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Modelling the foraging habitat selection of lesser kestrels: conservation implications of European Agricultural Policies

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Abstract

Cereal steppe habitat is a low intensive system that is rapidly disappearing as a result of changes in agricultural practices, and has the highest number of bird species with an Unfavourable Conservation Status of any habitat in Europe. A logistic regression model showed that the lesser kestrel, a globally threatened species, prefers to forage close to colonies, selects fields with livestock and avoids tree plantations. The conservation of this species is dependent on maintenance of extensive agriculture characterised by a rotation of cereal and grazed fallow. Abandonment of traditional agriculture and recent changes in agri-environmental programme support, which favour afforestation, are jeopardising the future of cereal steppes. Agri-environment measures are likely to be the most effective means of retaining the specific characteristics of cereal steppe habitat.

Keywords: Cereal steppe; Lesser kestrel conservation; Habitat selection; Logistic regression; CAP

1. Introduction

Pre-agricultural European landscape consisted of a combination of extensive open areas combined with closed forest (Svenning, 2002). These open areas are the natural habitat for many species that survived or flourish with agricultural practices and their wellbeing is now dependent on the continuation of farming practices such as mowing, stock grazing or scrub clearance (Ausden, 2004). Despite its artificial nature, European farmland supports an important community of open-country species.

Pseudosteppes, also known as cereal steppes, are open habitats with scattered trees, flat relief and an average rainfall bellow 700 mm, which historically resulted from various human activities, such as fires, felling woodland and scrub, ploughing and grazing (Suárez et al., 1997; van Dijk, 1991). Extensive cultivation of cereal crops is the main land use; the harvested fields remain uncultivated for one or more years (short-medium fallows) during which they are grazed extensively (Moreira, 1999; Suárez et al., 1997). Cereal steppes have the highest number of bird species with an Unfavourable Conservation Status in Europe (Tucker, 1997). Great bustard *Otis tarda*, little bustard *Tetrax tetrax*, black-bellied sandgrouse *Pterocles orientalis*, and lesser kestrel *Falco naumanni* are all threatened and declining southern European species that are strongly dependent upon cereal steppes.

The decline of many of these bird species is associated with land use changes (Martínez, 1991; Suárez et al., 1997; Tucker, 1997; Tucker and Heath, 1994; Wolff et al., 2001). In Southern Europe, cereal steppe habitat is a low intensive system that is rapidly changing as a result of changes in agricultural practices. Low intensity management generates low incomes, therefore farmers prefer to change to more profitable

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systems, particularly forestry or irrigated crops, both of which receive greater support from the European Common Agriculture Policy of the European Union (Donald et al., 2002; Pain and Pienkowski, 1997). The intensification of agriculture has been one of the major environmental problems of recent decades (Donald et al., 2001; Robinson and Sutherland, 2002) and this is likely to continue (Tilman et al., 2001).

The negative effects of intensive agriculture and biodiversity loss caused the introduction, in 1992, of agri-environment schemes in which farmers are paid to modify their farming practices to provide other services, particularly environmental benefits (Robson, 1997). Agri-environment programmes vary markedly between countries in Europe and their results for biodiversity conservation are poorly assessed and not always effective in promoting biodiversity (Kleijn et al., 2001; Kleijn and Sutherland, 2003). Effective species conservation and management requires an understanding of wildlife habitat requirements. If it is possible to identify the habitat variables that can be used to classify whether land is adequate for a species at a regional scale, then it should be possible to predict how populations would respond to habitat modifications. This could help wildlife managers to evaluate future effects of agricultural changes, and to predict which areas are suitable for the species and, thus, where conservation measures and suitable agri-environmental schemes could be implemented.

The lesser kestrel is an excellent target species for identifying management strategies for wildlife inhabiting European cereal steppes (Tella et al., 1998). It is one of the most endangered birds in Europe (Heredia et al., 1996) and is a Globally Threatened Species classified as Vulnerable (Stattersfield and Capper, 2000). In Europe the lesser kestrel has a Mediterranean range and its populations have shown a rapid and major decline across much of its breeding range (Tucker and Heath, 1994). Studies examining both landscape features around the colonies (Bustamante, 1997; Parr et al., 1995) and habitat selection through radio tracking procedures (Donazar et al., 1993; Tella et al., 1998) suggested that the recent decline of breeding populations has been mainly caused by agricultural changes affecting their foraging behaviour.

The lesser kestrels require high densities of available and suitable prey (Biber, 1996). They feed mainly on invertebrates, particularly large Orthoptera and Coleoptera (Choisy et al., 1999; Cramp and Simmons, 1990; Lepley et al., 2000), small mammals and lizards are taken infrequently (Franco and Andrada, 1976). The reduction in both the extent and quality of foraging habitat in its Western Palearctic breeding grounds appears to have been a primary cause of lesser kestrel decline (Peet and Gallo-Orsi, 2000). This species winters in Southern Africa, where habitat loss is also though to be a primary cause of population declines (Pepler, 1999).

