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Space and Habitat Selection by Female European Wild Cats (*Felis silvestris silvestris*)

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Abstract

Studies on the use of space and habitat selection of threatened species are useful for identifying factors that influence fitness of individuals and population viability. However, there is a considerable lack of published information regarding these factors for the European wildcat (*Felis silvestris*). Serra da Malcata Nature Reserve (SMNR), a mountainous area in the eastern centre of Portugal, hosts a stable wildcat population which constitutes a priority in terms of conservation. We studied space use and habitat selection of female wildcats in SMNR with the following objectives: 1) to describe seasonal space use and habitat selection and 2) to obtain information on priority habitats for wildcats in order to develop a proper conservation strategy. We used radio-telemetry as the basic tool for our study and we analysed habitat selection using an Euclidean distance-based approach to investigate seasonal and annual habitat selection by wildcats. We detected that during spring females exhibit smaller home ranges and core areas. Females exhibited habitat selection for establishing home ranges from the available habitats within the study area. In fact, females selected *Quercus pyrenaica* forests and *Quercus rotundifolia* and *Arbutus unedo* forests positively and avoided *Erica* spp. and *Cistus ladanifer* scrubland and other habitats. *Quercus pyrenaica* forests and *Quercus rotundifolia* and *Arbutus unedo* forests are important habitats for female wildcats because they provide shelter and food resources, such as small mammals. They also contain elevated tree cavities which can be use as dens. In contrast, *Erica* spp. and *Cistus ladanifer* scrubland is an extremely dense habitat with low associated biodiversity and so wildcats avoid it. We believe that this habitat, as well as pine stands, do not provide food and cover resources for wildcats. Home ranges with higher percentage of these habitat types tend to be larger, since females are required to use larger areas to meet their resource requirements. Our results emphasize the importance of the remaining autochthonous forests in wildcat conservation. Therefore, we recommend that current habitat policy for restoration and conservation should be continued and expanded in order to substantially increase the amount of natural forested land in Serra da Malcata.

Introduction

In Europe, the wildcat (*Felis silvestris*) presents a rather fragmented geographic distribution, ranging from the Iberian Peninsula to the eastern part of the continent [1]. Globally, this feline is included in Category 5C of the *Global Cat Species Vulnerability Rankings* [2] and it represents a Least Concern (LC) species according to the IUCN Red List [3]. However, in Portugal the wildcat is a Vulnerable (V) species according to the Portuguese Red Data Book [4]. Furthermore, in some European countries the wildcat became extinct and in most cases, changes and trends in distribution are poorly documented [5].

The major threats to the wildcat include habitat destruction and population fragmentation [5,6], poaching [1], vulnerability to pathologies [7,8] and hybridisation with domestic cats [9,10]. Another obstacle to wildcat conservation is the lack of adequate data on basic ecological aspects, particularly in Iberian ecosystems. In fact, specific knowledge on habitat use, home-range characteristics and spatial organization constitute crucial management information when aiming at developing correct conservation efforts towards wildcat conservation.

During the last decades, human activities have damaged natural landscapes, with a highly negative impact upon the amount and quality of available habitats [11]. Habitat and population fragmentation constitute major threats to a large number of mammals. In order to implement valid measures of wildlife management it is necessary to consider space use and habitat selection patterns, which will allow identifying areas and resources that influence the fitness of individuals and the viability of populations [12].

The Serra da Malcata Nature Reserve (SMNR) is a mountainous area in the eastern centre of Portugal. This area presents a stable wildcat population [13], which constitutes a priority in terms of conservation considering the above-mentioned status in agreement with the Portuguese Red Data Book [4].

According to several studies on feline species ecology, females tend to use space according to the availability of resources while males are usually distributed according to female territories [14-16]. Therefore, female spatial ecology may be a suitable indicator of habitat quality, which constitutes crucial information when assessing and restoring habitat for wildcat conservation.

The present study on female wildcats in SMNR aimed at describing seasonal space use and habitat selection and at obtaining information on priority habitats for wildcats in order to develop a proper conservation strategy.

