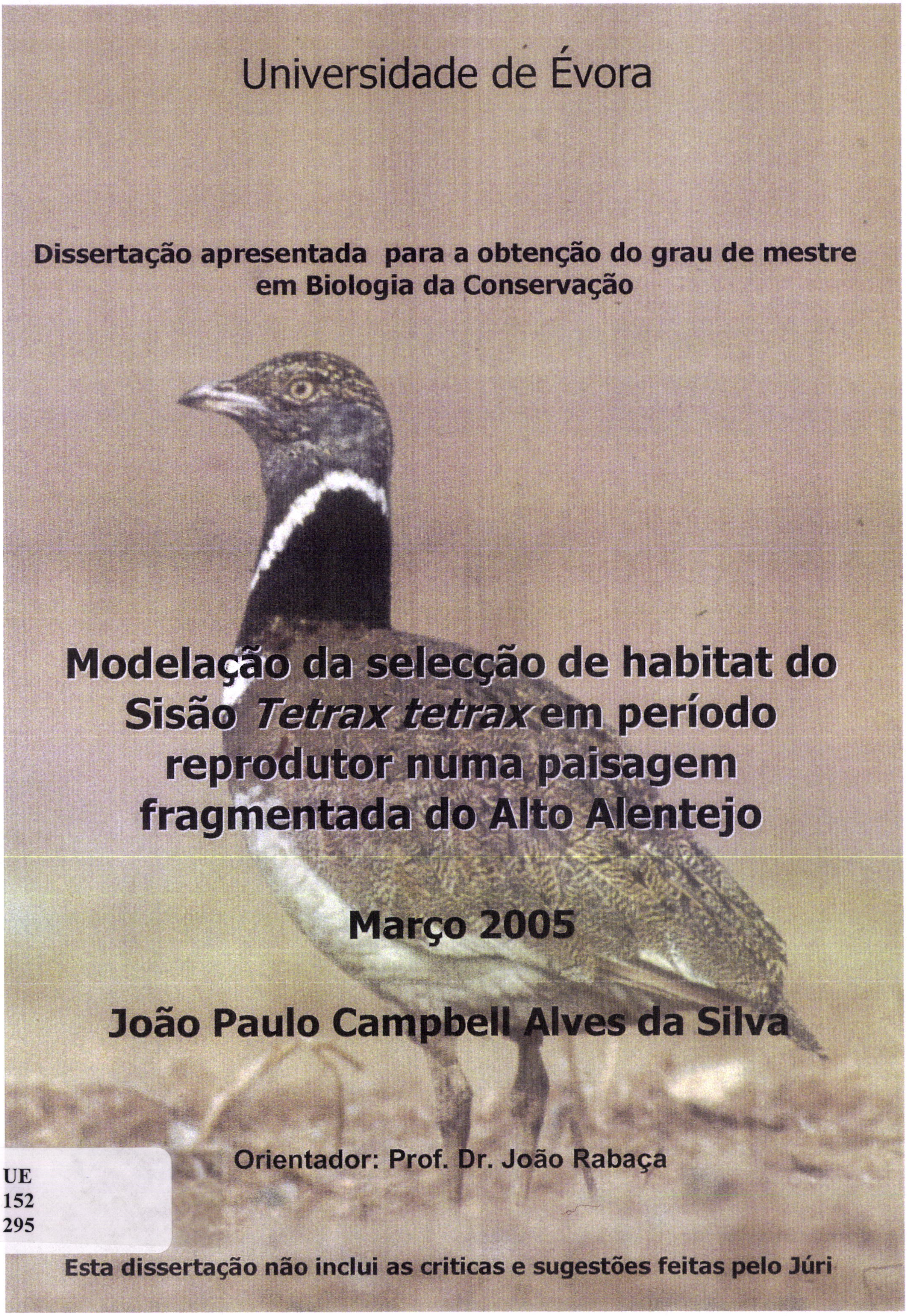

Universidade de Évora

Dissertação apresentada para a obtenção do grau de mestre em Biologia da Conservação

Modelação da selecção de habitat do Sisão *Tetrax tetrax* em período reprodutor numa paisagem fragmentada do Alto Alentejo

Março 2005

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Esta dissertação não inclui as criticas e sugestões feitas pelo Júri

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Índice

1. Resumo

A Península Ibérica alberga mais de metade da população mundial de sisão *Tetrax tetrax* dependendo, em larga medida, dos sistemas agrícolas extensivos para a sua sobrevivência. Sendo estes meios altamente intervencionados pelo Homem, torna-se fundamental compreender os factores ambientais que determinam a sua ocorrência e implementar as necessárias medidas de gestão, de forma a inverter a sua tendência de declínio. Neste sentido, foi efectuado um estudo de selecção de habitat do sisão durante o período reprodutor no Alto Alentejo, numa área que apresenta uma paisagem fragmentada com montados (de sobro e azinho) e olivais, mas dominado por área aberta, com zonas cerealíferas e pastagens. Foram considerados para análise os centros de parada e respectivos territórios de 54 machos reprodutores e um conjunto de 70 pontos aleatórios. Um modelo multivariado de regressão logística visou modelar as variáveis ambientais com os machos reprodutores. Os resultados salientam a importância das paisagens abertas com cultivos cerealíferos extensivos para determinar a ocorrência do sisão, particularmente os locais onde a estrutura da vegetação é adequada e com uma maior abundância de artrópodes. A probabilidade para a sua ocorrência foi também influenciada pelo número de machos na vizinhança dos centros de parada, o que sugere que estes podem não ocorrer de forma independente, em função da sua estratégia reprodutora. As medidas de gestão, recomendadas com base neste estudo, assentam na promoção dos sistemas cerealíferos extensivos nos meios abertos, onde seja garantida uma presença razoável de pousios na rotação cultural, devendo estes ser pastoreados de forma extensiva. Quando, em presença de populações com baixa densidade, julga-se mais vantajoso dirigir prioritariamente os esforços de conservação junto dos leks, ou na proximidade dos locais habitualmente utilizados como centros de parada.