The causes of the decline were analysed in detail for the species action plan (Biber, 1996; Heredia et al., 1996; Peet and Gallo-Orsi, 2000). However, causes of decline can differ from one area to the next. In Andalucia (Spain), several studies indicate that neither loss of nest sites (Forero et al., 1996) nor pesticide pollution (Negro et al., 1993) were causes of lesser kestrel decline. However, the reduction in the extent of suitable foraging habitat (natural pastures and fallow lands) during recent decades (Donazar et al., 1993) could explain the decline of the species at a local scale in the Guadalquivir River Basin. It is important to know if such changes in land use are also responsible for the decline of the lesser kestrel at a regional scale.

The shortage of suitable nesting sites is another suggested cause of lesser kestrel decline (Peet and Gallo-Orsi, 2000). This species is dependent upon buildings with undisturbed crevices, such as disused farm buildings, old churches or castles (Cramp and Simmons, 1990). Such sites are likely to be restricted due to lack of buildings with suitable cavities. To overcome this problem conservation bodies are trying to improve existing colonies and establish new colonies in purpose built structures. Therefore, knowing lesser kestrels' preferred foraging areas is critical for deciding where to improve and create colonies.

Statistical models are commonly used to examine species-habitat relationships; these models generally correlate the location of a species with selected abiotic and biotic habitat traits by either comparing sites where the species is present with those where it is absent, or by relating abundance to habitat variables. For presence/absence surveys, logistic regression is the most commonly used statistical model (Augustin et al., 1996; Brito et al., 1996; Bustamante, 1997; Franco et al., 2000; Hinsley et al., 1995; Luck, 2002; Osborne and Tigar, 1992). These models are mostly applied to explain the habitat use of species, but they can also generate predictions about probability of occurrence in different habitat types and some researchers have used logistic regression to predict the distribution of a species across landscapes (Austin et al., 1996; Franco et al., 2000; Mladenoff et al., 1999).

In order to predict the effects of habitat modifications on lesser kestrel populations at a regional scale, we studied the habitat selection of foraging lesser kestrels in the South of Portugal. In 1999, the study region was classified in two Special Protection Areas (SPA) under the European Birds Directive (79/409/EEC), but management plans have yet to be concluded. Currently the main force causing land use changes stems from the decisions of individual farmers' that are based on the provision of European subsidies and Council management plans. One of the study sites, the Castro Verde region, has a specific agri-environment scheme to encourage maintenance of traditional extensive agriculture (Castro Verde Zonal Programme), but the Rural Development Program in Portugal also supports the afforestation of agricultural areas (DGDR, 1999), so farmers select the scheme that gives them the highest economic benefit. This strategy is not possible inside the Castro Verde council that prepared a management plan defining areas for agriculture and for tree plantations.

The aims of this study were firstly to identify which habitat variables are associated with lesser kestrel occurrence at a regional scale; secondly, to produce maps of the probability of occurrence of lesser kestrels based on models of habitat suitability using Geographic Information Systems (GIS). These maps identify the areas where agriculture should be compatible with lesser kestrel conservation, and should therefore, be useful for the development of the SPAs' management plans; thirdly, to predict the effect of Common Agricultural Policy on extensive agriculture by the use of different support scenarios.

2. Methods

2.1. Study area

The study area is located in the South of Portugal, Baixo-Alentejo (41°70′N, 6°00′E) and includes two villages, Castro Verde and Mértola. It is divided into three sub-areas (Pardieiro – 45 km^2, Belver – 87 km^2 and Mértola – 52 km^2), each holds one of the three largest lesser kestrel colonies in Portugal. In total 75% of the Portuguese population was surveyed. Pardieiro and Belver have similar habitat composition, with more than 80% of the area consisting of a mixed extensively managed rotational system of grassland, cereal, fodder crops and grazed fallow land. The remaining habitat is open evergreen forest dominated by holm-oak *Quercus rotundifolia,* pine plantations from 1997, small areas of introduced *Eucalyptus* trees, shrubby vegetation, and orchards. The area around Belver and Pardieiro ranges from 110 to 250 m above sea level. The third area (Mértola) includes the only urban colony in Portugal. In this area, many (50%) of the traditional agricultural areas were abandoned or replaced by pine plantations (17%), leaving only 30% of the area extensively farmed. Altitude ranges from 10 to 220 m. The three sub-areas are classified as a Meso-mediterranean bioclimatic stage (Rivas-Martínez, 1981).

2.2. Field methods

The area was scanned uniformly along driven transects and from observation posts at high vantage points, which is considered a suitable method for lesser kestrel detection and habitat use (Franco et al., in press). The same number of transect counts was carried out in each sub-area to assure uniform sampling, twice a week. Transect counts were carried out along a standard route in each area but starting at different points and alternating directions and were not performed during poor weather conditions (Bibby et al., 1992; Gibbons et al., 1996). The open habitat and gentle slope of the area assured uniform sampling. Most pine plantations were from 1997, the pines with approximately 1.5 m still allowed good visibility in these areas. However, lesser kestrel detection might have been reduced in areas with open evergreen forest dominated by holm-oak trees, which is a limitation of this method. Data on foraging birds were collected from 25 March to 15 July 2001. Each foraging flock or isolated lesser kestrel detected was plotted on 1:25 000 maps.

