

## Land-use changes may explain the recent range expansion of the Black-shouldered Kite *Elanus caeruleus* in southern Europe

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Occasional observations of Black-shouldered Kites *Elanus caeruleus* in Europe date back to the mid-19th century, but it was only recorded as a breeding species in the early 1960s in Portugal and a few years later in neighbouring Spain. This recent colonization, possibly from Africa where the species is abundant, may be due to climate change, land-use changes in southern Europe, or both. As a first step to understanding this range expansion process we have developed a habitat selection model using data from the current strongholds of its European distribution. Comparing the proportion of different habitat types around 46 breeding sites and 45 randomly chosen plots, we have found that the area of cultivated parklands known as dehesas in Spain is a strong predictor of the current distribution range of breeding pairs of Black-shouldered Kites. Specifically, the percentage of dehesas with planted cereal and a low density of trees (i.e. < 7 trees/ha and thus a savannah-like habitat) within the study plots explained 44.6% of the residual deviance in our model. The minimal adequate model classified 81.3% of breeding sites and random plots correctly. Our results suggest that Black-shouldered Kites may have taken advantage of the gradual increase of cultivated dehesas in the second half of the 20th century to expand its range in Europe. This particular type of dehesa is structurally similar to the African savannahs where the species thrives and may offer a higher density of rodents than traditional dehesas, which primarily contain pastureland for livestock ranching.

**Keywords:** colonization, dehesa, habitat selection, land-use change, occurrence models, raptors.

The Black-shouldered Kite *Elanus caeruleus* is a relatively small bird of prey occurring in open grasslands with scattered trees (i.e. savannahs) in Africa, India and southeastern Asia (Brown & Amadon 1968, Del Hoyo *et al.* 1994). It is classified as vulnerable in the European Union (Tucker *et al.* 1994) and near-threatened in Spain (Martí & del Moral 2004). This raptor and its close relatives

(Roulin & Wink 2003) and congeners in the Americas (*E. leucurus*) and Australia (*E. axillaris* and *E. scriptus*) prey on small rodent eruptions at irregular intervals (Mendelsohn 1982, Mendelsohn & Jaksic 1989). Mainly inhabiting the Southern Hemisphere, the *Elanus* kites of the world have converged both morphologically and ecologically with the nomadic owls of the Northern Hemisphere (Negro *et al.* 2006). They are nomadic and irruptive themselves (Del Hoyo *et al.* 1994, Scott 1994), being able to disperse over long distances – up to many hundreds of kilometres between their natal areas and first

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breeding sites – and may disperse between successive breeding attempts (Mendelsohn 1983).

During the 19th century the presence of Black-shouldered Kites was recorded in several countries of Western and Central Europe, the majority of records being in France, but also in the Netherlands, Belgium, Italy and Germany. These observations may correspond to vagrant birds and most probably this bird of prey was a very rare visitor before the mid 20th century (Cramp & Simmons 1980). The first records of Black-shouldered Kites in the Iberian Peninsula occurred in 1864 in Portugal (Smiths 1868) and in 1865 in Spain (Lilford 1865). The Spanish individual was an adult bird, shot near the Doñana marshes in southern Andalusia. Those few birds sighted in Europe may have originated from Africa and in particular from Morocco, where the species is abundant (Bergier 1987). The first evidence of breeding was reported in 1963 from the Alentejo, Portugal (England 1963), and in 1975 from Spain in Extremadura and the neighbouring province of Salamanca.

The European population today has been estimated at 1000–2000 breeding pairs, occurring mainly in the southwestern portion of the Iberian Peninsula (BirdLife International/European Bird Census Council 2000). In the last 30 years, the Black-shouldered Kite has experienced a range expansion in Europe, with scattered breeding attempts in the majority of the Spanish provinces and also in southwestern France (Ferrero & Onrubia 1998, 2003, Duchateau & Delage 2006).

