Habitat use by European wildcats (*Felis silvestris*) in central Spain: what is the relative importance of forest variables?

J. Lozano

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Abstract

*Habitat use by European wildcats (*Felis silvestris*) in central Spain: what is the relative importance of forest variables?*— Habitat preferences of wildcats are controversial. Although they are usually considered a forest species, alternative environments such as scrubland can be preferred. In this study we compared five habitat types in relation to wildcat occurrence. Sampling was carried out between 2001 and 2002 on a series of transects in search of wildcat scats to calculate an abundance index. Structural variables of landscape and rabbit abundance were also estimated and summarised as orthogonal factors using a principal component analysis (PCA). *A priori* contrasts showed that wildcats tended to be more abundant in areas with Mediterranean mountain vegetation, although agricultural steppes also provided suitable habitat. The forest variables were not included in the general linear model (GLM) obtained, indicating that wildcats are mainly associated with scrubland mosaics with rabbits in this region.

Key words: Abundance, Agricultural steppe, Forest, Habitat, Scrubland, Wildcat.

Resumen

*Uso del hábitat por el gato montés (*Felis silvestris*) en España central: importancia relativa de las variables forestales.*— El hábitat del gato montés es un tema controvertido: se le consideraba una especie forestal, pero otros hábitats, como el matorral, pueden ser más utilizados. En este estudio se comparan cinco tipos de hábitat, muestreando entre los años 2001 y 2002 una serie de transectos en busca de excrementos de gato montés para calcular el índice de abundancia. También se estimaron variables estructurales del hábitat y la abundancia del conejo (resumidas en un análisis de componentes principales, ACP). Las Comparaciones Planificadas (contrastes *a priori*) mostraron que la especie fue más abundante en las áreas de vegetación mediterránea de montaña, y que la estepa no es un hábitat rechazado por el gato montés. Un análisis mediante modelos lineales generalizados (GLM) no incluyó variables forestales, lo que sugiere que esta especie se encuentra especialmente asociada a los mosaicos de matorral con conejos.

Palabras clave: Abundancia, Estepa agrícola, Bosque, Hábitat, Matorral, Gato montés.

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Jorge Lozano, Depto. de Biología y Geología, Univ. Rey Juan Carlos, c./ Tulipán s/n., E–28933 Móstoles, Madrid (Spain).

Corresponding author: J. Lozano. E–mail: j.lozano.men@gmail.com

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Introduction

The wildcat (*Felis silvestris* Schreber, 1775) is distributed over a wide geographical area that stretches from Western Europe to central India and Africa (Sunquist & Sunquist, 2002). The European subspecies (*F. s. silvestris*) is present from the Caucasus to the Iberian Peninsula (Driscoll et al., 2007), showing a fragmented pattern of distribution (Stahl & Artois, 1991). The species is of conservation concern and is included both in Appendix II of the Bern Convention and in Annex IV of the European Habitats Directive (92/43/CEE). But despite this legal protection, the wildcat is facing a number of threats throughout its range (see a review in Lozano, 2009); human persecution (predator control) and habitat alteration (Lozano et al., 2007; Virgós & Travaini, 2005) are probably the most important of these.

It is clear from the species' wide distribution that it inhabits many different habitat types (Stahl & Leger, 1992). However, few studies have investigated the wildcat's ecological requirements and habitat preferences (see Lozano et al., 2003) and its preferred habitat continues to be a controversial matter. The first research in Europe was carried out central Europe and it was stated that the wildcat is a forest species (Guggisberg, 1975; Parent, 1975; Ragni, 1978; Schauenberg, 1981). None of these studies, however, truly investigated habitat selection. Other early reports provided information which called this assumption into question (Artois, 1985; Corbett, 1978; Langley & Yalden, 1977). The "forest hypothesis" gained favour, however, and the Council of Europe (1993) recommended good management of forests as the principal measure for wildcat conservation. This recommendation was accepted in Spain and the Spanish Red Data List for Mammals (Palomo et al., 2007) stated that wildcats are mainly forest inhabitants. Indeed, some studies showed that wildcat individuals may positively select forests to shape their home ranges (Daniels et al., 2001; Klar et al., 2008; Sarmento et al., 2006; Wittmer, 2001). More recent reports, however, have found that wildcats may prefer habitats other than forest, especially scrubland and pasture areas (see Easterbee et al., 1991; Lozano et al., 2003, 2007; Monterroso et al., 2009). In still other studies the role of forest cover remains unclear. Lozano et al. (2007), for example, found that only one of three abundance models included forest cover.

