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Spatial ecology of the European wildcat in a Mediterranean ecosystem: dealing with small radio-tracking datasets in species conservation

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Abstract

Despite some populations of European wildcat *Felis silvestris* in central Europe are stable or increasing, the Iberian subpopulation is in decline and is listed as 'vulnerable'. In Portugal, little is known about wildcat populations, making conservation policies extremely difficult to define. Furthermore, the secretive behaviour of these mammals, along with low population densities, make data collection complicated. Thus, it is crucial to develop efficient analytical tools to interpret existing data for this species. In this study, we determine the home-range size and environmental factors related to wildcat spatial ecology in a Mediterranean ecosystem using a combined analysis of habitat selection and maximum entropy (Maxent) modelling. Simultaneously, we test the feasibility of using radio-tracking locations to construct an ecologically meaningful distribution model. Six wildcats were captured and tracked. The average home-range size (MCP95) was 2.28 km^2 for females and 13.71 km^2 for one male. The Maxent model built from radio-tracking locations indicated that the abundance of the European rabbit *Oryctolagus cuniculus* and limited human disturbance were the most important correlates of wildcat presence. Habitat selection analysis revealed that wildcats tend to use scrubland areas significantly more than expected by chance. A mosaic of scrublands and agricultural areas, with a higher proportion of the former, benefits wildcat presence in the study area; however, species distribution is mainly constrained by availability of prey and resting sites. The Maxent model validation with camera-trapping data indicated that highly adequate model performance. This technique may prove useful for recovering small radio-tracking datasets as it provides a new alternative for handling data and maximizing the ecological information on a target population, which can then be used for conservation planning.

Introduction

The European wildcat *Felis silvestris* is widely distributed, ranging from the Iberian peninsula to Eastern Europe (Nowell & Jackson, 1996; IUCN, 2007). Nevertheless, its current distribution is highly fragmented, mainly as a result of severe population declines and local extinctions that occurred across its range since the 17th century (Stahl & Artois, 1991; Sunquist & Sunquist, 2002). Currently, some stable or increasing subpopulations exist, for example in Germany and Switzerland. The Iberian subpopulation, however, is suspected to have decreased at a rate of $>30\%$ over three generations and consequently the European wildcat is listed as 'vulnerable' (IUCN, 2007). A previous assessment of wildcat distribution in Portugal suggested its presence in scattered and isolated population nuclei (B. Pinto & M. Fernandes, unpubl. data).

Despite being generally considered to be a species specialized in consuming rodents (Nowell & Jackson, 1996), this might not be the case in Mediterranean ecosystems, where rabbits tend to be the preferred food source (Lozano, Moleón & Virgós, 2006). Habitat preferences also diverge between the temperate bioclimatic region, where the species is considered to be bound to forests (Nowell & Jackson, 1996), and Mediterranean ecosystems, where a mosaic of shrub-pasturelands is the elected landscape configuration (Lozano *et al*., 2003). However, there is a lack of detailed information on wildcat biology and spatial ecology across Portugal to facilitate adequate conservation planning.

Their elusive behaviour and low population densities make field studies and direct observation difficult (Wilson & Delahay, 2001). Among the methodological alternatives available, radiotracking and camera trapping are broadly used (Kenward, 2001; Wilson & Delahay, 2001). While the former produces quality data concerning animal location, movement and activity, it is very time consuming and requires considerable effort. For these reasons, radio-tracking studies often focus on a sub-sample that may not be representative of the studied population. An alternative method that has recently become popular is camera trapping. It is widely used in the study of cryptic and inconspicuous species (Wilson & Delahay, 2001), providing continuous and unequivocal data of species activity and distribution. Nevertheless, this method is not without weaknesses. Camera-trap placement in the field is critical, and human scent left on the equipment may cause carnivores to avoid cameras (Wilson & Delahay, 2001).

