

# HABITAT SUITABILITY MODELS FOR ASSESSING BIRD CONSERVATION GOALS IN ‘SPECIAL PROTECTION AREAS’

## USO DE MODELOS DE HÁBITAT PARA EVALUAR OBJETIVOS DE CONSERVACIÓN EN “ZONAS DE ESPECIAL PROTECCIÓN PARA LAS AVES”

José María FERNÁNDEZ<sup>1</sup> \* and Mikel GURRUTXAGA<sup>2</sup>

**SUMMARY.**—*Habitat suitability models for assessing bird conservation goals in ‘Special Protection Areas’.*

In this study, we have used predictive habitat suitability models to test whether spatial coverage by an SPA classified for Bonelli’s eagle, golden eagle, Egyptian vulture, peregrine falcon, eagle owl and turtle dove achieved conservation goals at home range, foraging and nesting habitat scales. GIS data and high-resolution modelling techniques were useful in demonstrating insufficient spatial coverage, mainly for foraging habitats associated with lowland and agricultural areas. This lack of coherence between formal conservation goals and spatial needs of populations was related to SPA design based on expert judgement, or taking into account only incomplete or short-term occurrence data. Spatial improvements in SPA design were suggested, to increase perspectives for long-term species persistence.

**Key words:** conservation goals, foraging habitat, nesting habitat, Northern Spain, predictive models, raptors, Special Protection Areas.

**RESUMEN.**—*Uso de modelos de hábitat para evaluar objetivos de conservación en “Zonas de Especial Protección para las Aves”.*

En este estudio se emplearon modelos de hábitat y predictivos para evidenciar si la cobertura espacial de una ZEPa clasificada para águila-azor perdicera, águila real, alimoche común, halcón peregrino, búho real y tórtola europea, cubría los objetivos de conservación a escalas de dominio vital, hábitats de alimentación y de nidificación. Los datos en formato SIG y las técnicas de modelización a escala de detalle sirvieron para mostrar insuficiencias, sobre todo en cuanto a hábitats de alimentación, asociados a fondos de valle y terrenos agrícolas. Esta falta de ajuste entre objetivos de conservación y requerimientos espaciales de las poblaciones se relacionó con un diseño de la ZEPa basado en criterio experto, en datos incompletos o procedentes de censos puntuales. Se sugirieron mejoras en el diseño espacial de la ZEPa, con el fin de incrementar las perspectivas de conservación de las especies a largo plazo.

**Palabras clave:** aves rapaces, hábitat de alimentación, hábitat de nidificación, modelos predictivos, norte de España, objetivos de conservación, Zona de Especial Protección para las Aves.

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<sup>1</sup> IKT SA. Granja Modelo s/n, E-01192 Arkaute, Álava, Spain.

<sup>2</sup> Departamento de Geografía, Prehistoria y Arqueología, Universidad del País Vasco. E-01006 Vitoria, Álava, Spain

\* Corresponding author: jfernandez@ikt.es

## INTRODUCTION

Selection and management of protected areas is one of the most commonly used tools for the conservation of populations and species worldwide (Godet *et al.*, 2007; Jackson *et al.*, 2009). As a consequence, the science behind reserve design has been an active topic in conservation literature since the 90s (Pressey *et al.*, 1993). Part of the debate has been focused on implementation of algorithms to maximise protection (i.e. size and number of populations included within the reserve network) while minimising areas (number or surface, i.e. costs) and ensuring long-term persistence of target species (Pressey *et al.*, 1996; Cabeza and Moilanen, 2001; Chave *et al.*, 2002; Carroll *et al.*, 2003). Habitat suitability and ecological niche models have become important tools for assessing the performance of reserve networks in meeting species conservation goals (Williams and Araújo, 2000; Cabeza *et al.*, 2004). Paradoxically, these approaches have not been extensively applied in real conservation planning. Although conservation practitioners need to make decisions at detailed (i.e. plot, patch, site) scale, model resolution is not always suitable for addressing local conservation problems (Araújo *et al.*, 2004; Moilanen, 2005; Márcia *et al.*, 2010). This lack of fine-grain studies may result in low effectiveness of protected areas, i.e. the extent to which these areas maintain relevant biodiversity features (Gaston *et al.*, 2006).

