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Modelling the habitat of a wild ungulate in a semi-arid Mediterranean environment in southwestern Europe: Small cliffs are key predictors of the presence of Iberian wild goat

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ABSTRACT

After a drastic contraction in the species' range, the Iberian wild goat *Capra pyrenaica* (Schinz, 1838) has recolonized semi-arid steppe areas where the availability of resources is lower than it is in the species typical habitat. There is a gap in the habitat characteristics that allow the species to survive in an environment that lacks high cliffs and rocky outcrops. We hypothesize that microhabitat characteristics allow the species to find the resources necessary for survival in atypical areas. To test that, we measured several topographic variables (slope, distance to small cliffs and elevation) as well as land use/cover variables (distance to bushes, forests, agriculture, artificial and rivers). To model the habitat in the Middle Ebro Valley, Spain, we used data from 7-yr of monitoring of the species in an averaged-model with Generalized Linear Mixed Model (GLMM-Logit). Distance to small cliffs and distance to bushes explained most of the variance in the model which reflected a fragmented potential habitat. The fragmented structure of the habitat which might act as a metapopulation system, and the spatial configuration of fragments along rivers might act as corridors that favour the dispersal should be taken in consideration in the conservation and management of the species.

1. Introduction

Over centuries human activities have caused the loss of natural populations which has led to contractions in species' ranges (Butchart et al., 2010; Hoffmann et al., 2010). In recent decades, however, socioeconomic changes in Europe and North America have contributed to the recovery of some populations, particularly of wild ungulates (Apollonio et al., 2010). The Iberian wild goat (Capra pyrenaica Schinz, 1838) has responded to those changes (Gortázar et al., 2000), and its recovery is a good example of the phenomenon. The species is endemic to the Iberian Peninsula and, historically has occurred throughout the entire region (Cabrera, 1911). Overexploitation, habitat fragmentation and competition with domestic livestock were the primary reasons for the extinction of two of the four subspecies (Cabrera, 1911; García-González and Herrero, 1999) and the near extinction of the species. Since the 1970s, however, populations of the two extant subspecies of the Iberian wild goat have grown (Fandos, 1989) and have recolonized new areas and been reintroduced into others (Acevedo and Cassinello, 2009; Pérez et al., 2002; Prada and Herrero, 2013), which prompted the IUCN to categorize the species as Least Concern (Herrero and Pérez, 2008). The newly occupied areas include the mountains of Central Iberia, the mountains of the peri-Mediterranean arc, and the South bank of the Ebro River (Acevedo and Cassinello, 2009).

Habitat preferences of the Iberian wild goat include Holm oak

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(*Quercus ilex* L.) forests, pine (*Pinus* sp.) forests, broom (*Cytisus* sp.) scrublands, and the presence of rocky outcrops and cliffs is essential (Acevedo and Cassinello, 2009; Acevedo et al., 2007a, 2007b; Alados, 1985; Escós and Alados, 1992a, 1992b; Gonzales, 1982). In the Middle Ebro Valley (MEV), Spain, however, are few mountain formations, few rocky areas and steppe vegetation is predominant, and there are few forests. The habitat preferences of the Iberian wild goat, as indicated by previous research and used as basis for the conservation and management of the species (Guisan and Zimmermann, 2000) has not included some of the ecosystems in which the species is present and had been present, historically, which limits predictions of the species potential habitat and distribution (Austin, 2002).

Iberian wild goat can have a substantial impact on an ecosystem (Cuartas and García-González, 1992; Zamora et al., 2001) and it has the potential to have a significant affect on the vegetation in a semiarid region where large mammals strongly influence vegetation dynamics (Allred et al., 2012; Manier and Hobbs, 2007). In the highly developed MEV, where agriculture is at the forefront of human–wildlife conflict's, herbivory by Iberian wild goat can cause significant damage to agricultural crops in this highly developed area, where agriculture is one of the primary forms of human–wildlife conflict (Herrero and Pérez, 2008). In addition, the species is a highly prized game animal that is hunted legally in Spain, only, which produces significant economic benefits (Herrero and Pérez, 2008). A study of the species' habitat preferences in recently recolonized areas can improve our understanding about the factors that limit the species' distribution, help to identify unknown areas that provide suitable habitat, and quantify the quality and extent of areas for potential population expansion at a local/range scale (Herrero et al., 2013; Moco et al., 2006; Prada and Herrero, 2013). That information would help in identifying the areas of conflict and benefit, and aid in establishing zoned areas for the conservation and management of the species (Ficetola et al., 2014).