It is clearly difficult to make appropriate decisions concerning habitat conservation if we do not know exactly what the preferred habitat is, or what the basic ecological requirements for the species are. Furthermore, perhaps because of the suggestion that wildcats are forest animals, treeless environments have never been evaluated as potential habitats (except in Scotland; see Easterbee et al., 1991), even though the species is usually found in such settings (Stahl & Leger, 1992). In Spain there are various types of open habitat which might be suitable for wildcats, such as semi–arid environments, or agricultural steppes where the landscape is dominated by crops (Lozano, 2008).

The aim of this study was to assess the relative importance for wildcats of different habitats in a region of central Spain where a wildcat occurrence study was carried out several years ago, and a first abundance model was obtained (Lozano et al., 2003). In this work agricultural steppe was considered for the first time in wildcat habitat studies. We generated a new abundance model, on a regional scale, to reveal the structural features explaining wildcat occurrence in Central Spain. Results and the new model were compared with those of Lozano et al. (2003) for the same region. Given that steppes were not considered in the first study, it was possible to test how the model changed by including a new type of habitat.

Material and methods

Study area

Fieldwork was conducted in central Spain, mainly in the province of Madrid, but also including nearby areas in the north of Toledo and the south of Segovia provinces (fig. 1). Between autumn 2001 and spring 2002 a number of trails throughout the region were sampled, covering a total length of 101 km. The trails were distributed across different habitat types, involving those considered by Lozano et al. (2003), plus trails crossing agricultural steppes to the south and east of Madrid.

Five habitat types were considered, defined in the present study as vegetation types: Mediterranean vegetation in plains (500–800 m a.s.l.), Mediterranean mountains (950–1,050 m a.s.l.), deciduous forests (1,250–1,700 m a.s.l.), mountain pine forests (1,250–1,800 m a.s.l.), and agricultural steppes (located in flat areas around 500 m a.s.l.).

Mediterranean vegetation both in the plains and the mountains is a mixture of forests dominated by holm oak (*Quercus ilex* L.) and scrublands, with *Cistus ladanifer* L. and *Retama sphaerocarpa* L. as the main understory shrub species. These mosaics are occasionally interspersed with Mediterranean pines (*Pinus pinea* L. and *Pinus pinaster* Aiton, 1789) and *Juniperus oxycedrus* L. The predominant climate is dry and hot with a strong drought in summer, though this is less pronounced in the mountain areas (Rivas–Martínez et al., 1987). In addition to the climatic and elevation differences, these Mediterranean areas showed marked differences in vegetation structure and human land use, with the plains being basically devoted to hunting and the mountains to cattle raising.

Deciduous forests comprise Pyrenean oaks (*Q. pyrenaica* Willdenow, 1805), with *Cistus laurifolius* L. and *Citysus scoparius* L. as the main understory shrub species. In this habitat, the forest is dominant and scrub areas are spatially restricted. Climate is more humid and cooler than in the Mediterranean vegetation areas and there is a less pronounced drought. Mountain pine forests comprise Scots pine (*Pinus sylvestris* L.), with a smaller understory shrub cover (*Citysus* sp.). They have harsher climatic conditions than deciduous forests, with colder winters that may allow several

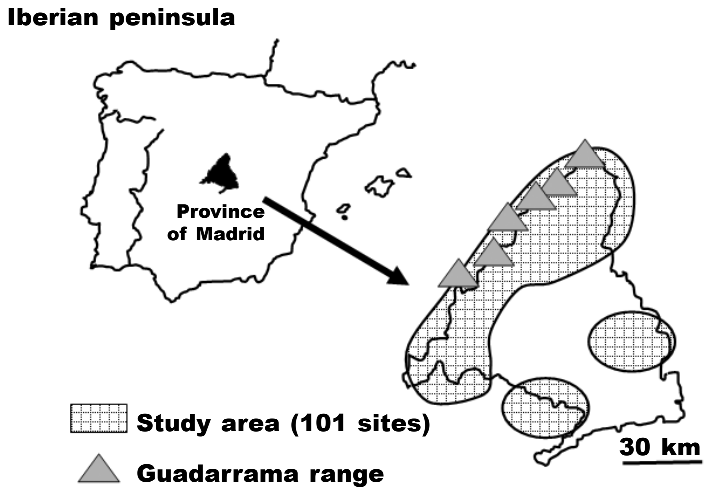

Fig. 1. Study area in the Iberian peninsula, within the province of Madrid. A total of 101 transects with a length of 1 km each across the region were surveyed.