2. Abstract

Modelling the breeding habitat selection of the little bustard (*Tetrax tetrax*) in an Iberian fragmented landscape

The Iberian Peninsula harbours the most viable populations of little bustard *Tetrax tetrax*, a threatened grassland bird, which is mostly dependent on extensive agricultural schemes for survival. Being highly reliant on active management, understanding the factors that influence this species distribution is essential to promote sound agricultural practices to reverse its declining tendency. A habitat selection study was conducted during the breeding season at a fragmented open landscape in southern Portugal, with olive groves and oak forests, but dominated by open land, mainly cereal fields and pastures. Overall 54 breeding males were considered for analysis, based on the readings at the display centres, along with a set of 70 random locations. A multivariate logistic regression modelled the environmental variables with breeding males, including a spatial autocorrelation term, based on the range of neighbouring males. The final model highlights the importance of unfragmented open landscapes, with abundant fallow land to determine its occurrence, mainly at the locations with higher arthropod abundance and adequate vegetation structure. The probability for its occurrence was also influenced by the number of neighbouring males, which suggests that males might not occur independently as result of their mating system. Habitat suitability is likely to be achieved by ensuring the openness of the landscape with extensive cereal farming, where fallows are grazed in non intensive schemes. Low density populations could benefit by proper management practices promoted within the lek areas or at the sites nearby frequently used display centres.

3. Introdução geral

A transformação dos habitats naturais em zonas agrícolas deu-se de forma lenta e gradual, o que permitiu a adaptação e consequente expansão de muitas espécies a estes novos habitats (Tucker, 1997). Mediante a destruição dos habitats primários, como sejam as verdadeiras estepes, muitas destas espécies ficaram a depender dos sistemas agrícolas extensivos e dos usos a eles inerentes (Tucker, 1997).

Contudo, os avanços tecnológicos, o desenvolvimento económico e as iniciativas políticas a partir de meados do Séc. XX, conduziram a uma intensificação agrícola na Europa, numa escala sem precedentes (Pain & Dixon, 1997). A intensificação da agricultura acentuou-se com a introdução da mecanização e aumento muito significativo do uso dos agro-químicos, principalmente através dos incentivos da Política Agrícola Comum (Potter, 1997). Como consequência pode-se salientar a especialização da agricultura, o sobre-pastoreio e o incremento de insecticidas e pesticidas (Tucker, 1997).

Actualmente as estepes e os sistemas agrícolas extensivos enquadram-se entre os ecossistemas mais ameaçados da Europa, mais do que as zonas húmidas e bosques, devido à rapidez com que o Homem as transforma e destrói (Criado & Heredia, 1996). Estes ecossistemas albergam um número muito significativo de aves, muitas das quais com estatutos de conservação desfavorável (Birdlife, 2004).

Na Península Ibérica os sistemas cerealíferos extensivos (também denominados como pseudo-estepes) são considerados, na actualidade, sistemas agrícolas economicamente marginais, verificando-se uma tendência para a intensificação agrícola nos solos mais produtivos e o abandono ou a florestação nos menos produtivos (Suárez *et al.* 1997). Estima-se que cerca de 81% das aves dependentes deste ecossistema sejam espécies cuja conservação requer preocupação (Suárez *op. cit*, 1997) e segundo a Birdlife (2004) com continuada tendência regressiva. De referir, para o caso de Portugal, o registo de algumas espécies que se consideram possivelmente extintas, associadas aos meios do tipo estepários, como é o caso da cotovia-de-Dupont (*Chersophilus duponti*) e o toirão (*Turnix sylvatica*) (Catry, 1999).

O sisão (*Tetrax tetrax* L. 1758) é a espécie objecto de estudo desta tese. Trata-se de uma ave de médio porte, originária de meios estepários, que se adaptou a ambientes agrícolas e a pastagens (Cramp & Simmons, 1980; Martinez, 1994). Tem uma distribuição Paleárctica e ocupa de forma fragmentada a faixa compreendida entre os paralelos 35º N e 50º N, distinguindo-se dois núcleos principais: um a Oeste abrangendo a Península Ibérica, França, Sul de Itália e possivelmente alguns locais de Marrocos e outro a Este, na Ásia, desde a Rússia ate ao Kasaquistão (del Hoyo *et al.*, 1996).

Desde os finais do Séc. XIX que o sisão tem vindo a sofrer um forte declínio, verificando-se a sua extinção em numerosos países do Centro, Sul e Leste europeu, assim como no Norte de África (Schulz 1985a). A população europeia apresenta um declínio acentuado entre 1970 e 1990 (Tucker & Heath, 1994): grande parte (80%) sofreu um declínio superior a 20%, mas em determinados casos registaram-se valores de declínio superior a 50%. No caso particular da população francesa registou-se, no espaço de 17 anos (entre 1980 e 1996), o declínio de pelo menos 80 % da população reprodutora (Jiguet 1997, *in* Inchausty & Bretagnolle, 2005). A sua regressão está sobretudo associada às alterações agrícolas (Schulz, 1985a; Goriup, 1994; ver também tabela anexa).

Actualmente a Península Ibérica alberga mais de metade do população mundial (Schulz, 1985a; Goriup, 1994; De Juana & Martinez, 1996), estimando-se para Portugal uma população entre 10000 e 20000 indivíduos (Tucker & Heath, 1994), distribuindo-se essencialmente pelo Alentejo (Rufino, 1989). Apresenta um estatuto de conservação desfavorável na Europa, considerado Vulnerável (Birdlife, 2004) e de interesse comunitário, constando como espécie prioritária no Anexo I da Directiva Aves (79/409/CEE).

Os sistemas cerealíferos extensivos, ocorrem com alguma regularidade, na Península Ibérica, formando um mosaico de habitats que inclui searas, forragens, leguminosas e pousios, que habitualmente são pastoreados (Suárez, 1997). O sisão tira partido deste sistema rotacional (Martinez, 1994;

Silva *et al.*, 2004) e, em época de reprodução, prefere os pousios (Martinez, 1994; Moreira, 1999; Delgado & Moreira, 2000) com vegetação baixa (Martinez, 1994; Salamolard & Moreau, 1999) e onde a disponibilidade alimentar é maior (Martinez, 1998; Salamolard & Moreau, 1999; Jiguet, 2002).