In this study, we investigate the habitat of the Iberian wild goat in a steppe region, with the objectives of (i) identifying the main environmental variables which explain its local distribution and (ii) predicting the potential habitat for the species in the area.

2. Material and methods

2.1. Study area

The study area was the MEV, in the northeastern Iberian Peninsula. The 32,099 km^2 area is delimited at the southwest by Iberian System Mountains (ISM), at the north by Pre-Pyrenees mountains and is towards by the Ebro River Plain (ERP) which crosses the area from the Northwest to the East (Fig. 1).

In the ISM, elevation ranges between 800 and 2313 m, and there are large canyons formed by fluvial erosion over a hard substrate, which has produced a rugged topography at a coarse scale. The ERP has wide valleys that were created by fluvial erosion over a soft, sedimentary soil (clay–limestone with a large proportion of gypsum), which has led to the formation of plateaus because some of the calcareous substrates present in the area have been highly resistant to erosion. Near the Ebro River, elevation ranges from 150 to 800 m, and topographically, at a coarse scale, the area is flat with some high cliffs near the main rivers, and at a fine scale, there are, smaller cliffs along the edges of the plateaus (Pellicer Corellano, 1989).

In the ISM average annual precipitation is > 500 mm, and inter-annual variation is high. Mean temperatures of the coldest and warmest months range spatially from 2.5 to 5 °C and 20–22.5 °C, respectively. A dry and fresh NW–SE wind generates high evapotranspiration rates (AEMET and IM, 2011). In the ERP, average annual precipitation is < 400 mm, inter-annual variation is high, and there are long periods of drought. The mean temperature in the coldest month ranges spatially between 5 and 7 °C, and, in the warmest month temperatures reach 22.5–27.5 °C (AEMET and IM, 2011).

In the ISM, at the time of our study, the predominant vegetation included *Quercus* spp., primarily, *Quercus ilex* L., forests, *Pinus halepensis* Mill., and *Pinus pinaster* Ait., forests, and *Cistus* sp. shrubs. In the ERP the vegetation has been highly transformed and agricultural land is the main habitat type. Natural vegetation include several species of trees (*Juniperus thurifera* L., *Juniperus phoenicea* L.), bushes (*Quercus coccifera* L.), and shrubs (*Rosmarinus officinalis* L., *Rhamnus lycioides* Brot., *Ononis tridentata* L., *Genista* spp., *Artemisia herba-alba* Asso, *Salsola vermiculata* L., *Salsola kali* L., and *Atriplex halimus* L.). In the ERP, the lowlands surrounding the main rivers have been intensively cultivated with fruit trees and irrigated crops, and thus little natural vegetation has remained (Escudero and Franchés, 2004). Iberian wild goat coexists with wild boar *Sus scrofa* L. and roe deer *Capreolus capreolus* L. throughout the whole area (ISM and ERP) and with red deer *Cervus elaphus* L. in some areas (González et al., 2013; Marco et al., 2011).

2.2. Field data

From 2006 to 2012 four systematic seasonal surveys (April, June, October and November) were undertaken by regional rangers and the authors. The surveys were conducted on foot or by car and from vantage points in the Survey Area, a continuous geographic area within Zaragoza province, in the south of the study area (Fig. 1a). In each survey the presence of groups of Iberian wild goat was recorded on a map that had a 200 m × 200 m sampling grid. Using the field data, we created two datasets for the presence of the species: (1) a dataset that was based in a single map that documented the presence of Iberian wild goat for the seven years of study (*presences survey area*: 407 positive cells), which was used to calculate Background Area (BA), Pseudopresence Area (PPA) and Pseudoabsence Area (PAA); and (2) a dataset that was based on individual maps that documented presence in each year, individually (*yearly presences*: a total of 508 positive cells), which were used to calculate and validate the model ($n_{2006} = 11$; $n_{2007} = 41$; $n_{2008} = 54$; $n_{2009} = 65$; $n_{2010} = 112$; $n_{2011} = 85$; $n_{2012} = 140$). The difference between the numbers of presences in the two datasets was a product of the repeated presence of Iberian wild goat in the same cell in multiple years. In addition, non-systematic surveys in the expansion areas (Areas where the presence of the species was unconfirmed) of the MEV were undertaken by regional rangers, which provided occasional sightings (2012–2015).