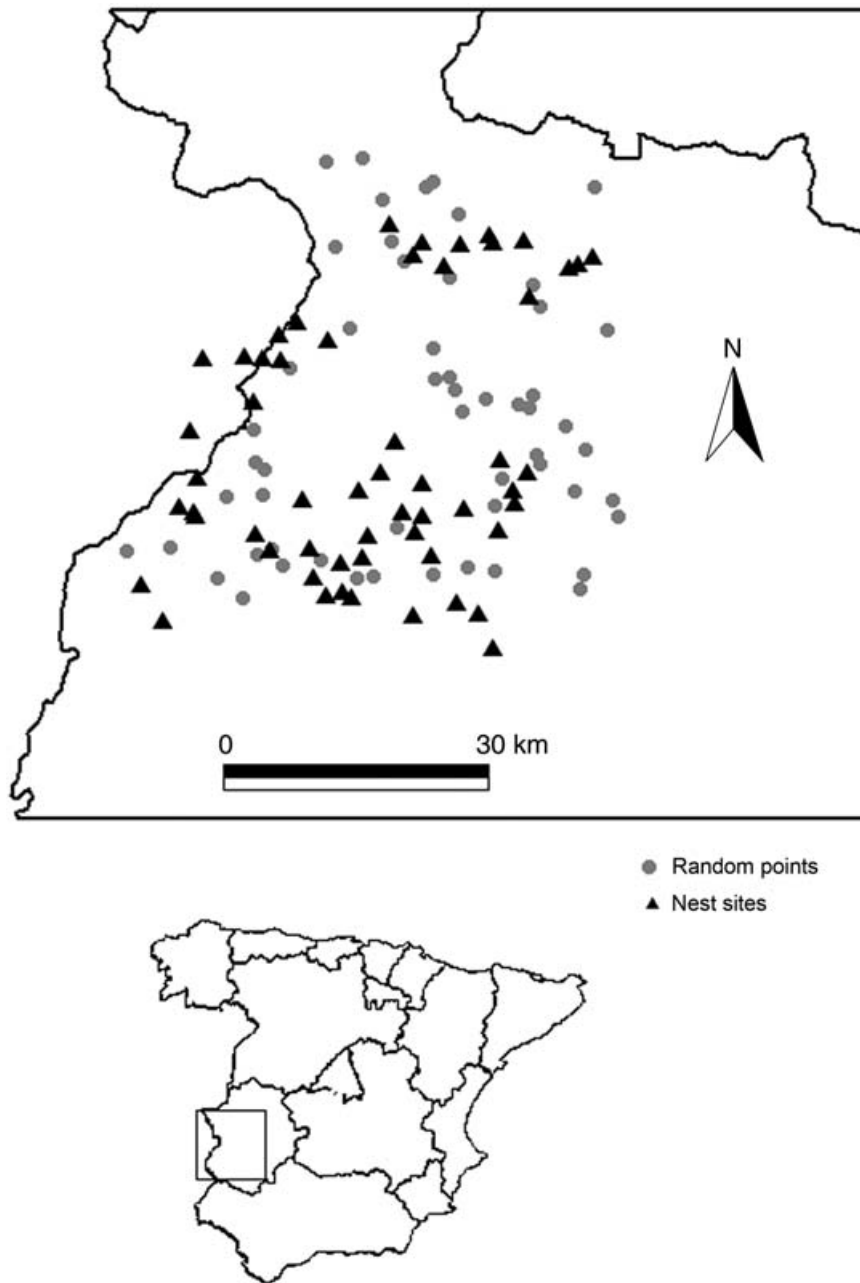
Predicting habitat suitability has multiple applications in the conservation of species of conservation concern because it allows government administrators to distribute available resources more efficiently among habitats. Identifying the habitat features that favour a species' survival and reproduction is a fundamental step that should be taken before planning any conservation programme (Manel *et al.* 2001). The dehesas in Spain appear to be closely associated with Black-shouldered Kite occurrence and consist primarily of scattered acorn and/or cork oak trees (*Quercus ilex* or *Q. suber*) in pastureland at a density of about 5–50 trees/ha. The dehesas are mainly used for raising livestock (primarily pigs, sheep and cattle; Carrete & Donazar 2005, Martín & Alés 2006). Today, dehesas cover a total area of about 2–2.5 million ha in the Iberian Peninsula, of which about 75% is found in southwestern Spain, and the remaining habitat in Portugal (Costa *et al.* 2005). This traditional land-use system of dehesas started to change at the

end of the 1950s, with the promotion by the Spanish government of a shift from livestock raising to cereal cultivation in huge extents of the territory. This land-use change involved the introduction of machinery and chemical fertilizers, which led to a large-scale land-use change in the dehesa system. Alvarado (1983) estimated that 1.8 million mature acorn oak trees were destroyed only in Badajoz, one of the two provinces of Extremadura, in just a decade (1967–1978). Elena *et al.* (1987) estimated a loss of about 25% of all oak trees in the whole of Extremadura between 1957 and 1982. The proportion of cultivated dehesas in Extremadura is unknown, but in Andalusia, the neighbouring region to the south, it has recently been estimated at 12% of the total surface area is occupied by dehesas (Costa *et al.* 2005).

Cultivated dehesas are precisely the habitat where most breeding attempts of the Black-shouldered Kites have been recorded in our study area (Rivera *et al.* 2006). These cultivated dehesas hold a lower tree density than traditional ones due to tree clearing and the fact that tree regeneration is precluded due to periodic tilling (Costa *et al.* 2005). Although the association between breeding Black-shouldered Kites and the dehesa habitat has long been recognized (Carbajo & Ferrero 1985, Ferrero & Onrubia 1998), we are not aware of any previous published study considering different dehesa types in terms of tree cover and land use. Therefore, the objectives of this research were two-fold: (1) to test the hypothesis that Black-shouldered Kites positively select cultivated dehesas over other habitat types, and (2) to develop mathematical models using variables describing the habitat at the landscape level that would facilitate identification of suitable breeding habitat for this species outside our study area.

## METHODS

We monitored breeding pairs of Black-shouldered Kites in an area of approximately 4900 km<sup>2</sup> located around the town of Badajoz (35°50'N, 6°59'W) in southwestern Spain (Fig. 1). The study area is an agricultural mosaic located on primarily flat relief in the Guadiana river basin. This human-created mosaic is composed of arable land with cereals (mainly wheat, oat and barley), other non-irrigated crops such as beets and chick peas, irrigated fields (mainly corn, tomato, cotton and alfalfa), as well as dehesas. Other common habitats are olive-tree groves, vineyards, fruit-trees, *Eucalyptus* tree plantations and riparian forests.



**Figure 1.** Study area showing 46 nest-site locations and 45 random points used to quantify nesting habitat and to build an occurrence model for the Black-shouldered Kite in Extremadura, southwestern Spain.

Breeding territories in this area were searched for and monitored from 2003 to 2007. We restricted our analyses to using data only from the 2004 breeding season. This was because the number of breeding territories have remained constant at about 50 during the study period and the majority of nesting pairs and nests were found in the same territories year on year (usually in the nearest tree). Hence to

avoid pseudoreplication we only analysed data from 2004.

Given that nest-sites are not re-used in this species, from January to July we searched the study area looking for signs of territorial pairs (i.e. territorial displays and delivery of nest material). Territories were considered to be active when the female laid eggs and incubated. In this species, some pairs can

**Table 1.** Explanatory variables in occurrence models used to predict breeding habitat of Black-shouldered Kites in circular sampling areas of c. 6 km<sup>2</sup> located in Extremadura, southwestern Spain.