A época de reprodução tem início em finais de Março ou princípios de Abril, com a formação de territórios dos machos adultos (Schulz, 1985b), segundo uma estratégia reprodutora que se pensa ser em leque disperso – "exploded lek" (Schulz, 1985b; Jiguet *et al.*, 2000, 2002). Nestes sistemas, os territórios dos machos ocorrem de forma agregada, onde exibem as paradas e são visitados pelas fêmeas para serem copuladas, sendo os cuidados parentais assumidos exclusivamente pelas fêmeas (Jiguet *et al.*, 2000). Os territórios podem ser de tamanho variável (Schulz, 1985b; Jiguet *et al.*, 2001), o que dificulta a percepção da agregação dos machos, variando em função da densidade, sex-ratio ou qualidade do habitat (Jiguet *et al.*, 2000).

Tratando-se de uma espécie que depende em larga medida de meios profundamente intervencionados pelo Homem, o presente estudo tem por objectivo compreender as variáveis ambientais que influenciam a sua selecção de habitat numa paisagem fragmentada do Norte Alentejo (Campo Maior).

Para o efeito foi tido em conta o seu sistema reprodutor, seleccionando criteriosamente os centros de parada dos machos reprodutores. As variáveis foram medidas centradas nestes centros de parada e a partir de outros 70 pontos aleatórios. Optou-se, em termos estatísticos, por uma abordagem multivariada com a construção de um modelo de regressão logística, modelando os factores preditivos com os machos reprodutores, considerando ainda um termo de autocorrelação espacial, baseado no número de machos reprodutores vizinhos.

4. Artigo submetido à Biological Conservation journal

Modelling the breeding habitat selection of the little bustard (*Tetrax tetrax*) in an Iberian fragmented landscape

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Running title: Breeding habitat selection of the little bustard in a fragmented landscape

Abstract

The Iberian Peninsula harbours the most viable populations of little bustard *Tetrax tetrax*, a threatened grassland bird, which is mostly dependent on extensive agricultural schemes for survival. Being highly reliant on active management, understanding the factors that influence this species distribution is essential to promote sound agricultural practices to reverse its declining tendency. A habitat selection study was conducted during the breeding season at a fragmented open landscape in southern Portugal, with olive groves and oak forests, but dominated by open land, mainly cereal fields and pastures. Overall 54 breeding males were considered for analysis, based on the readings at the display centres, along with a set of 70 random locations. A multivariate logistic regression modelled the environmental variables with breeding males, including a spatial autocorrelation term, based on the range of neighbouring males. The final model highlights the importance of unfragmented open landscapes, with abundant fallow land to determine its occurrence, mainly at the locations with higher arthropod abundance and adequate vegetation structure. The probability for its occurrence was also influenced by the number of neighbouring males, which suggests that males might not occur independently as result of their mating system. Habitat suitability is likely to be achieved by ensuring the openness of the landscape with extensive cereal farming, where fallows are grazed in non intensive schemes. Low density populations could benefit by proper management practices promoted within the lek areas or at the sites nearby frequently used display centres.

Keywords: *Tetrax tetrax*; habitat selection; fragmented landscape; extensive cereal farming; habitat management

1. Introduction

The little bustard *Tetrax tetrax* is a threatened Palaearctic grassland bird that has experienced a major, since late nineteenth century (Schulz, 1985a). Nowadays most of its population is found in the Iberian Peninsula (De Juana and Martínez, 1996; Birdlife, 2004), presenting a general negative trend (Birdlife, 2004; De la Morena et al., 2003). Reasons for this decline are mainly related to agricultural intensification (Schulz, 1985a; Goriup, 1994).

Pseudoesteppes are well represented in Iberia, formed by a mosaic of habitats including cereal crops, dry legumes and fallows that are usually grazed (Suárez et al., 1997). The little bustard takes advantage of this agricultural rotational system (Martínez, 1994; Silva et al., 2004) and during the breeding season it is found in a greater diversity of habitats (Martínez, 1994; Campos and López, 1996; Salamolard and Moreau, 1999; Wolf et al., 2001), preferring fallows (Martínez, 1994; Moreira, 1999; Delgado and Moreira, 2000), with short vegetation (Martínez, 1994; Moreira, 1999; Salamolard and Moreau, 1999) and were food resources are more available (Martínez, 1998; Salamolard and Moreau, 1999; Jiguet et al., 2002). Breeding habitat selection has been widely studied, however for most cases their mating system was not taken into consideration, by assuming male individual observations as independent.

This species is described to mate in an exploded lek system, were males display in an aggregated manner that females attend primarily for the purpose of mating (Schulz 1985b; Jiguet et al., 2000). Male territories are defended and vary in size, making it difficult to discern male aggregation, and are influenced by several factors such as density, sex-ratio or habitat quality (Jiguet et al., 2000). Territories are also thought to be set up at sites with resources potentially used by females as a way of increasing the probability of encounter between sexes (Jiguet et al., 2002; Wolf et al., 2002).

Because this species is dependent on a highly manipulated landscape, it is essential to understand the main factors that determine its occurrence, so that sound management practices can be established. Wolf et al. (2002) highlighted the benefits of managing habitats around important conservation areas for the little bustard within a context of fragmented true steppe. Portugal's cereal steppes have mostly originated from the clearance of natural evergreen oak *Quercus* sp. forests (Moreira, 1999) and this patchy landscape occurs quite frequently within the little bustard's range in the Alentejo region, however the effects of this fragmented landscape on the species occurrence is badly known (but see Faria and Rabaça, 2004 for a macro-habitat study).

This study aims to understand the little bustard's habitat selection in a fragmented landscape, modelling the environmental predictors with lekking males. For this purpose, variables are manipulated to evaluate potential benefits to the species.

2. Methods

2.1. Study area

The study was carried out in the Alentejo province, southern Portugal, next to the Spanish border, at the Special Protection Area (SPA) of Campo Maior and at a nearby site, covering an overall area of 11881 ha of a fragmented landscape (Fig.1). The topography is flat or undulating, with an altitude of 190 - 310 m. It is located in the

Meso-Mediterranean bioclimatic stage (Rivas-Martínez, 1981) with annual averages for temperature and rainfall of 15-17° and 500-600 mm respectively (H/COBA/HP, 1998).

Open fields with different land uses are dominant: cereal crops (19 %), fallows (6%), spring crops (6%), ploughed land (4%), pastures (19%) and recent oak (*Quercus* sp.) plantations (4%). Oak forests (*Quercus* sp.) were categorized as sparse forests (13%) and dense forests (11%), corresponding to between 10 and 20% and over 20% of forest coverage, respectively. Olive groves are also well represented in the study area (18%) and presented a minimum of 50% of arboreal coverage.