2.3. Explanatory variables

Four sets of descriptors were tested to explain the distribution of Iberian wild goat: (1) topographical variables, (2) water availability, (3) human disturbance and (4) food availability (Table 1).

Given the importance of topography to this species and the importance os selecting a scale that reflects the phenomena under study (Addicott et al., 1987; Ludwig et al., 2000; Schopf and Ivany, 1998; Wiens, 2002), we used a combination of two Digital Elevation Models (DEM): (1) a coarse DEM at 200 m × 200 m (available at https://www.cnig.es), which was used to extract characteristics of the relief at a broad scale; and (2) a high resolution DEM at 5 m × 5 m (available at https://www.cnig.es) which was used to identify fine patterns. From the coarse DEM, we obtained two variables: *Elevation*, the mean elevation value for each grid, and *Slope*, the percentage of slope in each grid unit as calculated by the

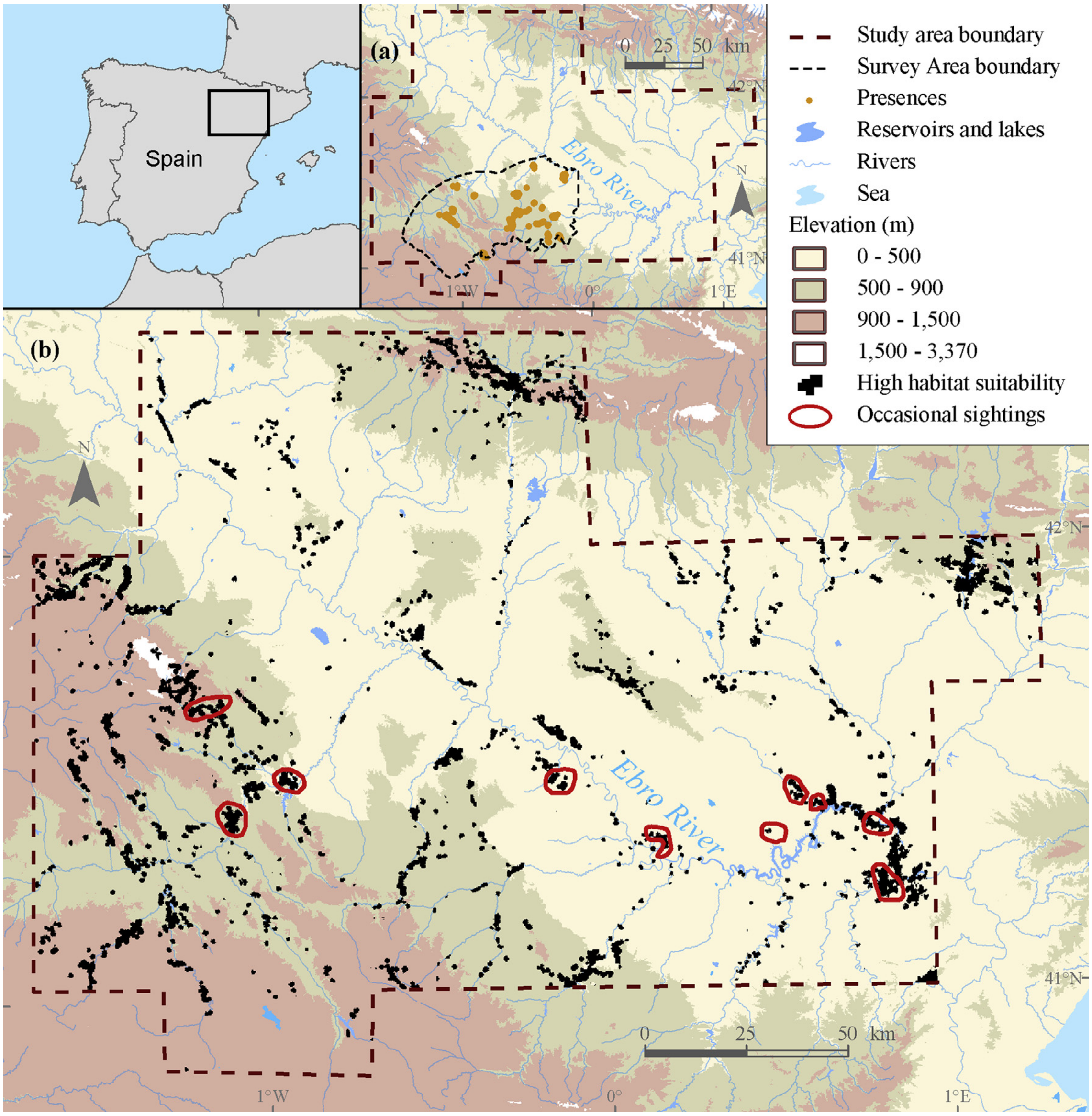

Fig. 1. Maps of the study area in the Middle Ebro Valley, Spain, illustrating (a) the presence of Iberian wild goat between 2006 and 2012 in systematic seasonal surveys and the Survey Area boundary, and (b) areas of high habitat suitability areas for the Iberian wild goat (predicted values with a probability of presence of Iberian wild goat ranging from 0.8 to 1) obtained from the resultant model.

Idrisi Taiga software package (Clark Labs, 2009). The high resolution DEM (5 m × 5 m) was used to identify small cliffs, which are undetectable with DEM at coarser resolutions, we used ArcMap 9.3 (ESRI, 2008) to calculate the slope from the 5 m × 5 m DEM and selected slope values > 150% (56°). The presence/absence of small cliffs was mapped on a 200 m × 200 m grid. Finally, we measured *Distance to Small Cliffs* as the Euclidean distance between each cell and the nearest cell that had small cliffs present using Idrisi Taiga software (Clark Labs, 2009).

In the study area water is scarce and inter-annual variation of precipitation is high, and as a result water availability might be an important driver of species' distribution (Bleich et al., 2010). Therefore, we included a descriptor of water availability, *Distance to Water*, which was the Euclidean distance between each cell and the nearest main river, reservoir or lake (http://www.chebro.es/).