2.3. Variable treatment

The study areas were divided into squares of 500 × 500 m Universal Transverse of Mercator grid that were classified according to each of the 25 independent variables used for model construction (Table 1). Land use was digitised and georeferenced from aerial photographs (1:40 000) taken in 1995, using ARCVIEW, and confirmed by field data.

Dry land agriculture systems were classified with the Braun–Blanquet vegetation scale: (0) absent or present in less than 1% of the square; (1) present in 1–5% of the square; (2) 6–25% of the square; (3) 26–50% of the square; (4) 51–75% of the square or (5) 76–100% of the square. Soil suitability for agriculture was classified from 1 (good) to 6 (poor) according to soil maps for agricultural use (S.O.R.A, 1962). Variables that consider nearest distance were categorised in classes of 500 m.

Presence/absence and distance variables were considered separately to allow the measurement of two different effects: occurrence of a certain characteristic and distance to it. A dummy variable was included to allow for the possible effect of the three sub-areas in the analysis. The co-ordinates of the squares were also included to examine location autocorrelation.

In total, there were 209 squares with lesser kestrel observations and 526 with absences. We defined a binary dichotomous response variable of 0 if lesser kestrels were absent from the square and 1 if lesser kestrels were present. For the multinomial analysis we used abundance data from all transect counts, and the response variable had four categories: 0 (if lesser kestrels were absent), 1 (1–5 birds were located in the square), 2 (6–10 birds) and 3 (more than 10 birds).

Table 1
Independent variables considered in the analysis (0/1 – presence/absence; 0–5 Braun-Blanquet vegetation scale and m-meters)

Variable	Description of the variable	Units
Colony	Dummy variable representing colony area	1–3
Coordinate *X*	Coordinate *X* of the square	
Coordinate *Y*	Coordinate *Y* of the square	
Livestock	Presence of livestock	0/1
Villages	Presence of villages	0/1
Human Settlements	Presence of human settlements	0/1
Unoccupied houses	Presence of non-inhabited houses and ruins	0/1
Paved roads	Presence of paved roads	0/1
Permanent water	Presence of permanent water	0/1
Slope	Number of isoheight lines crossing the cell	
Altitude	Value of lowest altitude curve in the cell	
Soil suitability	Soil capability for agriculture use	1–6
Cereal	Presence of cereal fields	0–5
Fallow	Percentage of fallow	0–5
Tree plantation	Percentage of tree plantations (+4 years)	0–5
Orchards	Presence or absence of orchards	0–5
Shrubs	Presence of shrubs	0–5
New plantations	Presence of pine and oak plantations	0–5
Other	Presence of other types of habitats	0–5
Distance to water	Distance to nearest stream or dam	m
Dist. to paved roads	Distance to nearest paved road	m
Dist. to human settlements	Distance to nearest human settlement	m
Dist. to villages	Distance to the nearest village	m
Dist. unoccupied house	Distance to non-inhabited houses and ruins	m
Dist. to colony	Distance to nearest colony	m

2.4. Model building process

From the initial set of squares, we choose two random sub-samples. One, with 675 squares, was used to build and assess the fit of the model. The remaining 60 squares were used to validate the accuracy of the final model predictions. The selection of the model and the validation sample were repeated 100 random times and a backward stepwise variable elimination was used to obtain the final models.

Firstly, a binary logistic regression model was built following the modelling procedure described by Hosmer and Lemeshow (2000). Secondly, as data on abundance were available for all study areas, an ordinal polytomous regression analysis was done using lesser kestrel abundance per square as the dependent variable. The Polytomous Logit Universal Models procedure (PLUM) available in SPSS 11.0 was used to give estimations for different levels (thresholds) of the dependent variable. The PLUM is used to model changes in intensity of use across habitats as a function of changes in environmental conditions. Although not commonly used, this method has the advantage of incorporating species abundance and not only presence/absence data. This method is a class of general linear models (McCullagh and Nelder, 1989) which relate an ordinal dependent variable (e.g., use-intensity categories) to a collection of independent variables (e.g., habitat measures), which may include both continuous and categorical variables (Borooah, 2001; Hosmer and Lemeshow, 2000).

A univariate analysis was performed, for each of the 25 independent variables, to measure the association of each with the response variable, according to the results of the Wald test (Hosmer and Lemeshow, 2000). In multivariate analysis, a backward stepwise elimination process was applied, in which all variables with a $P > 0.05$ in the Wald test and those whose Odds ratio estimation (95% confidence interval) included value 1, were removed from the model (Hosmer and Lemeshow, 2000).

The variables retained were tested for linearity, so each was transformed as x^2, $\log(x)$ and $\sqrt{(x)}$. Only transformations that improved the predictive power of the model were retained. Then, we looked for possible interactions between the variables, by adding the term *variable x. variable y* to the model. As previously, only interactions that improved the power of the model according to the *G* (maximum likelihood ratio) test were retained (Hosmer and Lemeshow, 2000).