Special Protection Areas (SPAs) are designated by national authorities within the framework of the European Birds Directive (2009/147/UE, previously 79/409/CEE). These areas constitute the basic policy instrument for the conservation of bird species and their habitats in the European Union, with the aim of including the most suitable territories for the survival and reproduction of target bird species, either migratory or listed in Annex I of Directive 2009/147/UE. But no

standard procedures have been established for assessing, within a scientific framework, whether the obligation imposed by the Directive regarding those targets is actually being satisfied at individual SPA level (López *et al.*, 2007a). In other words, the question is whether spatial resources protected within SPA boundaries allow survival and reproduction of populations of target species. Where they have been carried out, assessments tend to rely on expert judgement, which may be biased by uncertain, out-of-date or incomplete data on bird distribution, abundance or habitat selection.

In this paper, we explore the options for applying GIS data on local bird occurrence together with predictive habitat suitability models with the object of addressing several practical conservation issues: in particular, the importance of patches for fulfilling the spatial needs of given bird species at the levels of (1) home range, (2) nesting habitat and (3) foraging habitat. Home ranges for territorial individuals incorporate all ecological requirements for survival and reproduction, whilst nesting and foraging habitats refer to particular needs (Newton, 1998). Validation of spatial modelling as a tool to adapt actual design of SPAs or bird reserves to specific targets could be beneficial for long term conservation of bird populations.

## MATERIAL AND METHODS

Our study area was the Basque Country, a region of 7,230 km<sup>2</sup> in northern Spain. The SPA network comprises six sites and 5.3% of the territory. The regional government is responsible for SPA selection and management. We focused in particular on SPA ES000246 ‘Sierras Meridionales de Álava’ (42° 36’ N 2° 36’ W, 16,425 ha; figure 1), which was designated to preserve populations of Bonelli’s eagle *Hieraaetus fasciatus*, golden eagle *Aquila chrysaetos*, Egyptian

vulture *Neophron percnopterus*, peregrine falcon *Falco peregrinus*, eagle owl *Bubo bubo* and turtle dove *Streptopelia turtur*. The boundaries of this SPA were delimited by regional authorities on an 'expert knowledge' basis.

As bird occurrence data, we used the precise current (2005-2008) locations of nesting sites for golden eagle, Egyptian vulture, peregrine falcon and eagle owl, compiled from official censuses of diurnal raptors (Fernández and Gainzarain, 2009; Illana and Martínez de Lecea, 2009; Zuberogoitia, 2009), and our own field data for eagle owl. Potential breeding sites were surveyed in November-December (eagle owl) or February-April (other species), and occupation of particular cliffs by pairs was checked through observation of typical territorial or reproductive behaviours (Hardey *et al.*, 2006).

In the study area the only species with direct satellite-tracking data and actual home range estimation is Bonelli's eagle (C. Fernández and P. Azkona, unpublished). We checked SPA coverage for home range (minimum convex polygon and kernel polygons with 95% and 50% probability of occurrence; White and Garrott, 1990) estimated from available locations (N = 49) during 2007 for the female of the only existing territorial pair (Fernández and Azkona, 2006).

Specific extensions of home ranges for golden eagle, Egyptian vulture, peregrine falcon and eagle owl were locally estimated through average distance to nearest neighbour's core area of territory, as shown by nesting sites, calculated with the Animal Movement extension in GIS software ArcView 3.2. Regularity of spacing of territories was assessed by means of the G-statistic, calculated as the ratio between the geometric and the arithmetic mean of the squared nearest neighbour distance. The index ranged from 0 to 1; values > 0.65 indicated a uniform distribution (Penteriani *et al.*, 2001; Brambilla *et al.*, 2006).

Predictive niche models for golden eagle, Egyptian vulture, peregrine falcon and eagle owl nesting habitats were performed with MaxEnt (Phillips and Dudik, 2008), a software frequently used for this purpose at regional scale (Suárez-Seoane *et al.*, 2008; Stachura *et al.*, 2009). The method assigns an occurrence probability to each grid cell within the study area by means of a logistic function. Higher function values (close to 1) indicate more suitable conditions for the given species, while unsuitable habitats are indicated by lower function values (close to 0). MaxEnt allows presence-only data and environmental variables with fine-grain resolution, both continuous and categorical. We used the bird occurrence data described above as the response variable. Predictor variables were climatic (average temperature, annual rainfall), topographic (slope, orientation and altitude), biotic (habitat types proposed by the European Environment Agency in the EUNIS classification of habitats) and related to human pressure (intensity of land use, distance to roads and urbanised areas). Environmental data were provided by the Basque Government information system (<http://www.geo.euskadi.net/s69-15375/es/>) and introduced in MaxEnt at 100 x 100 m resolution.