Study area

Serra da Malcata (Fig. 1) is a 200 Km^2 mountainous area located in Portugal near the Spanish border, between 40º08´50´´ N - 40º19´40´´ N and 6º 54´10´´ W - 7º 09´14´´ W. The climate is characteristically Mediterranean. Vegetation is dominated by dense scrublands of *Cytisus* spp., *Halimium* spp., *Cistus* spp., *Erica* spp., *Chamaespartium tridentatum* and *Arbutus unedo* covering 43% of the area. Scattered woodlands of *Quercus rotundifolia* and *Quercus pyrenaica* trees constitute 15% of Serra da Malcata. Thirty percent (30%) is covered by industrial plantations of *Pinus* spp., *Eucalyptus globulus* and *Pseudotsuga menziezii* and the remaining 12% is cropland. Approximately 60% of Serra da Malcata is a protected area included in Serra da Malcata Nature Reserve.

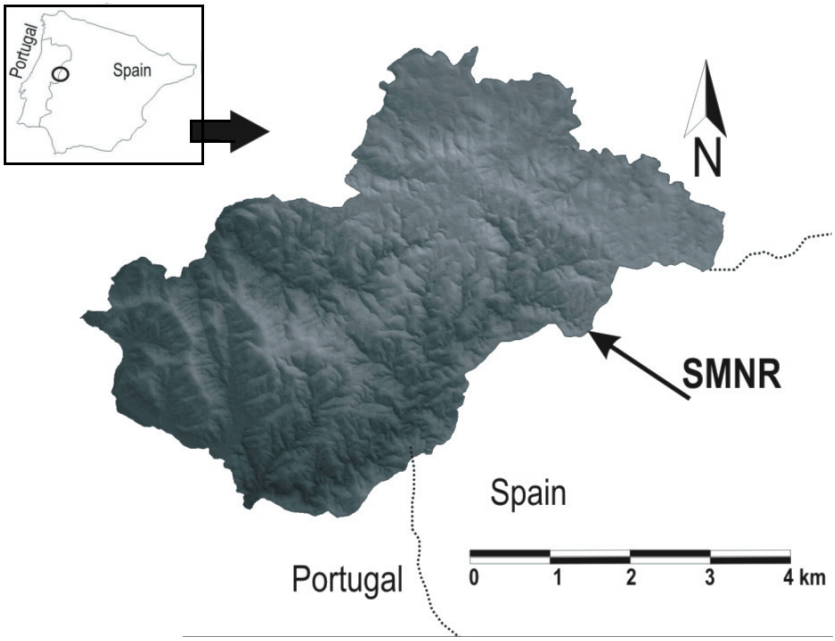

Fig. 1. Map of Serra da Malcata Nature Reserve in central-eastern Portugal.

Material and methods

Wildcat capture, immobilization, radio-tagging and radio-tracking

Wildcats were captured using baited home-made box-traps (1.8 m x 0.7 m x 0.70 m). Between April 1998 and September 2001, 6 females were caught during 879 trap-nights. The animals were immobilised with an intramuscular injection of a 5:1 combination of ketamine hydrochloride (100 mg/ml Imálgene® 1000) and xilazine hydrochloride (Rompum® 0.5) via hand-held syringe. Body temperature, heart and respiratory rates, induction and recovery times were monitored. Each immobilised cat was sexed, aged, weighted, measured, marked and fitted with radio-collars emitting at 145 - 148 MHz from Biotrack® (100 g, life span 12 - 18 months) (Dorset, UK) and Televilt® (50g, life span 18 months).

We estimated wildcat locations via triangulation using hand-held receivers and 2-element H-antennas (Televilt®). We determined the observer location using a handheld Global Positioning System and collected data from fixed or temporary telemetry stations. Wildcat positions were obtained using 4 or more fixes collected within 15 minutes, with angles between consecutive bearings around 30º, and angles between the 2 outermost bearings around 145º. We converted telemetry data into location estimates using the programme Tracker® 1.1 (A. Angerb- jorn, Sweden) and entered the Universal Transverse Mercator coordinates into a database. We estimated the 95% home ranges and the 50% core areas using fixed-kernel estimators in the Animal Movement and Spatial Analyst extensions of Arcview 3.2. We determined the independence of radio-fix data by using the Swihart and Slade method [17].

