*Biodiversity and Conservation* **12:** 921–935, 2003.


# Importance of scrub–pastureland mosaics for wild-living cats occurrence in a Mediterranean area: implications for the conservation of the wildcat (*Felis silvestris*)

J. LOZANO[1], E. VIRGÓS[2,*], A.F. MALO[3], D.L. HUERTAS[4] and J.G. CASANOVAS[5]

[1]*Grupo de Ecología Aplicada, C/Luis Mitjans 44, 1I, E-28007 Madrid, Spain;* [2]*Instituto de Investigación en Recursos Cinegéticos (CSIC-UCLM-JCCM), C/Libertad 7A, E-13004 Ciudad Real, Spain;* [3]*Departemento Ecología Evolutiva, Museo Nacional de Ciencias Naturales (CSIC), C/José Gutiérrez Abascal 2, E-28006 Madrid, Spain;* [4]*C/Doce de Octubre 25, 3° C, E-28009 Madrid, Spain;* [5]*Departemento de Ciencias del Medio Ambiente, Universidad Castilla-La Mancha, Avda. Carlos III s/n, E-45071 Toledo, Spain;* **Author for correspondence (e-mail: evirgos@irec.uclm.es)*

Received 19 October 2001; accepted in revised form 15 May 2002

**Key words:** *Felis silvestris*, Forests, Landscape and micro-habitat scales, Mediterranean area, Scrublands, Wild-living cats

**Abstract.** The European wildcat (*Felis silvestris*) is a threatened species in Europe. Suitable management of forests has been considered crucial for its conservation in Europe. However, this recommendation may not be general due to the lack of studies that test these hypotheses in the Mediterranean area, where landscapes are very different from those of central-north Europe. In this study, wild-living cat habitat associations were analyzed by means of scat surveys in 78 areas distributed in the four main vegetation types of the Mediterranean area of central Spain, where feral cat populations are probably scarce and restricted. Results show higher occurrences of wild-living cats in landscapes covered by scrub–pastureland mosaics rather than forests. Several applied recommendations are given: (1) to include the scrub–pastureland mosaics as protected habitats for wildcats; (2) to encourage further studies about the importance of this habitat in other areas; (3) to avoid the extensive scrubland removal associated with management practices against fires or infrastructure development; and (4) to promote land management practices that enhance these mosaics, and to use shrub species in the reforestation programmes founded by the European Agricultural Policy.

## Introduction

The European wildcat (*Felis silvestris*) is distributed over a wide geographical area that ranges from West Europe to central India, including Africa (Stahl and Artois 1991). However, detailed knowledge of wildcat distribution is lacking in most African countries, but also in European countries of the Mediterranean area such as Spain (Stahl and Artois 1991; Council of Europe 1992). Nevertheless, the Mediterranean area represents one half of the distribution range of the species in Europe, these wildcat populations living in lower human population density areas and thus probably suffering less introgression of domestic cat genes (Fernández et al. 1992). These conditions are considered by Daniels et al. (1998) as useful to define areas where conservation of wildcats may be prioritaire. Conservation of wildcats in the Mediterranean area may then be regarded as an important element of the wildcat conservation in Europe.

In Europe, the wildcat has disappeared from much of its original distribution area, resulting in severe fragmentation of its populations. This has caused an increase in wildcat extinction risk (see below), which, along with the lack of sufficient knowledge of its biology (Stahl and Artois 1991), led to the inclusion of this species in the II Appendix of the Bern Convention, where strictly protected Europe-wide taxa are registered.

The European Council underlines two basic extinction risks for this species (Stahl and Artois 1991). First, hybridisation between wildcats and domestic cats (*Felis catus*), which may threaten the status of wildcat as a genetically distinct species (Hubbard et al. 1992; Nowell and Jackson 1996). The distinction between wildcats, domestic cats and their hybrids appears to be difficult; probably the criteria to define wildcats are not exclusive and essentially there is a 'cline' of wild-living cats, ranging from domestic to wildcats (Daniels et al. 1998). Although the degree of interbreeding between domestic and wildcats is unknown, there is a lot of empirical evidence about the importance of this phenomenon in nature (see Daniels et al. 1998, 2001; Beaumont et al. 2001). So, guidelines for conservation need to recognize this threat and use different management or decision tools to mitigate the effects of hybridization [see Daniels et al. (1998, 2001) for recommendations].

The second extinction risk is habitat destruction, which leads to fragmentation and isolation of its populations. Thus, preservation of wildcat habitat is regarded as a guarantee for the long-term conservation of the species. The conservation of suitable habitats includes the need for conservation of the main prey of wildcats; to address this point it is necessary to know the relationship between wildcat occurrence and main prey abundance and distribution, as well as the relationship between prey abundance and habitat correlates. In most of Europe, wildcats are mainly rodent predators (Stahl and Leger 1992), but in Spain and other areas, the rabbit is a very important prey (Aymerich 1982; Gil-Sánchez et al. 1999) and probably to some extent shapes the distribution or abundance of wildcats.

