not occur are not shown, and dot size is proportional to abundance. / ***Figura 19.*** *Mapa de ocorrência de Cortiçol-de-barriga-preta (*Pterocles orientalis*). Os pontos de amostragem onde a espécie não ocorre não são assinalados. e a dimensão dos símbolos é proporcional à abundância.*

DISCUSSION

Spatial distribution patterns

The Corn Bunting was substantially more prevalent (almost in 80% of the points) than the other studied species across the region, probably because of a combination of large abundance and high detectability. Little Bustard, Calandra Lark and *Galerida* larks occurred in ca. 30% of the points whereas all the other species had a prevalence lower than 15%. Most species occurred all over the region, with no obvious spatial pattern of large areas of absence or spatially concentrated occurrence. This could be expected as we focused our effort in the central area of Castro Verde, composed mostly of steppe habitat suitable for the target species. However, areas of higher frequency (and abundance, for Corn Bunting) could be identified, and future monitoring should clarify whether these are determined mostly by annual variations in habitat availability or are consistent across time.

Species-habitats associations

The species studied could be grouped into four categories, in terms of relationship with the measured habitat variables: a) species clearly favouring fallow fields and permanent pastures include Calandra Lark and Little Bustard; b) a second category included species associated with cereal fields, namely Quail, Corn Bunting, Zitting Cisticola and Montagu's Harrier; c) a third group was composed of species associated with ploughed fields: Short-toed Lark, Black-eared Wheatear, Black-bellied Sandgrouse; d) a last group included species probably associated to more diverse habitat mosaics or to landscape variables not assessed at the scale used in the present study: *Galerida* larks, Red-legged Partridge, Hoopoe, Stone Curlew, Stonechat and Great Bustard. Some of these species did not show any association with the measured variables.

Population estimates

The population estimates obtained were not corrected for detectability, so they cannot be compared among species and should be considered

as an index for future within-species comparisons, assuming detectability remains constant over time (Martin *et al.* 2007). As they stand, they mostly consist of underestimates and, thus, minimum population sizes. Additionally, the estimates available for Portugal are often very crude, hindering the assessment of the national relevance of Castro Verde populations. Even with these constraints, when compared to previous population estimates (e.g. Costa *et al.* 2003), the present data show that the importance of Castro Verde for steppe birds is even higher than supposed. For Little Bustard, previous estimates of 360-3340 males (Costa *et al.* 2003, Silva *et al.* 2006) increase to 3400-5000 males. For Stone Curlew, previous estimates of 100-150 pairs now reached 580-1400 individuals. For Calandra Lark, estimates become more precise, with the minimum rising from 400 pairs (Costa *et al.* 2003) to 4900 pairs and the maximum decreasing from 8500 to 7400 pairs.

This work provides the first population estimates for Corn Bunting, Short-toed Lark, Tawny Pipit, Black-eared Wheatear). For other species, such as Great Bustard, Montagu's Harrier or Black-bellied Sandgrouse, the methodology used cannot be considered appropriate, and other census methods should be used to assess population status.

In terms of national importance, Castro Verde is extremely important for Great Bustard (80% of the Portuguese population), Calandra Lark (over 60%), Little Bustard (20%) and, probably, Montagu's Harrier. Additionally, the region probably holds relevant percentages (10% or more) of the national population of Short-toed Lark, Stone Curlew, Black-eared Wheatear and Black-bellied Sandgrouse. The area is probably also of relevance for the Corn Bunting, although there are no precise estimates of the national population for this species.

Again, we emphasise that this study was carried out in the spring of 2006, following the worst drought of the last 60 years in Portugal. This drought probably had important negative impacts on bird populations, mainly for resident species, which are likely to be reflected in the current results. Even agricultural management practices were changed, for example livestock grazing was introduced in failed cereal crops. Bird censuses at the national level have suggested a strong impact of the drought of 2004/2005 on bird populations (Hilton 2006).

Expected trends in habitats and populations – what will happen in the future?

As a final exercise, based on the obtained species-habitat associations, we hypothesize expected trends in species populations in relation to potential scenarios of land management changes in the region.

