Universidade de Aveiro Departamento de Biologia
2010

Pedro Bernardo Marques da Silva Rodrigues Sarmento

Habitat-species interactions in a carnivore community

Interações espécies-habitat numa comunidade de carnívoros

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em Biologia - - especialização em Ecologia, Recursos Naturais e Biodiversidade,realizada sob a orientação científica do Professor Doutor Carlos Manuel Martins Santos Fonseca, Professor Auxiliar com Agregação do Departamento de Biologia da Universidade de Aveiro.

Ao meu Pai que me ensinou que a vida é uma
brincadeira e por isso tem que ser levada
muito a sério.

o júri

presidente	Prof. Doutor Vasile Staicu professor catedrático da Universidade de Aveiro
	Prof. Doutor Amadeu Mortágua Velho da Maia Soares professor catedrático da Universidade de Aveiro
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	Prof. Doutor António Paulo Pereira Mira professor auxiliar da Universidade de Évora
	Doutor Eloy Revilla investigador titular, Estacion Biológica de Doñana-CSIC, Sevilha, Espanha

agradecimentos

Foi por volta de 1980 que, sob algumas influências, começou o meu interesse por biologia: o premiado “A Vida na Terra”, e aquele que Camões decreveu “ de *olhos encovados, e postura medonha e má*”. Apesar da brutalidade com que tratava uns miúdos subnutridos saídos do tempo do PREC, incutiu-nos o fascínio pelo mundo natural (“o maior espectáculo do Mundo”). Nos anos que se seguiram cruzei-me com *ciápodes, blémios e todos os outros monstros* não só mas acompanhado (..a famosa fotografia no cume). E em 1987 entrei para a FCUP, para tirar o curso de biologia por entre pó, bolores, paredes de esferofite e equipamento do séc XIX. No final dos estudos académicos, comecei a trabalhar com carnívoros de forma totalmente acidental e sem saber nada do assunto. Foi nesse momento que, após um ano a recolher amostras e a apanhar doenças, me perguntaram se eu gostaría de trabalhar com lince na Malcata e eu tive a lucidez de dizer que sim. Deste modo, e de forma completamente justa, o primeiro agradecimento formal vai naturalmente para mim. Os tempos que se seguiram foram de profunda descoberta da mais completa ignorância, o que me levou a recorrer a uma pessoa de peso que, naquela altura, tal como agora, arrastava multidões de desgraçados que lhe obdeciam cegamente. Em 1994 conheci-a. Eterna fonte de inspiração, conspiração e respiração que acabaria por fazer história. Do período que começou 2002, altura em que passei a ser mais responsável, tenho que destacar todos os que apesar dos ventos fortes que enfrentamos nunca desistiram de mim. E da era da coordenação nacional, aqueles que viveram entre linces, jaguares e os mais incompreensíveis modelos. Do outro lado da fronteira ensinaram-me a trabalhar com câmaras automáticas, introduziram-me aos sistemas de pedal e eu introduzi-os aos de infra-vermelhos, depois passamos para os digitais e eu acabei por fazer uma tese sobre o assunto. E claro que tenho que agradecer a quem me deixou ir para o DEBIO quando a minha história parecia terminada. Катерина foi fundamental no processo revolucionário em curso.

Os agradecimentos pelas participações especiais em trabalho de campo vão para: Anabela, Fernanda, Ana Lúcia, Marisa, Isabel, Bárbara, João, Puga, Duarte, Piranha e outros amigos imaginários. O agradecimento à minha famíla vai para os meus familiares vivos e mortos (dos quais me vou lembrando em *lembranças de lembranças*).

palavras-chave

Ocupação de carnívoros, ecossistemas mediterrâncios, programas de monitorização, taxas de ocupação, Serra da Malcata

