

The expansion process of the Iberian ibex in the Sierra de Guadarrama National Park, Madrid (Spain)

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Abstract

The expansion process of the Iberian ibex in the Sierra de Guadarrama National Park, Madrid (Spain). In this paper we explore the usefulness of MaxEnt to predict the most suitable areas for a wildlife species, the Iberian ibex (*Capra pyrenaica*). For two decades (1990–2010), the species was established in a small part of the National Park Sierra de Guadarrama (Spain) and there has been a process of expansion to other areas of this protected area since 2010. However, almost two decades have elapsed since the modeling methods (MaxEnt) were proposed and no studies have tested their effectiveness using real distribution data, i.e. data from past predictions, to see if they fit the current distribution. We generated a model with presence-only data from 2007 and verified accuracy from 2017 data concerning real presence. Our results show a relationship between models and the species' current presence. The generated model can be useful to define the preferred locations of the species. We detected several differences between males and females of the species. This work not only shows the importance of selecting climatic and ecological variables for the construction of models but also indicates that they must be adjusted, at least for some species, to each sex and period of the year.

Key words: *Capra pyrenaica*, Iberian Ibex, Distribution area, MaxEnt, Spain

Resumen

El proceso de expansión de la cabra montés en el Parque Nacional de la Sierra de Guadarrama en Madrid (España). En este trabajo estudiamos la utilidad del programa MaxEnt para predecir las zonas más adecuadas para una especie silvestre, la cabra montés (*Capra pyrenaica*). Durante dos décadas (1990–2010), la especie estuvo establecida en una pequeña parte del Parque Nacional de la Sierra de Guadarrama (España) pero desde 2010 ha seguido un proceso de expansión a otras zonas de este espacio protegido. Sin embargo, ya han pasado casi dos décadas desde que se propuso el uso de estos modelos (MaxEnt) y no hay estudios que aborden su eficacia con valores reales de distribución, esto es, que comprueben si las predicciones del pasado se ajustan a la situación actual real. Hemos generado un modelo solo con los datos sobre presencia obtenidos en 2007 y hemos verificado su precisión a partir de estos datos reales de presencia de 2017. Nuestros resultados muestran una relación entre los modelos y la presencia actual de la especie. El modelo generado nos ha permitido determinar las localizaciones preferidas de la especie. Se han detectado algunas diferencias en función del sexo de los contactos. Este trabajo no solo muestra la importancia de la selección de variables climáticas y ecológicas para la realización de los modelos, sino también que estos modelos deben ajustarse, al menos para algunas especies, en función del sexo y el período del año.

Palabras clave: *Capra pyrenaica*, Cabra montés, Área de distribución, MaxEnt, España

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Introduction

The Iberian ibex (*Capra pyrenaica*, Schinz, 1838) is an endemic wild Artiodactylan of the Iberian Peninsula that frequents areas with outcropping rock associated with several types of natural vegetation and some isolation. It is associated with rocky areas with mountain and subalpine vegetation in the Iberian Peninsula, ranging from alpine meadows to wooded and scrubland areas (Granados et al., 2007; Refoyo, 2012).

In the mid–nineteenth century the species showed a strong decline, both nationally and locally (Alados and Escos, 1995; Soriguer et al., 1998), possibly due to competition with other ungulates, habitat destruction and human pressure (Pérez et al., 2002; Acevedo and Cassinello, 2009). However, in recent decades, its interest as a game species led to its reintroduction in other Spanish mountain ranges, facilitating its expansion (Fonseca et al., 2017).

These restockings, however, have not been conducted following international criteria. Nor have they been carried out using habitat suitability studies or specific tools to determine the adequacy of the environment for the species (Refoyo, 2012). Knowing parameters such as land cover, anthropic influence, flora and fauna diversity is essential as such factors affect the species' relationship with the environment (Odum, 1986; Hui, 2006).

A good method to characterize these ecological niches is to assess correlations between a dependent variable, defined by the distribution of the species (presence/absence), and to select independent variables using binomial logistic regression (Elith and Burgman, 2002; Anadón et al., 2007). Many studies have established the potential of a territory using presence and absence data (Moisen and Frescino, 2002; Segurado and Araújo, 2004; Higgins et al., 2017). This method has been used in many studies related to plants (Zimmermann and Kienast, 1999), birds (Suárez-Seoane et al., 2004), mammals (Jaberg and Guisan, 2001), reptiles (Guisan and Hofer, 2003), invertebrates (Maggini et al., 2002) and diseases (Wint et al., 2002).

However, conducting this type of analysis is often limited by a lack of information (absence data) (Broms et al., 2014), especially in large areas. As a result, the current modelling techniques often used (SDM) require presence–only data (data that are abundant in official databases) (Converse et al., 2013; Gedir et al., 2013; Weber et al., 2017) and MaxEnt is considered one of the best of these modelling techniques for developing distribution models (Hernández et al., 2006; Palialexis et al., 2011; Magarey et al., 2017). Such models make it possible to establish the suitability of the territory for a particular species on the basis of the known presence data (precise locations) and the values of variables that characterize this presence (predictor variables), and also to establish the places that, in other areas of the territory, show a certain degree of similarity to these conditions.