2.2. Data Collection

From mid March until the end of June of 1998, the study area was surveyed intensively, along all available tracts, prospecting on foot remote habitats and ensuring observations from high vantage points. Since display activity is more intense in the beginning and at the end of the day (Jiguet and Bretagnolle, 2001) field work was performed during the first three hours after sunrise and last two hours before sunset.

An estimated 98 breeding males were found within the area. All perceptive display centres commonly used during the main displaying period (mid April to the end of May) were considered for this study. Display centres were defined on the basis of: i) displaying behaviour (see Jiguet and Bretagnolle, 2001) and ii) higher concentration of droppings, fcathers and footprints. For this, a minimum of three visits (at least once every 15 days) were assured and display sites in the immediate proximity of others with less usage were not taken into account. In all, 54 display centres were considered for analysis, which were marked in 1:25000 topographic maps along with a set of 70 random points and from where all variables were measured (Table 1). There was thus a total of 124 points.

2.3. Display centre habitat variables

Slope and *position on the hill* were estimated during field work, while *distance to the nearest road*, *track* or *inhabited house* were extracted from 1:25000 maps. Vegetation structure (height and cover) and arthropod abundance were measured within a radius of 20 m. For the first, nine readings of 50 x 50 cm quadrates averaged the *vegetation height* (measured with a ruler) and *vegetation coverage* (estimated perpendicularly to the ground). Readings were located at the centre and at 10 and 20 m radii in the four cardinal directions. The latest was estimated in a similar manner as Martínez (1998), carrying out direct counts, one minute long, at the same nine quadrates. Additionally, within the radius, two beating sheets of 40 m by two meters wide were performed using an insect sweep net with a 40 cm opening.

2.4. Male territory habitat variables

The criteria to establish the mean territory size of breeding males was based on literature. Mean territory size at French intensified sites with low male density (0.13 / 100 ha) was found to average 19 ha (Jiguet et al., 2000). Because breeding male density in our study area is higher (0.83 / 100 ha), territory size was assumed not to exceed the values estimated for the referred French populations. Therefore a radius of 200 m (approximately 19 ha) centred at the display centres and random points was used to evaluate the number and percentage of the following cover classes: *cereal*; *fallow*;

ploughed; *spring crops*; *olive*; *pasture*; *plantation*, *sparse forests* and *dense forests* of *Quercus* sp.. These variables were measured on 1:25000 land use maps, drawn with the aid of recent aerial photos (1:15000) and confirmed by field work.

2.5. Irregularity of the terrain

This variable was measured differently from the rest by counting the number of isoheights crossing a 1 x 1 Km square from 1:25000 topographic maps, centred at the random points and display centres.

2.6. Data analysis

Our analysis contrasts the habitat availability given by the readings centred at the 70 random points with the habitat features based at the 54 display centre sites.

At an exploratory level, landscape preferences were analysed using a chi-square test (χ^2), admitting minimum expected classes of 4 (Zar, 1996) and identifying selected or avoided categories calculating Bailey's confidence intervals (Cherry, 1996).

In order to understand the little bustard's habitat preferences in combination with all variables an explanatory multivariate logistic model was carried out (Hosmer and Lemeshow, 2000). Because there is evidence that this is a lekking species, a spatial autocorrelation variable was included in the analysis, based on the range of possible neighbouring display centres and considering twice the distance of the territories radius, i.e. 400 m.

The set of 70 random sites ensured an adequate representation of the study area and a proximate number of presences and absences in the model, preventing problems related with prevalence (Manel *et al.*, 2001). A Spearman correlation matrix was also generated to evaluate colinearity between variables and, whenever values over 0.7 were achieved, the variable that most improved the performance of the model was the one selected for analysis (Tabachnick and Fidel, 1996).

Variables were first selected for the model by performing univariate analysis based on the likelihood criteria, and those presenting a $p>0.25$ were excluded (Hosmer and Lemeshow, 2000). All non-linear variables experienced transformations and were included again in the analysis, however since none of these operations significantly improved the models, these were not considered. Backward stepwise selection based on likelihood criteria removed all variables with p 0.05 and tested the null hypothesis that the coefficient of the variable is zero. An adjusted cut-off point of 0.44 was used to maximise the number of correctly classified presences and absences (Franco et al., 2000). The phi coefficient ( ) evaluated the degree of association between quantified predicted and observed values, the significance of which was tested with a χ^2 (Daniel, 1990). The percentage of correctly classified locations and the area under the receiver operating characteristic curve (AUC) assessed the fit of the model (Perace and Ferrer, 2000). The final model was validated using the Jackknife procedure (North and Raynolds, 1996; Manel et al., 1999, 2001), performing logistic regression models by removing one location at a time and predicting its absence or presence (also using an adjusted cut-off point of 0.44). Correctly classified locations were tested for significance with a χ^2 test (see above) and predictions used to calculate the AUC.

All statistics were performed using SPSS 11.5 (SPSS, 2002).

3. Results

3.1. Univariate analysis

Table 2 shows the results of the univariate analysis for the variables that presented p-values under 0.25, according to the maximum likelihood test. The occurrence of the little bustards showed to be significantly related to shorter, less dense vegetation with a higher abundance of arthropods and at the upper parts of the hill. Proximity to roads presented a slight significant value, indicating that the species occurs preferably in nearby paved roads, but this result is likely to be biased with other factors, since unsuitable or less used habitats, such as *dense forests* or *pastures*, were found significantly further from roads (r_s=0.328; r_s=0.304, $p \leq 0.001$). A clear preference towards *follow* and avoidance of *olive* and *dense forests* was confirmed by the chi-square test (Fig. 2; χ^2=166.9, $p<0.001$). The little bustard's territories also occurred more than expected in *ploughed*, *spring crops* and *plantation*. *Pastures* and *cereal* were slightly underused.

3.2. Multivariate logistic regression

Only *vegetation height* and *vegetation coverage* were found to be highly correlated (r_s=0.716, $p<0.001$). The latest was selected for analysis because it best improved the predictive power of the model.