resumo

Na maioria das area protegidas nacionais existe uma considerável falta de informação científica relativa aos mamíferos carnívoros. A Reserva Natural da Serra da Malcata, localizada no centro-este de Portugal, tem vindo a desenvolver, desde os últimos 20 anos, estudos de ecologia e esta tese pretende dar seguimento a esse esforço de monitorização, através do desenvolvimento de métodos simples e eficientes, de monitorização de carnívoros, que possam servir como percursores de trabalhos a longo-prazo em áreas relevantes para a conservação. Através do uso de armadilhagem fotográfica, foram estudadas relações espécies-habitats para 5 espécies: gato-bravo (*Felis silvestris*), fuinha (*Martes foina*), raposa (*Vulpes vulpes*), gineta (*Genetta genetta*), e sacarrabos (*Herpestes ichneumon*). Foram desenvolvidos métodos para se determinar a densidade absoluta de raposa e gineta e a população de gato-bravo foi estudada em detalhe. As principais conclusões do estudo foram: 1) a ocupação de raposas é uniforme e parece ser independente de variáveis ambientais; 2) a ocupação de fuinha encontra-se relacionada com variáveis de habitat, estrutura paisagística e presas; 3) a ocupação de gineta está relacionada com a cobertura de folhosas e distribuição de presas; 4) para o sacarrabos verifica-se que a ocupação é influenciada pelas extensões de habitat arbustivos, 5) a população de gato-bravo sofreu um forte declínio durante o trabalho e requer urgentes medidas de conservação. Metodologicamente foi demonstrada a importância da modelação das probabilidades de detecção para espécies para as quais este parâmetros apresenta valores baixos ou é muito variável. Esta tese também demonstrou a grande importância da Serra da Malcata para a conservação de carnívoros e a necessidade do desenvolvimento de técnicas de monitorização padronizadas para uma correcta gestão adaptativa das áreas protegidas.

keywords

carnivore conservation, Mediterranean ecosystems, monitoring programmes, occupancy rates, Serra da Malcata

abstract

For most Portuguese Protected Areas only a few attention has been given to carnivores, and the overall scientific information is insufficient. Serra da Malcata, a Nature Reserve in central-eastern Portugal, has been developing ecological studies, since the last 20 years, and the current thesis aimed to use simple and efficient field and analysis methods for monitoring carnivores as a precursor to establishing long-term multispecies monitoring programs in areas relevant for conservation. Using camera trapping, we study species-habitats relations for five carnivore species: wildcat (*Felis silvestris*), stone marten (*Martes foina*), red fox (*Vulpes vulpes*), genet (*Genetta genetta*), and Egyptian mongoose (*Herpestes ichneumon*). We develop methods for determining the absolute density of foxes and genets, and we studied in detail the wildcat population. The major conclusions of the study were: 1) fox occupancy tends to be independent of environmental factors, 2) stone marten occupancy is related with habitat variables, landscape structure and preys, 3) common genet occupancy is related to broad leaf formations and preys, and 4) mongoose occupancy is higher in extensive areas of shrub habitats. Methodologically, we demonstrated the importance of modelling detection probabilities for species with low or variable detection rates. This thesis demonstrated that Malcata could be one of the most important areas in Portugal for conserving carnivores. In this context monitoring should contribute to our understanding of the dynamics of targets species and of how management practices may be altered to improve the prospects of the population of interest. In resume, an optimal and professional management of the Nature Reserve demands a well structured monitoring scheme that should be applied in regular time intervals.

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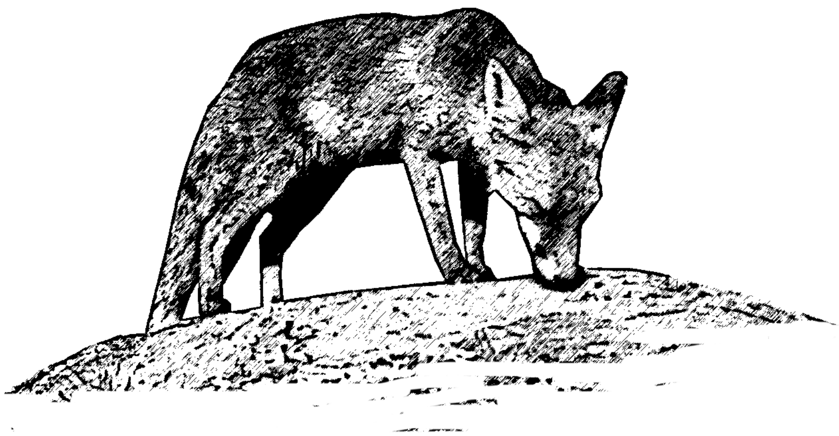
During my life I have done lots of mistakes, but there´s one thing I´ve never did: is to give up.
No matter what never give up.
Jim Sanderson – 1st Iberian lynx Seminar, Andújar 2002



CHAPTER 1

GENERAL INTRODUCTION AND OBJECTIVES

CARNIVORES AND CONSERVATION

THE PORTUGUESE DILEMMA

Carnivores are critical components of the ecosystems, with many of its members considered flagship, umbrella and indicator species (Noss, et al., 1996; Gittleman, et al., 2001). Therefore carnivore conservation is essential to maintain the structure and function of natural communities (Ginsberg, 2001).