For analyses we divided the tracking periods in 4-month seasons:

1 - Spring (March - June), which corresponds to the denning period;
2 - Summer (July - September), post-denning period;
3 - Autumn-winter (October - February), oestrus season.

We used all locations that met the telemetry and sampling protocol requirements to estimate seasonal and annual ranges (Table 1). In order to locate wildcats during all light and dark hours, an equal number of locations was obtained during each of the following 4 time periods: 1) 0001 - 0600 hours; 2) 0601 - 1200 hours; 3) 1201 - 1800 hours and 4) 1801 - 2400 hours. We estimated 24 seasonal and annual home ranges for six female wildcats (Table 1).

Table 1. Sample sizes in terms of home ranges estimated, and number of locations to estimate seasonal and annual home ranges for wildcats in Serra da Malcata Nature Reserve (Portugal).

	Sample sizes	N.º of locations		
Season	Home ranges	Mean	SE	Range
Spring	9	145.44	31.21	71 - 198
Summer	8	322.66	19.05	278 - 401
Autumn-Winter	8	566.44	45.67	467 - 617

The independent fixes were used to analyse home-range size and overlap [18]. Home range size was estimated by the Kernel method [19] and the core areas of each home range were identified as the 50% fixed-kernel estimators.
To analyse the home range seasonal stability we used the index of Cole [20], defined by the following equation:

$$C\% = (2AB / A+B) \times 100$$

Where A and B represent the home range sizes in two consecutive seasons and AB is the area common to those home ranges. This index varies from 0 (no coincidence) to 100 (total coincidence).

Habitat Classification

A Geographic Information System (GIS) database was built for Serra da Malcata Nature Reserve using aerial photographs. We delineated 6 habitat types within the study area: *Quercus pyrenaica* forests, *Cytisus* spp. scrubland, *Erica* spp. and *Cistus ladanifer* scrubland, Pine stands, agriculture fields and *Quercus rotundifolia* and *Arbutus unedo* forests (Table 2). We used aerial photographs and ground surveys to classify habitat types and digitized each habitat patch using Arcview 3.2. The GIS land covers encompassed home ranges of all monitored wildcats and natural and human landscapes features were added (e.g., roads, habitat edges, and rivers). Other habitat patches, which were totally intercepted by one of the home ranges, were also included in the analysis. Therefore, the study area includes all patches, which were possibly used by radiocollared cats although their presence has not been documented in those particular areas.

Table 2. Description of 6 habitat types used to investigate habitat selection of wildcats in Serra da Malcata Nature Reserve (Portugal), 1999 - 2001.

Habitat type	Description
Quercus pyrenaica forests	Northern areas or areas above 800 meters (asl) dominated by *Quercus pyrenaica* with reduced or absent understory, which is mostly concentrated in the watercourses. Human activities are generally absent.
Cytisus spp. scrubland	Areas dominated by tall shrubs (≥ 1,5 meters) of *Cytisus striatus* and *C. multiflorus*, mostly concentrated in the northern range of SMNR hedging *Quercus pyrenaica* forests.
Erica spp. and *Cistus ladanifer* scrubland	Areas dominated by dense shrubs of *Erica australis, E. umbellata* and *C. ladanifer*, occupying the central and southern areas of SMNR
Pine stands	Over 30-year old pine stands (*Pinus pinaster, P. radiata and P. pinea*).
agriculture	Areas lacking forest cover used for crop production (generally corn and wheat)
Quercus rotundifolia and *Arbutus unedo* forests	Late sucession Mediterranean forests with tall individuals (> 3 meter high) and reduced understory. Located in lower altitude areas (below 600 meters asl) in the south and centre of SMNR.