However, there are few studies in which ecological requirements and optimal habitat features for the species are described, and most of them are poorly performed (see critical review in Stahl and Leger 1992). Although Langley and Yalden (1977) stated that wildcat population decline in the British Isles was a consequence of deforestation, they also claimed that wildcat was not a typical forest species. Moreover, in other studies it is reported that wildcats use a wide variety of habitats (Stahl and Leger 1992), displaying an individual and seasonal variation in habitat selection (Wittmer 2001). Surprisingly, the idea that the wildcat is a typical forest species prevails in the literature, probably due to the first reports on the species (Parent 1975; Schauenberg 1981). In the Mediterranean region, particularly in the Iberian Peninsula, this idea is generally assumed in non-scientific reports (Aymerich 1993; Castells and Mayo 1993; Ferreras et al. 1999). From an applied and conservation perspective, this assumption may have serious consequences, given that the Council of Europe exclusively recommends the preservation of forests, agricultural land and their traditional practices as the conservation strategy for the wildcat. No reference is made to other habitats without protection in Europe, such as scrublands, which are widely distributed in the Mediterranean area but are very restricted or absent in central and northern Europe. These recommendations may be the key points of the future action plans for wildcats in some countries such as Spain, where species cited in the II Appendix of the Bern Convention are under a particular figure of protection, requiring these action plans for the conservation of the species listed in this conservation category. These plans are normally based on the scientific literature on the species, but for species with scarce scientific information, they are based on recommendations of the European Council, IUCN groups or other international agencies.

Thus, basic assumptions about the association between wildcat occurrence and habitat variables still remain to be tested. The aim of this work is to assess the relevance of different types of habitat in a Mediterranean region of central Spain, both at microhabitat and macrohabitat (landscape) scale. More precisely, we tested if forest cover, at landscape scale, or tree cover, at microhabitat scale, are the key habitat features for wildcat habitat selection in this area, or if, alternatively, scrublands or other highly available habitats (e.g. croplands, pasturelands) may play a key role for wildcats in the Mediterranean region.

## Methods

### *Study area*

Fieldwork was conducted in the centre of the Iberian Peninsula during autumns and springs from 1997 to 1999. We sampled 78 km of trails scattered in a region covering 2916 $km^2$ (Figure 1) and located in a region with a pronounced orography (500→2000 m) and relatively low human population; suitable conditions for a potential wildcat population and an 'area based approach' for wildcat conservation such as proposed by Daniels et al. (1998, 2001). The trails were distributed across different habitat types in this region. Interestingly, the pronounced orography created by the Guadarrama mountain range in our study area allows the occurrence, in a relatively small area, of the basic habitat types (defined in the present study as 'vegetation types') from the Iberian Peninsula: Mediterranean plain vegetation areas (500–800 m above sea level, hereafter m a.s.l.), Mediterranean mountainous vegetation areas (950–1050 m a.s.l.), deciduous oak habitats (1250–1700 m a.s.l.) and mountain pine habitats (1250–1800 m a.s.l.). Mediterranean vegetation, both in plains and mountains, is a mixture of forests dominated by the Holm oak (*Quercus ilex*) and scrublands whose main understory shrub species are *Cistus ladanifer* and *Retama sphaerocarpa*. These mosaics are occasionally interspersed with Mediterranean pines (*Pinus pinaster* and *Pinus pinea*) and *Juniperus oxycedrus*. The predominant climate is dry and hot with a pronounced drought in summer, but to a lesser extent in the mountains (Rivas-Martínez et al. 1987). In addition to climatic and elevation differences, these Mediterranean areas showed marked differences in vegetation structure and human land use, the plains being basically devoted to game hunting activities and the mountains to cattle raising. Deciduous oak habitats comprise Pyrenean oaks (*Q. pyrenaica*), with *Cistus laurifolius* and *Citysus scoparius* as the main understory shrub species. In this habitat, forests are dominant in the landscape, and scrublands are spatially restricted. Here, the climate is more humid and cooler than in the Mediterranean vegetation area and there is a less pronounced drought. Mountain pine habitats comprise *P. sylvestris* with a smaller understory shrub cover (*Citysus* sp.), and have harsher climatic conditions than deciduous oak habitats, with colder winters where snow may lie for several weeks (Rivas-Martínez et al. 1987).

*Wildcat surveys*

Wildcat middens (scat accumulations) were present in trails and paths scattered throughout the study area, as they are commonly used as scent marking sites by the species (Corbett 1979). Scat surveys were preferred over trapping campaigns or questionnaires as a measure of occurrence of wildcats at landscape scale. Large-scale (over a landscape) trapping campaigns are costly and associated risks (for example, harming individuals) could exceed potential benefits of a distribution study. Questionnaires submitted to experts, gamekeepers or forest rangers (Easterbee et al. 1991) are less expensive than trapping and equivalent to scat surveys, but data may be biased because they may reflect the interviewed people distribution rather than the species distribution, as a consequence of absence of sampling homogeneity.

Morphological characteristics, such as size, colour, odour or composition were

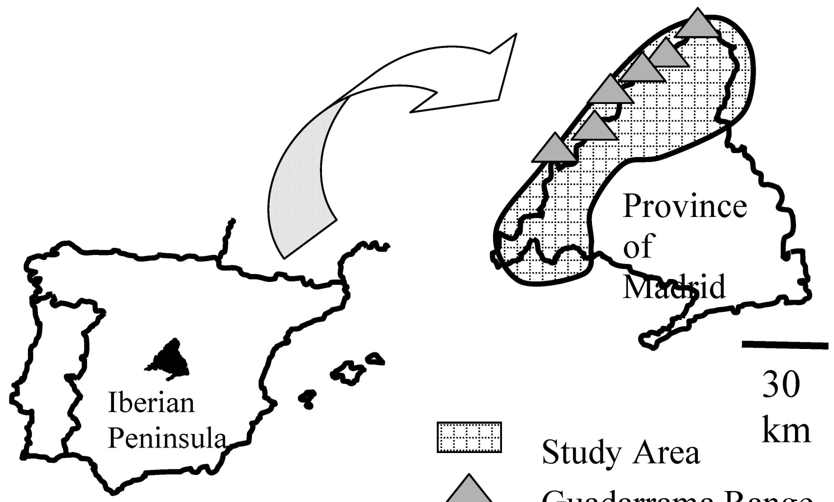



*Figure 1.* Location of the study area in the Iberian Peninsula and within the Madrid province.

used to distinguish wildcat scats from those of red foxes *Vulpes vulpes*, stone martens *Martes foina* or domestic dogs *Canis familiaris*. It was also possible to objectively differentiate wildcat scats from those of fox, using the dry scat weight (Hewson 1983).