Predictive models for bird nesting habitats were tested against 30% of random nesting sites, through receiver operating characteristic (ROC) curves. The value of area under curve (AUC) for test data indicates the prediction ability of the model, and values > 0.80 are considered accurate predictions (Fielding and Bell, 1997).

For the assessment of foraging habitats, we applied an indirect approach measuring ecotones or ecological boundaries (Fortin and Dale, 2005) as a proxy for rabbit *Oryctolagus cuniculus* and red-legged partridge *Alectoris rufa* abundance, as these animals form the bulk of prey species for golden eagle and eagle owl in the study area (Fernández, 1993).

We used a digital layer of the EUNIS habitat map at 1:10,000 scale, and reclassified EUNIS polygons into four structural categories: forest, shrubland, pastureland and cropland. Using GIS software (ArcView 3.2), we measured the length of borders of adjoining patches of shrubland, pastureland and cropland (cereal and vineyard), within the twenty-two 1 km sections of the southern

SPA boundary, to a depth of 0.25 km and 0.5 km on either side. We did not consider northern boundary because it is not included or close to prey-rich areas for large-sized raptors, as shown by annual hunting bags from game preserves (Asociación de Cotos de Caza de Álava, unpublished). We also excluded from analysis the few sections of the southern boundary that coincide with

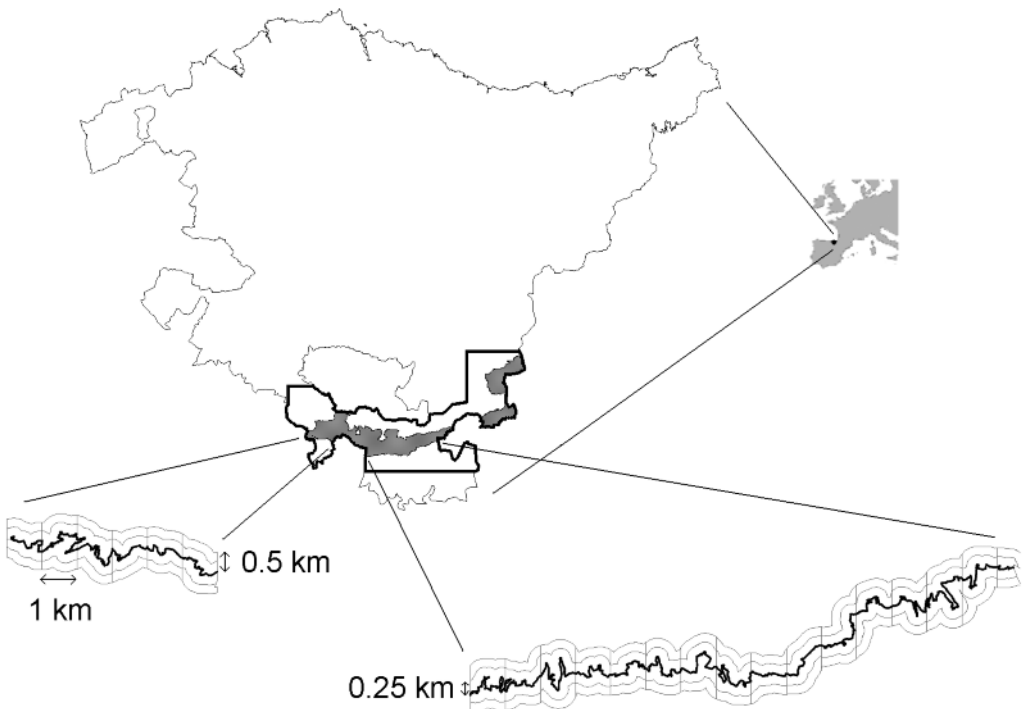


FIG. 1.—Study area: Basque Country in northern Spain and SPA ES000246 ‘Sierras Meridionales de Álava’ (shaded). The thick line indicates the geographic framework for the assessment of the SPA coverage in relation to nesting habitat suitability models for golden eagle, Egyptian vulture, peregrine falcon and eagle owl. The twenty-two 1 km long sections along the southern SPA boundary, where length of edges and percentage of habitat types were measured to a depth of 0.5 km and 0.25 km on either side of the boundary, are also shown.

