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, 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 km² 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.
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
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$^2$).

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 radiotracking 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, 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.

#### Table 1. Explanatory variables in occurrence models used to predict breeding habitat of Black-shouldered Kites in circular sampling areas of c. 6 km$^2$ located in Extremadura, southwestern Spain.

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>TREE</td>
<td>% of tree patches, mainly <em>Eucalyptus</em> sp.</td>
</tr>
<tr>
<td>DEHECEREAL L1</td>
<td>% of <em>dehesas</em> with dispersed density of trees &lt; 7 trees/ha (L1 = Level 1) over non-irrigated crops</td>
</tr>
<tr>
<td>DEHECEREAL L2</td>
<td>% of <em>dehesas</em> with medium density of trees 7–20 trees/ha (L2 = Level 2) over non-irrigated crops</td>
</tr>
<tr>
<td>DEHELIVESTOCK</td>
<td>% of <em>dehesas</em> used for livestock raising with a tree density of 20–40 tree/ha</td>
</tr>
<tr>
<td>SCRUB</td>
<td>% of scrub</td>
</tr>
<tr>
<td>NIRRIGA</td>
<td>% of non-irrigated crops</td>
</tr>
<tr>
<td>IRRIGA</td>
<td>% of irrigated crops</td>
</tr>
<tr>
<td>VINEYARD</td>
<td>% of vineyard</td>
</tr>
<tr>
<td>OLIVE</td>
<td>% of olive groves</td>
</tr>
<tr>
<td>PASTU</td>
<td>% of pasture</td>
</tr>
<tr>
<td>DRIVER</td>
<td>distance (m) to nearest river</td>
</tr>
<tr>
<td>DROAD</td>
<td>distance (m) to nearest road</td>
</tr>
<tr>
<td>DVILLA</td>
<td>distance (m) to nearest village</td>
</tr>
</tbody>
</table>
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, neighbours of squares i (Augustin et al. 1996). For this purpose, we built a grid covering our study area of 70 × 70 km formed by squares of similar size as the breeding territories (grid size 2850 m (2 × 1425 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
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 ± se) of 0.62 ± 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 ± se) of 0.79 ± 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 & Shrubb 1986, Pain & Pienkowski 1997, Pain *et al.* 1997, Berg & Gustafson...
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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

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.
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 Hieraaetus 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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