2.5. Assessing the fit of the model

Following the procedure of cross validation, the data was randomly split in two sets, one used to build the model and the other (10%) to assess the prediction error. This process was repeated 100 times and the most frequent of the 100 models generated was evaluated with diagnostic statistics and goodness-of-fit tests. Thus, the Pearson χ^2 was used resembling the presence/absence regression approach (Hosmer and Lemeshow, 2000). The prediction accuracy was assessed from the overall correct classification $((CN_i + CA)/TC)$, where TC is the total sample of squares in the test, CN_i represents the correct number of individuals, and CA the correct absences. To choose the best model we also used the Pearson χ^2 statistic and the classification table.

Models were obtained using a GIS package ARCVIEW that allowed the combination of several layers corresponding to the variables of the model. The final output was a map with the probability of occurrence of lesser kestrels throughout the study area. A final layer was added allowing visualisation of points showing species presence.

3. Results

3.1. Univariate analysis

Table 2 shows the results of the univariate analysis, for the variables with *P* values less or equal to 0.05 in the Wald test. Fig. 1 shows the relationship between the percentage of presences and absences for some of the significant variables. This graph and the coefficient signs of the univariate analysis show that lesser kestrels prefer to forage close to the colony and to unoccupied buildings; they prefer good quality soils and fields with livestock, but avoid shrubs and tree plantations. Lesser kestrels prefer to forage away from human settlements and on shallow slopes.

A correlation table was built to look for significant correlations between the independent variables (Appendix A). Although there were several variables with significant correlations, the values of the correlation coefficients ($|r_s| < 0.65$) indicate that there are no strong associations between the variables. Therefore, all these variables were included in the multivariate analysis.

3.2. Multivariate analysis

In the binary approach (presence/absence), the most frequent model represented 51 out of 100 built models (Fig. 2). The ordinal multinomial approach produced two models with similar frequencies (Fig. 2), model 1 was the most frequent in the binary approach and had 3 variables: distance to the colony, livestock and tree plantations. The second model had 5 variables, three in common with model 1 and two new variables, presence of paved roads and distance to human settlements. The variables retained were transformed and the linearity tested, but no transformation or interaction significantly improved the power of the model. All significant variables were included in the models (Table 3), showing that lesser kestrels preferred to forage close to the colony, in fields with livestock and without tree plantations; they avoided human settlements but preferred locations with paved roads. The small values of the coefficients and standard errors indicate that the independent variables are not highly correlated (Hosmer and Lemeshow, 2000).

3.3. Assessing the fit of the model

In order to select the best model, we used the classification tables, the *G* test for the fitted models and the Pearson χ^2 of both model and validation samples for the most frequent models. Table 4 presents the correct classifications for the models and validation samples, and the Pearson χ^2 for each of the models. Both models classify absence better than presence and describe the

Table 2
Variables with significant differences (*P* value <0.05) in the univariate analysis

Variable	Code	Relationship	*P* value
Distance to unoccupied buildings	DistUn	Negative	<0.001
Soil suitability for agriculture	SoilQu	Negative	<0.001
Presence of livestock	Livest	Positive	<0.001
Distance to the colony	DistCo	Negative	<0.001
Shrubs	Shrubs	Negative	0.001
Distance to villages	DistVi	Positive	0.002
Unoccupied houses	UnocHo	Positive	0.005
Distance to inhabited houses	DistIn	Positive	0.006
Distance to paved roads	DistPa	Positive	0.008
Tree plantations	TreePl	Negative	0.017
Slope	Slope	Negative	0.042

