Appendix A1

Evaluation of the selection criteria for reference and control species

For our analyses purposes of controlling and comparison we selected bird species with similar number of occupied 10 km grid-cells in Peninsular Spain to that of the short-toed eagle *Circaetus gallicus*, (see methods in the main text for more details).

We verified that the selection criteria used through the bird categories was consistent. That is, we tested for no differences between the excluded species of the family *Accipitridae*, selected species of the family *Accipitridae* (reference species) and those selected species different to *Accipitridae* (control species). Firstly, we plotted each of these species regarding their occupancy to visually explore to which extent they are analogous or not to the short-toed eagle. Then, we performed a one-way ANOVA including the number of occupied cells as the dependent variable and the bird categories as the between-subject factor. Post hoc comparisons were performed using Tukey’s HSD test (Quinn and Keough 2002). There were significant differences among the bird categories ($F_{2,23} = 32.57, p < 0.00001$, Fig. A1.1, A1.2), being the occupancy of the excluded species significantly lower than in the other two bird categories (Tukey’s tests: $p < 0.001$ in both cases, Fig. A1.1, A1.2). Moreover, occupancy between reference and control species did not differ significantly ($p = 0.99$, Fig. A1.1, A1.2).
Figure A1.1. Plots of each species regarding their number of occupied cells. a) Species of the family Accipitridae, either excluded (white bars) or selected (grey bars) species; b) Selected species of other bird families (control species). Short-toed eagle (black bar).
Figure A1.2. Mean ± SE of number of occupied grid-cells for the excluded species of the family Accipitridae (Excluded species), for the selected species of the family Accipitridae (Reference species), and for the selected species of other bird families (Control species).

References
Appendix 2

Spatial autocorrelation in GLM and GAM residuals

To examine the spatial autocorrelation in GLM and GAM models including all terms considered in this study, we calculated the Moran’s $I$ autocorrelation index. Moran’s $I$ gives values that ranges from –1 (perfect dispersion) to 1 (perfect clustering), where 0 denotes no autocorrelation at all (random arrangement). Correlograms were obtained with the software spatial analysis in macroecology (SAM, Rangel et al. 2006), which yields Moran’s $I$ values along growing distance classes in the study area.

Figure A2.1. Correlograms of residuals from a) GLM and b) GAM models of the short-toed eagle’s Spanish distribution, including all abiotic and biotic predictors and their first order interactions considered in the study.
For both GLM and GAM residuals, Moran’s $I$ coefficients were close to zero at all distance classes (Fig. A2.1) denoting a weak spatial autocorrelation (GLM: mean ± SE for positive range = 0.004 ± 0.002; mean ± SE for negative range = –0.009 ± 0.001; GAM: mean ± SE for positive range = 0.002 ± 0.001; mean ± SE for negative range = –0.01 ± 0). This indicates that misspecification in models was very low, being the predictor terms considered in this study reasonably representative. The fact, that correlograms of GLM residuals mirrored those of GAM, indicates that other non-linear relationships, in additions to those represented by the interaction terms, are not misspecified in GLM.

**References**

Appendix 3

Assessment of inter-model output variability, GLM vs GAM

We re-run all models described in the methods section of the main text, with the difference that we used here generalized additive models (GAM) instead of GLMs. A key difference is that GAM is a non-parametric model that does not necessarily assume linear relationships between the response variable and predictors (Hastie and Tibshirani 1990). GAMs were built by specifying a binomial distribution and a logit link term. To prevent overfitting the order of splines was limited to four degrees of freedom (Wood and Augustin, 2002). Once the percentages of deviances were obtained from GAMs, we replicated exactly all the same analyses previously performed with GLM’s deviances as explained in the main text.

Results

Testing and controlling for similarities of predictor’s explanatory capacity

The repeated measures ANCOVA showed that there were no significant effects of the bird category on the percentage of explained deviance by the distribution models ($F_{2,48} = 0.64, p = 0.53$). On the other hand, there was a significant main effect of the association with the covariable ($F_{1,24} = 53.85, p < 0.000001$), and the statistical interaction between the bird category factor and the covariable (reference raptor species’ deviances) was significant ($F_{2,48} = 16.06, p < 0.00001; \text{Fig. A3.1}$). This significant interaction shows that the slopes of the regression lines are different. The regression line expressing more similarity with the reference raptor species’ deviances (i.e. closer to the equality between x- and y-axis) was that of the short-toed eagle’s deviance (Fig. A3.1, A3.2a).
Figure A3.1. Linear regressions performed with the deviances explained (%) by each predictor term for the short-toed eagle distribution (solid black line), and the average for the control species (solid grey line) and null models (dashed black line) as a function of the deviances averaged from the reference raptor species modelled (independent variable). Deviances were obtained from each species’ distribution models as a function of each environmental predictor or their first order interactions (see methods). Short-dashed line represents equality between x and y scores.

Focusing on the regression line for the short-toed eagle (Fig. A3.2a), it can be appreciated how the arrangement of several predictor terms changed from crude data of deviances (y-axis in Fig. A3.2a) to residual scores of deviances (Fig. A3.2b). All prey terms except one, and all forest terms except one, had greater deviances than expected from their theoretical correspondence (i.e. the regression line) with the reference raptor species of the same family *Accipitridae* (Fig. A3.2b).
Figure A3.2. (a) Position of each environmental predictor of the distribution models in the linear regression between the deviances explained for the short-toed eagle models and for the average reference species models. Short-dashed line represents equality between x and y scores. (b) Residual scores from the linear regression of the short-toed eagle’s deviances on the reference species’ deviances. Residual scores are ordered as the magnitude of the departure from their expected position in the regression line.
The residual scores of prey terms deviances were significantly different among the bird categories ($F_{2,12} = 7.36, p < 0.01$; Fig. A3.3), being significantly higher for the short-toed eagle than for control species and null models (planned comparison, $F_{1,6} = 9.76, p = 0.02$). There were no significant differences among the bird categories either for forest terms ($F_{2,12} = 1.70, p = 0.22$; Fig. A3.3) nor for the other abiotic terms ($F_{2,24} = 3.35, p = 0.052$; Fig. A3.3).

When performing the same analysis for the prey terms but using the crude data of deviances before controlling for the reference raptor species, the deviance explained by the null models was significantly lower in all cases (repeated measures ANOVA: $F_{2,12} = 15.03, p < 0.001$; Tukey’s HSD tests: $p < 0.01$ in both cases). However, there were no significant differences between the deviances of the short toed eagle and control species for the prey terms ($p = 0.61$). Taken all together, the results obtained from analyses with GAM outputs were the same as those previously performed with GLM outputs.

![Figure A3.3](image-url)

Figure A3.3. Explained deviances for the short-toed eagle, control species and null models corrected by the reference raptor species. Residuals are represented as means ± standard errors of prey richness and its interaction terms (prey terms), density of forest and its interaction terms (forest terms), and the remaining climatic and topographic predictors and its abiotic interaction terms (other terms).
References