The use of the species distribution model (SDM) (Guisan and Zimmermann, 2000; Mateo et al., 2011) is an increasingly popular tool (Elith and Leathwick,

2009; Ferrer–Sánchez et al., 2017; Wu et al., 2018). It is even used in game species (Vargas et al., 2007; Acevedo et al., 2010; Yongyut et al., 2012), as in the case of the Iberian ibex (*Capra pyrenaica*) (Acevedo et al., 2007; Refoyo et al., 2014).

The use of SDM provides the possibility to conduct studies in both conservation and basic science that are difficult, and sometimes impossible, to address with other methods (Warren and Seifert, 2011). Even so, previous studies have also shown that many factors could affect the performance of SDM, such as the size and spatial biases of sampling data, algorithms (Wisz et al., 2008; Phillips et al., 2009; Shcheglovitova and Anderson, 2013) and thresholds used (Liu et al., 2005; Nenzen and Araujo, 2011; Bean et al., 2012) and, in particular, over–adjustment (Wenger and Olden, 2012). One of the assumptions of the SDMs is that the data used for model calibration are free of bias. However, this is never the case, especially in data collection (Fourcade et al., 2014; Tassarolo et al., 2014). Although there are statistical techniques to correct these errors and determine the robustness of the model (Warren and Seifert, 2011; Liu et al., 2015)—and they are good statistical approximations—the best way to determine the efficiency of the models is to check with real data after a certain period of time. Although almost two decades have passed since the use of these models was proposed (Guisan and Zimmermann, 2000) no study has yet related the actual values of species occurrence with the proposed distribution models. The species' low speed of dispersion and the difficulty to perform these distribution studies in areas other than those of origin of the data make this work difficult (Tinoco–Torres et al., 2014; Fonseca et al., 2017). Nevertheless, Iberian ibex were reintroduced in the Sierra de Guadarrama National Park (Madrid, Central Spain) in the 1990s and their demographic trend and distribution has been monitored, allowing us to validate these models with real data. Until 2007 and for several decades, the population showed an increase in a limited area of the Park (reintroduction zone) and there was no dispersion to other areas of the Park. However, since then, the population has occupied other areas (Refoyo et al., 2015, 2016). Here we analysed whether the distribution models generated from data concerning the species in 2007 (based on data collected in a survey carried out in 2007) fit the current distribution of the species (2017) in this National Park since its expansion.

To achieve our goal, we: i) estimated the suitable areas for the distribution of Iberian Ibex using presence–only distribution data (2007); ii) tested the model with data from 2017; and iii) analyzed whether there are differences in the models generated due to different behaviour between the sexes during breeding.

Material and methods

Study area

The study was carried out in the Community of Madrid (Spain) where there is an Iberian ibex population in

the northern region, in the National Park of Sierra de Guadarrama (25,317 ha). The park has a continental climate with large temperature variations between seasons and very dry summers (fig. 1). The vegetation includes shrubs (*Cytisus purgans*, *Juniperus communis nana*) and grassland (*Festuca indigesta*, *Nardus stricta*, *Festuca rubra*) in highland areas, Mediterranean shrubs (*Cistus ladanifer*, *Rosmarinus officinalis*, *Thymus vulgaris*, *Lavandula stoechas*) in the steeply sloped areas, and forests (of *Quercus ilex*, *Quercus pyrenaica*, *Pinus* spp.) in the valleys, and on hillsides.

Although it would be of interest to study the presence of the mountain goat throughout the whole area of the Sierra de Guadarrama National Park, reliable data using systematic procedures are scarce and digital layers of the variables used (specifically vegetation and rock cover) for modelling on the northern slope (Castilla y León) are lacking, ruling out the possibility to generalise the study with the necessary robustness for the entire park.

Generation of models

Dependent variable

Data used in this study consisted of 97 records from the sampling conducted in 2007 in 4,590 ha within the National Park of Sierra de Guadarrama (table 1, fig. 2.) where previous studies (2000, 2003, 2005 and 2007) determined the presence of the species (Refoyo, 2012). Eight people walked along 22 transects of an average length of 3.64 km between May 19th and June 12th to obtain the data by means of direct observation (Refoyo et al., 2015) using the distance sampling method (Buckland et al., 1993). For each contact, we recorded the habitat, the number of animals composing the group, sex, age of individuals (using 8 x 40 to 10 x 50 binoculars), and the perpendicular distance to the transect line using a laser distance meter (Bushnell Yardage Pro Sport). All transects were sampled on successive and climatically suitable days, either in the morning (2–3 hours after sunrise) or afternoon (2–3 hours before sunset) (Refoyo et al., 2015).