A modelling technique based on presence-only data may help to understand the ecological requirements of target species studied by the above-mentioned field methods. However, data originating from a small sample of the population, as is often the case in radio-tracking studies, may not be representative of that population and may thus produce biased models. Therefore, distribution models produced by such data should be carefully evaluated. The most realistic methods to evaluate the predictive capacity of statistical models rely on cross-validation. However, when few data are available, the exclusion of a subset for cross-validation is not realistic (Guisan & Zimmermann, 2000), and other source data on distribution should be used for model evaluation purposes. Camera trapping and radio-tracking provide statistically independent data of wildcat spatial distribution and abundance and thus fit these criteria. The former can be used to cross-validate the distribution models built by radio-tracking locations.

Given how little is known about wildcat biology and the vulnerability of Iberian populations, new approaches that contribute to our understanding of the spatial ecology of this species should be investigated. Thus, the two main objectives in this study are: (1) to assess the home-range size and determine the environmental factors related to wildcat spatial ecology in a Mediterranean ecosystem; (2) to test the feasibility of using radio-tracking locations from a population sub-sample to construct an ecologically meaningful distribution model, cross-validated with distinct source-data.

Materials and methods

Study area

This study was performed in the Guadiana Valley Natural Park (GVNP), a protected area located in Southern Portugal (37°84.7′N; 7°79.7′W to 37°52.4′N; 7°51.1′W). The climate is classified as attenuated thermo-Mediterranean (Alcoforado *et al*., 1982).

The landscape is highly fragmented with cereal croplands and agroforestry systems (Montado) of *Pinus pinea* L. and *Quercus ilex* L. Scrubland patches are mainly associated with steeper slopes and elevation ridges. The vegetation is dominated by the *Myrto communis–Querco rotundifoliae* S. series but other sub-serial stages can also be found (Costa *et al*., 1998). Game activity is extremely important in this region and about 86% of the land is included in hunting estates. The most appreciated game species include the red-legged partridge *Alectoris rufa* and the European rabbit *Oryctolagus cuniculus*.

For habitat selection, the study area was defined as the junction of the circular areas with a radius equivalent to the maximum travelled distance recorded and centred in the arithmetic mean of x and y positions for each individual home range. For distribution modelling, the study area included both the GVNP and the area defined for habitat selection, comprising *c*. 778 km^2.

Trapping and handling

Trapping was performed with 13 box-traps (180 × 80 × 80 cm), lured with Iberian lynx *Lynx pardinus* urine and live house pigeons (*Columba* sp.), unavailable to captured animals. Box-traps were placed in areas where wildcat presence was recorded frequently in previous surveys. Because of the mainly crepuscular and nocturnal activity of wildcats (P. Monterroso, unpubl. data), box-traps were checked daily after sunrise to minimize animal stress. A total of six individual wildcats (two males and four females) were captured in 377 trapping-days.

Captured animals were chemically immobilized with a combination of medetomidine hydrochloride (Domitor®, Espoo, Finland; 0.1 $\mathrm{mg\,mL^{-1}}$) and ketamine hydrochloride (Imalgene®, Lyon, France; 1 $\mathrm{g\,mL^{-1}}$) with average dosages of 0.28 (± 0.21) mL and 0.19 (± 0.20) mL, respectively. Animals were weighted, sexed and checked for any sanitary disorder. Blood samples were also collected for genetic confirmation of the taxonomic classification. Individuals were classified as juvenile, sub-adult or adult by analysing a combination of morphological traits such as tooth wear, body size, sexual development and overall body condition. After handling, individuals were returned to the capture location, where they were maintained in the dark, and released once they had completely recovered their reflexes (1–3 h).