Habitat selection analysis

We used an Euclidean distance-based approach to investigate seasonal habitat selection of wildcats [21]. We examined habitat selection at two spatial scales according to Johnson's [22] second and third orders of selection (selection of habitat for home range within the study area and selection of habitats within the home range, respectively). For second-order selection, we compared distances between random points in each individual home range and distances between random points throughout the study area and the nearest representative habitat type. For third-order selection, we compared distances from estimated wildcat locations and distances from random points generated throughout each home range to each of the nearest representative habitat type [23,24]. Distance from random points or wild cat locations within a certain habitat to that same habitat was considered to be zero. We generated a significant number of random points per home range (approx. 3,000) from uniform distributions to ensure robust mean expected distances for the study area. We calculated distances from random points and wildcat locations to each habitat type by using X-Tools and Geoprocessing extensions in Arcview 3.2. For each wildcat in each season, we created a vector of 6 distance ratios (one for each type of habitat) for both scales of selection. For second-order selection, ratios correspond to the mean distance of random points in the home range divided by the mean distance of random points throughout the study area. For third-order selection, the ratios were defined as the mean distance of wildcat locations divided by the mean distance of random points throughout the home range.

According to Benson and Chamberlain [23], the definition of the study area, which determines the area available for wildcats at third-order selection, probably affected the second-order selection analyses. Since the designation of study areas for free-ranging animal studies is generally subjective, this is a problem in virtually all

studies comparing habitat use with availability within a study area. In the present study, the whole SMNR was defined as the study area, since it represents a unique landscape identity presenting singular natural habitats and also due to its protection status.

In order to estimate the potential telemetry-associated error, we determined the location of collars placed at fixed sites, which were unknown to the observer ($n = 35$). The mean distance from the estimated location to true location was 67 m (SE = 35.41, range = 12.70 – 101.83). Euclidean distance habitat selection analyses does not require explicit telemetry error handling or modelling because this technique does not rely on classifying telemetry locations by type of habitat [25]. According to the distance-based approach, a telemetry fix in an incorrect habitat due to telemetry error, refers to an area in the vicinities of the real habitat where the monitored animals was actually present. Therefore, erroneous locations also contribute to the identification of preferred habitats.

Statistical analyses

The Kruskal-Wallis (when $k > 2$) and Wilcoxon (when $k = 2$) tests were used to compare seasonal home ranges within the study area. Statistical tests were considered significant when $P \leq 0.05$ and marginally significant when $0.10 > P > 0.05$.

We used multivariate analyses of variance (MANOVA) to test the null hypotheses that all habitats were equally used by wildcats by investigating second- and third-order selection. If the 6 ratio mean (number of habitats) differed from a vector of 1, which means that MANOVA was significant, we used a univariate *t*-test on each habitat type in order to determine which habitats were selected or avoided by female wildcats. Distance ratios significantly lower than 1 indicate positive selection, whereas ratios significantly higher than 1 indicate avoidance [21,23]. Habitat types were then ranked in order of preference based on the magnitude and direction of the respective *t*-statistics.

Results

Home ranges

Globally, we obtained 1,216 locations during 1,080 radio-tracking days of all 6 tracked individuals. Each cat was monitored, on average, on 198 ± 77 (mean ± S.E.) days (range 31 - 460) providing 202 ± 48 fixes per individual range (101 - 314).

Annual female wildcat home ranges vary between 1.81 and 3.67 km^2 (fixed-kernel 95%), with an individual-weight average of 2.89 ± 1.01 km^2 (mean; SE) (Table 3). The lowest value was reported for spring 1999 (0.89 km^2) and the highest for autumn - winter 2000 (3.71 km^2). The average stability of seasonal home ranges, which was quantified by measuring the degree of coincidence between home ranges in two consecutive seasons, was 59.08 ± 5.33%, indicating considerable stability. However, when comparing home range stability between autumn-winter and spring and also between spring and summer we obtained an average of 43.81 ± 7.66% ($n = 6$) and 39.77 ± 8.44% ($n = 8$). These values are considerably lower and indicate differences between the occupied area in spring and in other seasons (Table 3).

Table 3. Seasonal and annual mean-fixed-kernel home ranges (95%) and core areas (50%) estimates (km^2) for female wildcats, with standard errors (SE).