It was much more difficult to distinguish between domestic cat and wildcat scats, and this problem needs to be discussed further to analyse the relationship between habitat variables and cat scats. Although our study area is located in an area with good environmental correlates for the persistence of wildcat populations, it is clear that a potential interbreeding between wildcats and feral domestic cats may occur, and potentially, the co-existence of wildcats, feral cats and their hybrids is possible in nature (Daniels et al. 1998, 2001). In this respect, Daniels et al. (1998) proposed the term 'wild-living cats' to refer to these populations of cats of potentially diverse characteristics. We use this term hereafter because we considered that feral cats and wildcats show similar habitat preferences (Daniels et al. 1998, 2001); thus, wild-living cats' habitat preferences may fit well with wildcat preferences. Despite this, we considered that a great number of scats may be considered as pertaining to wildcats, because of orography, good historical wildcat populations (Blas Aritio 1964) and the following additional arguments: (a) we did not consider those scats greater than 6.1 cm length and less than 1.4 cm diameter, which are very probably of feral cats (Corbett 1979); (b) during the study period we performed a trapping campaign in a 45 $km^2$ area in the mountains of central Spain (252 trap-nights). We captured two wildcats and several other predators (including feral dogs), but never a domestic cat. Other researchers trapping wildcats in other Mediterranean mountain areas of central Spain indicated that domestic cats comprised less than 5% of all captures (F.J. García, personal communication).

Although scat surveys have been widely used in carnivore studies (Conroy and French 1987; Cavallini 1994; Virgós and Casanovas 1998), this methodology may present two possible drawbacks: (1) potential differences in the defecation or scat decay rates across seasons or habitat types, and (2) the likelihood of collecting scats from non-sedentary or dispersing individuals. In order to diminish the former possible drawback, we surveyed only during autumn and spring, since these two seasons present very similar climatic conditions in the Mediterranean region. We considered that defecation rate was not affected by habitat type, because the diet is composed of similar mammal species in all cases (Authors, unpublished data). Defecation rate is mainly affected by the consumption of fruits (Andelt and Andelt (1984) for coyotes *Canis latrans*), but wild-living cats rarely feed on fruits. Although decay rates may be affected by climatology and, therefore, they may change among habitats, wild-living cat scats may persist under normal rainfall conditions during a long period (see 'Survey design' subsection); they may even persist in the same location after heavy rainfalls (E. Virgós, unpublished data). In addition, we did not survey during snow, or under adverse weather conditions, and we always left a minimum of 2 days since the last rain before collecting scats from trails. The second possible drawback is not relevant to wild-living cats, because juveniles and dispersing adults are known not to conspicuously mark in trails, probably to avoid agonistic encounters with territorial individuals (Corbett 1979).

*Survey design*

The distribution of the 78 km was practically homogeneous throughout the four vegetation types: 16 km in the Mediterranean vegetation in the mountains, 16 km in the Mediterranean vegetation in the plains, 21 in deciduous oak habitats and 25 in the mountain pine habitats. The basic sample unit was 1 km survey along trails. Each kilometre sampled was separated from the next by at least 1 km in order to avoid spatial data dependence problems. Surveys were randomly selected in each vegetation type, provided that trail widths ranged from 1 to 3 m. Every sample unit was surveyed only once, for the following reasons: (1) resident wild-living cats mark their territories by depositing their scats in conspicuous places, such as low-height shrubs or rocks on paths and trails (Corbett 1979). Thus, assuming a wild-living cat mean home range area of 4 $km^2$ (Schauenberg 1981; Artois 1985; Stahl et al. 1988; Genovesi and Boitani 1992; Scott et al. 1992) and inter-sexual territory overlap (Stahl et al. 1988), there is a high probability of assessing wild-living cat presence by means of 1 km surveys; (2) to control for wild-living cat scat decay rates, four trails were surveyed regularly over a 6-month period (March–August 1999). Once a month scats were collected from each trail, two of them were known to be located within the home range area of two radio-tracked wildcats (Authors, unpublished data). We determined that the mean scat appearance frequency was $3.98 \pm 0.82$ per km per month. Nine scats were collected from the same trail in the first survey, suggesting that they can easily remain for 3 months in a Mediterranean environment before decaying. Furthermore, we know that wild-living cats frequently use trails as marking sites, since scats appeared regularly throughout the 6-month period on the study trails. Thus, the long decay rate of scats, together with the knowledge of the home-range area of wild-living cats, makes it likely that, if the species is present in the area, a scat will be recorded in one or more of the sample units (i.e. a kilometre) of the study trails.