Radiotracking

Individuals were fitted with Wildlife Materials Inc. (Murphysboro, IL, USA) HLPM 3320 radio-collars (80 g, approximate weight, frequencies ranging 150–151 MHz). Tagged animals were located by signal triangulation with the help of a four-segment direction antenna (Telonics®, Mesa, AZ, USA, model RA-14) and a portable receiver (Yaesu®, Cypress, CA, USA, model FT-290RII), and bearings were determined using a handheld global positioning system unit equipped with an electronic compass (Garmin®, Olathe, KS, USA, model E-Trex Summit). Triangulation was performed by a single researcher at different times of the day in order to cover the entire circadian cycle. Occasionally, tracking cycles were performed, during which animals were located at 1-h intervals between mid-afternoon and the end of the morning the following day. Triangulation consisted of at least three azimuths with an angle of no less than 30° between them, obtained within 15 min of each other (Kenward, 2001). All animals were located on average twice per week (SD = 0.31) during radio-tracking periods.

Land-cover datasets

Habitat selection

CORINE00 Land Cover vector, dated 2000 (CORINE00; Bossard, Feranec & Otahel, 2000), was reclassified into nine biologically relevant classes for the European wildcat, based on the authors' knowledge of the species and on the published literature. The spatial distribution, area and shape of vegetation classes were checked for significant changes by field verification and analysis of orthophotoimagery with 1 m pixel size, produced in 2001. Three land-use classes occupy 93% of the study area's surface: cropland (29.87%; 44 patches with average area of 527 ± 1254 ha), agroforestry (34.12%; 84 patches with average area of 316 ± 783.2 ha) and scrubland (29.56%; 103 patches with average area of 223 ± 633.6 ha) (Fig. 1). Cropland areas were almost exclusively used for wheat production (*Triticum* spp.).

Distribution modelling

For distribution modelling all variables were converted from the vector dataset into a 150 m pixel raster format. Both land-use and topographic variables were considered on a local scale, that is concerning the pixel value each location fell upon, and on a home-range scale, that is a 4 km^2 area surrounding each location (average home range, Lozano *et al.*, 2003). Prey availability was only considered on a local scale (Table 1).

Land-use datasets

The same classes as for habitat selection were used. The land-use variables considered for the home-range scale were determined as the proportion of each land-cover class in a 4 km^2 area.

Table 1 Ancillary variables considered for maximum entropy modelling of wildcat *Felis silvestris* distribution in the study area

	Scale	
Variable (code)	Local	Home range
Artificial areas (10)	Presence/absence	Continuous
Mineral extraction sites (13)	Presence/absence	Continuous
Croplands (21)	Presence/absence	Continuous
Permanent crops (22)	Presence/absence	Continuous
Agroforestry (24)	Presence/absence	Continuous
Broad-leave forests (311)	Presence/absence	Continuous
Coniferous forests (312)	Presence/absence	Continuous
Scrublands (32)	Presence/absence	Continuous
Inland waters (51)	Presence/absence	Continuous
Elevation	Continuous	Not considered
Slope	Continuous	Not considered
Maximum elevation	Not considered	Continuous
Elevation standard deviation	Not considered	Continuous
Maximum slope	Not considered	Continuous
Slope standard deviation	Not considered	Continuous
Rabbit abundance	Categorical (1–9)	Not considered

Topographic variables

A 25 m pixel digital elevation model (DEM) in raster format was obtained from a 1 : 25 000 scale vector format topographic data. The elevation values ranged from 3 to 368 m. Slope (SLP) was derived from the DEM using second-order finite differences, and ranged from 0 to 55°. The DEM and