The final model presented a good fit to the data =0.77, χ^2=74.3 ($p<0.001$), correctly classifying, 88.7% of the sites (87.1% of absences and 90.7% of presences) and presenting an AUC of 95.4%. The validation procedure was also highly explanatory

=0.75, χ^2=70.6 (p<0.001), resulting in similar figures: 87.8% of the locations correctly classified and an AUC of 93.8%. Five variables entered the model (Table 3), with presence of *olive* and *arthropod abundance* presenting the highest coefficients, followed by *vegetation coverage*, *fallow* and *neighbouring males*. This model shows that in territories without *olive*, a higher probability of display centre occurrence can be determined almost alone by arthropod abundance (Fig. 3). Higher probabilities of occurrence were also related to *fallows* combined with adequate *vegetation coverage* or *neighbouring males*. On the other hand, whenever *olive* is present within the breeding male's territories, low probabilities are estimated and fall accordingly with its proportion.

4. Discussion

Little bustard displaying activity was observed from the end of March until mid June, peaking from mid April until end of May, contrasting with the four months described for the Atlantic French populations (Jiguet and Bretagnolle, 2001). This could be related with the Mediterranean climatic features of our study area, that dries most of the natural grass vegetation during the summer season. Since most of the adult diet consists of green plant material even when arthropods reach their higher abundance (Jiguet, 2002), it is possible that some relation between male territory permanence and food resources availability can be established.

4.1. Habitat preferences at a fragmented landscape

Little bustards showed little tolerance to the presence of trees and clearly avoided land uses with over 20% of arboreal coverage. This is more evident with *olive*, possibly because it represents an abrupt transition with open fields, while a gradient is found for oak forests. In fact the avoidance of this habitat was the feature that most explained the little bustard's occurrence according to the logistic regression model (Fig. 3). A macro-habitat study in the Cabrela area (Portugal) shows that the little bustard's avoid the proximity of arboreal land uses as result of habitat fragmentation (Faria and Rabaça, 2004). Our results are concordant by indicating its sensitivity to the presence of arboreal land uses within the territories.

As reported in literature *fallow* was the preferred habitat. These showed correlates with shorter, less dense vegetation at sites with higher arthropod abundance (r_s=-0.291; r_s=-0.261; r_s=0.245, respectively, all with $p<0.01$), combining important habitat features for the species (see below). Up to some extent some of these characteristics were found on *spring crops* and *plantation*, however not evincing a clear tendency towards its selection. *Pastures* were mainly grazed by cows and were found to be very irregular among our study site, varying in way they were managed, and consequently with an unclear response by the little bustard. In the nearby area of Vila Fernando, Schulz (1985b) described sites that were more intensively grazed by herded cattle as being avoided by males and never chosen for display centres.

Little bustards were occasionally seen displaying in *ploughed* and taking cover in *cereal*. These land uses are commonly found contiguous and present an antagonistic vegetation structure in which the birds seem to take advantage of the different features of these habitats. The number of habitats within the little bustard's territories was not, however, a significant predictor, when the opposite was expected. This result is possibly related with the frequency that inadequate habitats occurred within the territory units, due to the fragmented landscape and so making it difficult to percept, within the open landscape, the importance of habitat diversity.

Regarding vegetation structure preferences, our results corroborate previous works by relating to short vegetation. *Vegetation coverage*, as mentioned before, was highly correlated with *vegetation height*, resulting in a more explainable model, thus indicating, that within areas of adequate grassy vegetation, patches with less coverage may be more suitable to achieve a compromise between cover and visibility, factors that have a decisive role in the species habitat selection, as argued by other authors (Martínez 1994; Salamolard and Moreau, 1999). The little bustard's preference for the upper parts of the hill, along with the selected vegetation structure, may also relate to locations that best balance the contrasting effects of protective and obstructive cover, as suggested in a winter study (Silva et al., 2004). *Irregularitly*, although quite correlated to *position on the hill* (r_s=0.444, p<0.001) did not show a significant result, possibly because of the scale at which it was measured, but is likely to have some effect on the little bustards occurrence (Suárez-Seoane et al., 2002).

The location of the display centres seemed to occur further from tracks and inhabited houses. However the avoidance of these parameters at a territory level is unlikely by making use of the habitat features in a larger extent. Martínez (1994) found a high degree of tolerance to human disturbances in cultivated areas of Central Spain.

4.2. Relating pattern of occurrence with the lek mating system

The distance considered to determine the number of male neighbours was more conservative than the one defined by Jiguet and Bretagnolle (2001), using 1 Km radius. Still, this factor was not only a significant predictor, but also influenced the probability of occurrence of breeding males according to the multivariate model, thus suggesting that they don't occur independently. On the other hand, *neighbouring males* was the last variable entering the model and so less contributing to determine its occurrence. This could eventually be related with its scattered lekking mating system, where other habitat requisites assume more importance, such as food resources or vegetation structure. Although there is no clear evidence that male density influences territory size (Jiguet et al., 2000) it is expectable that at higher densities, territory size to diminish. If so, in mosaic landscapes such as extensive cereal farming, with a higher density of males, *neighbouring males* may play a more important role in predicting its occurrence.

Contrasting with the adult diet, chicks feed exclusively on arthropods, mainly Orthoptera and Coleoptera, at least until two to three weeks old (Jiguet, 2002), presumably provisioned by the females (Inchausty and Bretagnole, 2005). Higher arthropod abundance was found in the display centres when compared with the random locations, a similar result to those obtained in other studies (Martínez, 1998; Salamolard and Moreau, 1999; Jiguet et al., 2002). In a multivariate perspective it was the most influential predictor within open land habitats. However it should be taken into account that arthropod abundance is intrinsically related to certain types of land use and how these are managed (Martínez, 1998). Because arthropods were not measured at the areas used by females, it wasn't possible to establish a relation with resource-based leks. Nevertheless these results are in accordance with the hypothesis advanced by Jiguet et al. (2002) and Wolf et al. (2002) that leks are located within areas where resources are potentially used by females, in order to increase the probability of encounter between males and females.