With decoupling, dry cereal cultivation will no longer be a profitable option for local farmers. Thus, one likely scenario will be for dry cereal abandonment and its replacement by pastures. This will be detrimental for species associated with cereal fields, such as Corn Bunting, Zitting Cisticola, Quail and Montagu's Harrier. But other species are expected to decline as the end of crop cultivation will probably also mean the end of field ploughing. Thus, species associated with ploughed land, such as the Black-eared Wheatear, Short-toed Lark and Black-bellied Sandgrouse, are also expected to decline.

As another management alternative, in the context of the end of cereal cultivation, afforestations of former agricultural land are increasing in the region. This is also a threat to most steppe birds, mainly species requiring large areas of fallow and pastures such as Calandra Lark and Little Bustard. On the other hand, afforestations could be beneficial for *Galerida* larks, at least in the short to medium term, and for Red-legged Partridges and Corn Buntings, if the long-term consequence is the increase of montados in the area.

On the other hand, the increase of permanent pastures could a priori be considered beneficial for species such as Little Bustard and Calandra Lark, but this will depend on the grazing system, livestock densities and resulting vegetation structure.

Finally, agricultural abandonment and subsequent scrub encroachment are expected, at least in the medium term, to improve habitat suitability for a few species such as *Galerida* larks, and Red-legged Partridges, but would be highly detrimental for typical steppe birds such as Great Bustard, Little Bustard and Calandra Lark.

Conclusion

This study provided the first data on detailed spatial distribution patterns and population estimates for several steppe birds in Castro Verde. The results suggest that the method used is a quick and effective

one for characterising occurrence patterns and making population estimates across relatively large areas of pseudo-steppe, as well as describing broad-scale bird-habitat relationships. The main value of the data obtained in this project is to use them as a baseline situation against which the results of future monitoring can be compared. We propose that changes in habitat and bird populations should be monitored at least every 5 years.

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REFERENCES

Akaike, H. 1974. A new look at the statistical model identification. *IEEE Transactions on Automatic Control* 19: 716-723.

Almeida, J. 1992. Censos de grous *Grus grus* invernantes em Portugal. *Airo* 3: 55-58.

Almeida, J. (coord.), P. Catry, V. Encarnação, C. Franco, J.P. Granadeiro, R. Lopes, F. Moreira, P. Oliveira, N. Onofre, C. Pacheco, M. Pinto, M.J. Pitta Groz, J. Ramos & L. Silva 2006. *Oenanthe hispanica* chasco-ruivo: pp. 373-74 in M.J. Cabral, J. Almeida, P.R. Almeida, T. Dellinger, N. Ferrand Almeida, M.E. Oliveira, J.M. Palmeirim, A.I. Queiroz., L. Rogado & M. Santos-Reis M (eds.). *Livro Vermelho dos Vertebrados de Portugal*. Instituto da Conservação da Natureza, Lisboa.

Alonso, J.C. & J.A. Alonso 1996. The Great Bustard *Otis tarda* in Spain: present status, recent trends and an evaluation of earlier censuses. *Biological Conservation* 77: 79-86

Arroyo, B.E. 1998. Effect of diet on the reproductive success of Montagu's Harrier *Circus pygargus*. *Ibis* 140: 690-693.

Bannerman, D.A. 1955. *The Birds of the British Isles – Vol. 4*. Oliver & Boyd, London.

Bibby, C., N.D. Burgess, D.A. Hill & S.H. Mustoe 2000. *Bird census techniques - 2nd edition*. Academic Press, London, UK.

BirdLife International 2004. *Birds in Europe: Population Estimates, Trends and Conservation Status*. BirdLife Conservation Series 10, BirdLife International, Cambridge.

Borralho, R., F. Rego & P. Vaz Pinto 1997. Demographic trends of Red-legged Partridges (*Alectoris rufa*) in southern Portugal after implementation of management actions. Gibier Faune Sauvage, *Game and Wildlife* 14: 585-599.