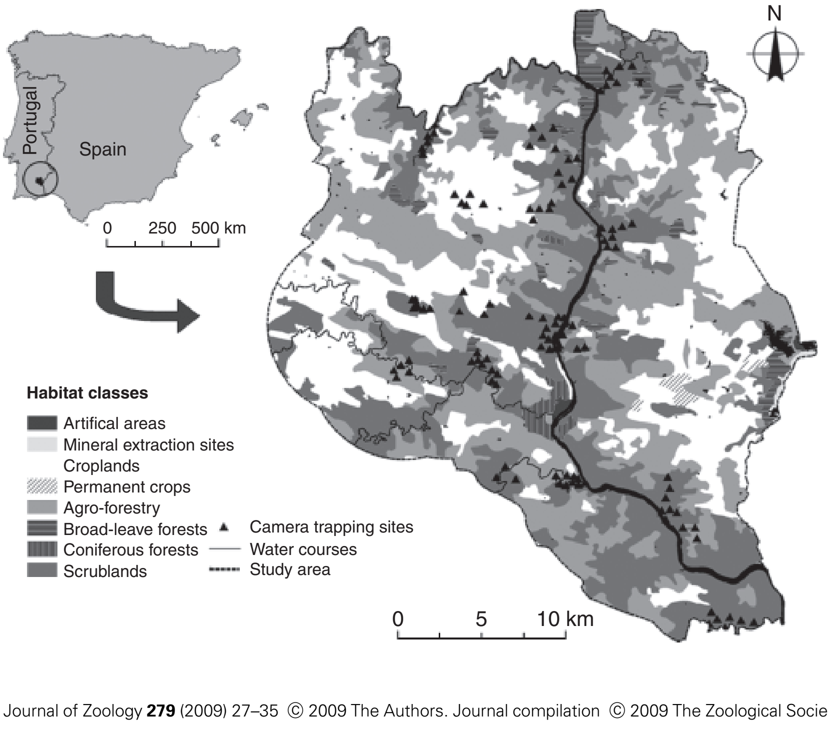

Figure 1 Location of the study area in the Iberian peninsula (small inset) and spatial distribution of habitat classes and camera traps.

SLP were converted to a 150 m resolution raster, by pixel averaging. The mean, maximum and standard deviation values were determined at the home-range scale.

Rabbit abundance

Wild-rabbit relative abundance was determined by latrine counts (Calvete *et al.*, 2004) in late May 2005 when densities peaked (Gonçalves, Alves & Rocha, 2002). Latrines, defined as groups of ≥ 50 pellets in an area of *c*. 30 cm diameter (Iborra & Lumaret, 1997), were counted along 300 m-long transects. Sampling effort comprised a total of 483 transects distributed across 183 grid squares of 1 km^2. As an index of rabbit relative abundance, we used the number of latrines per km (range 0–86.67 latrines km^{-1}). The continuous distribution of European rabbit abundance was interpolated by Ordinary Kriging (Isaaks & Srivastava, 1989). The final rabbit relative abundance vector dataset was converted into a 150 m resolution raster by averaging rabbit abundance values.

Data analysis

Home range

Home-range sizes were determined by 95% minimum convex polygon (MCP; Mohr, 1947). The minimum number of fixes required for reliable home-range estimation was determined by MCP bootstrap resampling analysis (Kenward, 2001). The number of locations was considered satisfactory for MCP home-range estimation when the relation between MCP percentages of total area versus the number of fixes achieved an asymptote.

Habitat selection

Type 3 selection, that is within home-range selection according to Johnson (1980), was evaluated for each individual wildcat, whereas landscape-level selection (type 2) was evaluated for the pooled radio-tracking dataset. The analytical method used for habitat selection was a modified Ivlev's selectivity index (Ivlev, 1961), adapted by Jacobs (1974). Only classes with availability above 5% were considered for analysis (Palomares *et al.*, 2000). The significance of the difference between the obtained index value and zero (randomness) was evaluated by 1000 replicates' bootstrap resampling (Manly, 1997) and by recalculating the Jacobs index for each bootstrap sample. The average index, standard deviation and 95% confidence intervals were then defined for each habitat type, considering each animal's locations individually and the overall fixes for all tracked animals. In order to avoid bias due to unequal representivity, bootstrap resampling of the pooled data was performed with an equal number of each animal's samples (fixes). Only temporally uncorrelated locations were considered to evaluate habitat selection. Time to independence was defined as the time required by an animal to travel between the two most widely separated points of its home range at the maximum recorded speed (Rooney, Wolfe & Hayden, 1998).