Code	Meaning
TREE	% of tree patches, mainly <i>Eucalyptus</i> sp.
DEHECEREAL L1	% of <i>dehesas</i> with dispersed density of trees < 7 trees/ha (L1 = Level 1) over non-irrigated crops
DEHECEREAL L2	% of <i>dehesas</i> with medium density of trees 7–20 trees/ha (L2 = Level 2) over non-irrigated crops
DEHELIVESTOCK	% of <i>dehesas</i> used for livestock raising with a tree density of 20–40 tree/ha
SCRUB	% of scrub
NIRRIGA	% of non-irrigated crops
IRRIGA	% of irrigated crops
VINEYARD	% of vineyard
OLIVE	% of olive groves
PASTU	% of pasture
DRIVER	distance (m) to nearest river
DROAD	distance (m) to nearest road
DVILLA	distance (m) to nearest village

lay two clutches in different nests within the same area during a single breeding season (Ferrero *et al.* 2003). If we suspected the latter had occurred, only the first active nest was considered for analysis. We measured 13 variables inside circular sampling plots to describe landscape features in 46 breeding territories and in 45 areas generated at random (Table 1). Analysis of the landscape features was based on circular plots centred on the focal spot (nest-site or random point) of each territory or of each randomly generated area. Plots had a 1425-m radius (half the nearest neighbour distance (NND) in the study area) in order to get a circular area of 637.9 ha (approximately 6 km<sup>2</sup>).

The spatial scale selected to study habitat preference may influence our results (Sánchez-Zapata & Calvo 1999, Martínez *et al.* 2003, Román-Muñoz *et al.* 2005). The scale we selected encompassed an area that was used by individuals not only for breeding but also for foraging, according to visual monitoring of hunting birds coupled to our radio-tracking data on 11 breeding individuals (authors' unpubl. data). The Black-shouldered Kite hunts its staple prey (rodents) in open habitat, field margins and irrigated fields after the harvest of cereals (authors' unpubl. data). Therefore, we feel that our chosen spatial scale does well to represent the home range of the Black-shouldered Kite, which usually results in better performance of the predictive models (Ferrer & Harte 1997, Suárez *et al.* 2000, Fernández *et al.* 2003, Martínez *et al.* 2003, Balbontín 2005). Random points were chosen inside the habitat available for adult Black-shouldered Kites. Available habitats were considered to be all habitats inside our study area having minimum requirements

for nesting. Therefore, generated random points located in areas lacking at least a suitable tree for nesting, on water courses or reservoirs, points closer than 19 m to the nearest road or less than 812 m away from the nearest village (i.e. the minimum distance recorded in our sample from a nest-site to a road or a village, respectively) were rejected. Because the study area was intensively searched, we are confident that we found the majority of nesting sites and hence those random points lacking a nest-site were considered as absences in the occurrence (presence/absence) models.

Landscape characteristics were analysed by means of a Geographic Information System. We used colour digital orthophotos taken from an airplane during summer 2002 with 0.5-m resolution (1 : 5000). The orthophotos were obtained from the Extremadura Regional Government (Junta de Extremadura). Percentages of habitat variables inside circular plots were measured after digitizing them using the Habitat Digitizer Extension for Arcview 3.2 (available at: <http://biogeo.nos.noaa.gov/products/benthic>). Other recorded variables included the distance from the focal point (nest-site or random point) to the nearest source of human disturbance (road or village) or the nearest stream/river.

### Statistical analyses

Mean values for the different variables collected at nest-sites and random plots were compared using Wilcoxon rank sum normal statistics with correction tests for the differences between means. All tests were two-tailed and statistical significance was set at  $P < 0.05$ ; means are given  $\pm$  sd.

We built occurrence (presence–absence) models using logistic regression via a Generalized Linear Model (using the GLM procedure of S-Plus 2000, Mathsoft 1999) to identify the set of variables that best separated breeding territories from random areas. We first built an environmental model using the explanatory variables that described habitat at the landscape level (Table 1). We used a binomial error distribution and a logit-link function. Investigation of dispersion plots suggested incorporation of some independent variables as main and quadratic effects in a maximal model to test if the inclusion of second-order effects would improve the final model. The explanatory variables included as second-order polynomials were: irrigated crops, different types of dehesas, scrub, pasture and trees. The statistical significance of each variable was tested in turn in the model using a backward stepwise procedure and models were fitted using a maximum-likelihood method (McCullagh & Nelder 1989). Because neighbouring circular plots could have similar environmental conditions, residuals from a fitted model might exhibit spatial autocorrelation (Bustamante & Seoane 2004). To control for possible pseudoreplication due to geographical proximity of sampled plots we added a term called *autocov* that averages the number of occupied squares among a set of  $k_i$  neighbours of squares  $i$  (Augustin *et al.* 1996). For this purpose, we built a grid covering our study area of  $70 \times 70$  km formed by squares of similar size as the breeding territories (grid size  $2850 \text{ m} (2 \times 1425 \text{ m})$ ). Each nest-site was assigned to the centre of the square  $i$  where it belongs. Those squares lacking a nest-site were considered as absence squares and those with a nest as presence squares. We also checked for autocorrelation by adding the geographical coordinates (longitude and latitude) as two new independent variables into our models.

We used two different methods to compare the performance of the model. First, we used a cross-validation leave-one-out re-sampling procedure to compare the performance of our model. We checked the stability of our final minimal adequate model by comparing the percentage of agreement between presence/absence predictions of the original model with those predictions obtained when using the cross-validation re-sampling procedure. This measures the average effect of a single observation on the model predictions. The presence or absence of predicted values was accepted at a threshold probability at which the sum of sensitivity and specificity was maximized (Albert & Harris 1987,

Zweig & Campbell 1993). For this purpose, we defined an objective cut-point above which to consider the species as present, classifying prediction values as present at all cut-points between 0.0 and 1.0 with an interval of 0.1 (Suárez-Seoane *et al.* 2002). The percentage of cases (random and nest-sites) classified correctly (CC) at selected cut-points was calculated and an optimum set at that cut-point where presence and absence sampling plots are equally predicted by the GLM model. Finally, we constructed a confusion matrix (Fielding & Bell 1997) and Cohen's Kappa was calculated (Cohen 1960). This statistic objectively computed the chance-corrected percentage of agreement between observed and predicted group memberships. Values of 0.0–0.4 indicate slight-to-fair, values of 0.4–0.6 moderate, 0.6–0.8 substantial and 0.8–1.0 almost perfect model performance (after Landis & Koch 1977). Secondly, we used a data-splitting strategy, developing the models with a random selection of 75% ( $n = 69$ ) of the sample (the training set) and then using the remaining 25% of the data ( $n = 22$ ) to evaluate the models (the test set). The cross-validated model using a data splitting strategy (i.e. prediction success) was assessed using the area under the receiver-operating characteristic (ROC) (Beck & Shultz 1986, Fielding & Bell 1997, Osborne *et al.* 2001).