4.3. Management and conservation implications

The logistic regression model successfully predicts the male's response to the measured variables, particularly with open land fragmentation. To an extent, the results can also relate to the effects of agricultural intensification, since its main impact, among cereal steppes, is loss of fallow land (Martínez, 1994; Delgado and Moreira, 2000; Henriques and Moreira, submitted). According to our data, shortage of *fallow* is generally associated with low probabilities for the occurrence of breeding males, varying with their quality (Fig.3). Lack of insects as consequence of agricultural intensification stands as one of the major causes for the declining French migrating little bustard populations (Inchausty and Bretagnolle, 2005). Reducing the proportion of fallows is likely to lead to a significant reduction of insects, since higher abundances of arthropods are found in this land use (Martínez, 1998; present study).

Although our study wasn't directed towards the adult's diet preferences, fallow land is also reported to hold high availability of their food preference, namely *Leguminosae* (Martinez, 1998). Therefore despite *fallow* entered after *arthropod abundance* and *vegetation coverage* in the modelling procedure (Table 3), thus with less predictive power, this land use is likely to best combine adult and chick biological needs with adequate food resources and vegetation structure.

Overall the model highlights the importance of maintaining open landscapes with extensive cereal farming, and therefore ensuring an unfragmented landscape with adequate vegetation structure and arthropod availability.

Management of key sites should therefore preserve the clearness of the landscape and promote extensive cereal farming schemes with a substantial amount of fallow land within the rotation, ensuring adequate vegetation structure that could be achieved by through low intensity grazing. Whenever aiming to increase low density populations, substantial gains are likely to be achieved by improving adequate habitat within the lek areas or at the sites nearby frequently used display centres.

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Table 1 – Variables measured to analyse the little bustard's habitat preferences.

Name	Source of data
Display centre variables (within a radius of 20 m)	
Slope	Field work
Position on the hill	Field work
Distance to road	Topographic maps
Distance to track	Topographic maps
Distance to house	Topographic maps
Vegetation height	Field work
Vegetation coverage	Field work
Arthropod abundance	Field work
Territory variables (within a radius of 200 m)	
Proportion of cereal	Land use maps
Proportion of fallow	Land use maps
Proportion of ploughed	Land use maps
Proportion of spring crops	Land use maps
Proportion of pasture	Land use maps
Proportion of olive	Land use maps
Proportion of plantation	Land use maps
Proportion of sparse forests	Land use maps
Proportion of dense forests	Land use maps
Number of habitats	Land use maps
Irregularity of the terrain (within a 1 x 1 Km square)	
Irregularity	Topographic maps

Table 2 - Variables with a $p<0.25$, according to the maximum likelihood test and considered for the multivariate logistic regression, ordered by decreasing values of significance. Asterisks denote variables with significant statistical result ($p<0.05$).

Name of variable	p-value	Relation with response variable
Fallow	<0.001*	+
Olive	<0.001*	-
Neighbouring males	<0.001*	+
Arthropod abundance	<0.001*	+
Position on the hill	<0.001*	+
Vegetation coverage	0.019*	-
Vegetation height	0.021*	-
Dense forest	0.027*	-
Distance to track	0.029*	-
Distance to road	0.044*	+
Distance to inhabited house	0.065	-
Pasture	0.111	+
Ploughed	0.127	+
Number of habitats	0.156	+

Table 3 – Values of coefficients, maximum likelihood test and its significance, for the variables that entered the final logistic regression model.

Variable	Coefficient	-2 log LR
Olive	-0.091	18671**
Arthropods	0.300	16609**
Vegetation coverage	-0.600	16253**
Fallow	0.038	14061**
Neighbouring males	0.872	10920*
Constant	-1.907	---

*p=0.001, **p<0.001

Legends of the figures

Fig. 1. Location of the study area within the Iberian Peninsula and general aspect the fragmented landscape of the study site.

Fig. 2. Proportion of available (white bars) and used (white bars) habitats by the little bustard in the study area. Asterisks indicate the classes for which observed and expected values differed significantly ($p<0.05$; according to Bailay's confidence intervals).

Fig. 3. Three scenarios contrasting the estimated probabilities computed from the final multivariate logistic regression of display centre occurrence within territories with different percentages of *fallow* and *olive* alone: a) assumes medium values for *vegetation coverage* with no *neighbouring males*, varying *arthropod abundance*; b) assumes medium values for *arthropod abundance* with no *neighbouring males*, varying *vegetation coverage*; c) assumes medium values for *vegetation coverage* and *arthropod abundance*, varying the number of *neighbouring males*.