Distribution modelling

Maximum entropy (Maxent)

Radio-tracking locations were used as the source data for Maxent, which is an appropriate general-purpose machine learning method (Phillips, Anderson & Schapire, 2006). Environmental correlates for species occurrence were conducted using Maxent 3.0.2 beta (http://www.cs.princeton.edu/~schapire/maxent), which is particularly useful when only scattered data are available and is capable of dealing with continuous and categorical variables simultaneously (Phillips *et al.*, 2006).

Maxent finds the most uniform species distribution with the constraint that the expected value for each variable should match the average value of a set of sample points taken from the target-species distribution (Phillips *et al.*, 2006). The probability distribution is exponential, ranging from 0.0 to 1.0, and sums to 1.0. This is achieved by dividing the sum of weighted probability values by a scaling constant. The modelling procedure begins with a uniform probability distribution (gain = 0) and a weight is altered consecutively so that the probability of occurrence of the source data is maximized, increasing the 'gain' towards an asymptote during a run. The 'gain' is a measure of the likelihood of the samples, meaning that the average sample likelihood of a model with 'gain' = 2 is $\exp(2) \approx 7.4$ times higher than that of a random background pixel (Phillips *et al.*, 2006).

Maximum entropy models were run, and the selected output grid format was 'logistic', in which pixel values range from 0 to 1.

Model validation

Evaluation of model fit

The receiver operating characteristic (ROC) curve was produced to evaluate the overall model fit, where the models' sensitivity versus 1−specificity is plotted (Liu *et al.*, 2005). Absence data were randomly generated by the software from background pixels (Phillips *et al.*, 2006). The fit of the model to the data was evaluated by the area under the ROC curve (AUC).

The data were Jackknifed to evaluate each ancillary variable's importance in explaining the observed distribution. Subsequently, a model was generated using each variable in turn and using all remaining variables, so that the most informative ones could be found (Phillips *et al.*, 2006). A stepwise procedure was used to exclude less informative variables sequentially.

The response of wildcats to each variable was analysed by examining the response curves, which represent the exponential changes, that is predicted suitability, as each variable varies by maintaining all others at their average sample value (Phillips *et al.*, 2006).

Model validation with camera-trapping data

A total of 121 camera-trapping stations were distributed throughout the study area from November 2002 to May

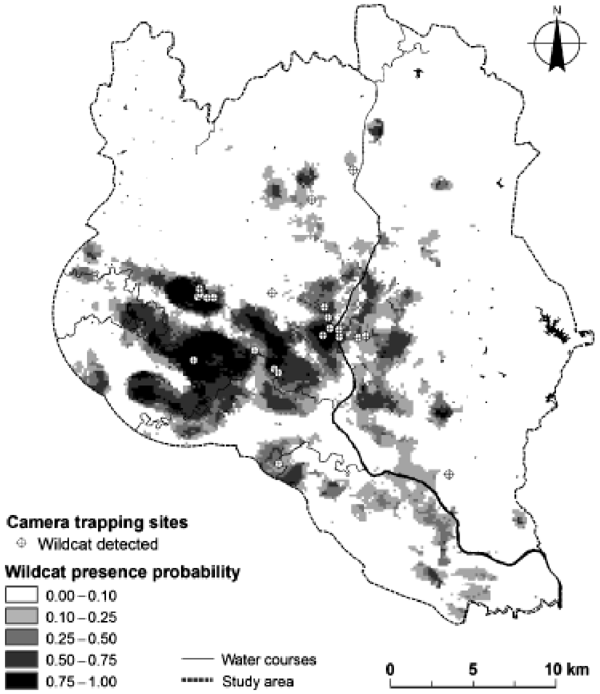

Figure 2 Distribution of camera-trapping stations with positive detections, and wildcat's *Felis silvestris* presence probability estimated by Maxent modelling.