Human disturbance and food availability descriptors were derived from Corine Land Cover (CLC) 2006 data (available at http://www.ign.es). As a proxy for human disturbance, we used the variable *Distance to Artificial*, which was the Euclidean distance between each cell and the nearest artificial surfaces (Category 1, Artificial Surfaces of the CLC), which included urban factories, industrial, commercial and transport lands, mines, dumps and construction sites. For food availability we measured three variables: (1) *Distance to Agricultural* which is the Euclidean distance between each cell and the nearest agricultural area (Category 2, Agricultural areas, of the CLC); (2) *Distance to Bush* was the Euclidean distance to the nearest bushes (Categories 3.2.3 and 3.2.4, Sclerophyllous vegetation and Transitional woodland/shrub, from the CLC) and (3) *Distance to Forest* which was the Euclidean distance to the nearest forests (Category 3.1, Forests, of the CLC).

2.4. Calculation of Background Area (BA), Pseudopresence Area (PPA) and Pseudo Absence Area (PAA)

In habitat models, the extent of the geographical area in which absences or pseudoabsences are recorded, has significant effects on

Table 1
Description of the variables used to model the habitat of the species. The source of the variables corresponds to the Instituto Geográfico Nacional (IGN, https://www.cnig.es) and the Confederación Hidrográfica del Ebro (CHE, http://www.chebro.es).

Variable	Definition (unit)	Dataset	Source
Topographical variables			
Elevation	Elevation above sea level (km)	MDT200	IGN
Slope	Slope (%)	MDT200	IGN
Distance to Small cliffs	Distance to slopes > 150% (km)	MDT05	IGN
Water availability			
Distance to Water	Distance to water surfaces, defined by rivers and reservoirs (km)	Rivers; Reservoirs	CHE
Human disturbance			
Distance to Artificial	Distance to artificial areas, defined by category 1, Artificial Surfaces (km)	CLC 2006	IGN
Food availability			
Distance to Agricultural	Distance to agricultural areas, defined by category 2, Agricultural areas (km)	CLC 2006	IGN
Distance to Bush	Distance to bushes, defined by categories 3.2.3 and 3.2.4, Sclerophyllous vegetation and Transitional woodland/shrub (km)	CLC 2006	IGN
Distance to Forest	Distance to forests, defined by category 3.1, Forests (km)	CLC 2006	IGN

the parameters, calibration and capacity for prediction of the predictive model (Anderson and Raza, 2010; Barve et al., 2011a; Lobo et al., 2008; VanDerWal et al., 2009). Barve (2011b) concluded that the extent of the geographical area should include the "M" space defined in the diagram of (Soberon, 2005), a space "that is reachable by the species from established distributional areas in ecological time". Although it is difficult to obtain detailed information about the dispersal of a species, even a simple examination of its distributional patterns can provide a more accurate estimate of geographical area than do the traditional criteria (e. g. political borders) used in habitat studies (Anderson and Raza, 2010).