[Área de estudio: País Vasco, en el norte de España, y ZEPa ES000246 “Sierras Meridionales de Álava” (sombreada). La línea gruesa enmarca el sector geográfico sobre el que se evaluó la cobertura de la ZEPa en relación con los modelos de adecuación del hábitat de nidificación para el águila real, el alimocho común, el halcón peregrino y el búho real. Se muestran también las 22 secciones de 1 km de longitud en las que se midió la longitud de ecotonos y el porcentaje ocupado por distintos tipos de hábitat, en bandas de 0,5 y 0,25 km de anchura, hacia el interior y hacia el exterior de la ZEPa.]

the border between the Basque Country and neighbour regions.

Finally, we used GIS software and the reclassified EUNIS habitat map to check the percentage cover of forested stands (basically holm-oak *Quercus ilex* woodland), shrubland, pastureland and cropland in the same inner and outer strips along the 1 km sections mentioned above. We measured the proportion of each habitat type in each pair of inner and outer strips along the SPA boundary, so as to compare availability of favourable turtle dove breeding habitats.

Differences between inner and outer strips were assessed by means of paired two-tailed Student's t-tests. Homogeneity of variances had been previously assessed by the Levene test. Where these were not homogeneous, a Wilcoxon signed ranks test was used instead. Statistical analysis was performed with SPSS 17.0. Values shown are mean  $\pm$  SE and range (minimum-maximum).

## RESULTS

Average distance to nearest neighbour nest for peregrine falcon was  $4.3 \pm 0.5$  km ( $N = 7$ ) and spacing pattern in this population was regular ( $G = 0.89$ ). So, theoretical home ranges in the study area should be around 20 km<sup>2</sup>, and two out of seven home ranges were insufficiently covered (less than 75% of its surface) by SPA ES000246. For golden eagle, average distance to nearest neighbour nest was  $7.3 \pm 0.8$  km ( $N = 5$ ); the spacing pattern was also regular ( $G = 0.86$ ) and theoretical home ranges were around 45 km<sup>2</sup>. Every golden eagle home range was inadequately covered. G tests applied to the Egyptian vulture and eagle owl nesting site distances showed clumped distribution of both species, so it was decided not to use the indirect approach to home range estimation.

The home range of the Bonelli's eagle clearly extended outside the SPA ES000246.

Only 29% of its home range, as estimated by minimum convex polygon, was included in the SPA. Using kernel estimators, 33% of home range (kernel 95%) and 38% of core home range (kernel 50%) were covered.

For the predictive models for nesting habitats, areas under curve (AUC) for test data were 0.869 for golden eagle, 0.871 for Egyptian vulture, 0.877 for peregrine falcon and 0.857 for eagle owl. In all cases, Jackknife randomization tests as implemented in MaxEnt (Phillips *et al.*, 2006) selected slope as the variable contributing most to models, with land use in second position. Considering an external framework for SPA ES000246 (figure 1), several adjacent, discrete areas could be identified containing aggregations of pixels with high favourability indices ( $> 0.75$ ) as nesting sites (figure 2).

The average length of edges between shrublands, pasturelands and croplands as measured in 0.5 km wide strips was significantly lower in inner strips than in outer strips ( $t_{21} = -2.86$ ,  $P = 0.009$ ; table 1). For the 0.25 km wide strips, the average length of edges was also lower in inner strips, but the difference did not reach statistical significance ( $t_{21} = -1.79$ ,  $P = 0.08$ ).

Average percentage of land cover for holm-oak woodland as measured in 0.5 km wide strips was significantly larger in inner strips than in outer strips ( $Z = -3.98$ ,  $P = 0.001$ ). As for 0.25 km wide strips, the difference in favour of inner strips was also statistically significant ( $Z = -3.51$ ,  $P = 0.001$ ).

Average percentage cover of shrubland was significantly larger in inner strips than in outer strips, either measured to a depth of 0.5 km ( $t_{21} = 3.93$ ,  $P = 0.001$ ) or 0.25 km ( $t_{21} = 4.11$ ,  $P = 0.001$ ). Finally, pastureland plus cropland occupied a much lower average percentage cover in inner strips than in outer strips, whether measured in 0.5 km wide strips ( $t_{21} = -8.25$ ,  $P = 0.001$ ) or 0.25 km wide strips ( $Z = -4.07$ ,  $P = 0.001$ ).