2005. They were placed in 2 × 2 UTM grid squares, randomly selected. Each square contained three to five stations, which were spaced 300–800 m from each other. The overall trapping effort comprised a total of 4367 trapping-days. Camera stations consisted of a scent-station with Iberian lynx *L. pardinus* or domestic cat *Felis catus* urine (Schlexer, 2008), and a photographic camera equipped with a heat sensor device (CamTrakker®, Watkinsville, GA, USA). In the study area, temperatures can increase to 45 °C in the summer; thus, an alternative system was used during this period, consisting of a 30 × 30 cm pressure pedal, connected to an auto-focus camera. Camera stations were maintained in the field for a minimum period of 28 days.

Model cross-validation was assessed by comparing presence/absence data from wildcat camera trapping with predicted wildcat presence probability obtained by maximum entropy modelling for each camera-trap location. One-way analysis of variance was used to evaluate the difference between the probability estimates predicted from the model built from radio-tracking locations, and wildcat presence and absence data obtained from camera trapping Fig. 2.

Results

Home range

Table 2 Weights, ages, capture dates, number of fixes and home-range size for each radio-tracked wildcat *Felis silvestris*

Code	Weight (kg)	Age	Capture date	Date of last fix	*n*	MCP95 (km^2)
Females						
FS01	–	A	13/07/2004	13/04/2005	71	2.75
FS02	3.50	A	15/07/2004	08/09/2004	16	
FS03	4.00	A	19/07/2004	06/12/2004	37	2.40
FS06	3.00	SA	25/07/2004	18/03/2005	82	1.70
Males						
FS04	5.00	A	30/07/2004	15/11/2004	23	
FS05	4.60	A	08/08/2004	20/04/2005	74	13.71

n, number of fixes; MCP95, 95% minimum convex polygon.

Seven captures of adult wildcats were obtained between July and August 2004, including the recapture of one female, FS03 (Table 2). Trapping success was 1.86 captures per 100 trapping. Genetic analysis revealed that all captured wildcats were 'pure' or without any indication of parental domestic heritage (Oliveira *et al.*, 2008).

Radio-tracking efforts produced a total of 303 individual wildcat locations (244 independent), averaging 50.5 ± 28.6 (SD) locations per animal (Table 2), and an average error ellipse area of 4.23 ± 10.44 ha (SD). Radiotracking was performed over a period of 10 months (July 2004 to April 2005), comprising almost the complete annual cycle of agricultural practices. As an asymptote was not achieved for specimens FS02 and FS04, home-range estimates and habitat selection were not performed for these animals. Female home-range size calculated by MCP95 averaged 2.28 ± 0.53 km^2, whereas that of the male wildcat, FS05, was 13.71 km^2.

Habitat selection

The Jacobs selectivity analysis for each individual revealed no significant association with habitat classes (Table 3). The only exception was the significantly lower use of scrublands than would be expected by chance by wildcat FS01. The same analysis for the pooled independent locations revealed that the Jacobs index was significantly different from zero for both croplands and scrubland classes. While scrublands were significantly selected in the landscape, croplands were avoided. The Agroforestry habitat type was used in the same proportion as its availability.

Environmental correlates of wildcat distribution

The maximum entropy model of wildcat distribution revealed an AUC of 0.978. Seven ancillary variables were selected for the Maxent wildcat model. Rabbit abundance was the most important variable in explaining wildcat distribution (Table 4). Slope and elevation unevenness were the second most important variables. The habitat-related variables explained a small proportion of the variability (6.8%; Table 4). The environmental variable with the highest gain when used in isolation is elevation standard deviation. Rabbit abundance is the variable that decreases the gain the most when it is

Table 3 Habitat selection indexes for pooled dataset and for individual wildcats *Felis silvestris*, according to Jacobs' (1974) method, and respective average, standard deviation and 95% lower and upper bounds as determined by 1000 replicates bootstrap analysis