Predictor variables

The presence of rocky places and cliffs in association with the various types of natural vegetation and certain altitudes seem to be essential conditions for the species. Nevertheless, some populations were observed at sea level while others appeared to prefer to be far from areas with high densities of infrastructure and human activities (Refoyo, 2012). Although the Iberian ibex does not seem to have a preference for any specific vegetation, some variability in the trophic resources available seems necessary (Refoyo, 2012).

The selection of variables was based on the criterion established in Refoyo (2012) and Olmedo et al. (2016):

Altitude (continuous variable): this variable was obtained from a digital elevation model (DEM) produced by the Spanish National Geographic Institute.

Vegetation/stoniness (categorical variable): to determine the trophic availability and the availability of outcrops for the species, we used a digital layer designed by the Department of Environment and Spatial Planning of Madrid. This layer considers both the vegetation present at a place (land use and type of vegetation) and the percentage of existing rock outcropping.

Roughness (continuous variable): roughness is described as the variation in three-dimensional orientation of grid cells within a neighborhood. This method effectively captures variability in slope and aspect into a single measure. Roughness values in the output raster can range from 0 (no terrain variation) to 1 (complete terrain variation). This layer was made from a digital mapping of slope angles and orientation following the method of Felicísimo (1994), who defined it as: 'the uniformity of the unitary vectors perpendicular to the surface in each cell and in those of the environment, given by the value of the module of the vector sum of those'. Where x_i , y_i and z_i are the rectangular coordinates of the unitary vector perpendicular to the surface at point i , their expressions as a function of slope and orientation, both in degrees, are:

$$\begin{aligned}x_i &= \sin(P_i) \times \cos(O_i) \\y_i &= \sin(P_i) \times \sin(O_i) \\z_i &= \cos(P_i)\end{aligned}$$

For a set of n vectors, the direction of the resulting vector coincides with the mean vector of the n vectors, a measure of dispersion between the different vectors being the value of the normalized modulus of its sum (R). R takes values between 0 and 1: a value of 1 indicates total dispersion and a value of 0 indicates null dispersion.

Anthropogenic influence (continuous variable): a new digital layer was created based on the isolation degree of the territory. The entire study area (Community of Madrid) was divided into grids of 20 x 20 m and the distance between each of these squares was calculated to the nearest linear infrastructure (digital linear infrastructure mapping of the Madrid government).

The values of these variables in all 97 presence data were obtained by the intersect point tools via GIS (Hawth's analysis tools).

Predictive modelling

The MaxEnt modelling approach is a discriminant technique that makes predictions or inferences from presence only data and estimates the probability of species presence. It also seeks a probability distribution that is as uniform as possible (maximum entropy) under the assumption that the expected value of each information layer must approach its empirical average (entropy) (Phillips and Shapire, 2004). Unlike the previous model, there is no need to enter the absence data into the program because it generates a number of randomly selected (pseudo-absences) observations (Mateo et al., 2011). To perform this analysis, we used the same predictor variables and 97 records from the sampling conducted in 2007 (Refoyo et al., 2015).



Fig. 1. Study area. The area of study in 2017 corresponds to the entire area of the National Park on its Madrid side while the 2007 census area corresponds to the area of presence of the species within the National Park in 2007.

Fig. 1. Área de estudio. El área de estudio de 2017 corresponde a toda la superficie del Parque Nacional en su vertiente madrileña, mientras que el área de censo de 2007 corresponde a la zona de presencia de la especie dentro del Parque Nacional en 2007.

For running MaxEnt models (Version Maxent 3.4.2), the following default parameters were used: a maximum number of 500 iterations; a convergence–threshold limit of 0.00001 and 10,000 points as the number maximum of background points; and a regularization multiplier equal to 1 (Phillips et al., 2006). Ten replicates were run for each model to assess the influence of data selection on the randomization, and the final model was constructed with the average of these replicates. In all cases, 30% of the records from the samples were randomly removed to be used as test points (i.e. a random sample was taken from the species presence localities in order to measure the quality of the model), and the remaining 70% of records was used to build the model.

Additionally, the ROC–AUC technique was used to analyse the goodness of the MaxEnt analysis in contrast to other assessment models, since it avoids the problem of selecting threshold values (Lehmann et al., 2002) and is also capable of measuring the model's

ability to discriminate between sites according to their species suitability (Fielding and Bell, 1997; Engler et al., 2004; Elith et al., 2010).

The data obtained were used to generate a suitable map of the territory with GIS tools (ArcGIS 10.0) (fig. 2).

Validation of the models

Obtainment of the current presence data: the monitoring studies were performed in an area of 25,317 ha (fig. 1). The Park has a marked difference in altitude, ranging from 900 m to 2,428 m, alternating very steep rocky areas with areas of gentle topography.

The population was monitored from the 6th to the 15th of June, 2017 (table 1) by direct observation of the animals along 48 transects with an average length of 4.5 km and a total length of 218.6 km using the distance sampling method (Buckland et al., 1993). All transects were sampled on successive and climatic-

Table 1. Total contacts, number of individuals, and average group size both for the total population and by sex for 2007 and 2017 records: Nc, number of contacts; Av, average group size; Ns, number of specimens.

