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ORIGINAL PAPER

The priority value of scrubland habitats for carnivore conservation in Mediterranean ecosystems

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Abstract Carnivores are umbrella species with a key role in ecosystems. In the Mediterranean, they face with several conservation problems, mainly habitat loss or transformation. In this region, scrubland habitats are considered of minor conservation relevance as compared to mature forest formations. Conservation of scrublands in Mediterranean ecosystems is also difficult because to control fires, they are removed over large areas. For carnivores, scrublands may be essential to guarantee shelter and food. Here, we analyzed the importance of scrublands and other habitat variables in determining the richness of medium-sized carnivores in a typical Mediterranean area of central Spain (Monfragüe Natural Park). The Park was divided into plots of 2 × 2 km (n = 30). In each plot, a 2 km-length survey route was walked searching for carnivore scats. We recorded the number of species of carnivores and we related this value to several habitat variables. Habitat variables were summarized by means of Principal Component Analysis (PCA). Habitat models were developed by, using multiple regression models, including PCA factors and the habitat type as predictors. The only variable included in the final model was the first PCA factor. Carnivore richness was positively associated with large tree, shrub, and rock cover areas, which is the typical habitat structure of scrublands. This habitat offers the best available area for shelter and may be considered as a key element for carnivore conservation in the Mediterranean region. To reconciliate carnivore conservation and forestry management, we proposed small-scale clearances as a management alternative to typical large scrubland removals.

Keywords *Felis silvestris* · Fire management · Forestry · *Martes foina* · Mediterranean · *Meles meles* · Scrublands · *Vulpes vulpes*

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Introduction

Carnivores face several conservation problems as a consequence of the dramatic increase in human activities in ecosystems around the world (Ginsberg and Macdonald 1990; Zielinski and Kucera 1995; Noss et al. 1996; Gese 2001; Wilson and Delahay 2001). Habitat loss and fragmentation are two of the main threats (Gittleman et al. 2001; Virgós et al. 2002), although our knowledge about the effects of these threats on different species and ecosystems is still scarce.

A preliminary and necessary step for conservation action for most species is developing accurate species or diversity-habitat models (Manel et al. 1999; Guissan and Zimmerman 2000; Carroll et al. 2001; Virgós 2001). Habitat models provide a first assessment of environmental attributes linked to species survival or occurrence which may guide conservation practices (Guisan and Zimmerman 2000; Scott et al. 2002). Despite the importance of autoecological (single-species) habitat studies, we need more research at higher levels, for example, in identifying priority areas or habitats for conservation (Travaini et al. 1997; Carroll et al. 2001; Gurd et al. 2001; Coppolillo et al. 2004; but see Andelman and Fagan 2000; Linnell et al. 2000). Because carnivores are indicator or umbrella species with a key role in ecosystems (Wilcox 1984; Noss et al. 1996; Zielinski 1997; Gittleman et al. 2001; Caro 2003; but see Linnell et al. 2000) and they cope with a myriad of potential threats, the carnivore-habitat models should be among the most relevant for managers and conservationists, especially at large spatial scales (Noss et al. 1996; Carroll et al. 1999; Mladenoff et al. 1999; Caroll et al. 2001).

In the southwest Mediterranean region we find a diverse and very particular carnivore community, which is still in moderate or good conservation status. Nevertheless, the increase of human activities as a consequence of fast development in the last three decades threatens the conservation status of most vertebrate species and their habitats (Díaz et al. 1997; De Juana 2004). Carnivore-habitat studies in this region are also interesting because the Mediterranean region is very different in its climatic and floristic features in relation to other European regions, such as temperate and boreal ecosystems. The Mediterranean region shows typical and unique habitats composed of plants adapted to dry and longer summers (Ozenda 1982). In the Mediterranean large areas are covered by a type of vegetation rarely found in other European ecosystems: the scrublands which are a mixture of several sclerophyllous shrubs and tree species (Ozenda 1982). This habitat has received some conservation interest due to its large diversity of plant species (Médail and Quezel 1997), importance for the appearance of strong mutualistic interactions (Herrera 1985), and the existence of large and old trees supporting nests of threatened bird species such as the Imperial eagle (*Aquila adalberti*) and black vulture (*Aegypius monachus*) (Ferrer 2001).