Borralho, R., C. Stoate, M. Araújo, A. Rito & S. Carvalho 1998. Factores ambientais que afectaram a ocorrência primaveril de Codorniz *Coturnix coturnix* no Baixo Alentejo: pp. 68-72 in Costa, L.T., Costa, H., Araújo, M. & Silva, M.A. (eds). *Actas do Simpósio Sobre Aves Migradoras na Península Ibérica*. Sociedade Portuguesa para o Estudo das Aves, Évora.

Borralho, R., S. Carvalho, F. Rego & P.Vaz Pinto 1999. Habitat correlates of the Red-legged Partridge (*Alectoris rufa*) breeding density on Mediterranean farmland. *Revue de Ecologie (La Terre et la Vie)* 54: 59-69.

Borralho, R., J. Carvalho, P. Vaz Pinto, J. Bugalho, D. Castro Pereira & M. Capelo 2000. Gestão cinegética e evolução demográfica de duas populações de Perdiz-vermelha (*Alectoris rufa*) do Centro e Sul de Portugal. *Silva Lusitana* 8: 49-59.

Brito, P.H. 1996. Nest site selection by the Stone Curlew (*Burhinus oedicnemus*) in Southern Portugal. pp. 231-238 in Gutiérrez, J.F. & Sanz-Zuasti, J. (eds.) Conservación de las aves estepárias y su habitat. *Actas del Simposium para la Conservación de las Aves Estepárias y su Habitat*. Unión de Grupos Naturalistas de Castilla Y León, Valladolid.

Burnham, K.P. & D.R. Anderson 2002. *Model selection and multimodel inferences. A practical information-theoretic approach - 2nd ed*. Springer, New York, USA.

Burnham, K.P. & D.R. Anderson 2004. Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods & Research* 33: 261-304.

Burroughs, P. 1995. Spatial aspects of ecological data. In *Data analysis in community and landscape ecology* (eds Jongman, Ter Braak & Van Togeren). Cambridge University Press, Cambridge, UK.

Cabral, M.J., J. Almeida, P.R. Almeida, T. Dellinger, N. Ferrand Almeida, M.E. Oliveira, J.M. Palmeirim, A.I. Queiroz., L. Rogado & M. Santos-Reis (eds.) 2006. *Livro Vermelho dos Vertebrados de Portugal*. Instituto da Conservação da Natureza. Lisboa.

Cardoso, A.C. 2005. *Censo Nacional de Cortiçol-de-barriga-negra e de Cortiçol-de-barriga-branca*. Relatório não publicado. Instituto da Conservação da Natureza.

Carvalho, S., Araújo, M., Borralho, R. & Stoate, C. 1996. Análise multivariada para identificação de guildas de aves num mosaico agrícola do Baixo Alentejo. pp. 122-124 in Farinha, J.C., Almeida, J. & Costa, H. (eds), *Actas do I Congresso de Ornitologia da Sociedade Portuguesa para o Estudo das Aves*. Sociedade Portuguesa para o Estudo das Aves, Lisboa.

Costa, L.T., M. Nunes, P. Geraldes & H. Costa 2003. *Zonas Importantes para as Aves em Portugal*. Sociedade Portuguesa para o Estudo das Aves, Lisboa.

Cramp, S. (ed.) 1988. *Handbook of the Birds of Europe, the Middle East and North Africa, (Tyrant Flycatchers to Thrushers), Vol. V*. Oxford University Press, Oxford.

DeSante, D. F. 1981. Censusing technique in a California coastal scrub breeding bird community. *Studies in Avian Biology* 6: 177–186.

Delgado, A. & F. Moreira 2000. Bird assemblages of an Iberian cereal steppe. *Agriculture, Ecosystems and Environment* 78: 65-76.

Delgado, A. & F. Moreira 2002. Do wheat, barley and oats provide similar habitat and food resources for birds in cereal steppes? *Agriculture, Ecosystems and Environment* 93: 441-446.

Díaz, M. 1994. Short-toed lark *Calandrella brachydactyla*. pp. 356-357 in Tucker, G.M., Heath, M.F. (eds). *Birds in Europe: their conservation status*. BirdLife Conservation Series No. 3. BirdLife International, Cambridge.

Díaz, M., B. Asensio, & J.L. Tellería 1996. *Aves Ibéricas – I. No Paseriformes*. J.M. Reyero Editor, Madrid.