Tabla 1. Número de contactos, número de individuos y tamaño medio de grupo, tanto para el total poblacional como por sexo para los registros de 2007 y 2017.

	2007			2017			
	Nc	Av	Ns	Nc	Av	Ns	Nc
Total	97	3.7	354	125	6.2	771	
Males	19	7.7	144	54	8.7	474	
Females	78	2.7	210	71	4.2	297	

lly suitable days, either in the morning (2–3 h after sunrise) or afternoon (2–3 h before sunset). For each contact, we recorded the total number of ibex and the total number for each sex using 8 x 40 to 10 x 50 binoculars (Refoyo et al., 2015).

Analysis model: we obtained 120 records. Each record was georeferenced and included the total number of individuals, the total number of males, and the total number of males and females. We obtained the suitability values (MaxEnt) (model generated by 2007 records) using the intersect point tools (Hawth's tools). These tools can assign the values of digital layers (territory suitability generated with Maxent from the 2007 contacts) to a layer of points (Contacts, 2017) (fig. 2).

The group size for each contact was associated with the suitability models using a simple regression analysis for the total number of individuals and the total number by sex. With this procedure and for each point of presence of the species, we obtained four variables: the suitability value of the terrain, the total number of specimens, the total number of males, and total number of females. All four variables had a normal distribution. Linear regression revealed suitability of the territory as the dependent variable, and the total number of goats, the total number of males and the total number of females as the independent variables. Quantile regression (Koenker and Bassett, 1978) was performed to assess changes near the upper limit of the distribution (Huston, 2002; Carrascal et al., 2017) according to the group sizes detected. In addition, we calculated the Moran index to determine the possible spatial autocorrelation of the contacts. We also carried out the same analyses considering that values are appropriate areas (index > 0.7) and not adequate (index < 0.7). All statistical analyses were performed using Statistica 7.0 (StatSoft Inc., Tulsa, OK, USA) and STATA 15 (StataCorp LLC, USA).

Results

The ROC curve produced by MaxEnt indicates a high accuracy of the model since the data analysis generated an area under the curve of 0.976 (fig. 3), a value that is above the optimum threshold (0.8) (Phillips et al., 2006). The variables of altitude, anthropogenic influence, and vegetation/stoniness were relevant for the presence of the species (fig. 4).

The regression analyses showed a relative relationship between the model and the current presence of the species, ($n = 133$; $r = 0.20$; $p = 0.02$) (fig. 5A). If we consider the distribution of the records by sex, males showed a better relationship with the model ($n = 67$; $r = -0.24$; $p = 0.004$) (fig. 5B) than females ($n = 78$; $r = -0.04$; $p = 0.59$) (fig. 5C). Regression by quantiles shows that for the 95% quantile the relationship with the model improved considerably, especially for males ($p = 0.018$; $R^2 = 0.16$) and total Ibex ($p < 0.001$; $R^2 = 0.18$). For females however, it remained at low levels ($p > 0.05$; $R^2 = 0.03$), although they were higher than in the previous analysis. Considering the 90% quantile, although the relationship improved for total Ibex ($p = 0.007$; $R^2 = 0.09$), it did not improve for males and females (fig. 6). Although we did not detect any spatial autocorrelation between contacts, for female groups located in the 2017 samples this autocorrelation was marginally significant (table 2).

According to these data, when we consider suitability values higher than 0.5, the model is significant only for males ($F_{(1;131)} = 4.7929$; $p = 0.0303$) while for females, the most suitable values are those with the lowest values ($F_{(1;131)} = 4.4351$; $p = 0.0371$). As a result, the global value is not significant (total ibex: $F_{(1;131)} = 1.2467$; $p = 0.2662$) (fig. 7).

The results are significant both for the total Ibex population ($F_{(1;131)} = 8.0127$; $p = 0.0054$) and for the total male population ($F_{(1;131)} = 11.598$; $p = 0.0009$) only when we consider suitability values higher than 0.7. They are not significant for the total female population ($F_{(1;131)} = 0.7502$; $p = 0.3880$) (fig. 8).

Discussion

Here we verified that the distribution of Iberian ibex can be accurately assessed using presence-only data. Our findings emphasise the importance of considering not only environmental variables but also population variables, such as sex, as this allows us to generalize such studies regarding the reintroduction of a species.

MaxEnt allows working presence-only data and is considered one of the best methods for species distribution models (Hernández et al., 2006; Palialexis et al., 2011). It is useful for numerous works based on the use of occurrence data (bibliographic records, museums and herbaria databanks) (Suárez-Seoane et al., 2008; Cano et al., 2014; Wu et al., 2018).