## RESULTS

Black-shouldered Kites tended to breed in cultivated dehesas with a low tree density ( $< 7$  tree/ha). The average percentage of this type of habitat at breeding sites within circular plots was 22.5% (143.5 ha), differing significantly from 1.53% (9.75 ha) found in circular plots generated at random ( $P < 0.001$ , Table 2). Breeding territories also had a greater area of cultivated dehesas with a medium density of trees (7–20 tree/ha) than random circular sampling areas. Breeding areas were also characterized by having a significantly greater area of non-irrigated crops ( $P = 0.009$ ) and a lower area of pastureland ( $P < 0.001$ ) than random areas. Variables related to human disturbance showed that breeding territories were located significantly further away from villages than random areas ( $P = 0.02$ ). Also, we detected a trend (although not statistically significant) for breeding territories being located further away from the nearest road than random areas, indicating a tendency to avoid areas used by humans.

The occurrence GLM model was highly significant ( $P < 0.0001$ ), explaining a total of 60.4% of the

**Table 2.** Difference between breeding sites and random sites in mean surface occupied by 11 habitat types measured within circular sampling areas of habitat deemed available to Black-shouldered Kites. Mean differences in the distance to the nearest road, village and water courses (e.g. rivers, reservoirs and streams) are also reported.

Code	Nesting sites (mean $\pm$ sd)	Random sites (mean $\pm$ sd)	Z	P
TREE (%)	0.14 $\pm$ 0.53	0.90 $\pm$ 2.36	1.73	0.08
DEHECEREAL L1 (%)	22.5 $\pm$ 19.5	1.53 $\pm$ 3.24	-6.75	< 0.0001
DEHECEREAL L2 (%)	2.63 $\pm$ 6.49	0.46 $\pm$ 1.54	-3.47	0.0005
DEHELIVESTOCK (%)	11.0 $\pm$ 16.2	22.7 $\pm$ 32.3	1.03	0.30
SCRUB (%)	0.61 $\pm$ 1.93	1.03 $\pm$ 2.89	0.27	0.78
NIRRIGA (%)	20.6 $\pm$ 15.2	15.7 $\pm$ 20.9	-2.59	0.009
IRRIGA (%)	27.7 $\pm$ 21.8	28.3 $\pm$ 34.8	-1.07	0.28
VINEYARD (%)	6.02 $\pm$ 8.60	8.36 $\pm$ 13.5	0.02	0.98
OLIVE (%)	3.53 $\pm$ 4.84	8.60 $\pm$ 13.8	0.25	0.79
PASTU (%)	2.21 $\pm$ 4.74	6.83 $\pm$ 11.3	3.39	0.0007
DRIVER (m)	1483.0 $\pm$ 1185.7	1568.1 $\pm$ 1585.0	-0.52	0.60
DROAD (m)	1650.6 $\pm$ 1317.0	1317.1 $\pm$ 1396.5	1855	0.08
DVILLA (m)	5772.3 $\pm$ 2775.3	4530.7 $\pm$ 2765.9	1184	0.02

**Table 3.** Minimal adequate GLM using predictors related to land-use and human disturbance measured in circular sampling plots to predict the presence and absence of suitable breeding territories of Black-shouldered Kite in southwestern Spain.

Term	Coefficient	se	Residual deviance	df
Null			126.1418	90
Intercept	-2.38916	0.630		
DEHECEREAL L1	0.28061	0.081	69.8131	89
IRRIGA	11.22230	4.591		
IRRIGA2	-10.80869	3.823	56.7013	87
DEHECEREAL L2	0.31776	0.167	49.8540	86