Fig. 1. Área de estudio en la península ibérica, dentro de la provincia de Madrid. Se muestrearon un total de 101 transectos de 1 km de longitud en toda el àrea muestreada.

weeks of snow cover (Rivas–Martínez et al., 1987). Agricultural steppes are artificial environments in the flat areas where the landscape has been profoundly transformed and is dominated by cereal croplands. However, scattered small patches of scrubland may also be present in these areas. More details about the ecological and climatic features of these habitat types can be found in Rivas–Martínez et al. (1987).

Survey design

The study design used by Lozano et al. (2003) was rigorously followed to allow direct comparisons. Thus, the same trails were considered (except the transects on agricultural steppes, which were new for this study) and their distribution was homogeneous across habitat types: 16 km in Mediterranean plains, 16 km in Mediterranean mountains, 21 km in deciduous forests, 25 km in pine forests, and 23 km in agricultural steppes. The sample unit (transect) was a one–kilometre survey along paths and tracks (1–3 m wide), thus accounting for a total of 101 transects of one km each. Moreover, each transect was separated from the next by at least one kilometre in order to avoid spatial data dependence problems.

For each transect we calculated an abundance index for wildcats based on the frequency of scats. This index was calculated as the number of segments of 200 m where a wildcat scat was found, divided by five (the total number of segments in each 1–km transect). In relation to the presence of domestic cats in the study areas, their scats can be differentiated from those of wildcats following the methods of Lozano et al. (2003) as it has been shown that in areas of sympatry only wildcats leave exposed scats along paths (Corbett, 1979; Lozano & Urra, 2007). Confusion with scats from other carnivore species seems negligible in view of the author's experience in cat excrement identification.

An abundance index for wild rabbit (*Oryctolagus cuniculus* L., 1758) was also obtained by recording the number of latrines found in each 200 m segment by means of transects (50 m long and 1 m wide) perpendicular to the principal trail (see also Virgós et al., 2003). This index was calculated as the simple sum of latrines found in the five 200–m segments for each 1–km trail.

To describe microhabitat structure, various variables were visually estimated along the main transect. As in Lozano et al. (2003), the microhabitat structure variables considered were: tree cover (%), shrub cover (%), open ground cover (%), rock cover (%), average tree height and a wildcat shelter index (shelter availability). These variables were visually estimated in a 25 m radius around the observer each 200 m. We calculated the mean value of the different covers for each transect. To calculate the shelter index we assigned a number from 1 to 5 according to the existence of cavities in rocks and trees, and the visual permeability of the site. Maximum values thus represented environment structures that were very dense due to rock and vegetation cover, reducing the visibility to few meters. The wildcat shelter index was finally calculated as the mean shelter value per transect.

Habitat characterisation at a landscape scale was determined for all the transects calculating the fol-

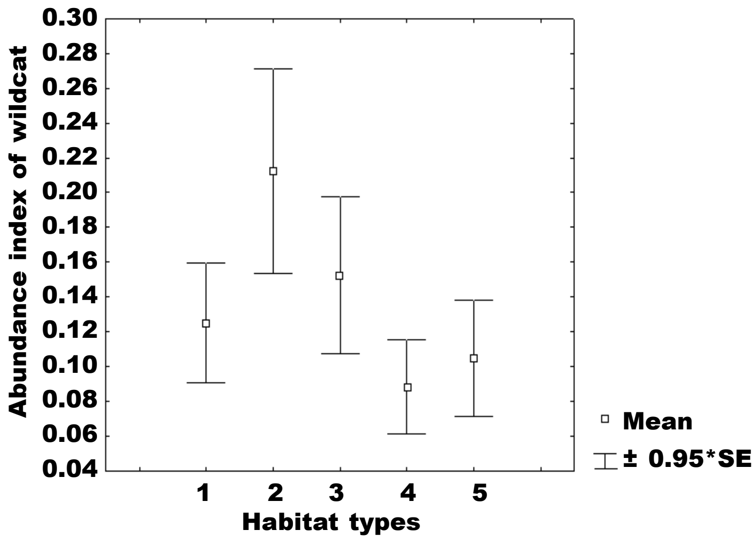

Fig. 2. Mean and standard error of wildcat abundance index for each habitat type considered: 1. Plains with Mediterranean vegetation; 2. Mountains with Mediterranean vegetation; 3. Deciduous forests; 4. Mountain pine forests; 5. Agricultural steppes. The only significant difference was between habitats 2 and 4.