*Wild-living cat occurrence indexes and variable measurements*

A wild-living cat occurrence index was calculated dividing the basic 1 km surveys into five sections of 200 m and subsequently recording the number of sections with wild-living cat scat occurrence (0 min–5 max/km). This value was used as a relative index of wild-living cat presence. The rabbit abundance index was calculated as the total number of latrines per kilometre (Palma et al. 1999). Rabbit latrines were recorded each 200 m by means of orthogonal transects (50 m long and 1 m wide) to the 200 m segment. To describe microhabitat structure, various variables were calculated, each 200 m along the main transect by means of visual estimation. Following Corbett (1979), Easterbee et al. (1991) and Stahl and Leger (1992), the microhabitat structure variables considered to be relevant for wild-living cat predatory and resting activities were: tree cover (%), shrub cover (%), open ground cover (%), rock cover (%), average tree height and a wild-living cat shelter index (shelter availability). Every 200 m these variables were visually estimated in a 25 m radius around one of us, and the wild-living cat shelter index was given a number from 1 to 5, according to the environment visual permeability and the existence of cavities in rocks and trees. The wild-living cat shelter index was finally calculated as the mean shelter value per surveyed kilometre.

Wild-living cat habitat characterisation at a landscape scale was determined calculating the following variables: forest cover (%), pastureland cover (%), cropland cover (%), scrubland cover (%), urban cover (%), number of watercourses, roughness index and mean elevation (m a.s.l.). These variables have been hypothesised to be determinants of wild-living cat suitability at a landscape scale (Easterbee et al. 1991; Stahl and Leger 1992). In order to quantify the landscape variables, we used land-use maps (1:50000) and defined an area of 9 $km^2$ around each particular trail surveyed. On this surface, landscape variables were measured through a grid with 121 evenly spaced points, where the number of points lying 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 (Scott et al. 1992; Urra 1997). In addition, a roughness index was measured as the mean number of 20 m elevation curves 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 the 9 $km^2$ area, 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 variance were verified for all variables, and those that did not account for parametric test requirements were normalised or tested for positive kurtosis (Underwood 1996). Original variables were summarised to a few orthogonal factors by means of principal component analysis (PCA). PCA factors entered as predictors in the subsequent multiple regression models employed. The wild-living cat occurrence index was used as response variable in the model and PCA factors and the vegetation type were entered in the model as predictors. Vegetation type was codified as dummy variables. To select the variables for the model, a forward stepwise method was performed ($F$ to enter = 4.00, $F$ to remove = 3.99). All statistical analyses were conducted with the STATISTICA 5.0 computer package for Windows.

## Results

### *Wild-living cat occurrence in the surveys*

Wild-living cat presence was recorded in 33 of the surveys, so that the species is absent in most of the surveys (45). Moreover, we have only found 83 scats over the whole survey. When only surveys with wild-living cat presence were considered, the mean number of 200 m segments with wild-living cat scats was 1.5 and the mean number of scats per surveyed kilometre was 2.43.

Wild-living cats showed a similar occurrence among the different vegetation types studied, with non-significant differences in the occurrence index ($F_{3,74} = 1.46$, $P = 0.23$, see Figure 2).

*PCA and multiple regression analysis*

The PCA performed with the original variables rendered five factors that explained 73.7% of the total variance. The first factor generated a gradient from elevated rough and dense covered forests (positive scores) to croplands with high rabbit abundance (negative scores). The second factor accounted for areas where pastureland and urban cover predominated (negative scores), as opposite to areas where scrublands and watercourses with abundant rabbits predominated (positive scores). The third

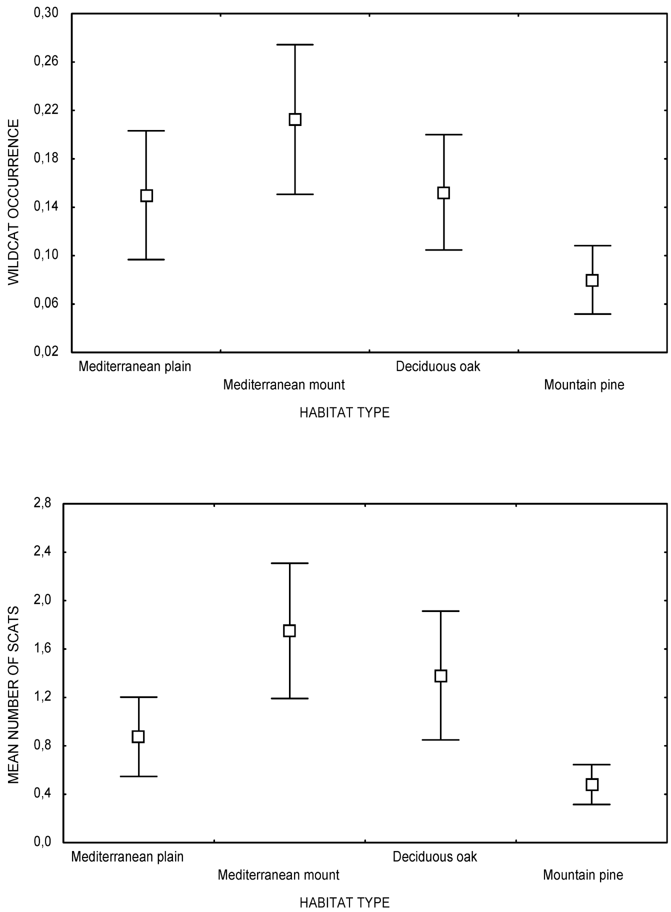



*Figure 2.* Mean and standard errors of wild-living cat occurrence and number of scats/km in the four habitat types sampled.

*Table 1.* Results from the PCA performed with microhabitat and macrohabitat variables used to describe the wildcat habitat (asterisks indicate significant correlations between original variables and factors).