Fig. 1

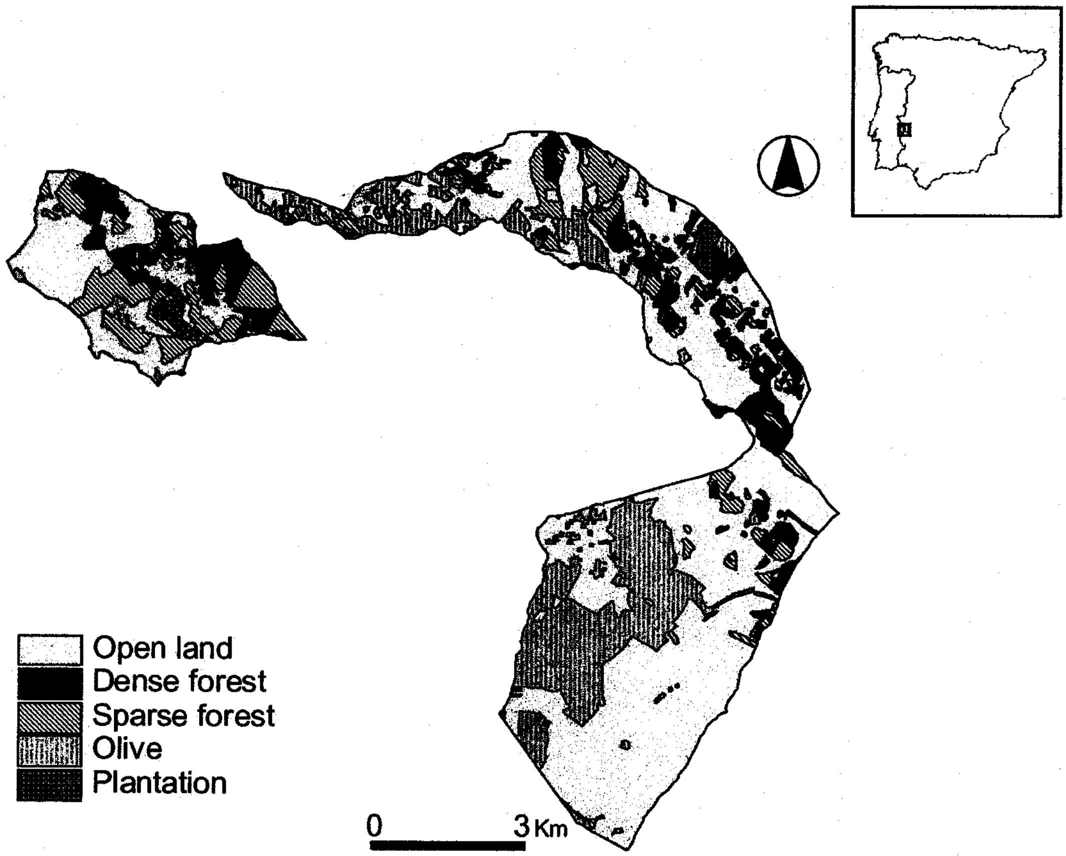
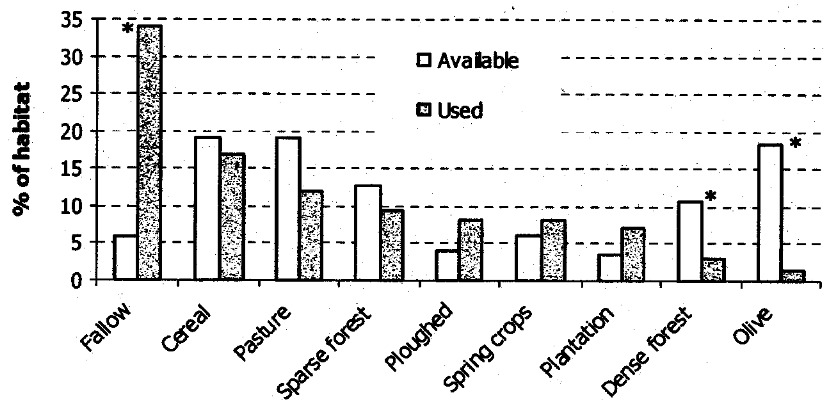
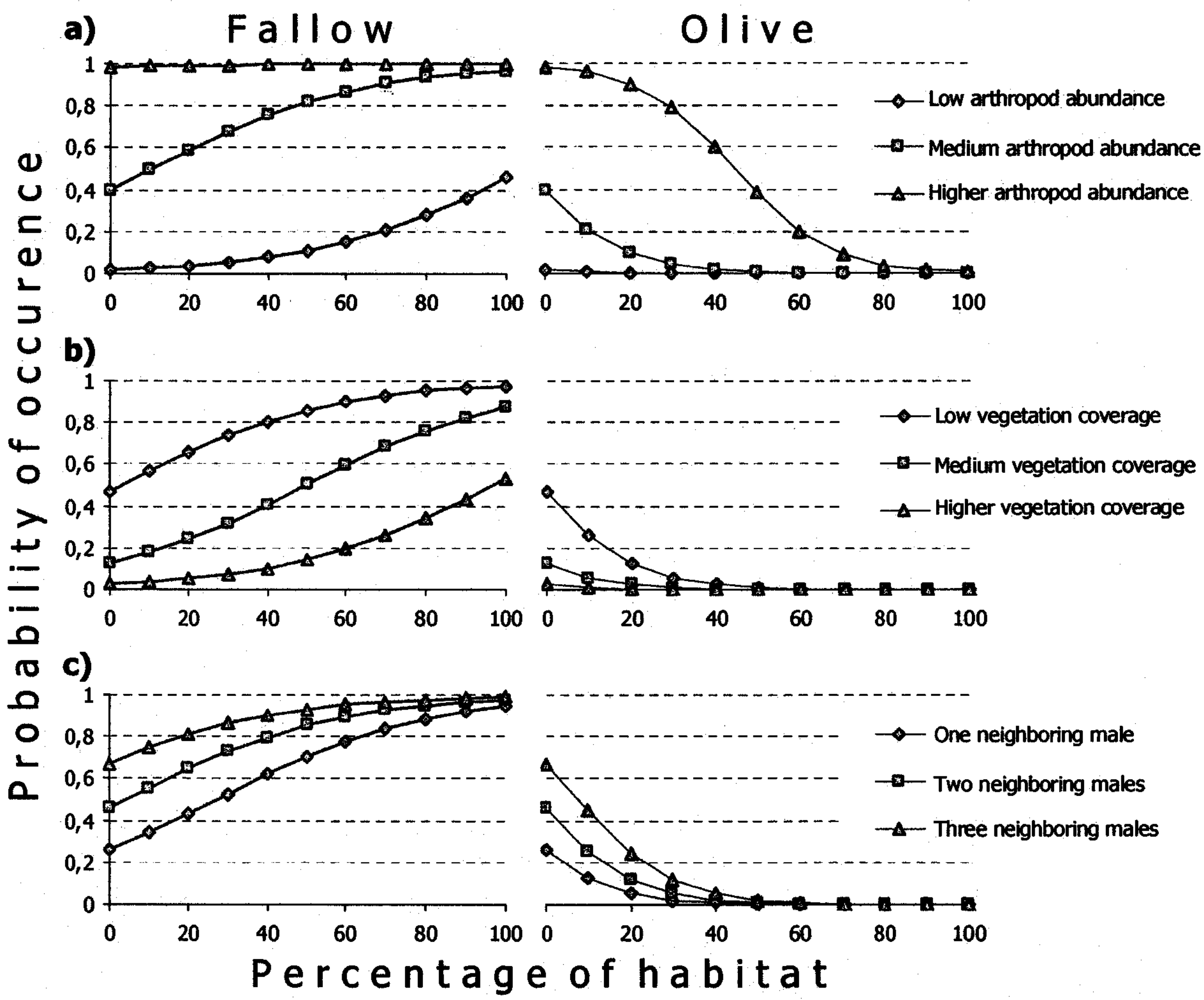

Open land
Dense forest
Sparse forest
Olive
Plantation
0
3 Km

Fig. 2



35
30
25
20
15
10
5
0
% of habitat
*
Available
Used
*
*
Fallow
Cereal
Pasture
Sparse forest
Ploughed
Spring crops
Plantation
Dense forest
Olive