Our results indicate that when no data are absent, MaxEnt can infer the distribution of the species in an acceptable way (Palialexis et al., 2011). The fact that the variables only explain 4% of the variance (6% in males and 2% in females) may be due to the short

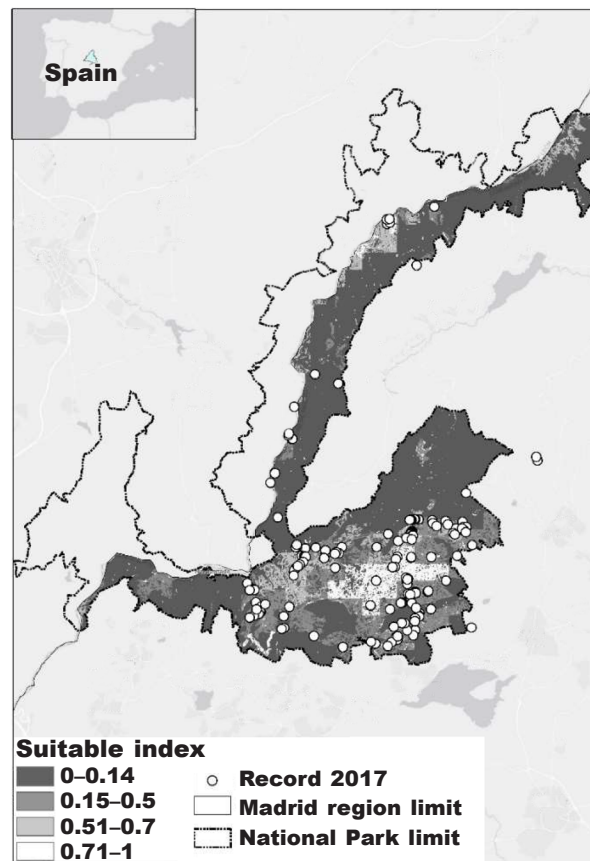


Fig. 2. Map of the suitability area obtained with MaxEnt (land suitability for the species is indicated in black).

Fig. 2. Mapa del área de idoneidad obtenido con MaxEnt (el color negro muestra la zona adecuada para la especie).

period of time elapsed (seven years), and it is foreseeable that in the near future, individuals will tend to occupy more suitable areas rather than areas close to the core area studied in 2007, thus increasing the R^2 . It is necessary to keep in mind that the expansion of the species in the National Park started in 2010.

When we analyzed the results according to sex we observed several differences. The model was better adjusted in the case of males than in females. For example, in the areas considered suitable (for suitability values of both 0.5 and 0.7), the male group size was larger than in the areas considered less suitable, indicating that the favourable conditions allow greater grouping of specimens. However, in the case of females, these differences did not appear. The reason for this could be related to the fact that in the breeding season females tend to form smaller family groups with the offspring (graphs 9 and 10).

As indicated by other authors (Huston, 2002; Carrascal et al., 2017), the model fit improves when assessing changes near the upper limit of the distribution according to the detected cluster sizes. When we analyse the 95% quantile, the regression models

better explain the relationship with territory fitness. However, the fit remains low for females, possibly due to the spatial autocorrelation of contacts and lack of statistical power. The more gregarious behaviour of females, especially in the breeding season, by requiring areas suitable for breeding (Refoyo et al., 2015), causes some spatial autocorrelation for the 2017 data and possibly influences the results. These differences can be explained by the different behaviour of males and females, addressed by many authors in several species. Johnson et al. (2007) stated three reasons for male-biased dispersal and female philopatry in amphibians: avoidance of inbreeding, local mating competition, and local resource competition. Sex-biased migration has also been reported as widespread among vertebrates (Houlahan and Findlay, 2003) and Morelle and Lejeune (2015) established variables such as food resources and thermal and safety cover for the wild boar case.

In our case, the data for the verification of the model (2017) were obtained during the breeding season when the differences in behaviour between males and females are greatest. While females usually limit

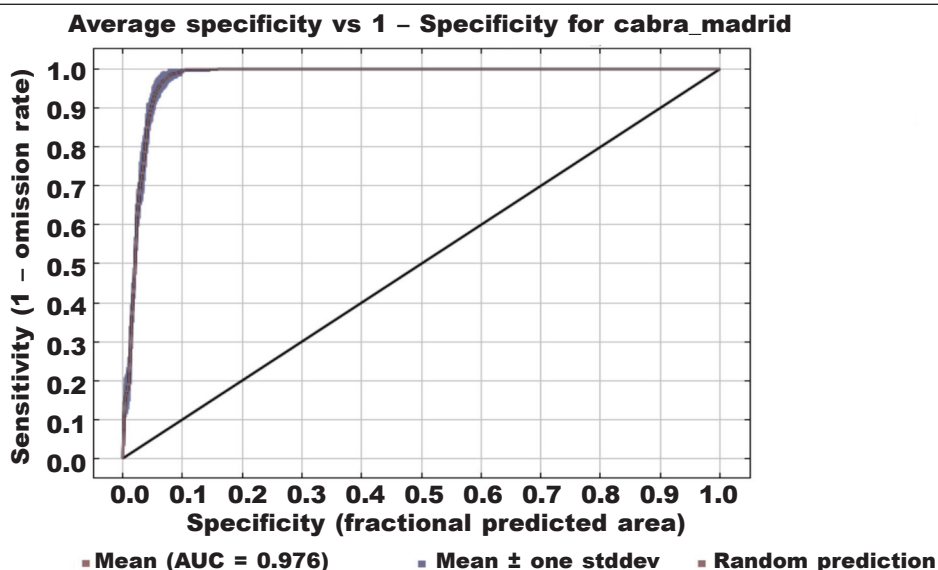


Fig. 3. ROC curve produced by MaxEnt.