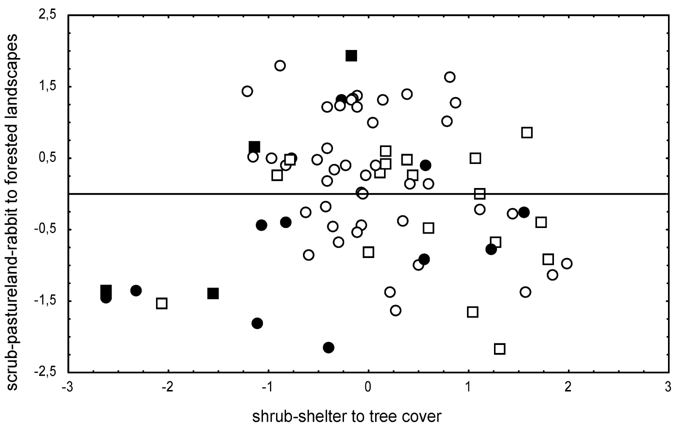
| Variables | Factors | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Rabbit abundance index | −0.761* | 0.241* | 0.087 | −0.311* | 0.029 |
| *Microhabitat variables* | | | | | |
| Tree cover | 0.675* | 0.035 | 0.400* | 0.340* | −0.231* |
| Shrub cover | −0.097 | 0.005 | −0.896* | −0.091 | −0.080 |
| Open ground cover | 0.141 | 0.012 | 0.154 | 0.095 | 0.891* |
| Rock cover | 0.207 | −0.219 | 0.040 | 0.428* | 0.189 |
| Tree height | 0.590* | 0.076 | 0.406* | 0.447* | −0.054 |
| Shelter index | 0.071 | 0.048 | −0.658* | 0.422* | −0.251* |
| *Macrohabitat variables* | | | | | |
| Forest cover | 0.467* | 0.123 | 0.029 | 0.819* | 0.095 |
| Pastureland cover | −0.191 | −0.466* | −0.084 | −0.683* | 0.058 |
| Cropland cover | −0.838* | 0.174 | 0.018 | −0.028 | −0.160 |
| Scrubland cover | −0.067 | 0.338* | 0.083 | −0.837* | −0.089 |
| Urban cover | 0.057 | −0.864* | 0.021 | 0.037 | −0.026 |
| Number of watercourses | −0.154 | 0.411* | −0.339* | −0.512* | 0.405* |
| Roughness index | 0.800* | 0.064 | 0.091 | 0.076 | 0.152 |
| Elevation | 0.906* | 0.088 | 0.038 | 0.189 | 0.054 |
| Eigenvalue | 3.91 | 1.42 | 1.73 | 2.93 | 1.19 |
| % Explained variance | 26.0 | 9.5 | 11.6 | 19.6 | 8.0 |

factor generated a gradient that separates areas with high shrub cover (microhabitat) and shelter index (negative scores) from areas with high tree cover (microhabitat) and high vegetation height (positive scores). The fourth factor included both microhabitat and macrohabitat variables and separated forested areas with high tree and rock cover (positive scores) from those with high scrub and pastureland cover and abundant rabbits (negative scores). Finally, the fifth factor separated areas with high open ground cover and abundant watercourses (positive scores) from dense tree cover with high shelter index (negative scores) (see Table 1).

These PCA factors were used in a multiple regression analysis which yielded a significant model ($F_{2,75} = 5.62$, $P = 0.005$; explained variance: 13%). This model included the third and fourth factor, both of them negatively associated. Vegetation types (included as dummy variables) were not included in the regression model. The wild-living cats occurrence index was associated to areas where shrub areas with high shelter at a microhabitat scale predominate (factor 3), as well as to those areas with scrub–pastureland mosaics and rabbit abundance at a macrohabitat scale (factor 4; Figure 3, Table 2).

In summary, wild-living cats were not linked to areas where forest cover or tree cover predominated. In contrast, they were mainly associated to mosaics of scrublands and pasturelands at landscape scale or to areas where shrub cover was high at microhabitat scale. Watercourse abundance was also associated to the wild-living cat occurrence index, and rabbit abundance was positively linked to the occurrence index.

a)




b)

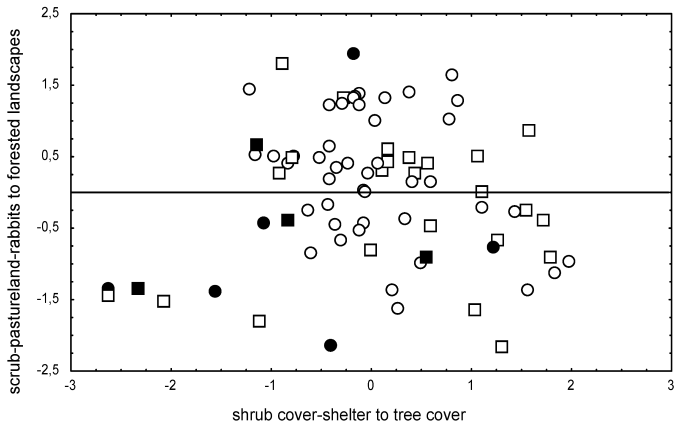



*Figure 3.* Distribution of survey trails in the environmental gradients generated by the third and fourth factor from PCA. Graph (a) shows the data from wild-living cat occurrence (open circles: 0; open squares: 0.2; solid circles: 0.4; solid squares: 0.6–0.8). Graph (b) shows the data from number of scats/km (open circles: 0; open squares: 1–2/km; solid circles: 3–4/km; solid squares: 5–10/km).