Fig. 2. Media y error estándar del índice de abundancia del gato montés para cada hábitat estudiado: 1. Llanuras con vegetación mediterránea; 2. Montaña con vegetación mediterránea; 3. Bosque caducifolio; 4. Montaña con bosque de pinos; 5. Estepa agrícola. Solamente se encontraron diferencias significativas entre los hábitats 2 y 4.

lowing variables: forest cover (%), pasture cover (%), agricultural cover (%), scrub cover (%), urban cover (%), number of watercourses, roughness index and mean elevation. As in Lozano et al. (2003), to quantify the landscape variables we used land–use maps (1:50.000) to define an area of 9 km^2 around each particular trail surveyed. In this area, landscape variables were measured through a grid with 121 evenly spaced points, on which the number of points in each cover type was recorded. The 9 km^2 area used covers the majority of wildcat home range sizes reported in the literature, except for extreme values (Lozano, 2009). The roughness index was calculated as the mean number of 20 m contour lines intercepted by four lines (one in each cardinal direction) originating from the centre of the 9 km^2 area. Watercourses were recorded by counting their total number in each 9 km^2 unit, and the mean elevation was calculated as the average value of the 121 points used in the landscape cover estimate.

Statistical analyses

Normality and homogeneity of variances were verified for all variables, and those that did not fulfil parametric test requirements were normalized or tested for positive kurtosis (Underwood, 1996). Differences in wildcat abundance indices between the considered habitat types were tested by performing *a priori* contrasts. All variables describing the environmental structure (both microhabitat and landscape variables) and the rabbit abundance index were summarized to a few orthogonal factors using a Principal Component Analysis (PCA), as recommended by Graham (2003) to avoid spurious effects due to multi–colinearity in multiple regression analyses. A general linear model (GLM), generated by a forward stepwise method (F to enter = 4; F to remove = 3.99), was obtained using the wildcat abundance index as a response variable and the PCA factors (which described the environment) as predictors. All statistical analyses were conducted with the software package Statistica 6.0 (StatSoft, 2001).

Results

Wildcats were found in all the habitats studied, although the species was only recorded in 42 of the 101 sampled trails. However, *a priori* contrasts showed that the wildcat abundance index tended to be higher in the areas with Mediterranean mountain vegetation (fig. 2), according to marginally non–significant results (p = 0.063). Comparison of the abundance index in this habitat and in pine forests (the habitat type showing the lowest mean value for the abundance index) showed significant differences (p = 0.038). No difference in wildcat abundance was found between agricultural steppes and the other habitats (p = 0.37), although the abundance index tended to be lower than

Table 1. Factor loadings from the Principal Component Analysis (PCA) performed with variables used to describe the structure of wildcat habitat (asterisks indicate significant correlations between variables and factors, $p < 0.05$).

Tabla 1. Componentes resultantes del Análisis de Componentes Principales (ACP) realizado con las variables utilizadas para describir la estructura del hábitat del gato montés (los asteriscos indican una correlación significativa entre las variables y los factores, p *< 0,05).*

	Factor 1	Factor 2	Factor 3
Microhabitat variables			
Rabbit abundance index	–0.562*	0.499*	0.112
Tree cover	0.88*	0.144	0.022
Shrub cover	0.382*	0.698*	–0.079
Open ground cover	–0.539*	–0.691*	0.072
Rock cover	0.562*	–0.021	–0.12
Tree height	0.868*	0.082	0.022
Shelter index	0.493*	0.589*	–0.144
Landscape variables			
Forest cover	0.896*	–0.097	0.097
Pastureland cover	0.041	0.777*	–0.323*
Cropland cover	–0.774*	–0.576*	0.049
Scrubland cover	–0.068	0.763*	0.302*
Urban cover	0.056	–0.087	–0.929*
Number of watercourses	0.083	0.756*	0.275*
Roughness index	0.816*	0.343*	0.032
Elevation	0.882*	0.036	0.09
Eigenvalue	5.7	3.81	1.21
% Explained variance	38	25	8

in the Mediterranean mountain vegetation ($p = 0.076$). Finally, no difference was observed between mountain environments and plains ($p = 0.35$).

The PCA performed with the original variables generated three factors that explained 71.54% of the total variance (see table 1). The first factor represented a gradient from elevated, rough and dense forests (positive scores) to plains with crops and high rabbit abundance (negative scores). The second factor accounted for rough areas shaped by a scrub–pastureland mosaic with rabbits and watercourses (positive scores) as opposed to pure croplands (negative scores). The third factor generated a gradient that separated scrublands with watercourses (positive scores) from urbanized areas and pasturelands (negative scores).