A species' characteristics and landscape features influence the spatial patterns of a species' population (Bowman et al., 2000). Bowman et al. (2000) used spline correlograms to examine spatial patterns of autocorrelation of abundance (an index of demographic variability) of various small-mammal species and concluded that dispersal and demographic variability operated at the same scale. Distances at which spatial autocorrelation was high coincided with the species' home range size, and intervals at which spatial autocorrelation was low were correlated with their dispersal ability. We used spline correlograms, to identify the scale at which dispersal of Iberian wild goat was operating in the VME, and the distance estimate was used to delimit the extent of the geographical area in our habitat model.

We used the dataset of presence of the Iberian wild goat (*presences survey area*) to generate the pseudoabsences (*pseudoabsences survey area*), which were randomly extracted from the survey area in the same number as the presences as follows: $n_{pseudoabsences\ survey\ area} = 407$ ($n_{total\ survey\ area} = n_{presences\ survey\ area} + n_{pseudoabsences\ survey\ area}$; $n_{total\ survey\ area} = 814$). To quantify the spatial autocorrelation within the *presences survey area* and the *pseudoabsences survey area* we used spline correlograms with the 'ncf' package in R-Program V. 2.15.0 (R Development Core Team, 2012). To calculate (1) Background Area (BA), (2) Pseudopresence Area (PPA), and (3) Pseudoabsence Area (PAA), we used the distance delimitated by high spatial autocorrelation (h distance, spatial autocorrelation = 0.9) and the distance delimitated by low spatial autocorrelation (d distance, spatial autocorrelation = 0.1). Calculations of BA were based on a circle with a radius of d distance around each presence data cell, which is an area that, based on the analysis of spatial autocorrelation, probably is accessible to the species. Calculations of PPA were based on a circle with a radius of h distance around each presence data cell, which is an area in which is highly probable that the species is present. The PAA was an annulus, a ring-shaped area that is delimited by the area between the two concentric circles (area between the circle with radius of d and the circle with radius h), which is considered an area that is accessible to the species, but outside the high -probability area occupied by the species (Fig. 2b).

To model the distribution of the species, we extracted new pseudoabsences the dataset of individual *yearly presences*, but, in this case, they were randomly extracted from the PAA (*pseudoabsences PAA*). The number of pseudoabsence data grid cells extracted was the same as the number of *yearly presences*; thus $n_{pseudoabsences\ PAA} = 508$ ($n_{total\ model} = n_{yearly\ presences} + n_{pseudoabsences\ PAA}$; $n_{total\ model} = 1016$). We used data splitting for each year: models were developed based on a random selection of 70% of *yearly presences* and *pseudoabsences* PAA (the training data set, $n_{training} = 712$) and the remaining 30% was used to evaluate the resulting model (the evaluation data set, $n_{evaluation} = 304$).

2.5. Analysis

To assess the significance of the variables, we used a Generalized Linear Mixed Model (GLMM) with a binomial family and logit link function, year as a random factor, using the 'glmmadmb' function in the 'glmmADMB' package of the R-Program. To avoid multicollinearity between explanatory variables, we calculated Spearman's correlation for all pair-wise correlations, and strongly correlated variables ($r > 0.7$) were removed from the model (Zuur et al., 2010).

We built all possible models using all combinations of the explanatory variables. For each model, we calculated the ΔAICc (the difference between the minimum AICc of all models and the AICc of each model) and the Akaike Weight. Parameter estimates were calculated based on model averaging, which makes formal inferences from multiple models (Burnham and Anderson, 2010) based on model selection with AIC (Lukacs et al., 2010).

Typically species habitat models have spatial autocorrelation problems; therefore, we used spline correlograms to quantify the spatial autocorrelation in the residuals. In cases in which spatial autocorrelation in the residuals was detected, we used an autocovariate method when for the analysis (Lemeshow and Hosmer, 2000). To evaluate the validity of our model, we compared the predicted values of the model for the evaluation data set and the observed values, and calculated the correct classification rate (the proportion of all cases that were predicted correctly), sensitivity (the proportion of true positives that were predicted correctly), and specificity (the proportion of true negatives that were predicted correctly, Fielding and Bell, 1997).