*Table 2.* Variables included in the final model from the forward stepwise multiple regression between wildcat occurrence and PCA factors.

| Variable | $\beta$ | B | $t_{(75)}$ | $P$-level |
|---|---|---|---|---|
| Intercept | | 0.141 | 6.46 | <0.001 |
| Factor 3 (shrub vs. tree cover gradient) | −0.270 | −0.055 | 2.51 | 0.014 |
| Factor 4 (scrub–pastureland vs. forest cover gradient) | −0.239 | −0.049 | 2.22 | 0.029 |

## Discussion

### *Use of scat surveys as occurrence index*

Scat surveys have been widely used as an indirect method to estimate an occurrence index in different carnivore species (Conroy and French 1987; Cavallini 1994; Virgós and Casanovas 1998). Scat surveys allow us to quickly and cost-efficiently obtain baseline data to established main conservation guidelines for evasive and rare species. Then, we consider that this approach is suitable to study associations between habitat and wild-living cat occurrence over a large-scale study area. In addition, we avoid the main drawbacks from this approach (differences in defecation or decay rates, age-specific differences in marking behaviour, and so on).

### *Wild-living cat–habitat relationships*

Parent (1975) was probably the author who contributed the most to extend the idea of the wildcat as a typical forest species, although other studies (Guggisberg 1975; Ragni 1978; Schauenberg 1981) also supported this idea. Parent (1975) stated that wildcat survival and dispersal patterns relied on continuous forest and dismissed the importance of scrublands, considering them mere corridors through deforested areas. However, Corbett (1978) showed that wildcats in northeast Scotland were particularly abundant in underdeveloped coniferous forests associated with dense shrub cover. Easterbee et al. (1991) suggested that this could be due to a higher rodent abundance in this type of forest, which diminishes as the forest advances to maturity; thus implying that habitat suitability for the wildcat would depend on tree structure and prey availability. This would explain the progressive abandonment of certain forests suggested by Easterbee et al. (1991) and the general view that the wildcat avoids large and homogeneous coniferous forests (Castells and Mayo 1993; Roncadell-SECEM 1997).

The significance of scrubland, being a medium rich in preys (mainly rodents and rabbits; Moreno and Villafuerte 1995) and shelter, has been pointed out in various radiotracking studies (Corbett 1979; Artois 1985) and has also been reported elsewhere with other methodological approaches (Dötterer and Bernhart 1996; Sarmento 1996). Data reported in these studies underline the relevance of scrublands for wild-living cats. In the present study the results show that wild-living cats prefer a scrub–pastureland mosaic landscape with abundant watercourses and rabbits and high shrub cover at a microhabitat scale, rather than forests at a macrohabitat scale or high tree cover at a microhabitat scale. Interestingly, whereas vegetation type did not influence the wild-living cat occurrence index, vegetation structure was quite important, probably due to the prey availability and shelter it offers. Thus we suggest that wild-living cat scarcity in mountain pine habitats would mainly be due to the poor shrub cover, rather than to the fact of it being a coniferous forest, apart from other possible factors such as enhanced climatic severity (e.g. snow depth and snow endurance; Ragni 1981; Dötterer and Bernhart 1996) or prey availability, such as rabbit and rodent absence as a consequence of scarce grass cover (Rivas-Martínez et al. 1987).

These results confirm the suggestion of other authors that the wild-living cats and wildcats in particular are not exclusively forested species (Langley and Yalden 1977). Moreover, Hossfeld et al. (1992) showed that in the Taunus mountains (Germany) half of the wildcat observations reported in the questionnaires were recorded in non-forest habitats. Furthermore, Easterbee et al. (1991), in their study across Scotland, showed that wildcats select mosaics constituted by open fields and reforested patches, in which open fields occupy a significantly greater area than the reforested patches. Moreover, Stahl and Leger (1992) showed that wildcats are found in a great range of habitats.

In general, from the above-mentioned studies and our results, it can be stated that the wild-living cats appear to need areas with two basic patch types. First, closed structure patches, in which the wild-living cat would rest and have its shelter. Second, open patches such as pastures in which the wild-living cats would hunt (Corbett 1979; Stahl et al. 1988). The patch type that constitutes the mosaic would depend on the different habitat types available, shelter sites and prey abundance in each region. Forest areas are the only shelter sites left in most of central Europe. Here, extensive agriculture management techniques have led to the destruction of natural areas and scrublands are non-existent or very local (but see Corbett 1978; Dötterer and Bernhart 1996). Nevertheless, in the Mediterranean region, the situation evolved in a different manner. Deforestation started earlier and scrublands developed as a secondary habitat which is currently as extended as forests, and it may also be used as shelter sites and hunting places, whereas pastures are used only for hunting. Thus, forests may not be as critical for wild-living cats as in other European regions, and the mosaics of scrub–pastureland may be considered as a key habitat for the conservation of this species in the Mediterranean region.

Nevertheless, it is possible that a part of the unexplained variance observed in our study may be due to other factors not considered, such as direct persecution, changes in the last two decades in the distribution and abundance of one potential competitor, the Iberian lynx (*Lynx pardinus*), and of rabbits, one of the most important preys in the Iberian Peninsula. Moreover, it has been suggested (anonymous gamekeepers, shepherds and field naturalists) that wild-living cat abundance has increased during the last two decades. This has probably been caused by lynx extinction in a great part of its range, as a consequence of rabbit crash due to haemorragic epizootic. Wild-living cats would invade regions where lynxes have disappeared, because although rabbits are absent in some of these areas, the relatively generalist dietary habits of wild-living cats allow them to shift their diet to small mammals such as rodents (Authors, unpublished data). Unfortunately, there is a lack of empirical data on wild-living cat population trends in the Iberian Peninsula.