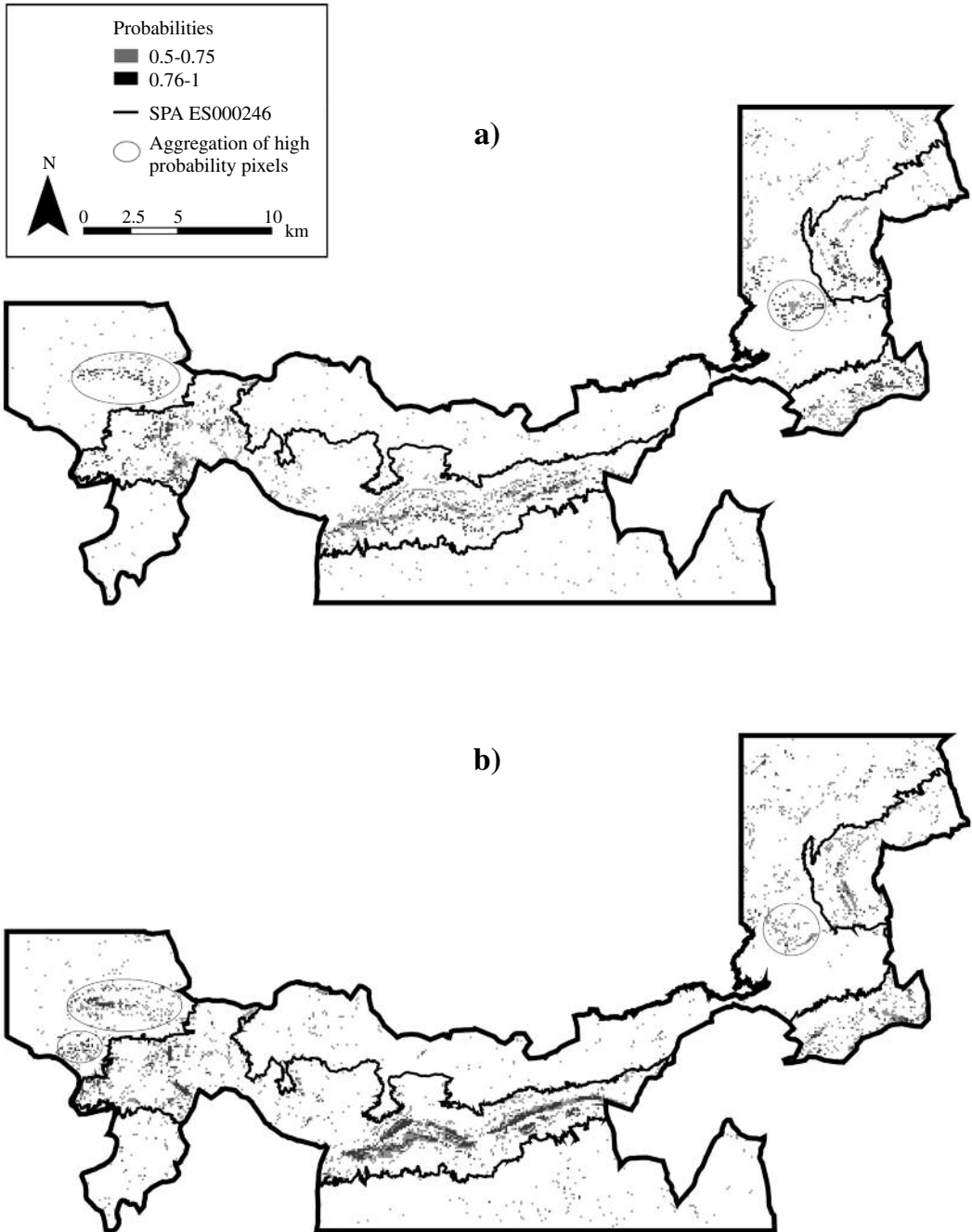


FIG. 2.—Predictive maps showing probabilities of occurrence for golden eagle (a), Egyptian vulture (b), peregrine falcon (c) and eagle owl (d) nesting habitats in the study area. Areas with aggregation of high probability pixels ( $> 0.75$ ) adjacent to SPA ES000246 are indicated.



FIG. 2. (cont.)—[Mapas predictivos de probabilidad de aparición para los hábitats de nidificación del águila real (a), alimoche común (b), halcón peregrino (c) y búho real (d) en el área de estudio. Se indican áreas adyacentes a la ZEPA ES000246 con agregación de píxeles de alta probabilidad ( $> 0,75$ ).]