Fig. 3



a)
Fallow
Olive
Low arthropod abundance
Medium arthropod abundance
Higher arthropod abundance
b)
Low vegetation coverage
Medium vegetation coverage
Higher vegetation coverage
c)
One neighboring male
Two neighboring males
Three neighboring males
Probability of occurence
Percentage of habitat

5. Considerações finais

Os machos mostraram ser pouco tolerantes à presença de árvores e evitaram claramente os usos do solo com mais de 20 % de coberto arbóreo. Os olivais são evitados de forma mais evidente, provavelmente por apresentarem, na maioria das situações, uma transição abrupta com os meios abertos, enquanto que para os montados de sobro e azinho é encontrado um gradiente variado de cobertura florestal. Segundo o modelo de regressão logística, a presença de olivais nos territórios dos machos reprodutores foi a variável mais explicativa, indicando a sensibilidade da espécie à presença de habitats com coberto arbóreo.

Por outro lado o pousio foi o único uso significativamente seleccionado. Apesar de ter sido, na análise multivariada, um factor menos preditivo que a abundância de artrópodes ou cobertura da vegetação herbácea, trata-se provavelmente do uso que melhor combina as necessidades biológicas dos adultos e das crias, durante a época de reprodução.

A cobertura proporcionada pela vegetação herbácea mostrou-se positivamente muito correlacionada com a altura da vegetação, pelo que a sua selecção sugere que os sisões preferem uma estrutura de vegetação que faculte tanto a visibilidade como a possibilidade de obterem protecção (Martínez, 1994; Salamolard & Moreau, 1999). Ao estarem sobretudo associados aos topos dos montes poderão igualmente tirar partido das situações que melhor combinam os efeitos de protecção e obstrução do meio (Silva *et al.*, 2004).

A sua relação com os locais de maior abundância de artrópodes poderá estar associada com as preferências de habitat das fêmeas (Jiguet *et al.*, 2002; Wolf *et al.*, 2002) ao serem o alimento preferencial das crias (Jiguet, 2002). No entanto, por não se ter avaliado este factor nos locais onde ocorreram as fêmeas, não foi possível estabelecer uma relação com o tipo de "lek" em que se reproduzem: se em verdadeiro "lek disperso" (Jiguet *et al.*, 2002) ou de acordo com o modelo de "hotspot" (Wolf *et al.*, 2002). Estudos detalhados sobre as preferências de habitat das fêmeas poderão contribuir para aprofundar esta questão.

A vizinhança de outros machos também influiu na probabilidade de ocorrência dos machos em parada o que, provavelmente, estará associado ao seu sistema reprodutor em "lek" e sugere que estes poderão não ocorrer de forma independente. No entanto, segundo esta análise, factores como a disponibilidade de alimento ou estrutura da vegetação aparentam ser mais importantes, ao nível da selecção de habitat.

Face a estes resultados salienta-se a importância das paisagens abertas com sistemas cerealíferos extensivos para a ocorrência do sisão, assegurando-se desta forma meios pouco perturbados por árvores, com uma adequada estrutura da vegetação e disponibilidade de artrópodes.

Por último, as implicações deste estudo ao nível das recomendações de gestão assentam na manutenção dos meios abertos com cultivos cerealíferos extensivos, onde sejam incluídos na rotação cultural uma proporção razoável de pousios com vegetação baixa, por intermédio de um pastoreio extensivo.

Para os casos em que se pretenda incrementar populações com baixas densidades de machos, julga-se que poderá ser mais vantajoso a promoção de medidas adequadas de gestão nos locais onde ocorrem os "leks" ou na proximidade das áreas habitualmente utilizadas como centros de parada.

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Anexo

Tabela 1 – Principais ameaças que afectam o Sisão, adaptado de Almeida *et al.* (*in prep.*) e Tucker e Dixon (1997)

AMEAÇAS	IMPACTES	RELEVÂNCIA
1. Perda e fragmentação de habitat		
1.1.Transformação de sequeiro em regadio - perda de habitat	Introdução de culturas Outono / Inverno desadequadas Crescimento rápido das culturas com a consequente formação de uma estrutura da vegetação desfavorável à nidificação / alimentação Redução muito significativa da área de pousio e os que subsistem tem uma duração inferior a um ano Aumento na aplicação de agro-químicos (ver 3.3) Aumento significativo da perturbação	elevada
1.2. Florestação das terras agrícolas e expansão de cultivos permanentes	Alteração da estrutura de habitat adequado para as aves estepárias Nas áreas adjacentes induz ao aumento da taxas de predação	elevada
1.4 Abandono agrícola e do pastoreio extensivo	Alteração da estrutura de habitat com o desenvolvimento de matos Nas áreas adjacentes induz ao aumento das taxas de predação	média
1.5. Construção de estradas, albufeiras, outras infra-estruturas e introdução de outras actividades humanas	Perda de habitat adequado à alimentação e reprodução Constituem um importante factor de perturbação Constitui igualmente um factor de fragmentação de habitat (ver 2)	média/localmente elevada
2. Fragmentação das populações		
2.1. Linhas eléctricas, vedações, estradas	São factores de fragmentação das populações, ao restringirem a livre circulação das aves.	média /localmente elevada
3. Degradação de habitat (não constitui, por si só, perda de habitat)		
3.1. Monocultura cerealífera	Redução do mosaico agrícola com decréscimo da diversidade de habitat, em particular: o redução da área do pousio, geralmente com menos de 1 ano, ocorrendo frequentemente as lavras no inicio da época de reprodução o desaparecimento do gado como complemento das explorações, com implicações na estrutura da vegetação em período não-reprodutor o desaparecimento das leguminosas de sequeiro no revestimento do alqueive Aumento na aplicação de agro-químicos (ver 3.3)	elevada
3.2. Sobre-pastoreio	Causa perturbação, que, em período reprodutor poderá contribuir para o insucesso reprodutor pisoteio poderá levar a perdas directas das posturas	baixa/localmente elevada
3.3. Uso de agro-químicos / pesticidas	A utilização excessiva na aplicação de agro-químico reduz a disponibilidade alimentar (qualitativa e quantitativa), fundamental para o sucesso reprodutor.	desconhecida