According to Valenzuela-Galván et al. (2008), carnivore conservation is different from ‘‘biodiversity’’ conservation for ecological and social aspects. One of the main issues in carnivore conservation is the potential conflicts with human activities, as a direct effect of feeding habits, range and habitat requirements, along with the human awareness of threats posed to individuals or livelihoods (Sillero-Zubiri et al., 2007). At one extreme are species that can, directly or indirectly, threaten humans. Although the perception of threat may be greater than the reality, the conflict results in many carnivores being persecuted (Ginsberg, 2001).

In this context, Portugal is no exception and during centuries carnivore species were persecuted for several reasons: fur trade, food supply, competition for game species, livestock damages, etc. These actions were legal and encourage by authorities till the mid 1960s when the first carnivore species, the Iberian lynx (*Lynx pardinus*) was legally protected. From the subsequent years till the present, carnivores continued to be persecuted by legal and illegal means. Species such as the red fox (*Vulpes vulpes*) and the Egyptian mongooses (*Herpestes ichneumon*) are still legally hunted, with the aim of reducing potential impacts on game species, which are far from being demonstrated (Rosalino et al., 2008). A total of 13 native carnivore species inhabit Portugal, with 2 of them being endangered (Table 1).

If for more charismatic species attention in terms of conservation is present at least since the mid 1980s (e.g. Iberian lynx and Iberian wolf *Canis lupus signatus* that have specific legislation), for other carnivores, particularly smaller species, awareness seems to be reduced or even absent. Some of this bias undoubtedly reflects historical associations, and the evolution of the conservation movement in response to declines of larger species. Furthermore, these large carnivores have intrinsic appeal for both conservationists and the general public (Entwistle & Stepheson, 2000). Species such as the wildcat (*Felis silvestris*) could be suffering major constraints in its geographic range, without the knowledge or consciousness of governmental agencies. This is the result of a lack in long-term monitoring tradition in Portugal, and also of the low charisma of small carnivores, which often are disregarded.

Table 1. List of terrestrial carnivore species present in Portugal and respective conservation status (from Cabral et al., 2005).

	Category (Portugal)	IUCN	Berne Convention	Habitats Directive
Canidae				
Iberian wolf *Canis lupus signatus*	EN	LC	II	B-II B-IV
Red fox *Vulpes vulpes*	LC	LC		
Mustelidae				
Stout Mustela erminea	DD	LR	III	
Weasel *Mustela nivalis*	LC	LR	III	
Polecat *Mustela putorius*	DD	LR		B-V
Stone marten *Martes foina*	LC	LR	III	
Marten *Martes martes*	DD	LR	III	B-V
Badger *Meles meles*	LC	LR	III	
Otter *Lutra lutra*	LC	NT	II	B-II B-IV
Viverridae				
Genet *Genetta genetta*	LC	LR	III	B-V
Herpestidae				
Egyptian mongoose Herpestes ichneumon	LC	LR	III	B-V
Felidae				
Wildcat *Felis silvestris*	VU	LC	II	B-IV
Iberian lynx *Lynx pardinus*	CR	CR	II	B-II B-IV

Categories: CR- critically endangered; EN – endangered; VU – vulnerable; NT- Near threat; LC – Least concern; DD- Data deficient.

Besides from direct human persecution carnivores are substantially threat by human-caused habitat alterations (Sunquist, et al., 2001). This phenomenon has accelerated recently and the general concurrence is that increasing rates of habitat degradation, loss, and fragmentation, together with the ecological effects of isolation and patch dynamics, are mostly responsible for escalating the rate of species decline and endangerment (Berger, 1999; Ginsberg, 2001; Clark et al., 2001). In Portugal threat factors for carnivores habitats include: 1) intensive forestations; 2) intensive agriculture; 3) urban development; and 4) infrastructures (roads, dams etc.) (Cabral et al., 2005). The effect of these factors augmented significantly during the second half of the XXth century, and currently only about 15% of the country is occupied by natural or semi-natural landscapes (Corinne Land Cover).