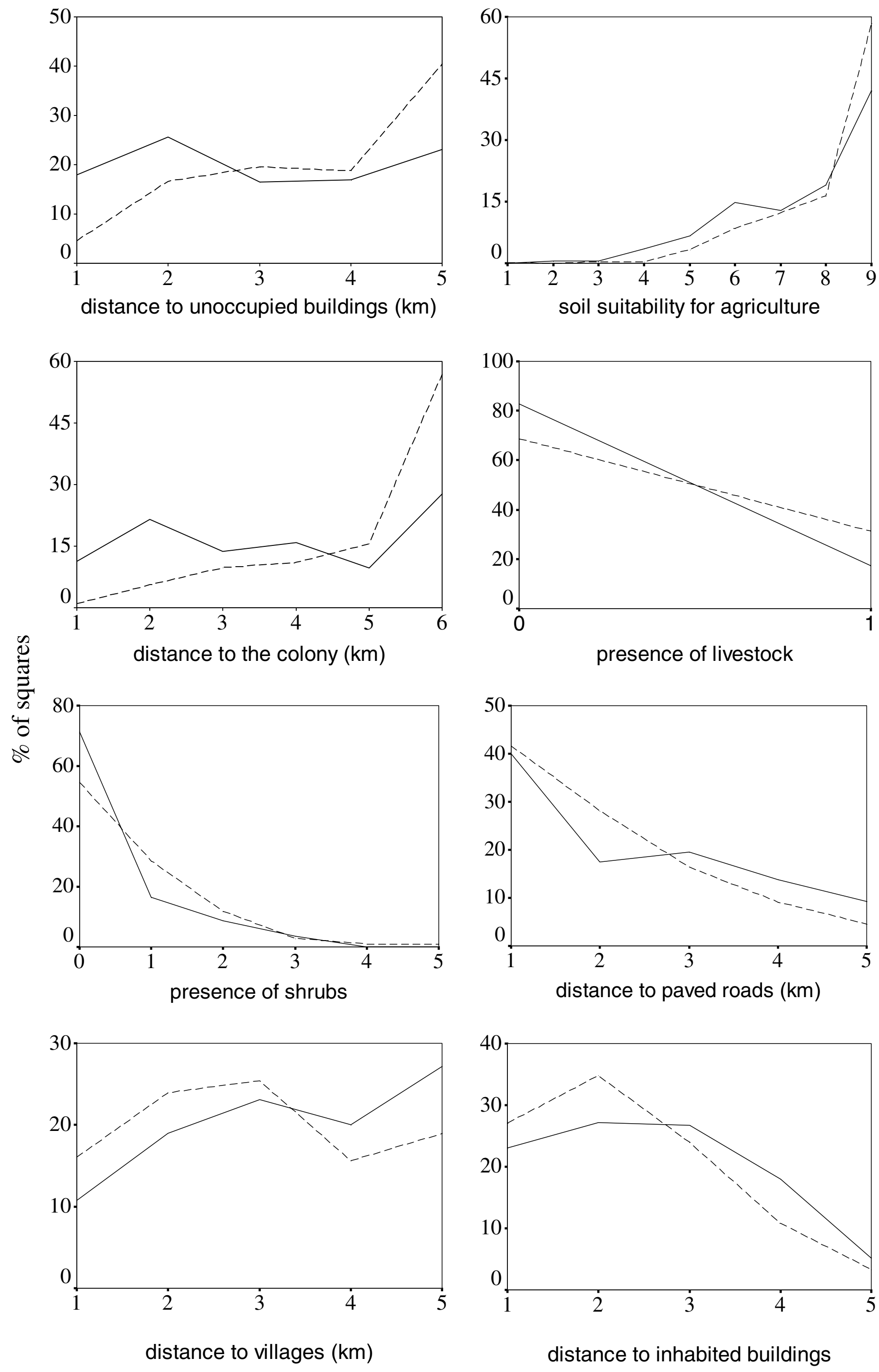

Fig. 1. Plot of the first eight variables that were significant in the univariate analysis. The continuous line represents the percentage of squares the lesser kestrels used; the dashed line represents the percentage of squares without observations.

data well (model 1 $\chi^2_{0.05,671} > 672.37$ and model 2 $\chi^2_{0.05,669} > 665.01$).

In the validation sample, model 1 was better at classifying correct squares: 78% of the squares were correctly classified (Table 4); nevertheless, there was no significant difference between the correct classification rates of the two models ($\chi^2_2 = 0.03$, n.s.). The two models are similar, but model 1 (with the variables distance to the colony, livestock and tree plantations) has fewer variables and is the most frequent model using the presence/absence data, so was selected as the best model.

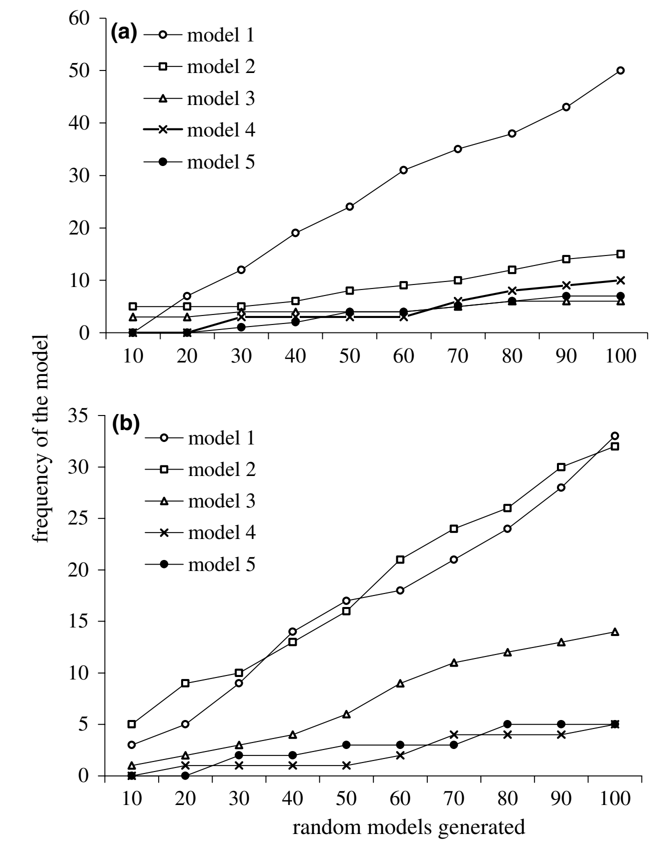

Fig. 2. Frequency of the models generated in the 100 random built models. (a) represents the most frequent binary (presence/absence) models and (b) the most frequent multinomial models.