All the above-mentioned aspects need further re-evaluation in other Mediterranean regions, where human disturbance regimen, wildcat population status and trends or prey and competitor abundance may be important factors shaping the wild-living cat occurrence pattern.

Due to the predominance of studies performed in areas lacking scrublands, namely the northern-central Europe region, forests and agricultural lands have been considered crucial habitat types for wildcat conservation Europe-wide (Council of Europe 1992). This fact may have serious consequences for wildcat conservation in the Mediterranean area, given that scrublands are the main vegetation type in this region (Ozenda 1982). This work highlights the key importance of scrublands for wildcats in a Mediterranean area.

European habitat conservation policy for the wildcat should take into account the particularity of the Mediterranean habitats. This fact is even more important if we consider that the majority of the distribution range of this species is included in the Mediterranean area, probably representing the most abundant and continuous populations of Europe. Then, we suggest that European guidelines for wildcat conservation should include the following recommendations: (1) to protect scrub–pastureland mosaic areas in order to assure long-term wildcat conservation, including some of them as European Communitary Interest Areas; (2) to encourage further studies on the importance of this habitat in other Mediterranean areas, as well as the role of size and distribution of scrub–pasture patches in wildcat presence and survival, which affects rabbit abundance (Langley and Yalden 1977) and probably rodent abundance and diversity; (3) to manage landscape, taking into account the damaging effects of the extensive removal of scrublands, a common practice associated with fire prevention strategies and infrastructure developments; and (4) to manage landscapes promoting a configuration that combines scrublands and pastures and to take into account in the reforestation practises promoted by the European Agricultural Policy the use of their main shrub species.

## Acknowledgements

G. Solís, U. Villavicencio and E. Vergaño helped us with the field work. C. Herrero, P. Cuadrado and E. Belinchón, K. Bastidas and V. Febrero also helped in some parts of this work. Comments and suggestions by J. Cassinello improved an earlier draft of the manuscript. E.V. was under a post-doc grant from the project 1FD97-2299 during the manuscript preparation and submission period.

## References

Andelt W.F. and Andelt J.H. 1984. Diet bias in scat deposition rate surveys of coyote density. Wildlife Society Bulletin 12: 74–77.

Artois M. 1985. Utilisation de l'espace et du temps chez le renard (*Vulpes vulpes*) et le chat forestier (*Felis silvestris*) en Lorraine. Gibier Faune Sauvage 3: 33–57.

Aymerich M. 1982. Etude comparative des régimes alimentaires du lynx pardelle (*Lynx pardina*) et du chat sauvage (*Felis silvestris*) au centre de la péninsule Ibérique. Mammalia 46: 515–521.

Aymerich M. 1993. Situación y conservación del gato montés en Europa. Quercus July: 6–11.

Beaumont M., Barratt E.M., Gotelli D., Kitchener A.C., Daniels M.J., Pritchard J.K. et al. 2001. Genetic diversity and introgression in the Scottish wildcat. Molecular Ecology 10: 319–336.

Blas Aritio L. 1964. Estudio de la Distribución de Algunas Alimañas Españolas incluidas en la Clase Mammalia. S.N.P.F.C., Madrid, Spain.

Castells A. and Mayo M. 1993. Guía de los Mamíferos en Libertad de España y Portugal. Ed. Pirámide S.A., Madrid, Spain.

Cavallini P. 1994. Faces count as an index of fox abundance. Acta Theriologica 39: 417–424.

Conroy J.W.H. and French D.D. 1987. The use of spraints to monitor populations of otters (*Lutra lutra*). Symposia of the Zoological Society of London 58: 247–262.

Corbett L.K. 1978. Current research on wildcats: why have they increased? Scottish Wildlife 14: 17–21.

Corbett L.K. 1979. Feeding ecology and social organization of wildcats (*Felis silvestris*) and domestic cats (*Felis catus*) in Scotland, Ph.D. Thesis, University of Aberdeen, Aberdeen, UK, 296 pp.

Council of Europe 1992. Seminar on the biology and conservation of the wildcat (*Felis silvestris*). Nancy, France, 23–25 September 1992. Council of Europe, Strasbourg, France.

Daniels M.J., Balharry D., Hirst D., Kitchener A.C. and Aspinall R.J. 1998. Morphological and pelage characteristics of wild living cats in Scotland: implications for defining the 'wildcat'. Journal of Zoology London 244: 231–247.

Daniels M.J., Beaumont M.A., Johnson P.J., Balharry D., Macdonald D.W. and Barratt E. 2001. Ecology and genetics of wild-living cats in the north-east of Scotland and the implications for the conservation of the wildcat. Journal of Applied Ecology 38: 146–161.

Dötterer M. and Bernhart F. 1996. The occurrence of wildcats in the southern Swiss Jura Mountains. Acta Theriologica 41: 205–209.

Easterbee N., Hepburn L.V. and Jefferies D.J. 1991. Survey of the status and distribution of the wildcat in Scotland, 1983–1987. Nature Conservancy Council for Scotland, Peterborough, UK.

Fernández E., de Lope F. and de la Cruz C. 1992. Morphologie crânienne du chat sauvage (*Felis silvestris*) dans le sud de la Peninsule ibérique: importance de l'introgression par le chat domestique (*Felis catus*). Mammalia 56: 255–264.

Ferreras P., Revilla E. and Delibes M. 1999. Pequeños y medianos carnívoros ibéricos. Biológica 28: 14–37.