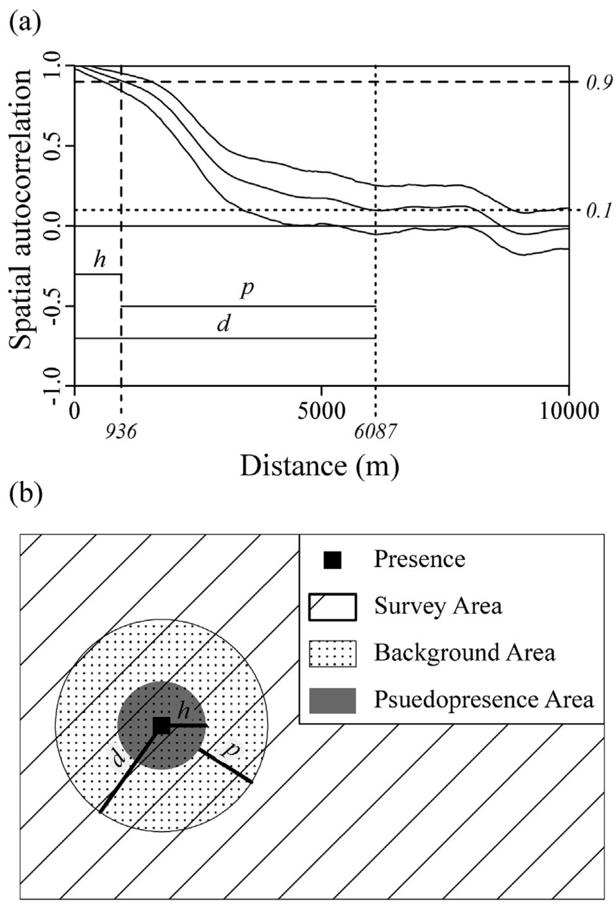

Fig. 2. Spline correlograms showing the spatial autocorrelation for the presence of Iberian wild goat for all years of the study ($n_{presences\ survey\ area}$) and pseudoabsence of the species in the Survey Area ($n_{psedoabsences\ survey\ area}$). The value of spatial autocorrelation of 0.1 and 0.9 delimits h (936 m) and d (6087 m), respectively, and p, p = d-h (5151 m, a panel). Those distances (h, d, p) were used to calculate Pseudopresence Area (PPA, a circle of h radius around each presence data grid cell), Background Area (a circle of d radius around each presence data grid cell) and the Pseudoabsence Area (PAA), which was calculated as a ring-shaped area around each presence data grid cell delimited by the two concentric circles (PPA and BA) and is the area from which the pseudoabsences were extracted randomly for calculate the model (b panel).

2.6. Prediction

The parameter estimates from the model were used to predict the potential distribution of the Iberian wild goat based on a logistic regression model for the entire study area and a 200 m × 200 m grid. Based on the prediction, we selected areas of high habitat suitability (predictions that had a probability of presence of Iberian wild goat between 0.8 and 1).

3. Results

For distance <1070 m, spatial autocorrelation in the species presence data (Fig. 2a) was high (>0.9, *h* distance). Spatial autocorrelation was not significant (<0.1, *d* distance) for distances >5953 m. We rounded the distance values to the nearest multiple of the 200 m pixel (the resolution of the map used to document presence/pseudoabsence of Iberian wild goat) so that Pseudopresence Area (PPA) and Background Area (BA) were within circles with a radius of 1000 m and 6000 m, respectively, centred in each pixel that indicated the presence of Iberian wild goat. Consequently, Pseudoabsence Area (PAA), from which the pseudoabsences were randomly extracted, was the area within 6000 m but outside the first 1000 m within each cell that indicated the presence of Iberian wild goat.

None of the explanatory variables were strongly correlated (Table S1, Supplementary data). In the averaged-model, *Distance to Bush* and *Distance to Small cliffs* explained the largest amount of the variance in the distribution of Iberian wild goat in the MEV, Spain. Those variables had negative parameter estimates, which indicated that Iberian wild goat was likely to be present father away from those landscape features. Other variables explained some of the variance in the distribution of the Iberian wild goat: Presence was negatively correlated with *Distance to Water* and *Distance to Forest*, and positively correlated with *Distance to Artificial*, *Slope* and *Elevation* (Table 2).