Having selected the best model, it was necessary to decide which of the 33 models obtained, with the same variables but slightly different coefficients, was to be used to build the probability of occurrence map. Therefore, we calculated the mean sum of squares for the coefficients of all models and selected the one that had the least square differences (thresholds: $y = 0$, 1.701; $y = 1, -0.222$; $y = 2, -1.426$ and coefficients: $0.76 \times$ livestock $-0.587 \times$ distance to the colony $-0.458 \times$ tree plantations). In Fig. 3, we present the mapped probability of occurrence according to the above model, overlaid with the data from field observations.

4. Discussion

4.1. Selection of the best model

From the 100 models generated we selected the most frequent as the best model. The analysis of the most frequent model is especially important because it shows that if only one model is generated, a less frequent model could have been incorrectly selected. The selected model was the most frequent model, both in the binary and multinomial logistic regression, reinforcing the results. The main advantage of using ordinal multinomial logistic regression is its ability to establish a relative measure of use-intensity, providing a finer analysis of habitat variables (North and Reynolds, 1996).

Both model and validation samples are well adjusted to the data. However, the application of the current model is probably limited to the area where the model was generated, or areas with similar habitat conditions. The model was built with data from three study sites (180 km^2) within a region of approximately 800 km^2 characterised by extensive cultivation of cereal. A large part of this area consists of two SPAs, therefore the model is especially useful for providing conservation recommendations, regarding lesser kestrels, for implementation in the SPAs' management plans. However, to obtain a more general predictive model, it is necessary to extend this research to other regions.

Table 3
Coefficients (β), standard errors (S.E.), significance (P) and odds ratio for each variable of the two most frequent ordinal multinomial models and G test results

Variable	Model 1				Model 2			
	β	S.E.	P	Odds ratio	β	S.E.	P	Odds ratio
Threshold ($y = 0$)	−1.701	0.279	<0.001		−0.969	0.391	0.013	
Threshold ($y = 1$)	0.222	0.277	0.412		0.949	0.396	0.017	
Threshold ($y = 2$)	1.426	0.329	<0.001		2.141	0.437	<0.001	
Livestock	0.760	0.207	<0.001	2.14	0.868	0.211	<0.001	2.38
Distance to the colony	−0.587	0.058	<0.001	0.56	−0.572	0.060	<0.001	0.56
Tree plantations	−0.458	0.110	<0.001	0.63	−0.440	0.113	<0.001	0.64
Paved roads					0.429	0.219	0.050	0.65
Dist. inhabited houses					0.199	0.088	0.024	0.81
G test	144.2*		(df 3)		147.3*		(df 5)	

* Independent variables significantly improve the model adjustment.

Table 4
Correct classification rates of the two models analysed for both model and validation sample

Cells correctly classified	Model 1		Model 2	
	Model sample ($n = 675$)	Validation sample ($n = 60$)	Model sample ($n = 675$)	Validation sample ($n = 60$)
As $y = 0$	0.94	0.93	0.95	0.98
As $y = 1$	0.23	0.36	0.26	0.25
As $y = 2$	0	0	0	0
As $y = 3$	0	0	0	0
Overall	0.72	0.78	0.74	0.73
χ^2	672.37 (df 671)	40.82 (df 56)	665.01 (df 669)	68.66 (df 54)

The dependent variable y is 0 for absences, 1 for cells with 1–5 lesser kestrels, 2 for cells with 6–10 and 3 for more than 10 lesser kestrels. χ^2 is the Pearson χ^2 value for the model adjustment.