Despite this appreciable conservation value, the relevance of this ecosystem is low compared to mature forest formations in the current programs for species or habitat conservation (MIMAM 2002). Moreover, the conservation of scrublands in Mediterranean ecosystems faces an important constraint. The Mediterranean area suffers from systematic and strong fires during hot and long summers, which may affect conservation values but also human interests such as pine plantations, urbanization, or croplands (Prodon et al. 1984; Prodon 1987; Terradas 1996). Most of the management practices of wild Mediterranean ecosystems are then centered on stopping these fires (Terradas 1996). To control fires, forest managers try to considerably reduce the available combustible material. Shrubs are considered as potentially enhancing factors for fires, and therefore in most Mediterranean areas, management is based on shrub removal over large areas (Terradas 1996; Camprodon 2001). This management practice was applied without a general knowledge of the role of

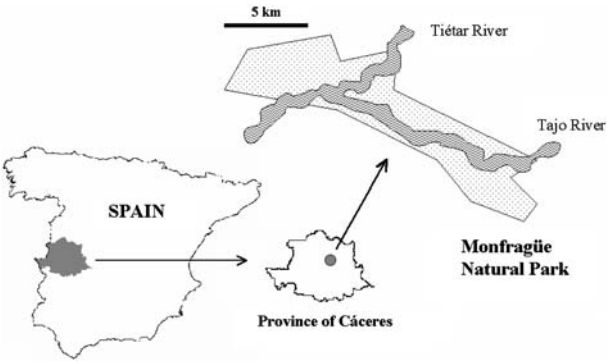

Fig. 1 Location of the study area, Monfragüe natural park, on the Iberian Peninsula within the province of Cáceres

shrubs in the conservation of species and assumed a 'low' value as a type of vegetation compared to forests or other habitats, both in economic and ecological terms.

Several species of medium-sized carnivores depend on scrublands or areas of dense shrub cover to display some of their activities, especially for shelter, but also to find prey. Recent studies have emphasized the role of scrublands in wildcat *Felis silvestris* conservation (Lozano et al. 2003), and other studies revealed its key role for genets *Genetta genetta* (Virgós and Casanovas 1997) and badgers *Meles meles* (Revilla et al. 2001). Nevertheless, we do not have data about the role of areas of large shrubs in promoting hot spots of high diversity for medium-sized carnivores in Mediterranean ecosystems. Although medium-sized carnivores such as badgers, wild cats, or martens are of less conservation concern than large carnivores, they are an important part of ecosystem function (Clutton-Brock 1996; Zielinski 1997; Gittleman et al. 2001) and they may depend on well conserved areas to maintain sustainable populations.

In this study, we analyzed the importance of several habitat elements in determining the richness of medium-sized carnivores in a typical Mediterranean area of central Spain as a first attempt to test the role of scrublands in the conservation of this group of mammals in Mediterranean ecosystems.

Materials and methods

Study area

The study was conducted in the Natural Park of Monfragüe (western-central Spain) in the province of Cáceres during the spring of 2004 (end-March until mid-May) (Fig. 1).

Monfragüe is a moderately elevated small mountain system located in a region surrounded by flat landscapes. The altitudinal range of this mountain system is narrow (between 250–470 m.a.s.l.) when compared to other Mediterranean mountains of central Spain (e.g. between 700–2300 m.a.s.l. in the Central System mountain range). The climate is typical Mediterranean, with hot and dry summers, mild winters, and moderately rainy autumns and springs (Font 1983).

The Natural Park of Monfragüe is a typical example of Mediterranean vegetation in central Spain; it is of international conservation interest due to the abundant presence of several threatened species such as black vulture (*Aegypius monachus*), Iberian imperial

eagle (*Aquila adalberti*), and black stork (*Ciconia nigra*). It is mainly covered by scrublands where the tree layer is dominated by cork oak (*Quercus suber*) or holm oaks, but the shrubs predominate: strawberries *Arbutus unedo*, *Cistus* spp, *Phyllirea angustifolia*, and *Erica* spp. (Peinado and Rivas-Martínez 1986). In addition to scrublands, in some areas, the landscape is dominated by eucalyptus and pine plantations, deforested areas (mainly as a product of activities promoted to remove *Eucalyptus spp.* in the landscape), and dehesas (formations with cork oaks and holm oaks without an understory shrub layer). Thus, the landscape in Monfragüe may be characterised by large areas covered by scrublands as opposed to areas with lower shrub cover or plantations of coniferous species which also exhibit a low shrub cover.