Fig. 3. Curva ROC producida por MaxEnt.



Fig. 4. Jackknife representation of each variable. In light grey the gain of the model without the variable, in black the contribution of the variable to the model, and in dark grey the gain of the models with all the variables.

Fig. 4. Representación de Jackknife de cada variable. En gris claro se representa la ganancia del modelo sin la variable; en negro, la contribución de la variable al modelo, y en gris oscuro, la ganancia de los modelos con todas las variables.

their distribution to rocky areas –a variable that was little relevant in the models generated (fig. 4) where offspring protection is easier– we observed that males showed a greater dispersion between the available habitats (Refoyo et al., 2015, 2016).

This result matches those reported by Cao et al. (2013) that focus on habitat suitability rather than climate suitability that reported general over-predictions (Graham and Hijmans, 2006; Dubuis et al., 2011; Guisan and Rahbek, 2011). By including fea-

tures such as altitude, anthropogenic influence, land cover and roughness, our models can be considered better than other models that use climate–suitability only to describe suitable habitats. Nevertheless, the differences detected between sexes imply that models may still be underfitted, not only for the environmental requirements of the species under study but also for the specific characteristics of each sex and the differential behaviour that the species presents at different times of the year.

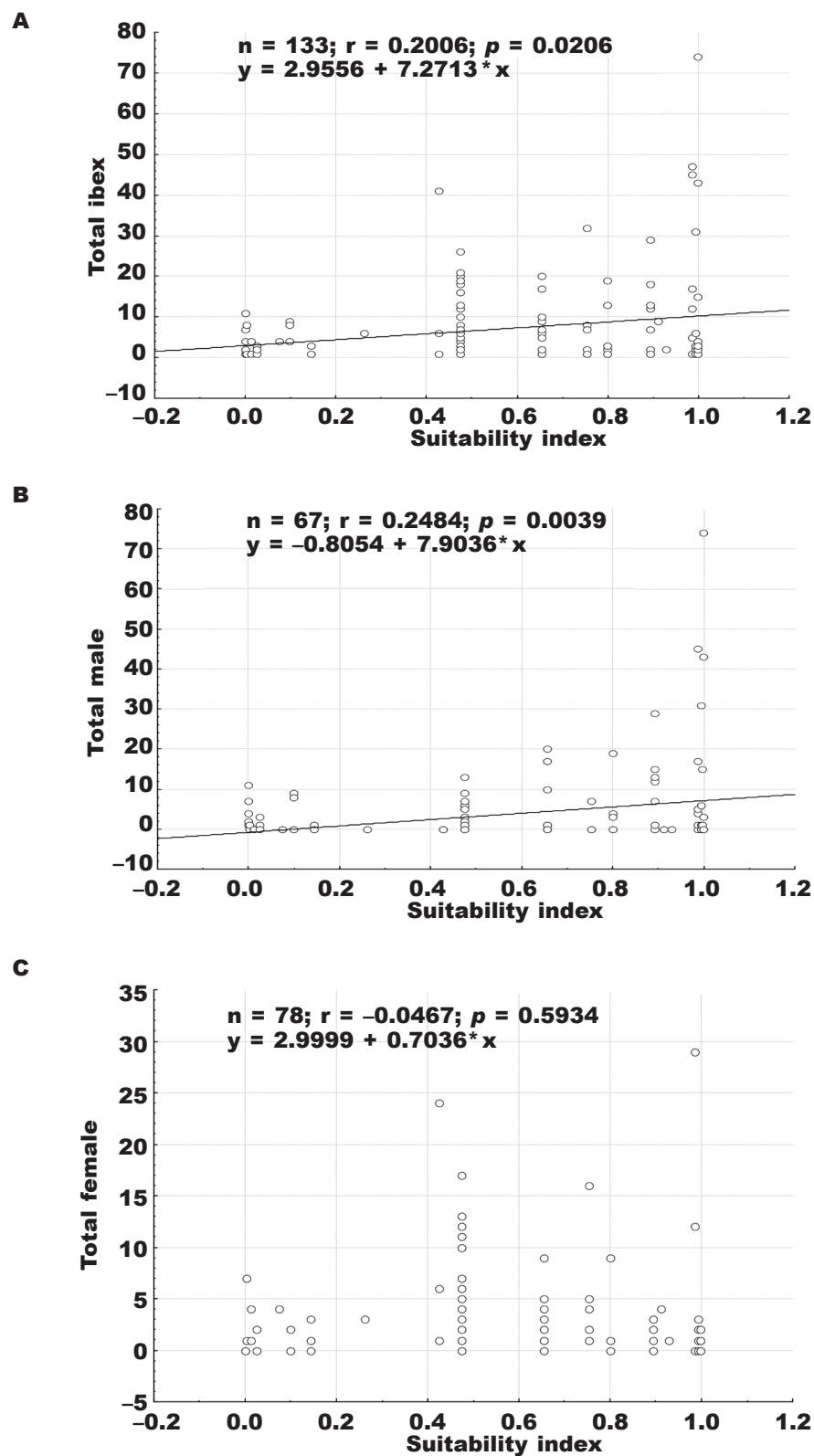


Fig. 5. Simple regression between suitable area (MaxEnt) and real presence of ibex (A), of males (B), and of females (C) in 2017.

Fig. 5. Regresión simple entre el área adecuada (MaxEnt) y la presencia real de cabras (A), de machos (B) y de hembras (C) en 2017.

Table 2. Autocorrelation spatial model using Moran's index for total data and sex data for 2007 and 2017: MI, Moran index; V, variance; P, p-value.

Tabla 2. Autocorrelación espacial utilizando el índice de Moran para los datos totales y desglosados por sexo para 2007 y 2017: MI, índice Moran; V, varianza; P, valor p.

	MI	V	P
Total ibex 2007	0.165	0.05	0.43
Total male 2007	0.165	0.10	0.46
Total female 2007	0.232	0.04	0.23