These PCA factors, which described the structure of environments, were used as predictors in multiple regression analyses (general linear model GLM, forward stepwise method) with the wildcat abundance index as a response variable. A highly significant model was obtained ($F_{1,99} = 12.02$, $p < 0.001$; explaining 10.82% of the variance). Only the second PCA factor was included (positively associated) in the model (table 2). Thus, the model shows that wildcats were more numerous in scrub–pasture mosaics, with abundance of rabbits and watercourses, whereas the species was scarce in the areas where only crops were present (fig. 3).

Discussion

Since the first studies in central Europe were published it was thought that the wildcat was mainly a forest species and so its occurrence would depend on the presence of large forests (Guggisberg, 1975; Parent, 1975; Ragni, 1978; Schauenberg, 1981; Stahl & Leger, 1992). However, as previously discussed (Lozano et al., 2003), the apparent importance of forests for wildcats in those central regions of the continent can be explained by the lack of alternative environments (see also Klar et al., 2008). Thus in many places wildcats simply live where they can, it being incorrect to derive general rules about habitat preferences and try to apply them to areas with different availability of habitats. On the basis of this erroneous extrapolation, the "forest hypothesis" spread.

Table 2. Variables included in the general linear model (GLM), generated by a forward stepwise method, between wildcat abundance index and PCA factors: * Scrub–pastureland mosaics *vs.* cropland.

*Tabla 2. Variables incluidas en el modelo lineal generalizado, obtenidas mediante el método de regresión paso a paso, entre el índice de abundancia del gato montés y los factores del ACP: * Mosaicos de matorral comparado con tierras de cultivo.*

Variable	Beta	B	$t_{(99)}$	p
Intercept		0.131	7.424	< 0.001
Factor 2*	0.329	0.061	3.466	< 0.001

Perhaps the strongest evidence against the forest hypothesis came from Great Britain. It was shown that patterns of deforestation and wildcat disappearance were not closely associated, in contrast with what would be expected for a true forest species (see Langley & Yalden, 1977). Furthermore, the first study on wildcat habitat selection, carried out in Scotland and considering almost thirty potential habitat types, found clearly that the most preferred habitat of Scottish wildcats was not forests, but a mainly open environment without trees (Easterbee et al., 1991). Available evidence therefore seems to confirm that the "forest hypothesis" is based on an incomplete habitat survey. It probably survived, nevertheless, for two reasons. First, because the Scottish study was published as a technical report rather than in a scientific journal; it did not thus reach the wider scientific community. Secondly, this habitat preference was apparently interpreted as a particularity of Scottish wildcats, as distinct from the continental populations (Kitchener, 1991).

The perception of European wildcats as a forest species remained until new studies were published in scientific journals more than a decade later. Lozano et al. (2003) derived an abundance model based on the frequency of scat occurrence, and conducted in a region of central Spain (Madrid province). This model showed again that forest was not the most important habitat for wildcats, their presence being more abundant in mosaics of scrubland and pasture. Likewise, another wildcat abundance model obtained for the Monfragüe National Park, in Cáceres province (also in central Spain), highlighted the key role of scrublands for wildcats (Lozano et al., 2007). The same conclusion was also reached in another Mediterranean area (Monterroso et al., 2009).