The implementation, in 1999, of the Natura 2000 network, together with the recent increase in social awareness towards conservation, and the approval, in 2002, of the Portuguese Strategy for Nature Conservation and Biodiversity established an urgent necessity for effective conservation measures and ecosystems restoration. However this is only possible with an adequate scientific understanding regarding species status, ecological requirements, and threat factors (e.g Biodiversity Information System for Europe) (European Environment Agency, 2010).

For most Portuguese Protected Areas only a few attention has been given to carnivores, and the overall scientific information is extremely narrow. In fact, besides from wolf and lynx no other species have been submitted to a national census and their status remains poorly known (Cabral et al., 2006). Because of their particularities Protected Areas can function as essential areas for carnivore conservation, especially by maintaining relevant patches of important habitats, controlling poaching activities and other threat factors, and by promoting scientific research (Gittleman et al., 2001).

According to Clark et al. (2001) the goal of carnivore conservation is to reverse declines in populations and to secure remaining populations in ways that gain enduring public support. Clearly, carnivore conservation rests both on reliable scientific knowledge and informed public consent (Minta et al., 1999). But despite some progresses, such as the approval of the Iberian lynx conservation action plan (Governamnetal dispatch 12697/2008) after more than 10 years of compromises, carnivore conservation is clearly a mistreated issue, and there are probably no places in Portugal where long-term conservation is assured. Despite the general recognition that are significant "human dimensions" involved in the problem, little attention has been devoted to these factors (probably the only exception is the Iberian wolf). Ignoring key aspects can lead to inaccurate definitions of the problem, inadequate solutions, and continuing losses (Clark et al., 1994). The Iberian lynx virtual extinction in the country is one of the most remarkable examples of inaccurate surveys, bad science and even worst practices. During years the species presence in the south of Portugal was considered as stable (Palma et al., 1999), captive breeding was delayed and when a more consistent approach was carried the species was probably extinct (Sarmento et al., 2009).

It is clear that a more effective, contextual, and coherent approach to carnivore conservation is urgently needed. The Institute of Nature and Biodiversity Conservation (ICNB), the Portuguese institution responsible for Nature conservation, generally neglected carnivore conservation. In the last 15 years only a total of 20 studies in carnivore ecology were financed in 11 protected areas (only 9% of all financed studies) (Fig. 1). Four of them were general mammal inventories, and the remaining was focused on lynx, wildcat, otter (*Lutra lutra*) and wolf (Fig. 2). What is also a matter of concern is the fact that important Natural Parks such as Tejo Internacional, S. Mamede, and Serra de Aire e Candieiros don´t have financed, in the last 15 years, a single study on carnivore ecology. So, generally the level of knowledge on carnivores in Portuguese protected areas is rather low, and to improve the decision-making process is clear that a new scientific based approach is necessary. Clearly, theres has been no national coordinated, enduring system for monitoring Portugal´s terrestrial mammals, including carnivores.

STATUS OF CARNIVORE RESEARCH IN PORTUGAL

According to Clark et al. (2001), carnivore research should be focused in four basic steps:

- First, it is critical not only to advance the biological and ecological research on carnivores, but also to direct this research towards conservation needs;
- Second, social science research is also important, and such work would examine the social and decision processes at play in any given case. Specifically, this would involve detailing using sociological, anthropological, or political science methods the practices that support carnivore conservation;
- Third, an interdisciplinary approach that synthesizes reliable information is needed to systematically integrate biological and social knowledge into a unified conservation program;
- Fourth, applications of the interdisciplinary method, as well as more traditional conservation programs, should be systematically documented and studied for the propose of learning what has worked and what has not.

The learning approach described by Clark et al. (2001) is the only basis for adaptative management. Comparisons should be carried out at regular intervals at professional meetings. The lessons should be published and disseminated extensively. A constant replication of this approach – field work using interdisciplinary approaches, comparison of results, lesson finding, distribution of lessons, refining methods, and new field work – offers a way to learn continuously and to improve carnivore conservation (Clark et al., 1994).