Total ibex 2017	-0.328	0.04	0.12
Total male 2017	0.157	0.04	0.34
Total female 2017	-0.421	0.04	0.04

It is also of note that the model generated with data of presence-only requires that the threshold

indexes for their consideration are higher than 0.7, as suggested by other works (Tellería et al., 2012; Shartell et al., 2013; Fernández-Marchán et al., 2015). In any case, the MaxEnt model is a powerful tool not only to understand the biology of the species but also to understand management aspects.

In this sense, having a predictive method based only on presence data is particularly useful for works related to the management of a species that is clearly increasing in number, as is the case of the Iberian ibex. Precise knowledge of the variables that characterize the presence of the species and the location of suitable areas is especially useful not only to determine natural processes of a species' expansion. Such knowledge is also often used for introductions of species, such as in hunting, in which case it is essential to know the most suitable areas for the species in order to optimize the available resources and carry out a specific analysis by sex and time of year.

Identifying areas where species are most abundant has been an invaluable tool for the design of biological reserves and for the reintroduction of game species (Araújo and Williams, 2000). Applying SDM to the systematic planning of conservation or management of wild fauna and flora can be effective in protecting populations, but besides environmental variables related to the suitability of the territory it is necessary to study

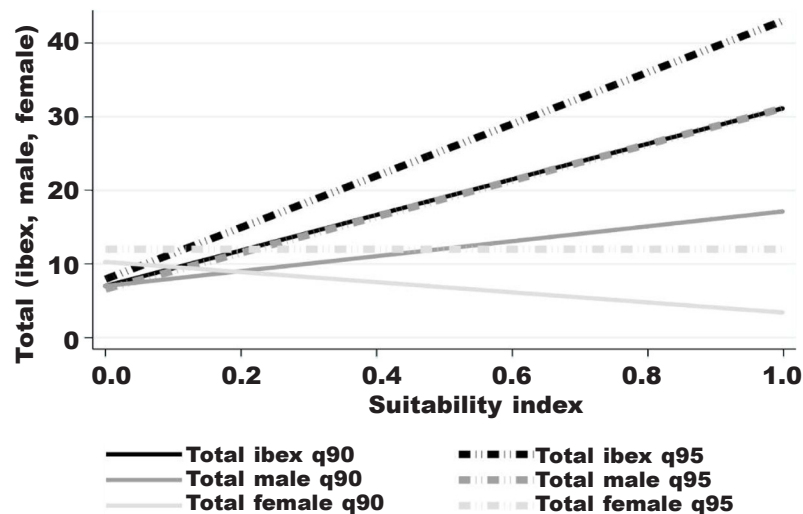


Fig. 6. Representation of the regression values for 90 and 95% quantiles by sex and total contacts (statistically significant for males and total ibex in the 95th quantile and not significant for females in any quantile and males for quantiles at 90%) (total cabras q95 = $7.93 + 35.14 * \text{suitability}$; total cabras q90 = $7 + 24.169 * \text{suitability}$; total machos q90 = $7 + 10.142 * \text{suitability}$; total machos q95 = $6.95 + 24.58 * \text{suitability}$; total hembras q90 = $10.268 - 6.88 * \text{suitability}$; total hembras q95 = $12 + 0 * \text{suitability}$).