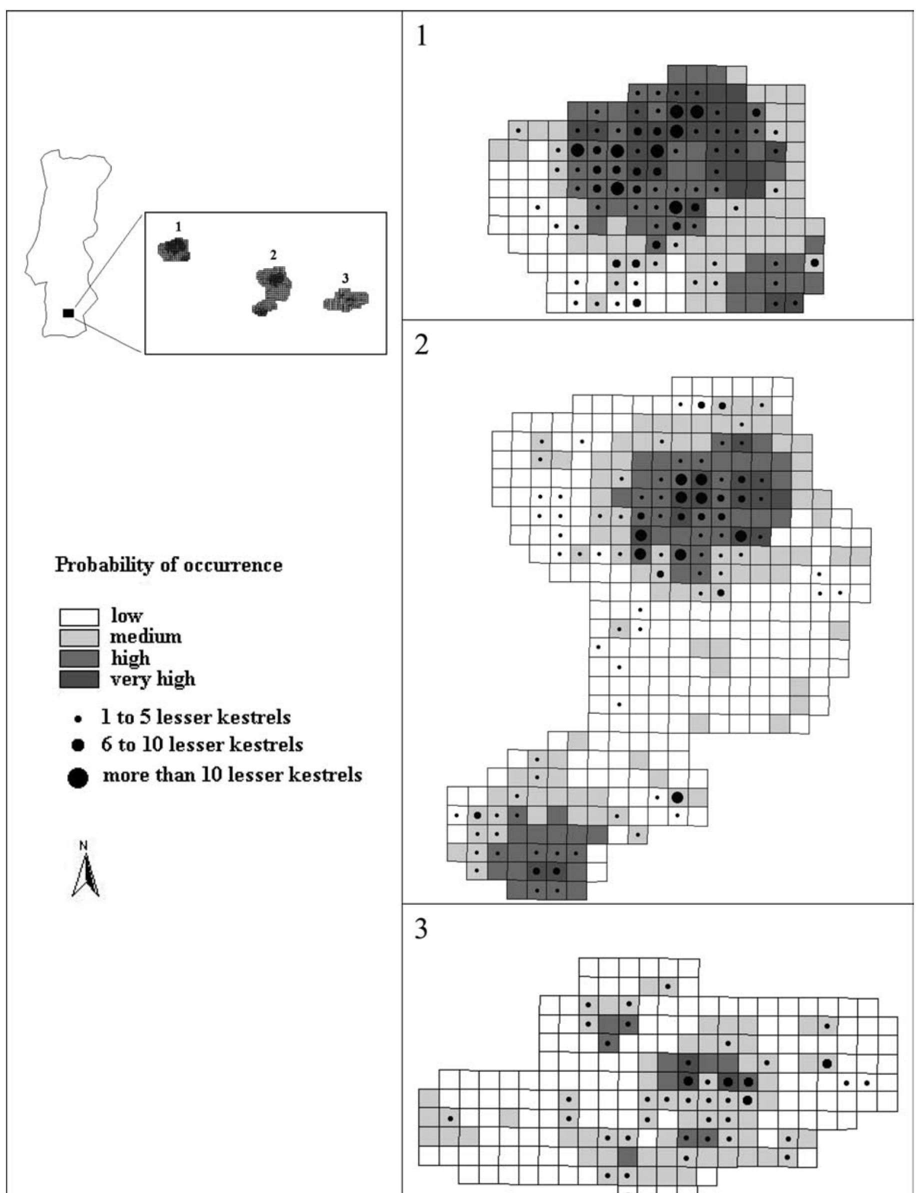

Fig. 3. Probability of occurrence of lesser kestrels in the study areas, according to the final model, in each square of 500×500 m.

When comparing two models, it is important to be aware of the conservation implications that might come from the selection of one. It is only meaningful, in terms of species conservation, to include in the model variables that have biological meaning. Furthermore, models with fewer variables have smaller standard errors and become less dependent of observed data (Hosmer and Lemeshow, 2000). The selected model includes livestock, tree plantations and distance to the colony. The second best model obtained includes these three variables and two other variables, presence of roads and human settlements. The selection of paved roads is unlikely to be a product of bias because the transect counts and the observations from high vantage points allowed all the study areas to be surveyed homogeneously. The likely explanation for this is the association of roads with presence of electrical pylons that give good perching sites for lesser kestrels, but since perching sites were not otherwise examined, it was better not to include this variable in the model. The avoidance of human settlements shown in the second model was expected because the Portuguese colonies are associated with uninhabited buildings (but the Spanish populations frequently nest in town centres). The selected model does not include these variables and, being very general, can probably be extrapolated to other areas with similar habitat conditions.

4.2. Foraging habitat selection

The selected model predicts well the species' distribution in the study areas, with most lesser kestrel observations located in squares predicted to have high probability of occurrence. The lesser kestrel distribution is negatively related to distance to the colonies, showing that lesser kestrels remain closer to them than expected from a random distribution. Pine tree plantations are avoided presumably because foraging is not possible. Livestock is positively selected, which might be related to livestock raising maintaining the vegetation of fallows at a height that allows higher foraging success (Toland, 1987). Many invertebrates are associated with the grazing animals (Ausden and Treweek, 1995), which may also explain why the lesser kestrels prefer these areas. Grazed habitat was also important to other species like Short-toed lark *Calandrella brachydactyla* and Calandra lark *Melanocorypha calandra* (Moreira, 1999).

Livestock and more specifically grazing intensity is one of the major controllable factors influencing vegetation height and density in fallows. Habitat structure seemed to be important through its effect on prey availability. Moreira (1999) showed that vegetation height, presence of shrubs and extent of bare ground differentially influenced the densities of different bird species in the same area. In the study areas, the main method used is rotational grazing which is especially beneficial for invertebrates because it creates a patchwork of different swards (Ausden and Treweek, 1995). From an agricultural management perspective, these factors can be controlled in order to promote good foraging habitat for lesser kestrels.

The results of this study indicate that lesser kestrels are dependent upon sympathetic management of farmland. Traditional agriculture with its typical 4-year rotation is very extensive both in grazing and in crop management and has resulted in a historical landscape worthy of conservation for its importance for many endangered species. Therefore, abandonment, intensification, or afforestation can all be serious threats.