Sampling protocol

The Park was divided in plots of 2 × 2 km following UTM coordinates. A total of 29 plots were sampled. In each plot, a 2 km-length survey route was walked searching for carnivore scats. Four carnivore species were searched, red fox (*Vulpes vulpes*), badger, stone marten (*Martes foina*), and wildcat. These species are the most abundant in Mediterranean habitats and are easily detected by means of scat surveys following linear structures (see below) (Virgós 2001 for all carnivores; Tuyttens et al. 2001 for badgers; and Webbon et al. 2004 for red foxes). Genets and, to a lesser extent, grey mongoose (*Herpestes ichneumon*) are also present but they cannot be detected along trails or other linear structures and therefore have not been included in the analyses.

The survey routes were located along paths between 2 and 5 m wide, avoiding those with intense car traffic. However, the Natural Park is restricted to public use and most paths and roads are of very limited use. Scats from different species were identified by shape, size, smell and location; when the assignment of a particular scat was not clear, the scat was not considered. The biases produced by sampling at different seasons (e.g. different defecation rates, Andelt and Andelt 1984; Cavallini 1994) were avoided in our study by reducing considerably the window time of the sampling.

In order to estimate the variables used in this study, each survey route was divided into segments of 200 m-length, resulting in 10 segments per survey route. First, we estimated by eye the cover of shrubs of >50 cm height in a circle of 15 m radius around the sampling point. In addition to shrub cover, we estimated other variables related to habitat structure: tree cover, shrub cover <50 cm height, herb cover, rock cover, average tree height, and average shrub height. All these variables were used as surrogates of habitat quality for carnivores (Virgós et al. 2002). All these variables were also estimated every 200 m by means of visual estimation in a circle of 15 m radius. For each survey route, we averaged the value obtained at the 10 sampling points. Before the sampling, the different people involved in the estimation of variables (the same three people throughout the study) performed a trial to homogenize their estimations.

The richness of carnivore species may be determined by the presence of small game lands and its associated predator control (Virgós and Travaini 2005). In our study area, predator control is forgotten and probably very anecdotal. Then, in this particular scenario, the key role of predator control in other circumstances is probably very low in this study.

Statistical analyses

We correlated the richness of carnivore species to habitat structure and habitat type (areas covered by north slope scrublands and areas covered by other types of scrublands or dehesas).

Table 1 Correlations (factor loadings) between original variables and the three PCA factors obtained

	Factor 1	Factor 2	Factor 3
Tree cover (%)	0.699	0.029	−0.472
Shrub cover <50 cm (%)	0.520	0.228	0.659
Shrub cover >C 50 cm (%)	0.392	−0.721	−0.322
Herb cover (%)	−0.319	0.689	−0.431
Rock cover (%)	0.794	0.402	−0.184
Tree height (m)	0.812	0.151	0.148
Shrub heigth (cm)	0.092	−0.858	0.023
Eigenvalue	2.313	1.971	1.004
% Explained variance	33.05	28.15	14.35

Habitat variables were summarized in new independent variables by means of Principal Component Analysis (PCA). PCA factors are independent of each other (James and McCullogh 1990), allowing their use in further multiple regression analyses without problems due to multicollinearity (MacNally 2000; Graham 2003). We then used a principal component general linear model (Graham 2003) with the species richness in each plot as the dependent variable and the PCA factors as continuous explanatory predictors. The model selection was performed by a backward elimination procedure. Before performing the multiple regression analysis, we checked for normality of all the variables.

Statistical analyses were performed with the STATISTICA 6.0 package.

Results

The maximum richness of carnivores was only reached in 6 plots of the 29 sampled. However, in all plots at least 2 different species were detected; we did not record 0 or 1 species in some of the plots, indicating a relatively good distribution of all carnivore species in this area.

The PCA analysis rendered 3 orthogonal factors (see Table 1 for factor loadings). The first factor represented a gradient from areas with high tree, shrubs, and rock cover (in the positive scores) to areas with scarce tree, shrub, and rock cover. It may then be interpreted as a gradient from typical scrubland formations in the positive side towards deforested or dehesa habitats in the negative side. The second factor is interpreted as a gradient from areas covered by large shrubs (positive scores) to those covered by grass (herb cover in the negative scores). Finally, the third factor separated areas of high cover of small shrubs (positive scores) from dehesas (large tree and herb cover in the negative scores). Then, the 3 factors allowed a very accurate representation of the habitats of the sampled area.