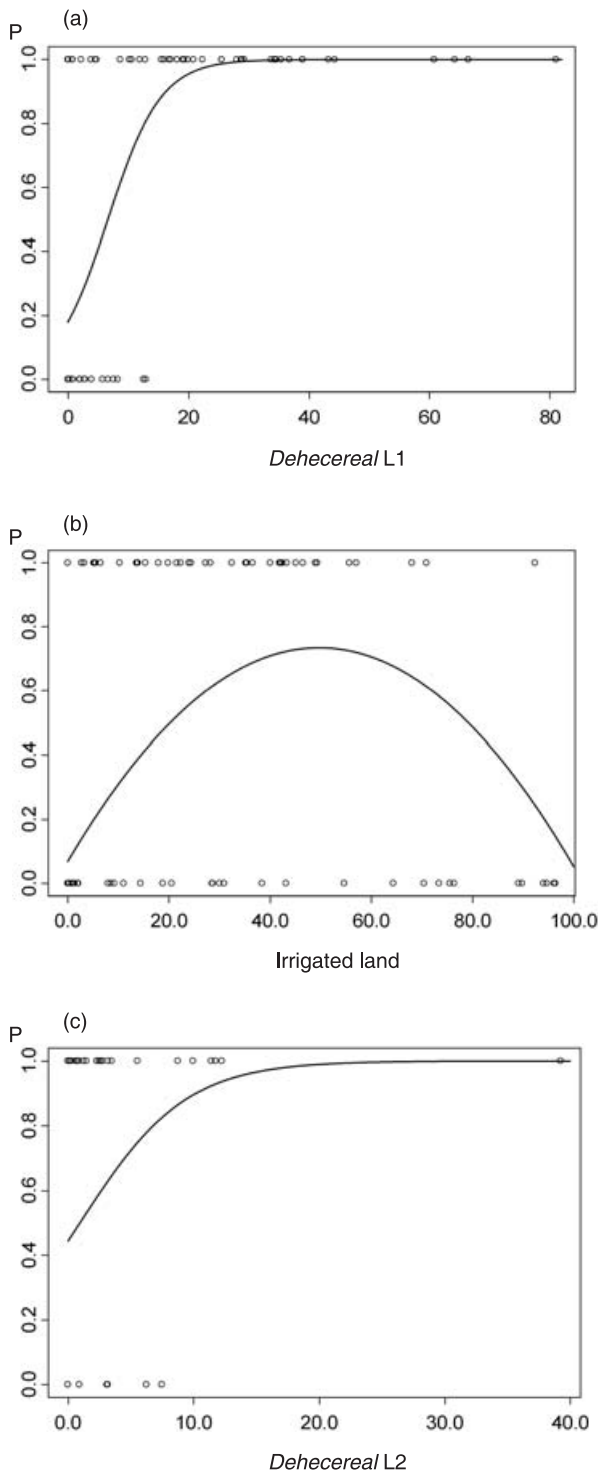
residual deviance. Three of the environmental variables were retained by the model: the percentage of cultivated dehesa with low (*dehecereal* L1) or medium (*dehecereal* L2) densities of trees entered the model as main effects, and the percentage of irrigated crops entered the model in its quadratic form (Table 3). As univariate statistics suggested, *dehecereal* L1 had the greater effect on the response variable, explaining 44.6% of the residual deviance: the higher the area in the circular plots occupied by this type of habitat, the higher the probability of finding a breeding pair of Black-shouldered Kites. However, the probability of finding a breeding pair is 100% at about 40% of the circular sampling area occupied by this type of habitat (Fig. 2a). The Black-shouldered Kites showed a preference for a particular range of the area occupied by irrigated crops, with an optimum at around 50% of the circular sampling area occupied by this type of habitat. The response curve showed that below this threshold there is a

positive relationship between the percentage of irrigated crops and the probability of finding a breeding pair, and above it the opposite trend occurs (Fig. 2b). The extent of scattered trees at medium densities (*dehecereal* L2) also correlated directly with the probability of classifying a given area as suitable for breeding (Fig. 2c). The environmental model was not affected by spatial autocorrelation; neither the spatial coordinates ( $P > 0.05$ ) nor the *autocov* variable ( $P > 0.05$ ) showed a significant increment of the residual deviance after removing them from our minimal adequate model.

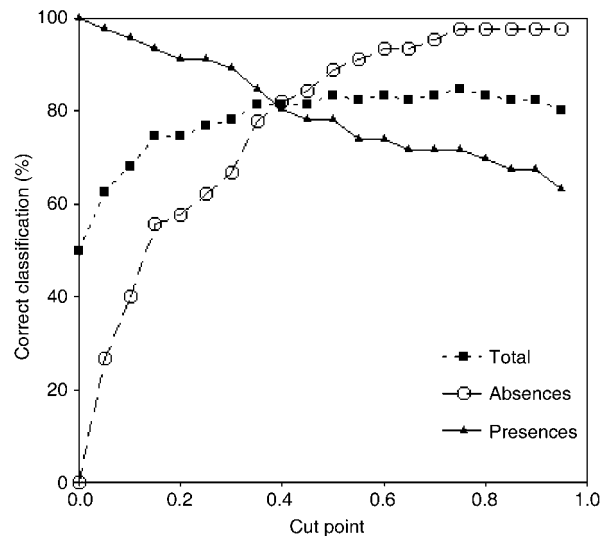
After applying the cross-validation leave-one-out re-sampling technique, our final model showed a Cohen's Kappa value (mean  $\pm$  se) of  $0.62 \pm 0.08$ , suggesting a robust performance. When taking the cut-point at 0.4 (Fig. 3), the model correctly reclassified 80.4% of breeding sites and 82.2% of the random plots (overall = 81.3%). The model was also stable, showing 85.7% of coincidences when comparing the predictions done by the original model with those obtained using the cross-validation re-sampling technique. When using the data-splitting strategy with 40 random iterations, this gave an AUC output (mean  $\pm$  se) of  $0.79 \pm 0.08$ , indicating that our model was sufficiently robust for predicting the presence or absence of breeding pairs outside our study area.

## DISCUSSION

Changes in farming practices during the 20th century have influenced many bird populations in Europe (O'Connor & Shrubbs 1986, Pain & Pienkowski 1997, Pain *et al.* 1997, Berg & Gustafson



**Figure 2.** Response curves for three significant explanatory habitat variables entering the minimal adequate model. The curves show the effect of each variable (x-axis) on the probability of finding a breeding site in a given sampling area (y-axis): (a) *dehecereal* L1, (b) irrigated land and, (c) *dehecereal* L2.



**Figure 3.** The proportion of cases (random and nest-sites) classified correctly in the occurrence model is represented on the y-axis with the selected cut points varying between 0.0 and 1.0 on the x-axis. The cut-point that classified equally well the presence and absence of breeding pairs within our sampled circular sampling areas was optimum at a predicted cut point of 0.4.

2007) and this may be responsible in part for the fact that 81% of the bird species breeding in farmlands are classified as of European Conservation Concern and that 76% have shown recent population declines (Suárez *et al.* 1997). How these changes in land-use have affected individual species is still poorly understood. The case of the Black-shouldered Kite may represent a reversal of these trends, as it seems to be a natural and recent addition to Europe's biodiversity in agricultural landscapes.