ESRI. 2004. *Arc GIS 9*. Environmental Systems Research Institute, Redlands, USA.

Faria, N. & J.E. Rabaça 2004. Breeding habitat modelling of the Little Bustard *Tetrax tetrax* in the site of community importance of Cabrela (Portugal). *Ardeola* 51: 331-343.

Fortuna, M.A. 2002. Selección de hábitat de la perdiz roja *Alectoris rufa* en período reproductor en relación con las características del paisaje de un agrosistema de la Mancha (España). *Ardeola* 49: 59-66

Fuller, R.J. & D.R. Langslow 1984. Estimating numbers of birds by point counts: how long should counts last? *Bird Study* 31: 195-202.

Franco, A., I. Malico, H. Martins & N. Sarmento 1996. Abundância e reprodução do tartaranhão-caçador (*Circus pygargus* L.) na região de Castro Verde. *Ciência e Natureza* 2: 21-28.

Hagemeijer, E.J.M. & M.J. Blair (Editors) 1997. *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance*. T&AD Poyser, London.

Hilton, G. 2006. *Censo de aves comuns em Portugal. Dados preliminares de 2004 e 2005*. SPEA, Lisboa.

Hiraldo, F., F. Fernández & F. Amores 1975. Diet of Montagu's Harrier (*Circus pygargus*) in southwestern Spain. *Doñana, Acta Vertebrata* 2: 25-55.

INAG 2005. *Seca 2005. Relatório de balanço*. Instituto da Água, Lisboa.

Leitão, D. & F. Moreira 1996. Estrutura e composição das comunidades de aves nidificantes na região de Castro Verde. *Ciência e Natureza* 2: 103-107.

Manrique, J. & M. Yanes 1994. Thekla Lark *Galerida theklae*. pp. 362-363 in Tucker, G.M. & Heath, M.F. (eds). *Birds in Europe: their conservation status*. BirdLife Conservation Series No. 3. BirdLife International, Cambridge.

Martin, J., W.M. Kitchens & J.E. Hines 2007. Importance of well-designed monitoring programs for the conservation of endangered species: case study of the Snail Kite. *Conservation Biology*, in press.

Martínez, C. & F.J. Purroy 1993. Avifauna reprodutora en los sistemas esteparizados ibericos. *Ecologia* 7: 391–401.

Millon, A., J.-L. Bourrioux, C. Riols & V. Bretagnolle 2002. Comparative breeding biology of Hen Harrier and Montagu's Harrier: an 8-year study in north-eastern France. *Ibis* 144: 94-105.

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. & D. Leitão 1996a. A comunidade de aves nidificantes nos pousios da região de Castro Verde. *Ciência e Natureza* 2: 109-113

Moreira, F. & D. Leitão 1996b. A preliminary study on the breeding bird community in fallows of cereal steppes in Southern Portugal. *Bird Conservation International* 6: 255–259.

Moreira, F., R. Morgado & S. Arthur 2004. Great bustard (*Otis tarda*) habitat selection in relation to agricultural use in southern Portugal. *Wildlife Biology* 10: 251-260.

Moreira F., P. Beja, R. Morgado, L. Reino, L. Gordinho, A. Delgado & R. Borralho 2005. Effects of field management and landscape context on grassland wintering birds in Southern Portugal. *Agriculture, Ecosystems and Environment* 109: 59-74.

Morgado, R. & F. Moreira 2000. Seasonal population dynamics, nest site selection, sex-ratio and clutch size of the Great Bustard *Otis tarda* in two adjacent lekking areas. *Ardeola* 47: 237-246.

Muñoz, A.R. & M. Altamirano 2003. Abubilla *Upupa epops* pp. 348-9 in R. Martí & J.C. del Moral (eds.). *Atlas de las Aves Reproductoras de España*. Dirección General de Conservación de la Naturaleza – Sociedad Española de Ornitología, Madrid.

Pinto, M., Rocha, P. & Moreira, F. 2005. Long-term trends in great bustard (*Otis tarda*) populations in Portugal suggest concentration in single high quality area. *Biological Conservation* 124: 415-423.