			Jacobs index				
Wildcat	Habitat	Availability (%)	Average	SD	Lower bound	Upper bound	Selection
FS01							
	Scrublands	82.918	−0.285	0.124	−0.504	−0.047	−
	Broad-leave forests	11.547	0.220	0.168	−0.213	0.500	NS
FS04							
	Croplands	19.252	−0.092	0.234	−0.585	0.272	NS
	Agroforestry	12.430	0.341	0.179	−0.031	0.587	NS
	Scrublands	68.318	−0.085	0.175	−0.423	0.306	NS
FS05							
	Croplands	15.141	−0.275	0.223	−0.802	0.143	NS
	Agroforestry	16.907	0.116	0.168	−0.219	0.410	NS
	Scrublands	62.596	−0.057	0.144	−0.357	0.237	NS
FS06							
	Agroforestry	89.194	−0.134	0.170	−0.412	0.231	NS
	Scrublands	7.037	−0.052	0.258	−0.682	0.315	NS
Total of locations							
	Croplands	36.377	−0.502	0.058	−0.608	−0.392	−
	Agroforestry	28.680	0.084	0.056	−0.023	0.190	NS
	Scrublands	30.493	0.300	0.051	0.198	0.400	+

Areas with availability below 5.0% are not represented.
+, significant selection; −, significant avoidance; NS, no significant selection.

Table 4 Ancillary variables selected for the Maxent modelling of wildcat *Felis silvestris* distribution in the study area

		Jackknife of regularized training gain	
Variable	Contribution (%)	Without variable	With only variable
Rabbit abundance	40.2	1.8764	1.0073
Elevation standard deviation	27.7	2.1134	1.3435
Slope standard deviation	17.4	2.1289	0.8192
Maximum slope	7.8	2.1611	0.7181
Scrublands (home-range scale)	2.7	2.184	0.3005
Agroforestry (home-range scale)	2.1	2.1867	0.0696
Arable land (home-range scale)	2.0	2.1414	0.074
Total	100	2.196	

Maxent, maximum entropy.

omitted, meaning that it contains the most information not present in the other variables (Table 4).

Model validation by camera trapping

A total of 35 wildcat detections were obtained in 20 (16.5%) camera-trap stations. Out of 15 (12.4%) camera traps located within radiotracked wildcat home ranges, a subset of five obtained wildcat detections.

The presence probability (derived from radiotracking) at locations where wildcats were and were not detected by camera trapping (mean ± SE: 0.603 ± 0.314 and 0.183 ± 0.305, respectively) was significantly different ($F = 31.46$; $P < 0.001$).

Discussion

Home range

Female home-range size was on average almost three times smaller than male home-range size. This was expected as males explore wider home ranges as a way to maximize their chances of coming into contact with females (Urra, 2003). In contrast, females tend to select home ranges so that resource availability is maximized, thus achieving better conditions for reproduction and cub weaning (Liberek, 1999; Urra, 2003).

Wildcat home-range size varies considerably across Europe, ranging from 1.95 to 50.17 km^2 and 0.69 to 13.85 km^2, for males and females, respectively (Urra, 2003; López-Martin, 2005; Potocnik *et al.*, 2005). Our results reveal that wildcat MCP home ranges in the GVNP are slightly lower than the overall average obtained from other European studies on this species (15.7 and 5.7 km^2 for males and females, respectively). In general, home-range size among mammals and birds is related to resource distribution and density (Haskell, Ritchie & Olff, 2002). We therefore suggest that the smaller home ranges seen in this study, especially for female wildcats, are related to the abundance of European rabbits, on which the wildcats prey.

Environmental factors related to wildcat spatial ecology and conservation

Our Maxent modelling results are consistent with the assertion that food resources and availability of breeding sites are strongly related to population persistence over time in a given area (Fahrig & Merriam, 1994). Remarkably, prey availability and topography-related variables explained up to 85% of the species occurrence in the study area.

Despite being generally considered to be a species bound to forest habitats, where it mainly feeds on rodents (Nowell & Jackson, 1996), the European wildcat elects the European rabbit as preferred prey whenever it is available (Lozano *et al.*, 2006). Our modelling results suggest that rabbit abundance is the most important factor shaping wildcat distribution in the GVNP. Virgós, Tellería & Santos (2002) observed a similar pattern in Spain, where wildcats were heavily dependent on prey availability.

