



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.

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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 semi-arid 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 km² 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 of 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

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