Poeiras, A.S. 2003. *Selecção de habitat do Cortiçol-de-barriga-preta (*Pterocles orientalis*) no Parque Natural do Vale do Guadiana*. Relatório de Estágio da Licenciatura em Biologia. Universidade de Évora, Évora.

Rocha, P. 1999. *A interpretação ecológica de imagens de satélite e a utilização de Sistemas de Informação Geográfica aplicados à conservação da abetarda* Otis tarda *no Biótopo Corine de Castro Verde*. Tese de Mestrado em Gestão de Recursos Naturais. Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Lisboa.

Rocha, P., A. Araújo & C. Cruz 1996. A evolução das populações portuguesas do francelho-das-torres *Falco naumanni*. pp. 97-98 in Farinha, J.C., Almeida, J., Costa, H. (eds) *Actas do I Congresso de Ornitologia da SPEA*. Sociedade Portuguesa para o Estudo das Aves, Lisboa.

Rossi, R.E., D.J. Mulla, A.G. Journel & E.H. Franz 1992. Geostatistical tools for modelling and interpreting ecological spatial dependence. *Ecological Monographs* 62: 277-317.

Rufino, R. 1989. *Atlas das Aves que nidificam em Portugal Continental*. Centro de Estudos de Migrações e Protecção de Aves, Serviço Nacional de Parques Reservas e Conservação da Natureza, Lisboa.

Santos, C. 2000. Succession of breeding bird communities after the abandonment of agricultural fields in South-east Portugal. *Ardeola* 47:171–181

Santos, T., F. Suárez, F. & J.L. Tellería 1981. The bird communities of Iberian Juniper woodlands (*Juniperus thurifera* L.). pp. 79-88 in F.J. Purroy (Ed.) *Censos de aves en el Mediterrâneo*. Universidad de Léon, Léon.

Silva, J.P., D. Leitão, E. Santos, F. Moreira, I. Prego, M. Pinto, M. Lecoq, T. Catry, & R. Pedroso 2006. Preliminary results of Little Bustard census in Alentejo (Portugal), in Leitão, D, C. Jolivet, M Rodriguez & JP Tavares (eds). *Bustard Conservation in Europe on the last 15 years*. Royal Society for the Protection of Birds. Sandy.

Snow, D.W. & C.M. Perrins 1998. *The Complete Birds of the Western Palearctic CD-ROM – Version 1.0*. Oxford University Press & Optimedia Software, Oxford.

Soares, P. 1999. Cartaxo-comum *Saxicola torquata*. pp. 302-303 in Elias, G.L., L.M. Reino, T. Silva, R. Tomé & P. Geraldes (eds). *Atlas das Aves Invernantes do Baixo Alentejo*. Sociedade Portuguesa para o Estudo das Aves, Lisboa.

Stoate, C., R. Borralho. & M. Araújo 2000. Factors affecting Corn Bunting *Miliaria calandra* abundance in a Portuguese agricultural landscape. *Agriculture, Ecosystems and Environment* 77: 219-226.

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

Suárez, F., V. Garza & M. Morales 2002. Habitat use of two sibling species, the short-toed *Calandrella brachydactyla* and the lesser short-toed C. rufescens larks, in mainland Spain. *Ardeola* 49: 259-272.

Tellería, J.L., T. Santos, G. Álvarez & C. Saéz-Royuela

1988. Avifauna de los campos de cereales del interior de España. pp. 173-317 in Bernis, F. (Ed.). *Aves de los medios urbano y agrícola en las mesetas españolas*. Monografias de la Sociedade Española de Ornitologia 2, Sociedad Española de Ornitologia, Madrid.

Tucker, G.M. 1997. Priorities for bird conservation in Europe: the importance of the farmed landscape. pp. 79-116 in Pain, D.J. & M.W. Pienkowski (eds.). *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation*. Academic Press, San Diego.

Tucker, G.M. & M.F. Heath 1994. *Birds in Europe: Their Conservation Status*. Birdlife International, Cambridge.

Yoccoz, N., J.D. Nichols & T. Boulinier 2001. Monitoring of biological diversity in space and time. *Trends in Ecology and Evolution* 16: 446-453.