4.3. Effects of European agricultural policies

The majority of European lesser kestrel populations are presently dependent on agricultural systems, which have been subjected to significant changes driven by European agricultural policies. Such changes have been causing the decline of the lesser kestrel (Donazar et al., 1993) and are likely to continue so it is very important to predict the effect of different agricultural policies.

If EU cereal support decreases (the abandonment scenario) cereal fields and stubbles are likely to be replaced by pastures and fallow land. Therefore, food availability during the chick-rearing period is likely to be reduced. Nevertheless, an increase in stock density would lead to changes in vegetation structure, reduced vegetation height, and greater areas of bare ground that could benefit lesser kestrels through an increase in prey availability. However, this could be detrimental to some other steppe bird species, especially great bustard, little bustard and corn bunting (Delgado and Moreira, 2000). The most dramatic consequence of the abandonment scenario is the replacement of cereal steppes by either scrub or tree plantations. In the intensification scenario, there would be loss of fallow land and its transformation to other crops (e.g., sunflowers), these other crops involve intensive chemical treatments against arthropods, which would influence negatively the lesser kestrel, as well as the little bustard and corn bunting (Delgado and Moreira, 2000).

To overcome abandonment or intensification, agri-environment schemes are potentially one of the most effective means of conservation. The Castro Verde zonal programme, created under the scope of agri-environmental measures in 1995, is a good example of how extensive agricultural practices can be effective for protecting and increasing endangered bird populations (Borralho et al., 1999). This programme promotes, among other measures, the traditional rotation system; a reduced use of pesticides and herbicides; a controlled grazing intensity (0.5–0.7 stock units/ha); and maintenance of water points throughout the summer for wild animals. Despite its proven success, its subsidies decreased by 20% in 2001. This decrease in support is jeopardising the future of Castro Verde Special Protection Area as a cereal steppe area since intensification and afforestation became more attractive for farmers than the continuation of traditional agriculture.

The potential threat to the Castro Verde SPA has already occurred in Mértola region, where traditional agriculture was abandoned and farmland transformed into pine plantations. Mértola has the highest percentage of pinewoods and pine plantations of all the areas analysed, and consequently has few squares with high probability of occurrence of the species. In Mértola, lesser kestrels have the lowest breeding rate of all regions (authors unpublished results) and the number of breeding pairs has decreased by 50% in the last 15 years (Rocha, pers. commun.). In this region lesser kestrels have to travel long distances to find food which might be the cause of the low breeding success (Reis and Rocha, 2001).

Changes in land use have occurred during the last 10 years. The surface area of pine and other plantations has increased by 17% within Mértola SPA and 5% in the Castro Verde SPA, although it has been classified as an SPA for the protection of steppe birds. The Portuguese agri-environment programme is giving priority to afforestation of marginal farmland areas (DGDR, 1999) which can be severely detrimental for lesser kestrel conservation. There is clearly a need for redefinition of priorities. If a commitment to the protection of the SPAs is assumed, then the agri-environment measures that protect the endangered habitats and species should be the most attractive schemes and preclude dramatic changes in land use.

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Appendix A

Correlation table with the significant variables of the univariate analysis (* for $p < 0.05$ and ** for $p < 0.01$).

Variables	DistUn	SoilQu	Livest	DistCo	Shrubs	DistVi	UnocHo	DistIn	DistPa	TreePl	Slope
DistUn	–	0.323**	–0.115**	0.553**	0.319**	–0.082*	–0.241**	–0.032	–0.189**	–0.063	0.084
SoilQu	0.323**	–	–0.048	0.235**	0.545**	–0.075	–0.164**	0.015	–0.025	0.239**	0.466**
Livest	–0.115**	–0.048	–	–0.127**	–0.091*	–0.083*	–0.089*	–0.114**	–0.079*	0.018	–0.031
DistCo	0.553**	0.235**	–0.127**	–	0.327**	–0.166**	–0.176**	–0.047	–0.279**	–0.144**	0.056
Shrubs	0.319**	0.545**	–0.091*	0.327**	–	–0.092	–0.123**	0.016	–0.079*	0.061	0.415**
DistVi	–0.082*	–0.075	–0.083*	–0.166**	–0.092	–	0.041	0.646**	0.543**	–0.126**	–0.170**
UnocHo	–0.241**	–0.164**	–0.089*	–0.176**	–0.123**	0.041	–	–0.008	0.006	–0.018	–0.038
DistIn	–0.032	0.015	–0.114**	–0.047	0.016	0.646**	–0.008	–	0.498**	–0.124**	–0.133**
DistPa	–0.189**	–0.025	–0.079*	–0.279**	–0.079*	0.543**	0.006	0.498**	–	–0.033	–0.087*
TreePl	–0.063	0.239**	0.018	–0.144**	0.061	–0.126**	–0.018	–0.124**	–0.033	–	0.422**
Slope	0.084	0.466**	–0.031	0.056	0.415**	–0.170**	–0.038	–0.133**	–0.087*	0.422**	–

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