Analysis of the spatial autocorrelation in the residuals (Fig. S1, Supplementary data) showed that there was no spatial autocorrelation in the model, and the autocorrelation was significantly less than the autocorrelation in the presence/absence data (Fig. 2a). The correct classification rate of the model was 0.905, the sensitivity of correctly predicting presences was 0.934, and the specificity of correctly predicting absences was 0.875.

Validation of the resultant model indicated that it could be used to make an accurate prediction of the potential habitat for the species in the MEV, which indicated new potential habitat fragments that might be occupied by Iberian wild goat in the future. In fact, occasional sightings have indicated that the species is present in some of those areas (Fig. 1b). High suitability areas (range of predicted values = 0.8–1) for the Iberian wild goat covered 1852 km^2 (5.8% of the total study area), which was split among 705 fragments in a logarithmic distribution (maximum = 69.08 km^2, mean = 2.63 km^2, median = 1.16 km^2, third quartile = 2.16 km^2).

4. Discussion

The prediction over the study area indicated a potential fragmented habitat, and the presence of bushes (*Distance to Bushes*) and small cliffs (Distance to Small cliffs) explained the largest amount of the variance in the distribution of the Iberian wild goat in the MEV, Spain.

The distance at which positive spatial autocorrelation was similar to the approximate radius (987 m) of the home range of the species (3.06 km^2 with home range simplified to a circle which suppose a distance of 987 m if we simplify the home range to a circle), although it varies by sex and food availability throughout the year (Escós and Alados, 1992b). In our study, the estimated dispersal distance was <5953 m and, although to our knowledge there are no published accounts of the dispersal of the species, some demographic studies suggest that dispersal process occurs within short distances (Fandos et al., 2010).

In our study and others (Acevedo et al., 2007a), slope-related variables explained a significant amount of the variation in the distribution of Iberian wild goat which is typical of *Caprinae* species (Shackleton, 1997). Iberain wild goat use cliffs as a refuge from predators; their short, strong legs and adaptations for these areas allow them to avoid predators.

Cliffs and slopes areas can be identified from DEMs, but different resolutions of DEMs provide different information (Thompson et al., 2001). In our study because of the pattern and size of the extant cliffs, the resolution of the Digital Elevation model (DEM) played an important role in identifying them. The fine-resolution DEM detected the small cliffs, which were important for the Iberian wild goat in the MEV. The coarse-resolution DEM did not provide enough information to allow us to discriminate between cliffs and continuous slopes. In semi-arid/arid areas cliffs are important to many other species because they can act as a buffer against extreme conditions and global warming (Correia et al.,

Table 2
Relative importance, estimates, standard error (SE) and coefficients intervals (CI) for the averaged GLMM explaining the habitat of the Iberian wild goat.

Variable (Code)	Relative importance	Estimate	SE	Lower CI	Upper CI
Topographical variables					
Elevation	0.29	−0.39	0.980	−2.17	1.39
Slope	0.35	0.02	0.019	−0.02	0.05
Distance to Small cliffs	1.00	−3.12	0.288	−3.60	−2.64
Water availability					
Distance to Water	0.27	0.00	0.077	−0.14	0.13
Human disturbance					
Distance to Artificial	0.27	0.00	0.074	−0.12	0.11
Food availability					
Distance to Agricultural	0.27	0.03	0.450	−0.76	0.81
Distance to Bush	1.00	−2.61	0.396	−3.32	−1.90
Distance to Forest	0.28	−0.03	0.086	−0.17	0.11

2015; Maclean et al., 2015); therefore, identifying small cliffs might make a significant contribution to understand the ecology of Iberian wild goat in these environments (Ashcroft et al., 2012). We strongly recommend using a DEM resolution that is appropriate for the topographic elements important to the species in a given study area, which will help to improve of the species distribution model. Multiple studies have demonstrated the importance of bush areas to Iberian wild goat, which reflects the importance of food availability (García-González and Cuartas, 1992). The species is a food generalist, and the availability of resources, digestibility and fibre content influence food selection. In general, the species consumes herbs if they are present and ligneous plants when natural grassland are unavailable (Cuartas and García-González, 1992; Fandos, 1991; Martínez, 1994; Martínez et al., 1985). In the MEV, natural grasslands were scarce and, therefore, the main source of food resources would have been from bushes.