The recent transformation of densely forested traditional dehesas for livestock grazing into more open cultivated dehesas may have benefited Black-shouldered Kite populations in the Iberian Peninsula. We have demonstrated that this raptor shows a strong preference for cultivated dehesas for breeding, and this dehesa type has only become widely available in the last 50 years (Costa *et al.* 2005). The *Elanus* kites throughout the world are rodent specialists and their respective distribution patterns, population densities, movements and breeding performance are largely dependent on rodent abundance and availability (Mendelsohn & Jaksic 1989). In southwestern Spain the Black-shouldered Kites staple prey are mice of the genus *Mus*, specifically the Algerian Mouse *Mus spretus* that constitutes 44.5% of prey found in pellets during the breeding

season in Extremadura (J. J. Ferrero unpubl. data). Other small mammals, such as the Wood Mouse *Apodemus sylvaticus*, voles of the genus *Microtus* (*M. duodecimcostatus*, *M. arvalis*) and shrews (*Crocidura* spp.) have also been found among prey remains (Parejo *et al.* 2001, Mañosa *et al.* 2005). It has to be noted, however, that diversity and abundance of microtine rodents in Mediterranean areas of the Iberian Peninsula are among the lowest in Europe (Soriguer *et al.* 2003). Cultivated dehesas may be an exception to this general pattern, at least in terms of rodent abundance, as they harbour relatively large populations of *Mus* and *Apodemus* (authors' unpubl. data).

Interestingly, our results showed that a range between 0% and 50% of the circular sampling area occupied by irrigated fields increases the probability of occurrence of a breeding pair. The reason may be that the Black-shouldered Kite frequently uses irrigated fields as temporary feeding habitats, both inside and outside the breeding season (Parejo *et al.* 2001).

Overall, the occurrence model explained a high percentage of the deviance and its predictive power was high when compared with other studies on raptors (Seoane *et al.* 2003 and references therein). The variance that remained unexplained could be due to overlooked factors, including for example interspecific interactions (Sergio *et al.* 2004), which might be important in this small-sized species sharing the same habitat with other birds of prey, including the Short-eared Owl *Asio otus*, the Common Buzzard *Buteo buteo*, the Black Kite *Milvus migrans*, the Booted Eagle *Hieraetus pennatus* and the Eurasian Kestrel *Falco tinnunculus*. Predation of both juvenile and adult Black-shouldered Kites by other raptors in our study area in the period 2003–07 was the highest observed mortality factor in this population (authors' unpubl. data).

As for the applicability of our model to evaluate habitat availability at a broader scale, our bootstrap re-sampling procedures gave us confidence in the performance of the occurrence model and we believe it could provide a basis for suitable habitat conservation for the species outside our study area. However, the possibility of building predictive distribution maps is as yet limited, because raster cover considering cultivated dehesas as a land-use class has not been included in available maps and many databases. For instance, European CORINE land-use/land-cover digital maps cluster all types of dehesas into a single agro-forestry class.

The primary result of this study is that there is a

clear association between the presence of breeding pairs and cultivated dehesas. This kind of habitat, suitable for both breeding and foraging, has become increasingly available in the second half of the past century, in parallel to Black-shouldered Kites colonization. Other factors overlooked in the present study could also be responsible for colonization and subsequent expansion of this kite in southern Europe. Recent shifts in distribution ranges for many species have been related to climate change (e.g. Valiela & Bowen 2003, Crick 2004, Carrillo *et al.* 2007). Available climate data indicate an increase in mean global temperature in the past century (IPCC 2001) in southern Spain and northern Africa. It is possible that the increment in mean temperature has favoured the expansion of the Black-shouldered Kite in the Iberian Peninsula. However, the contribution of both mean temperatures and availability of preferred habitat are difficult to separate because they have increased concurrently.

Today, the traditional dehesa is protected by law (e.g. in Extremadura since 1986); tree clearing is illegal and tree planting is encouraged with subsidies. However, cultivated dehesas are unstable habitats because they constitute a transitional step between the traditional dehesa devised and managed for keeping livestock and an agricultural pseudo-steppe with no trees. Today and probably in the future, the transformation of cultivated dehesas into extensive cereal monocultures and the agricultural practices associated with them, such as the clearing of field margins and the use of pesticides, could negatively affect Black-shouldered Kite populations. This bird of prey needs trees or tall bushes to build its nests, to preen, to shelter from predators and to roost at night. If cultivated dehesas become scarce in the future a possible management practice to favour the presence of this raptor would be to plant trees on cereal field margins. Extensive cereal monocultures in Spain and Portugal may hold enough small mammals for the Kites, but only if vegetation on field margins is respected and pesticide use minimized. However, these habitats are not currently used by Black-shouldered Kites due to the absence of adequate substrates for nesting or perching. There is also a lack of hedges in most cereal-producing areas of Spain. This kind of vegetation should be promoted by government policies because it would bring benefits not only for the Black-shouldered Kite but also for other species including game and their predators. Furthermore, for an expanding species, if cereal-growing dehesas are regressed to their former condition of



grounds for livestock ranching, or new cultivations are introduced, the Black-shouldered Kite may face the risk of extinction in Europe, as this species seems to be highly selective in terms of breeding habitat.