The Portuguese situation regarding scientific research and conservation projects on carnivores is still in a very premature step. Therefore a specialized approach, in the sense of the Clark et al. (2001) definition, appears as a very distant milestone. Since 2000 only a total of 24 scientific papers have been publish on carnivore related topics in Portugal. Most studies were focused in feeding ecology, a well known topic for most species (Fig. 3).

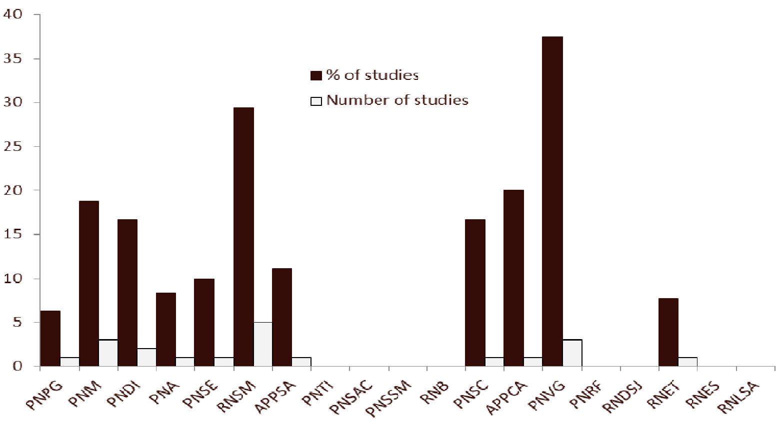


Fig. 1. Number and percentage of studies focusing carnivore ecology financed in Portuguese protected areas in last 15 years. PNPG – Gerês National Park, PNM – Montesinho Natural Park; PNDI – Douro Internacional Natural Park; PNA – Alvão Natural Park; PNSE – Serra da Estrela Natural Park; RNSM – Malcata Nature Reserve; APPSA – Serra do Açor protected area; PNTI – Tejo Internacional Natural Park; PNSAC – Serra de Aire e Candeeiros Natural Park; PNSM – Serra de S.Mamede Natural Park; RNB – Berlenga Nature Reserve; PNSC – Sintra-Cascais Natural Park; APPCA – Costa da Caparica protected area; PNVG – Vale do Guadiana Natural Park; PNRF – Ria Formosa Natural Park; RNDSJ – Dunas de S. Jacinto Nature Reserve; RNET – Estuário do Tejo Nature Reserve; RNES – Estuário do Sado Nature Reserve; RNLSA- Lagoa de Santo André Nature Reserve.

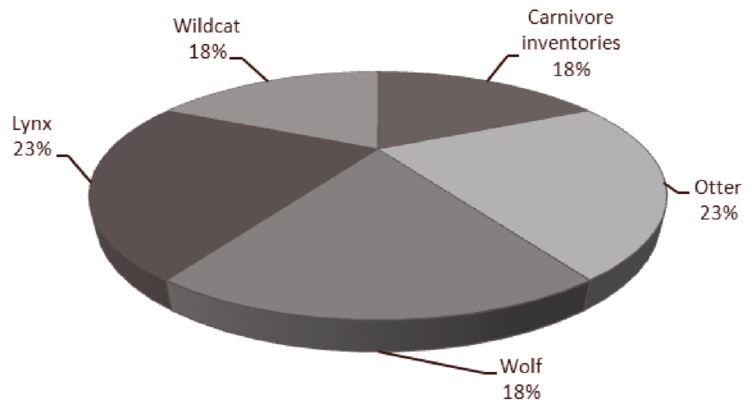


Fig. 2. Distribution of financed carnivore studies in protected areas according to species.(source www.icnb.pt)