Other studies have shown that the species prefers forested areas because they provide food resources (García-González and Cuartas, 1992) or they provide cover, which allows individuals to avoid open areas, where they are more vulnerable to predators (Alados, 1985), In the MEV, however, the presence of forests did not explain a significant amount of the variation in the species' distribution because it was scare and where it was located. Most of the forests were in low mountains in the southwest, where cliffs, were scarce. In the MEV, bushes, rather than forests, were the most common and densest vegetation cover, which can be used by the Iberian wild goat as food resource and refuge.

In our study the averaged model included other variables that had little or no explanatory power for the distribution of the species: *Distance to water*, was not important, even though water resources were limited, which suggest that, at least, it was not a limiting factor. *Distance to agricultural* might have been unimportant because, typically, these areas are flat and cliffs and bushes are scarce. *Distance to artificial* areas had little explanatory power, even though the species does not actively avoid urban areas (pers. obs.).

Although other studies have reported that elevation had a significant effect on the distribution of Iberian wild goat (Acevedo and Cassinello, 2009; Acevedo et al., 2007a, 2007b; Acevedo and Real, 2011), in the MEV, that was not the case. Several factors might have been responsible for that difference. Our study area covered a small portion of the species' range, and did not include all of the landscapes in which the species often is present; e.g., mountains. Other studies have investigated the species' habitat preferences in mountainous areas. The species suffered a substantial range contraction in the past (Cabrera, 1911; Fandos, 1989) and ranges have been contracting because of anthropogenic forces that have biased estimates of the habitat preferences of the species because local extinctions usually occur at the lowest elevations, thus remaining the last populations of the species in its more elevated areas causes (Fisher, 2011; Laliberte and Ripple, 2004). In the process of range expansion, Iberian wild goat disperses into the nearest suitable areas, these areas are more probable to be areas of higher elevations because of positive spatial autocorrelation of elevation.

The MEV seemed to be a potential area in which species' range might be extended, but additional research on the abundance/productivity of the species in the area is needed to determine whether the newly recolonized areas are of high quality or Iberian wild goat are making use of secondary habitats.

At local/population scale, for populations living in fragmented habitat, like the potential habitat of Iberian wild goat in the MEV, the spatial structure of the habitat is of important for the conservation of the population (David Tilman and Kareiva, 1997; Hanski, 1999b; Jordi Bascompte and Solé, 1998; Levins, 1969; MacArthur and Wilson, 1967). In these populations, the potential risk of extinction of a fragment is very high and conservation of the population relies on the sum of probabilities of extinction of all fragments and the effects on a fragment will have effects on the surrounding fragments and the entire population (Levins, 1969). Among the characteristics and the matrix of habitat fragments that play a role in the conservation of the population (Fahrig and Merriam, 1994), two are very important: (1) the size of the fragment (extinction probability and fragment size are inversely correlated) (Hanski and Gyllenberg, 1997), and (2) the connectivity between fragments (extinction probability and connectivity are inversely correlated) (Gyllenberg and Hanski, 1992; Hanski and Gyllenberg, 1997, 1993). In general, in the MEV, the large fragments were in the west and the northeast, but the species was not present. The predicted habitat indicated the presence of many small fragments. Those small fragments follow the cliffs that had been formed by the erosion of the rivers, and the fragments formed a linear structure that minimized distances between habitat fragments, which increased the connectivity in the area. As such, those fragments acted like stepping stones (discontinuous small fragments of habitat that connect otherwise isolated habitat fragments occupied by a species, Hanski, 1999), which increase the efficiency of the movement of individuals through a matrix and more importantly, increase the probability that an unoccupied fragment will be recolonized and reduce the probably of extinction for the population (Kajtoch et al., 2012; Uezu et al., 2008).

We recommend that the conservation and management of the species in the MEV should recognize that (1) the presence of small cliffs and bushes dictate the species distribution in this area, (2) the highly fragmented habitat in the MEV requires that the conservation of the species need to have account that policies/measures of conservation need to integrate all fragments and not be focus to individual fragments; (3), given the probabilities for the recolonization of new potential habitat and in the location of the habitat fragments, two priority areas for conservation of the species should be established in the MEV: (1) the fragments in the northeast in the north bank of the Ebro river for a the recolonization of the Pyrinees and (2) the fragments in the west (for recolonization of Sierra del Moncayo and adjacent canyons and mountains).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jaridenv.2016.02.008.

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