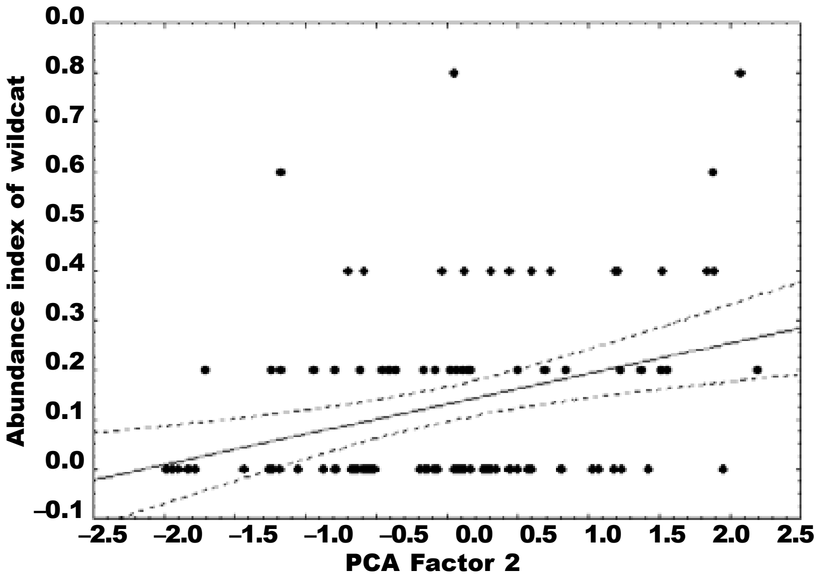

Fig. 3. Relationship between wildcat abundance index and Factor 2 from the PCA (cropland *vs.* scrub–pastureland): wildcat abundance is higher in scrubland and pasture areas with rabbits, and lower in pure croplands without scrub and rabbits.

Fig. 3. Relación entre el índice de abundancia del gato montés y el Factor 2 extraído del ACP (tierra de cultivo comparado con matorral): la abundancia del gato montés es mayor en áreas de matorrales y pastizales con conejos, y menor en cultivos intensivos, carentes de matorral y conejos.

Taking all these studies into account, it appears that although the wildcat can live in forests, this is not the preferred habitat if alternative environments are available –especially scrublands in Mediterranean areas– and therefore the species can not be considered a true forest species.

Nonetheless, the relative importance of forests at the landscape scale and tree cover at the microhabitat scale could be high even in Mediterranean regions. Indeed, the third best model obtained by Lozano et al. (2007) also included forest variables. Moreover, wildcat presence in agricultural areas can be favoured by both forest patches (Virgós et al., 2002) and riparian woodlands (Virgós, 2001). In a study in Portugal several wildcats selected forests (Sarmento et al., 2006). But it has also been shown that wildcat occurrence depends more on availability of prey and shelter than the habitat type categorically considered (Easterbee et al., 1991; Klar et al., 2008; Lozano et al., 2003, 2007; Monterroso et al., 2009).

This study has demonstrated wildcat presence in all the studied habitat types, including the agricultural steppes, showing similar abundance indices in all cases. Wildcat abundance appeared to be higher in mountain areas with Mediterranean vegetation, due to the structural elements that this environment offers in accordance with the GLM model obtained: a mosaic landscape formed by scrubs, pastures and watercourses, and with high rabbit numbers (as previously found by Lozano et al., 2003). The lowest value for the abundance index corresponded to mountain pine forests exhibiting very different structural features. Moreover, according to the GLM model the worst environmental structure for wildcats was the intensive cropland, where the lack of shelter, water and prey are probably strong limiting factors.

The case of agricultural steppes is very interesting. On the basis of compared abundance indices, these habitats were used by wildcats as much as the other habitats: this is the first time that such a result has been reported. Certainly, on many occasions the agricultural steppes included small areas of shrubs and pastures, as well as intensive crops, and they provided sufficient shelter for the feline. Furthermore, the populations of rodents and even rabbits in such cultivated areas could be high and such mammals are the main prey for wildcats (Lozano et al., 2006a; Malo et al., 2004). These small scrub patches thus appear to fulfil a similar function to that of forest fragments and riparian forests within an agricultural matrix (Virgós, 2001; Virgós et al., 2002), explaining wildcat presence in farmed steppe landscapes.

It is important to take into account, nevertheless, that the explanatory power of the obtained abundance model is low, around 11% of variance. Indeed, most distribution and abundance patterns of wildcat in this area of central Spain remain unexplained when only habitat variables are considered, indicating that habitat structure alone is not the predominant factor for wildcat occurrence. In relation to forests, and in clear contrast to previous studies, forest variables were not included in the wildcat abundance model, not being necessary to explain the observed patterns of abundance.

As a principal conclusion for conservation purposes, wildcat populations should be protected wherever they are found, regardless of habitat type. If the species has one key element of environmental structure, this appears to be the presence of scrubland, at least in Mediterranean regions. Destruction of this vegetation type should therefore be prevented (Lozano et al., 2003; Mangas et al., 2008). Priorities for rural land management must be to preserve mosaic landscapes formed by both open and closed habitat patches, and to recover rabbit populations (Lozano et al., 2003, 2007; Lozano, 2009). Finally, for the long term conservation of wildcat populations, and to allow the species to recover in those areas where it is extinct, it is essential to eradicate predator control activities in hunting areas, as this is currently one of the main problems that the species is facing in Spain (Lozano et al., 2006b; Virgós & Travaini, 2005).

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