Landscape variables related to topographic unevenness were also considered key features for wildcat distribution. The intensively managed landscape observed in the study area confines undisturbed sites to areas of steeper slopes, where human activity is limited by terrain characteristics. We suggest that these topographic features may provide localities of tranquility, a factor that is seldom accounted for. As areas with little disturbance and steeper topography provide better conditions for wildcat resting and breeding sites (Ragni, 1978), suitable conditions for wildcat population persistence may be confined to locations with some degree of topographic harshness.

The Maxent modelling and individual wildcat selection analysis approaches suggest that landscape composition in the GVNP is a less important factor governing wildcat distribution and space use. The landscape found in the GVNP is a mosaic of cereal crops, agroforestry systems and scrubland patches, in roughly the same proportions. There, the wildcats' hunting strategy of ambushing prey (Ragni, 1978) takes advantage of the ecotone between areas with and without shrub cover. These landscape characteristics also favour the European rabbit (Calvete *et al.*, 2004), and are important elements that contribute to the availability of prey.

Nevertheless, the selection analysis for the pooled dataset revealed that wildcats spend more time inside scrublands than expected by chance, taking advantage of the protective cover. Conversely, croplands were significantly avoided due to increased exposure to humans, as well as visibility to prey. Open habitats such as croplands are mainly used during the night for foraging and hunting (Ragni, 1978). Agroforestry systems still maintain an unclear effect as they may be used for agricultural purposes where the understorey is dominated by cereal crops, or left alone, causing the understorey to become dominated by shrub vegetation.

Our results stress the importance of resting sites and low disturbance as determinant factors for wildcat population conservation. Habitat configuration may be improved essentially to enhance rabbit availability and provide scrubland patches and ecological corridors. Therefore, we believe that special conservation efforts for the wildcat in the Mediterranean region should focus not only on managing habitat, to provide a mosaic of scrub and agricultural areas, but essentially on (1) preserving areas with irregular topography, promoting the development of natural vegetation and low disturbance; (2) managing the landscape to promote ecological corridors between wildcat population nuclei in order to prevent population decrease, restricted contact and potential genetic structuring; (3) managing European rabbit populations so that their availability meets the ecological purposes.

Model evaluation

Model evaluation revealed a highly adequate fit. Concordantly, camera-trapping data revealed significantly higher prediction values for locations where wildcats were present, than for locations where the method failed to detect them. Absence records in species surveys may not reflect true species absence, especially in the case of elusive and secretive species (Barea-Azcón *et al.*, 2007). Because Maximum Entropy Modelling requires presence location as the only input data, it provides a modelling alternative. As radiotracking provides presence-only data from a subset of the target population it can be used to predict the species potential distribution by modelling its niche (Phillips *et al.*, 2006). Camera trapping provided a completely independent wildcat occurrence dataset, not bound to a restricted number of population individuals or to the tracked individuals' home range. Cross-validation of the model with camera-trapping data revealed that the model for wildcat distribution in the GVNP was highly suitable, even though source data originated from an unequal sample of six individuals.

The power of Maxent modelling for carnivore conservation

Because radiotracking is expensive and extremely laborious, many studies became restricted to a small number of tracked animals. At the same time, logistic constraints may prevent the acquisition of an adequate number of locations per tracked individual. These constraints may be so severe that data become unusable to infer population patterns. Our case study with wildcats revealed that a small sample of six individuals from a population, with an average of 50 locations per individual, provided a meaningful distribution model that identifies the main environmental factors related to the species conservation in the study area. Therefore, we suggest that Maxent modelling may be a useful tool for carnivore conservation as it recovers formerly disregarded radio-tracking data, providing a helpful ecological evaluation of a target population, which can be used for conservation planning.

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