	Home ranges		Core areas	
Season	Mean	SE	Mean	SE
Spring	1.81	1.01	0.45	0.24
Summer	3.42	1.43	1.21	0.34
Autumn-Winter	3.09	1.78	0.97	0.29
Annual	2.89	1.01	0.98	0.42

The core areas (50% fixed-kernel) presented a mean size of 0.90 ± 0.32 km^2 (n = 24 home ranges), varying between 0.41 and 1.31, indicating that, on average, about 31.74 ± 4.50% of the home range is intensively used. In spring, we obtained the lowest values for core areas (average of 0.45 ± 0.25 km, n = 9).
Significant differences among spring ranges and other season's ranges were detected (Kruskal-Wallis test: home range, $H_3 = 9.71$ and $P = 0.016$; core area, $H_3 = 8.51$ and $P = 0.015$). During spring, females exhibited 1.3 – 1.9 times smaller home ranges than in summer, autumn – winter and also comparing to annual home ranges (Wilcoxon test: home range $P = 0.016$; core area $P = 0.043$) (Table 3). We did not detect differences between summer, autumn – winter and annual home ranges and respective core areas (Wilcoxon test: home range, $P = 0.021$ and $P = 0.017$).

Habitat selection

Second-order habitat selection

Females exhibited habitat selection when establishing their home ranges considering the available habitats within the study area (MANOVA: $F_{6,24} = 27.49$, $P < 0.001$) (Tables 4 and 5) and it was also possible to verify that selection did not present a seasonal character (univariated t-test: $P = 0.57$). Wildcat females selected *Quercus pyrenaica* forests and *Quercus rotundifolia* and *Arbutus unedo* forests and avoided *Erica* spp. and *Cistus ladanifer* scrubland and other habitats (Tables 4 and 5). In terms of habitat ranking, *Quercus pyrenaica* forests appear as the most preferred habitat.

Table 4. Total area (km^2) and composition (%) of the 6 habitat types available to female wildcats in Serra da Malcata Nature Reserve (Portugal), 1999-2001. Habitat type rankings and results of univariate t–tests for second and third order habitat selection by female wildcats.

	km^2	%	2nd order			3rd order		
Habitat type			Rank[a]	t [b]	P	Rank[a]	t [b]	P
Quercus pyrenaica forests	19.35	28.30	1	-19.76	< 0.001	1	-17.51	< 0.001
Cytisus spp. scrubland	11.21	16.40	3	1.34	0.149	3	1.29	0.119
Erica spp. and *Cistus ladanifer* scrubland	4.72	6.90	6	6.10	< 0.001	6	8.14	< 0.001
Pine stands	8.88	12.99	5	2.21	0.311	5	3.49	0.311
Agriculture	5.88	8.60	4	1.79	0.171	4	1.63	0.198
Quercus rotundifolia and *Arbutus unedo* forests	18.33	26.81	2	-11.39	< 0.001	2	-14.07	< 0.001

a. Rank of habitat types in order of preference.
b. Univariate t–tests comparing distance ratio with value of 1 (negative t–value indicates selection, positive t–value indicates avoidance).

Table 5. Habitat type rankings and results of univariate *t*–tests for third order season habitat selection of 6 habitat types by female wildcats in Serra da Malcata Nature Reserve (Portugal), 1999-2001.

	Spring			Summer			Autumn - Winter		
Habitat type	Rank[a]	*t* [b]	*P*	Rank[a]	*t* [b]	*P*	Rank[a]	*t* [b]	*P*
Quercus pyrenaica forests	1	-18.36	< 0.001	1	-17.07	< 0.001	1	-17.59	< 0.001
Cytisus spp. scrubland	3	-3.37	0.035	3	-2.10	0.038	3	-2.66	0.058
Erica spp. and *Cistus ladanifer* scrubland	6	9.59	< 0.001	6	9.31	< 0.001	6	10.33	< 0.001
Pine stands	5	3.37	0.376	5	4.01	0.478	5	5.41	4.77
Agriculture	4	1.87	0.150	4	1.63	0.143	4	1.42	1.88
Quercus rotundifolia and *Arbutus unedo* forests	2	-15.79	< 0.001	2	-16.32	< 0.001	2	-15.24	< 0.001

a. Rank of habitat types in order of preference.
b. Univariate *t*–tests comparing distance ratio with value of 1 (negative *t*–value indicates selection, positive *t*–value indicates avoidance).