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## REFERENCES

- Albert, A. & Harris, E.K.** 1987. *Multivariate Interpretation of Clinical Laboratory Data*. New York: Marcel Dekker.
- Alvarado, E.** 1983. *El Sector Forestal en Extremadura. Ecología y Economía*. Institución Cultural El Brocense. Cáceres, Spain: Diputación Provincial de Cáceres.
- Augustin, N.H., Muggleston, M.A. & Buckland, S.T.** 1996. An autologistic model for spatial distribution of wildlife. *J. Appl. Ecol.* **33**: 339–347.
- Balbontín, J.** 2005. Identifying suitable habitat for dispersal in Bonelli's eagle: an important issue in halting its decline in Europe. *Biol. Conserv.* **12**: 74–83.
- Beck, J.B. & Shultz, E.K.** 1986. The use of relative operating characteristic ROC curve in test performance evaluation. *Arch. Pathol. Lab. Med.* **110**: 13–20.
- Berg, A. & Gustafson, T.** 2007. Meadow management and occurrence of corncrake *Crex crex*. *Agri. Ecosyst. Environ.* **120**: 139–144.
- Bergier, P.** 1987. Les rapaces diurnes du Maroc. Statut, répartition et Ecologie. *Annales du CEEP* **3**.
- BirdLife International/European Bird Census Council.** 2000. *European Bird Populations: Estimates and Trends*. BirdLife Conservation Series No. 10. Cambridge: BirdLife International.
- Brown, L. & Amadon, D.** 1968. *Eagles, Hawks and Falcons of the World*. New York: McGraw-Hill.
- Bustamante, J. & Seoane, J.** 2004. Predicting the distribution of four species of raptors Aves: Accipitridae in southern Spain: statistical models work better than existing maps. *J. Biogeogr.* **31**: 295–306.
- Carbajo, F. & Ferrero, J.J.** 1985. On the ecology and status of the Black-shouldered Kite (*Elanus caeruleus*) in Extremadura, SW Spain. In Newton, I. & Chancellor, R.D. (eds) *World Conference on Birds of Prey: Conservation Studies on Raptors*. Cambridge, MA: ICBP Tech. Publ. No. 5.
- Carrete, M. & Donazar, J.A.** 2005. Application of central-place foraging theory shows the importance of Mediterranean *dehesas* for the conservation of the cinereous vulture, *Aegypius monachus*. *Biol. Conserv.* **126**: 582–590.
- Carrillo, C., Barbosa, A., Valera, F., Barrientos, R. & Moreno, E.** 2007. Northward expansion of a desert bird: effects of climate change. *Ibis* **149**: 166–169.
- Cohen, J.** 1960. A coefficient of agreement for nominal scales. *Educ. Psychol. Meas.* **20**: 37–46.
- Costa, T.M., Morla, C. & Sáinz, H.** 2005. *Los Bosques Ibéricos. Una Interpretación Geobotánica*. Barcelona: Editorial Planeta.
- Cramp, S. & Simmons, K.E.L. (eds)** 1980. *The Birds of the Western Palearctic*, Vol. 2. Oxford: Oxford University Press.
- Crick, H.Q.P.** 2004. The impact of climate change on birds. *Ibis* **146**: 48–56.
- Del Hoyo, J., Elliot, A. & Sargatal, J. (eds)** 1994. *Handbook of the Birds of the World*, Vol. 2. Barcelona: Lynx Edicions.
- Duchateau, S. & Delage, F.** 2006. Évolution, paramètres reproducteurs et facteurs limitants de l'Élanion blanc *Elanus caeruleus* dans le sud-ouest de la France. *Alauda* **74**: 385–398.
- Elena, M., López, J.A., Casas, M. & Sánchez del Corral, A.** 1987. *El Carbón de Encina y la Dehesa*. Madrid: INIA, Ministerio de Agricultura, Pesca y Alimentación.
- England, M.D.** 1963. Observations on the Black-winged Kite in Portugal, with preliminary notes on its status. *Br. Birds* **56**: 444–452.
- Fernández, N., Delibes, M., Palomares, F. & Mladenoff, D.J.** 2003. Identifying breeding habitat for the Iberian Lynx: inferences from a fine-scale spatial analysis. *Ecol. Appl.* **13**: 1310–1324.
- Ferrer, M. & Harte, M.** 1997. Habitat selection by immature Spanish imperial eagles during the dispersal period. *J. Appl. Ecol.* **34**: 1359–1364.
- Ferrero, J.J. & Onrubia, A.** 1998. Expansión del área de cría y distribución actual del Elanio Común *Elanus caeruleus* en España. In Meyburg, B.-U., Chancellor, R.D. & Ferrero, J.J. (eds) *Holarctic Birds of Prey*: 159–171. Berlin: WWGBP-Adenex.
- Ferrero, J.J. & Onrubia, A.** 2003. Elanio común *Elanus caeruleus*. In Martí, R. & del Moral, J.C. (eds) *Atlas de las Aves Reproductoras de España*: 158–159. Madrid: Dirección General de Conservación de la Naturaleza-Sociedad Española de Ornitología.
- Ferrero, J.J., Grande, J.M. & Negro, J.J.** 2003. Copulation behavior of a potentially double-brooded bird of prey, the Black-shouldered Kite *Elanus caeruleus*. *J. Raptor Res.* **37**: 1–7.
- Fielding, A.H. & Bell, J.F.** 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environ. Conserv.* **24**: 38–49.
- IPCC.** 2001. Climate change 2001: the Scientific Basis. In Albritton, D.L. & Meira Filho, L.G. (eds) *Third Assessment Report of Working Group I*. Cambridge: Cambridge University Press.
- Landis, J.R. & Koch, G.G.** 1997. The measurement of observer agreement for categorical data. *Biometrics* **33**: 159–174.
- Lilford, L.** 1865. Notes on the ornithology of Spain. *Ibis* (2) **1**: 166–177.
- Manel, S., Williams, H.C. & Omerod, S.J.** 2001. Evaluating presence-absence models in ecology: the need to account for prevalence. *J. Appl. Ecol.* **38**: 921–931.
- Mañosa, S., Montés, G., Bota, G. & Bonfil, J.** 2005. Black-shouldered Kite *Elanus caeruleus* diet in an area recent colonized in the north-east of the Iberian peninsula. *Revista Catalana d'Ornitologia* **21**: 11–16.
- Marti, R. & Del Moral, J.C. (eds)** 2004. *Atlas of Breeding Birds of Spain: 1998–2002*. Madrid: Dirección General de Conservación de la Naturaleza-Sociedad Española de Ornitología.