Genovesi P. and Boitani L. 1992. Spacing patterns and activity rhythms of a wildcat (*Felis silvestris*) in Italy. Seminar on the biology and conservation of the wildcat (*Felis silvestris*), Nancy, France, 23–25 September 1992. Council of Europe, Strasbourg, France, pp. 98–101.

Gil-Sánchez J.M., Valenzuela G. and Sánchez J.F. 1999. Iberian wild cat *Felis silvestris tartessia* predation on rabbit *Oryctolagus cuniculus*: functional response and age selection. Acta Theriologica 44: 421–428.

Guggisberg C.A.W. 1975. Wild Cats of the World. David and Charles, Newton Abbott, UK.

Hewson R. 1983. The food of wild cats (*Felis silvestris*) and red foxes (*Vulpes vulpes*) in west and north-east Scotland. Journal of Zoology London 200: 283–289.

Hossfeld E., Reif U. and Reith U. 1992. The wildcat in the Taunus mountains: results of preliminary investigations and a draft of a research and protection project. Seminar on the biology and conservation of the wildcat (*Felis silvestris*), Nancy, France, 23–25 September 1992. Council of Europe, Strasbourg, France, pp. 46–51.

Hubbard A.L., McOrist S., Jones T.W., Boid R., Scott R. and Easterbee N. 1992. Is survival of European wildcats *Felis silvestris* in Britain threatened by interbreeding with domestic cats? Biological Conservation 61: 203–208.

Langley P.J.W. and Yalden D.W. 1977. The decline of the rarer carnivores in Great Britain during the nineteenth century. Mammal Review 7: 95–116.

Moreno S. and Villafuerte R. 1995. Traditional management of scrubland for the conservation of rabbits and their predators in Doñana National Park, Spain. Biological Conservation 72: 81–85.

Nowell K. and Jackson P. 1996. The wild cats: status survey and conservation action plan. International Union for Nature Conservation/Cat Specialist Group, Gland, Switzerland.

Ozenda P. 1982. Les vegetaux dans le biosphère. Doin Editeurs, Paris.

Palma L., Beja P. and Rodrigues M. 1999. The use of sighting data to analyse Iberian lynx habitat and distribution. Journal of Applied Ecology 36: 812–824.
Parent G.H. 1975. La migration récente, à caractère invasionnel, du chat sauvage, *Felis silvestris silvestris* Schreber, en Lorraine Belge. Mammalia 39: 251–288.
Ragni B. 1978. Observations on the ecology and behaviour of the wild cat (*Felis silvestris* Schreber, 1777) in Italy. Carnivore Genetics Newsletters 3: 270–274.
Ragni B. 1981. Gatto selvatico *Felis silvestris* Schreber, 1777. In: Distribuzione e biología di 22 specie di mamíferi in Italia, Roma. Consiglio Nazionale delle Ricerche, Rome, pp. 105–113.
Rivas-Martínez S., Fernández-González F. and Sánchez-Mata D. 1987. El Sistema Central: de la Sierra de Ayllón a Serra da Estrela. In: Peinado M. and Rivas-Martínez S. (eds), La vegetación de España. Publicaciones Universidad de Alcalá, Madrid, Spain, pp. 419–451.
Roncadell-SECEM 1997. Atlas provisional de los carnívoros de la Comunidad Valenciana. Dirección General del Medio Natural, Generalitat de Valencia, Valencia, Spain.
Sarmento P. 1996. Feeding ecology of the European wildcat *Felis silvestris* in Portugal. Acta Theriologica 41: 409–414.
Schauenberg P. 1981. Elements d'ecologie du chat forestier d'Europe *Felis silvestris* Schreber, 1777. Revue d'Écologie (Terre et Vie) 35: 3–36.
Scott R., Easterbee N. and Jefferies D. 1992. A radio-tracking study of wildcats in western Scotland. Seminar on the biology and conservation of the wildcat (*Felis silvestris*), Nancy, France, 23–25 September 1992. Council of Europe, Strasbourg, France, pp. 94–97.
Stahl P., Artois M. and Aubert M.F.A. 1988. Organisation spatiale et déplacements des chats forestiers adultes (*Felis silvestris*, Schreber, 1777) en Lorraine. Revue d'Écologie (Terre et Vie) 43: 113–131.
Stahl P. and Artois M. 1991. Status and Conservation of the Wild Cat (*Felis silvestris*) in Europe and around the Mediterranean Rim. Council of Europe, Strasbourg, France.
Stahl P. and Leger F. 1992. Le chat sauvage (*Felis silvestris*, Schreber, 1777). In: Artois M. and Maurin H. (eds), Encyclopédie des Carnivores de France. Société Française pour l'Etude et la Protection des Mammifères (S.F.E.P.M.), Bohallard, Puceul, France.
Underwood A.J. 1996. Experiments in Ecology. Cambridge University Press, Cambridge, UK.
Urra F. 1997. Utilización del espacio por el gato montés (*Felis silvestris*) en Navarra. In: III Jornadas españolas de conservación y estudio de mamíferos, Castelló d'Empúries (Girona), 5–7 Diciembre 1997. Sociedad Española para la Conservación y Estudio de los Mamíferos (SECEM), Malaga, Spain, pp. 86.
Virgós E. and Casanovas J.G. 1998. Distribution patterns of the stone marten (*Martes foina*) in Mediterranean mountains of central Spain. Zeitschrift für Säugetierkunde 63: 193–199.
Wittmer H.U. 2001. Home range size, movements, and habitat utilisation of three male European wildcats (*Felis silvestris* Schreber, 1777) in Saarland and Rheinland-Pfalz (Germany). Zeitschrift für Säugetierkunde 66: 365–370.