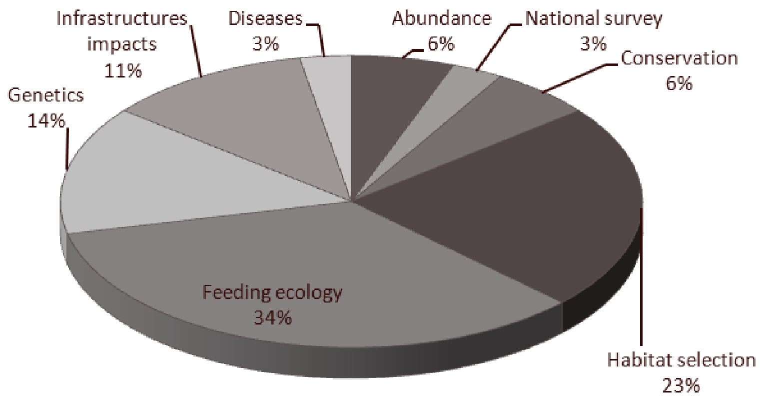


Fig. 3. Proportion per subject of published scientific papers on carnivore biology and ecology in Portugal, (2000-2009). Source Web of Science.

THE CONTEXT OF SERRA DA MALCATA NATURE RESERVE

Serra da Malcata is integrated in the Mediterranean basin, one of the four most radically changed hotspots on Earth (Myers et al., 2000), that has been exhaustively affected by human populations for centuries (Vallejo et al., 2005). As a result, only 4.7% of its primary vegetations remains, the agricultural lands, evergreen woodlands and maquis habitats that dominated the hotspot today are the result of anthropogenic disturbances over several millennia. Nevertheless, the assimilation of natural ecosystems and traditional human activities is one of the reasons for the high environmental diversity that differentiates the region (Preiss et al., 1997; Maiorano et al., 2006).

Serra da Malcata is referred as an important area for biodiversity, at least since the XIXth century (Travassos Lopes, 1899). For centuries this area has been settled by shepherds and farmers, which favored carnivores by firing and cutting the scrublands, and by ploughing the resulting open ground, because these altered habitats might have sustained denser rabbit, and at the same time enough forest was left in the landscape (Delibes et al., 2000). So, several small open patches were interspersed within the forest matrix creating a highly suitable landscape form most carnivores and birds of prey.

By the mid 1970s the first scientific assessment of the Iberian lynx population was performed, which concluded that a population composed by 30 adult individuals should inhabit the area (Palma, 1977). By the beginning of the 1980s Serra da Malcata Nature Reserve was created, as a result of a campaign conducted by the Portuguese League for Nature Conservation (LPN) for preventing the total destruction of the lynx habitat by a paper mill company. A large proportion of Serra da Malcata was already allocated to forestry, and the original habitats were extensively replaced with conifer and eucalyptus plantations for timber and wood pulp production. Rabbits and other preys such as small mammals are very scarce or absent within such plantations (Delibes-Mateos et al., 2008). Although these actions were fairly controlled in the centre and south areas of the Reserve, they continued in the north and outer areas as a consequence of a misconception, and incorrect application, of a European afforestation program, whose main aim was to take advantage of agriculture removal to improve environmental value and to increase biodiversity. This plan financed the conversion of old fields into forested areas. However, many scrubland patches, important for carnivores, were classified as improductive fields, then removed and replaced by a new plantation, often conifers (mainly pines) or other quickly growing species, which do not represent the best choice to recover the original Mediterranean forest (Vallejo et al. 2005).

In the beginning of the 1990s several studies on fauna and flora were started (Abreu 1991; Casto 1992; Gonçalves 1993), and continued through the following 15 years (e.g Sarmento et al. 2003). In fact, when the Management Plan for the protected area was concluded, in 2005, the Malcata Reserve was one of the protected areas with a highest level of knowledge on it´s natural heritage. This knowledge was greatly increased with the application of two major conservation projects, which aimed recovering habitats and preys for a future Iberian lynx reintroduction:

- The LIFE project “Recovery of habitat and preys for the Iberian lynx in Serra da Malcata” (1999-2003); and
- The FEDER project “Management of priority species and habitats in Serra da Malcata”(2004-2006).