- Martin, A. & Alés, R.F.** 2006. Long term persistence of dehesas. Evidences from history. *Agroforest. Syst.* **67**: 19–28.
- Martínez, J.A., Serrano, D. & Zuberogoitia, I.** 2003. Predictive models of habitat preference for the Eurasian eagle owl *Bubo bubo*: a multiscale approach. *Ecography* **26**: 21–28.
- Mathsoft, I.** 1999. *S-plus 2000 Guide to Statistics*. Seattle, WA: Data Analysis Products Division.
- McCullagh, P. & Nelder, J.A.** 1989. *Generalized Linear Models*, 2nd edn. Monographs on Statistics and Applied Probability. London: Chapman and Hall.
- Mendelsohn, J.M. & Jaksic, F.M.** 1989. Hunting behaviour of Black-shouldered Kites in the Americas, Europe, Africa and Australia. *Ostrich* **60**: 1–12.
- Mendelsohn, J.M.** 1982. The feeding ecology of the Black shouldered Kite *Elanus caeruleus* Aves: Accipitridae. *Durban Mus. Novit.* **13**: 75–116.
- Mendelsohn, J.M.** 1983. Social-behaviour and dispersion of Black-shouldered Kite. *Ostrich* **54**: 1–18.
- Negro, J.J., Pertoldi, C., Randi, E., Ferrero, J.J., López-Caballero, J.M., Rivera, D. & Korpimäki, E.** 2006. Convergent evolution of *Elanus* kites and the owls. *J. Raptor Res.* **40**: 222–225.
- O'Connor, R.J. & Shrubbs, M.** 1986. *Farming and Birds*. Cambridge: Cambridge University Press.
- Osborne, P.E., Alonso, J.C. & Bryant, R.G.** 2001. Modelling landscape-scale habitat use using GIS and remote sensing: a case study with great bustard. *J. Appl. Ecol.* **29**: 458–471.
- Pain, D.J., Hill, D. & McCracken, D.I.** 1997. Impact of agricultural intensification of pastoral systems on bird distributions in Britain 1970–1990. *Agri. Ecosyst. Environ.* **64**: 19–32.
- Pain, D.J. & Pienkowski, M.W.** 1997. *Farming and Birds in Europe*. London: Academic Press.
- Parejo, D., Aviles, J.M., Ferrero, J.J., Rivera, D. & Casas, J.M.** 2001. Communal roosting and diet of Black-shouldered Kites (*Elanus caeruleus*) wintering in southwestern Spain. *J. Raptor Res.* **35**: 162–164.
- Rivera, D., Negro, J.J., Balbontín, J., Casas, J.M., Ferrero, J.J. & Sarasola, J.H.** 2006. Seguimiento de una población extremeña de Elanio azul. *Quercus* **239**: 10–15.
- Román-Muñoz, A., Real, R., Márcia Barbosa, E. & Mario Vargas, J.** 2005. Modelling the distribution of Bonelli's eagle in Spain: implications for conservation planning. *Divers. Distrib.* **11**: 477–486.
- Roulin, A. & Wink, M.** 2003. Predator–prey polymorphism: relationships and the evolution of colour: a comparative analysis in diurnal raptors. *Biol. J. Linn. Soc.* **81**: 565–578.
- Sánchez-Zapata, J.A. & Calvo, F.J.** 1999. Raptor distribution in relation to landscape composition in semi-arid Mediterranean habitats. *J. Appl. Ecol.* **36**: 245–262.
- Scott, T.A.** 1994. Irruptive dispersal of Black-shouldered Kites to a coastal island. *Condor* **96**: 197–200.
- Seoane, J., Viñuela, J., Díaz-Delgado, R. & Bustamente, J.** 2003. The effects of land use and climate on red kite distribution in the Iberian peninsula. *Biol. Conserv.* **111**: 401–414.
- Sergio, F., Rizzolli, L., Marchesi, L. & Pedrini, P.** 2004. The importance of interspecific interactions for breeding-site selection: peregrine falcons seek proximity to raven nests. *Ecography* **27**: 818–826.
- Smiths, A.C.** 1868. A sketch of the birds of Portugal. *Ibis* (2) **4**: 428–460.
- Soriguer, R.C., Carro, F., Márques, F.J. & Fandos, P.** 2003. La diversidad y abundancia de los Micromamíferos Ibéricos. In Perez Jiménez, J.M (ed) *In Memoriam al Profesor Isidro Ruiz Martínez*: 439–478. Jaén: Universidad de Jaén.
- Suárez, F., Naveso, M.A. & De Juana, E.** 1997. Farming in the dry lands of Spain: birds of the pseudo-steppes. In Pain, D.J. & Pienkowski, M.W. (eds) *Farming and Birds in Europe. The Common Agricultural Policy and its implications for Bird Conservation*: 297–330. London: Academic Press.
- Suárez, S., Balbontín, J. & Ferrer, M.** 2000. Nesting habitat selection by booted eagles *Hieraetus pennatus* and implications for management. *J. Appl. Ecol.* **37**: 215–223.
- Suárez-Seoane, S., Osborne, P.E. & Baudry, J.** 2002. Response of birds of different biogeographic origins and habitat requirements to agricultural land abandonment in northern Spain. *Biol. Conserv.* **105**: 333–344.
- Tucker, G.M., Heath, M.F., Tomialojć, L. & Grimmett, R.F.A.** 1994. *Birds in Europe: Their Conservation Status*. BirdLife Conservation, Series 3. Cambridge: BirdLife International.
- Valiela, I. & Bowen, J.L.** 2003. Shifts in winter distribution in birds: effects of global warming and local habitat change. *Ambio* **32**: 476–480.
- Zweig, M.H. & Campbell, G.** 1993. Receiver-operating characteristics ROC plots: a fundamental evaluation tool in clinical medicine. *Clin. Chem.* **39**: 561–577.

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