The PCA multiple regression model with a backward elimination procedure indicated that the only variable included in the final model was the first PCA factor ($r = 0.50$, $P < 0.01$, see also Fig. 2), the other two PCA factors and habitat type were dropped from the model in the first steps of the backward procedure. Carnivore richness was positively associated with areas with large tree, shrub, and rock cover.

Discussion

Carnivore richness was higher in the areas of higher protective cover, composed of a mixture of trees, tall shrubs, and abundant rocks, the typical composition of scrublands in

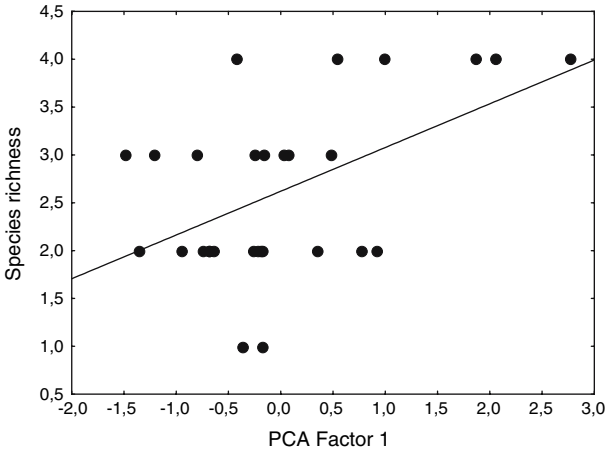

Fig. 2 Correlation between the species richness of carnivores and the scores of factor 1 from the Principal Component Analysis

Mediterranean ecosystems. In contrast, carnivore richness was very low in areas where shrub and tree cover is low, including areas of dehesas (with moderate tree cover but without shrubs), pine or eucalyptus plantations (with large tree cover but low shrub cover), and open areas produced by eucalyptus removal by the administration in the last five years.

We have previously indicated that shrubs could be very valuable for carnivores because of its role in providing cover for predatory activities, shelter, or minimizing predation risk (e.g. for raptors or large carnivores such as stray dogs). The results supporting that cover value may be the main element when carnivores selected scrublands to live. This habitat composed of a mixture of large shrubs, large trees, and rocks offer the best available area for shelter. Other studies in central Spain have emphasised the role of scrubs or mosaic of scrubs and other habitat elements in guaranteeing refuge and/or food for medium-sized carnivores (Virgós and Casanovas 1997; Revilla et al. 2001; Lozano et al. 2003).

Mediterranean scrublands are typical vegetation formations of the Mediterranean region; they are the reservoir of several unique species and its conservation value should be large for this reason. However, some of the Mediterranean scrublands associated with serial types are usually neglected as important for conservation and are under substantial pressure for removal in order to mitigate potential fire sources and their progression (Terradas 1996; Camprodon 2001). This social pressure was even higher in the last two years, coinciding with very dry summers which reinforce the appearance of strong and faster fires. The Spanish and Portuguese governments decided to undertake exceptional measures to mitigate fires and shrub removal was one of the most central measures. Over decades, in rural areas, people conducted small shrub removal by cattle grazing or by facilitating access to exploitation areas. Nowadays, most Mediterranean areas are covered by scrublands as a consequence of progressive rural abandonment (Tellería and Sáez-Royuela 1984; Terradas 1996). In this scenario, managers decide to remove scrublands, but in most situations this removal is not similar to those produced by traditional practices. Forestry practices tend to remove large areas of shrubs, which may be very negative for species dependent on shrubs. We proposed as a management alternative that managers may simulate or enhance the traditional removal pattern produced by sheep or goat grazing (Pons 2001). In a similar line of reasoning, Camprodon (2001) suggested that removal should be used only in exceptional cases and associated with tracks or forest edges. Although management of Mediterranean

ecosystems needs to take fire risks into consideration, our results point out the relevance of scrublands for carnivore conservation on a local scale. Managers need to consider this fact in the decision-making process, and not only economic, social, or purely forestry guidelines (see also Camprodon 2001).

The large value found for scrublands needs to be also reconciliated with the importance of dehesas or mosaics of pasturelands and scrublands for other key species in Mediterranean habitats (Tellería 2001; Carrete and Donázar 2005). Managers of natural resources need to integrate the conservation values of different habitats in their environmental decisions, but our results demonstrate the need for a better appreciation for the large conservation value of scrublands in Mediterranean ecosystems.

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