Fig. 6. Representación de los valores de regresión para los cuantiles 90 y 95 por sexo y total de contactos (estadísticamente significativa para machos y total de cabras en el cuantil 95 y no significativa para hembras en ningún cuantil y para machos en el cuantil 90 (idoneidad del total de cabras q95 = $7,93 + 35,14 * \text{idoneidad}$; total de cabras q90 = $7 + 24,169 * \text{idoneidad}$; total de machos q90 = $7 + 10,142 * \text{idoneidad}$; total de machos q95 = $6,95 + 24,58 * \text{idoneidad}$; total de hembras q90 = $10,268 - 6,88 * \text{idoneidad}$; total de hembras q95 = $12 + 0 * \text{idoneidad}$).

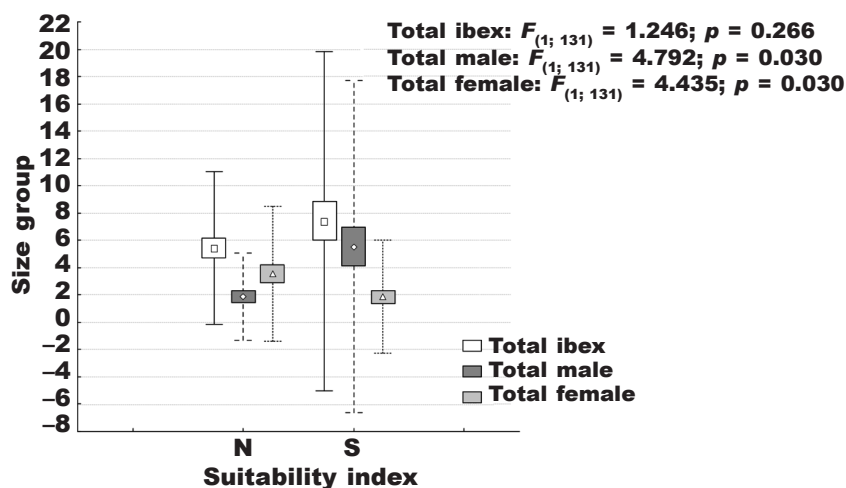


Fig. 7. Box-plot indicating the size of the total ibex group, the total male group, and the total female group in relation to the suitability of the area: N, suitable Index < 0.5; S, suitable Index > 0.5 (mean: box, mean ± SE; whisker, mean ± SD).

Fig. 7. Diagrama de cajas en el que se indica el tamaño de grupo: total cabras, machos y hembras en relación con la idoneidad de la zona: N, índice de idoneidad < 0,5; S, índice de idoneidad > 0,5 (media: caja, media ± EE; intervalo, media ± DE).

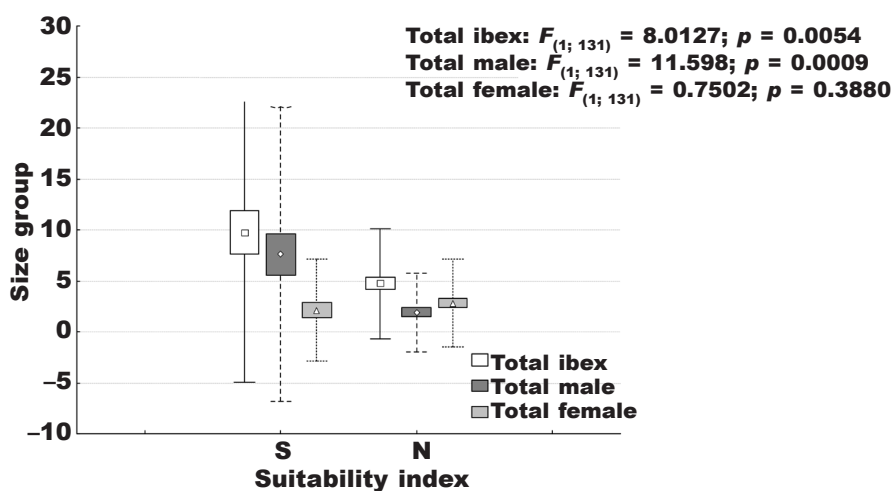


Fig. 8. Box-plot showing the size of the total group of ibex, and of males, and females in relation to the suitability of the area: N, suitable index < 0.7; S, suitable index > 0.7 (mean: box, mean ± SE; whisker, mean ± SD).

Fig. 8. Diagrama de cajas en el que se indica el tamaño de grupo: total cabras, machos y hembras en relación con la idoneidad de la zona: N, índice de idoneidad < 0,7; S, índice de idoneidad > 0,7 (media: caja: media ± EE; intervalo: media ± DE).

variables related to the ethology of the species itself, especially regarding taxa with differential behaviour between sexes, for example, or age. In our case, the different behaviours between male and female

Iberian ibex allows us to establish differences between the suitability of the territory for one or the other sex, and will facilitate the selection of the more suitable territories for reintroduction.

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