TABLE 1

Length of edges between patches of shrubland, pastureland and arable land, and percentage of land cover for holm-oak woodland, shrubland and pastureland plus cropland, measured in inner and outer 0.5 km and 0.25 km wide strips along the twenty two 1 km sections of the SPA ES000246 southern boundary. The statistical significance of differences between inner and outer strips is shown by P-values.

[Longitud de bordes entre teselas de matorral, pastizal y cultivos, y porcentaje de cobertura de encinar, matorral y pastizal más cultivo, medidos en bandas de 0,5 y 0,25 km de anchura, interiores y exteriores al límite meridional de la ZEPA ES000246, a lo largo de 22 secciones de 1 km de longitud. Se muestra la significación estadística de las diferencias entre las bandas interiores y exteriores con el valor P.]

|                              | 0.5 km wide strips |            |              |            |        |
|------------------------------|--------------------|------------|--------------|------------|--------|
|                              | Inner              |            | Outer        |            | P      |
|                              | Mean ± SE          | Range      | Mean ± SE    | Range      |        |
| Edges (km)                   | 3.25 ± 0.74        | 0-12.51    | 5.77 ± 0.53  | 0.8-11.15  | 0.009  |
| Holm-oak woodland (%)        | 13.87 ± 3.20       | 0-61.58    | 0.63 ± 0.28  | 0-5.75     | 0.0001 |
| Shrubland (%)                | 24.17 ± 3.37       | 2.58-63.18 | 7.57 ± 2.16  | 0.1-41.18  | 0.001  |
| Pastureland and cropland (%) | 40.17 ± 5.14       | 3.6-83.57  | 83.65 ± 3.05 | 52.6-99.29 | 0.001  |

|                              | 0.25 km wide strips |            |              |             |       |
|------------------------------|---------------------|------------|--------------|-------------|-------|
|                              | Inner               |            | Outer        |             | P     |
|                              | Mean ± SE           | Range      | Mean ± SE    | Range       |       |
| Edges (km)                   | 2.32 ± 0.48         | 0-8.28     | 3.4 ± 0.33   | 0.56-6.22   | 0.08  |
| Holm-oak woodland (%)        | 7.09 ± 2.29         | 0-44.9     | 0.6 ± 0.22   | 0-3.81      | 0.001 |
| Shrubland (%)                | 25.21 ± 3.42        | 3.2-56.07  | 7.73 ± 2.35  | 0-46.79     | 0.001 |
| Pastureland and cropland (%) | 50.69 ± 5.56        | 6.28-91.89 | 85.17 ± 2.88 | 45.56-99.13 | 0.001 |

## DISCUSSION

Supporting conservation planning and selection of reserves are among the main applied uses for predictive modelling of species distributions (Ferrier, 2002; Guisan and Thuiller,

2005; Fitzgerald *et al.*, 2008). Although models have obvious advantages in remote regions or where only opportunistic, incomplete data are available (Guisan and Thuiller, 2005; Costa *et al.*, 2010), they can also maximize the utility of biodiversity data in other



contexts. For instance, habitat suitability is correlated to population persistence (Cabeza *et al.*, 2004; Rodríguez *et al.*, 2007), so the efficiency of reserve selection and management would benefit from identification and protection of optimal areas.

In our case, validation of a previously designated SPA through consideration of habitat-specific requirements and their spatial perspective led to the identification of several weaknesses as far as the conservation of target species was concerned. For instance, the exclusion of highly favourable nesting habitats for golden eagle, Egyptian vulture, peregrine falcon and eagle owl from SPA ES000246 has probably decreased the biological coherence and efficiency of this protected area. First, an improvement of the conservation status of these populations would require the establishment of new territorial pairs in currently vacant territories. Second, reproductive strategies of these raptors include nesting site rotation (Fernández and Azkona, 1993; García and López, 2006), to cope with ectoparasite loads and expropriation of nests by other cliff-nesting species, like the griffon vulture *Gyps fulvus* (Fernández and Donazar, 1991), whose population in the study area and elsewhere in Spain has greatly increased in recent decades (Parra and Tellería, 2004). As a result, potential alternative nesting sites not indicated by short-term censuses should also be protected.