Third order-habitat selection

Wildcat females exhibited habitat selection within their home ranges (MANOVA, $F_{6,25} = 5.77$, $P < 0.001$), but selection was not affected by season (univariated *t*-test: $P = 0.21$). Females selected *Quercus pyrenaica* forests and *Quercus rotundifolia* and *Arbutus unedo* forests, and avoided *Erica* spp. and *Cistus ladanifer* scrubland during all seasons (Table 5). For third-order habitat selection, *Quercus pyrenaica* forests also constitute the most important habitat type for female wildcats during all seasons.

Discussion

Home range size in wildcats may be influenced by a variety of factors, including food abundance and the landscape-level configuration of preferred habitats [14]. The present results indicate an average annual home range of 2.89 km^2 (SE= 1.02), which represents larger areas than those estimated by Stahl *et al.* [14] (1.8±0.5 km^2; *n*=7; 0.67) and slightly larger than those obtained by Monterroso *et al*. [26] for a Mediterranean ecosystem in Portugal (2.23 km^2; *n* = 4, 0,77). The existence of low quality habitats in SMNR and the fragmentation of preferred habitats may explain our results, since the study of Stahl *et al.* [14] was conducted in continuous areas of broad-leaved forest, thus with higher quality habitat, and the report of Monterroso *et al*. [26] referred to an area with higher prey density (rabbits, particularly).

We document different patterns of space use between female wildcats during spring when compared to other seasons. In spring, which corresponds to the denning period, females tend to use smaller home ranges and travel lower distances.

Quercus pyrenaica forests and *Quercus rotundifolia* and *Arbutus unedo* forests are important habitats for female wildcats because they provide shelter and food resources, such as small mammals, which are particularly abundant [27], and constitute the major prey type for this species [28]. With respect to shelter, these forests offer tree cavities located high above ground, which can be used as dens [5]. Parturition and early maternal care occur mostly in these types of cavities and so, the availability of secure dens is particularly important to increase cub survival and breeding success. At

landscape level, females select these habitats within their home range not only during the breeding season, but also throughout the year and therefore these vegetation types are crucial for wildcat conservation as they provide cover, foraging opportunities and denning sites. The present study is in agreement with Stahl and Leger [1], who reported that European wildcats are primarily associated with forests and their highest densities occur in broad-leaved or mixed forest. Coniferous forests are considered a marginal habitat for wildcats [29]. In general, territories occupied by wildcats are characterized by low human density, with cultivation typically taking the form of grazing areas divided into small patches [30].

In contrast, *Erica* spp. and *Cistus ladanifer* scrubland is an extremely dense habitat with low associated biodiversity and so wildcats avoid it. We believe that this habitat as well as pine stands do not provide food and cover resources for wildcats. Home ranges with higher percentage of these habitat types tend to be larger, since females need significant areas to meet their resource requirements.

In this part of Portugal, large-scale habitat destruction acts as a critical threat to many species. Since the 1940s, natural habitats preferred by wildcat and rabbits have been converted in agriculture fields and industrial plantations and, by the 1970s, most optimal habitat areas had disappeared.

Our results emphasize the importance of the remaining autochthonous forests for wildcat conservation. These habitats present a considerable diversity and high density of small mammals, particularly *Apodemus sylvaticus* [27]. Also, the recent colonization by the red squirrel (*Sciurus vulgaris*) could constitute an additional food resource for several species including the wildcat.

We recommend that current habitat policy for restoration and conservation should be continued and expanded to substantially increase the amount of natural forested land in Serra da Malcata. The reforestation efforts conducted in the last years should provide additional habitats for wildcats allowing the population to increase and expand.

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