Detected bias was caused by (1) absence of information about species occurrence at scales that are also important for habitat selection, like home ranges or foraging sites, and (2) use of criteria to design the SPA other than habitats for target birds ('*ad hoc* reserve selection' in the terminology of Pressey, 1994). For the first source of bias, large birds and raptors in particular present multiscale habitat selection patterns (Martínez *et al.*, 2003; Brambilla *et al.*, 2006; López *et al.*, 2007b) that should be accounted for in reserve design. For the second, SPAs have sometimes

been delimited on the basis of land property, excluding private estates to avoid conflicts with landowners. Alternatively, SPA limits have been fitted to 'mature' or extensively managed habitats, like forests, excluding ecotones and arable land, which are prey-rich (Lombardi *et al.*, 2003), foraging areas for raptors in Mediterranean ecosystems (Sergio *et al.*, 2006; Martínez *et al.*, 2007). As a consequence of mismatches between explicit goals and policy in actual reserve designation, improvement of conservation status for target species is unlikely to occur (Bonn and Gaston, 2005). But only criteria based on bird habitats can be employed in SPA design, as the European Court of Justice has laid down in its interpretation of the stipulations of the Birds Directive (judgments in cases C-355/90, C-44/95, C-3/96 and C-378/01).

Despite their increased use at continental or national scales (e.g. Beresford *et al.*, 2010), there are still few examples of bird habitat suitability models being applied at the local scale as an aid to practical decision making. This is partly due to either low availability of high-resolution environmental data or lack of databases with fine-grain species distribution data (Brambilla *et al.*, 2009; Márcia *et al.*, 2010). But conservation practitioners often face conflicts in local contexts, and spatial models have proved useful for assessing the appropriateness of reserve limits and of management options on target bird species, in a given SPA (Seoane *et al.*, 2006).

An expert-based approach to delimiting reserves seems to have been widely applied in Spain and elsewhere (López *et al.*, 2007a). Although this technique can incorporate pragmatic management options (Cowling *et al.*, 2003), it tends to exclude lowland and agricultural areas that may have a relevant role in fulfilling species-specific requirements (Jiguet and Villarrubias, 2004; Guisan and Thuiller, 2005; Seoane *et al.*, 2005). In our study area, we detected insufficient coverage and protection in relation to foraging habitats

for Bonelli's eagle and golden eagle, and possibly Egyptian vulture and eagle owl.

On the contrary, turtle dove breeding habitat selection favours forested stands including patches of shrubs (Browne and Aebischer, 2003; Bakaloudis *et al.*, 2009). A probabilistic model for turtle dove breeding habitat selection, developed in our study area (M. Sáenz de Buruaga, A. Onrubia, F. Canales, M. Á. Campos and J. M. Fernández, unpublished) described optimal features for the species: holm-oak woodland below an altitude of 750 m, including 20-30% of pastureland or cropland cover and 10-20% of shrubland. The current SPA includes higher quality habitats than off-site. Outside the SPA, we observed the absence of holm-oak woodland and much lower shrubland cover. Again, this was a consequence of designing the SPA to include only forested habitats, regardless of target species and their spatial requirements. But in this case, an extension of the SPA boundary would not improve cover of the turtle dove's preferred breeding habitats.

For the peregrine falcon, habitat selection at home range scale is not influenced by habitat structure (Gainzarain *et al.*, 2000), probably due to its wider prey spectrum, which provides an adequate prey supply regardless of habitat composition and spatial pattern.

Predictive habitat suitability models show limitations and uncertainties, derived from methodological and biological constraints (Seoane and Bustamante, 2001; Guisan and Thuiller, 2005). Modelling current conditions does not take into account history and dynamics in habitat-species relationship (Vallecillo *et al.*, 2009). In addition, in our study we made several assumptions which should be tested in the study area –like circular home ranges– or used surrogates –like length of ecotones for rabbit and partridge abundance (Fortuna, 2002; Gortázar *et al.*, 2002; Virgós *et al.*, 2003). But spatial reserve design can benefit from assessing quantitative local probabilities of occurrence, because

this systematic and cost-effective framework tackles the problem of incomplete or biased sampling (Rodríguez *et al.*, 2007). Moreover, this approach can incorporate connectivity, dispersal and colonization of unoccupied but still suitable sites, which allows metapopulation persistence in fragmented landscapes (Loiselle *et al.*, 2003; Cabeza *et al.*, 2004; Seoane *et al.*, 2006; Van Teeffelen *et al.*, 2006).

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