Conservation actions consisted in creating artificial warrens for rabbits, implementation of pasturelands, rabbit restockings, forestation with autochthons species and cause-and-effect monitoring[1]. One of the indicators that were used to measure the project’s success was carnivore abundance and distribution, since most species should be positively affected by conservation measures (Sarmento et al., 2003). Another important reason for monitoring carnivores in Serra da Malcata, and other areas of the Iberian lynx historical range is the International Union for Conservation of Nature and Natural Resources (IUCN) guidelines for reintroduction (IUCN, 1998). These establish a checklist of activities for carnivore reintroduction programs, including a feasibility study (habitat and potential threats). The risk of disease transmission between wild

[1] Cause-and-effect monitoring investigates the mechanisms that underlie habitat and species response to management and other forms of disturbance (Holthausen et al., 2005).

species and reintroduced animals represents an topic of concern, and so for a appropriate conduction of future conservation actions is fundamental to fully comprehend carnivore abundance, distribution, and habitat use. Carnivore status is also important to evaluate the conservation conditions of priority habitats, such as Mediterranean woodlands, since several species are associated to this vegetation type and can be used as indicators of ecosystem fitness (Virgós et al., 2001; Virgós et al., 2002)

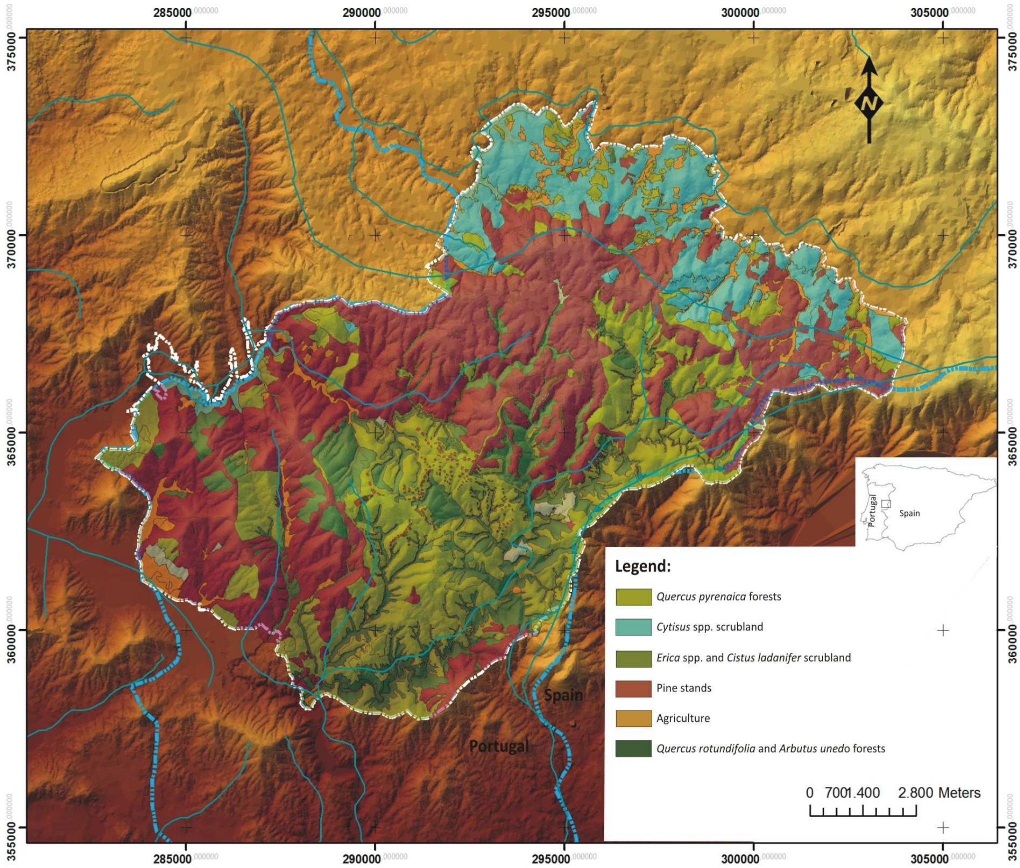


Fig. 4. Study area location and most important types of habitats.

THESIS OBJECTIVES

Considering the context pointed above, this thesis aimed to developed simple and efficient methods for monitoring carnivore populations, in a context of recurring management of protected areas. The specific objectives were:

- To access absolute abundance and distribution of foxes and genets in Serra da Malcata Nature Reserve using camera trapping;

- To evaluate the adequacy of this technique as a tool for subsequent surveys.
- To evaluate the evolution of the wildcat population (a priority conservation species in the Nature Reserve) since the 1990s;
- To determine carnivoran site occupancy and related environmental factors as a foundation for future long-term multispecies monitoring programs in wider areas.

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A black cat crossing your path signifies that the animal is going somewhere.
Groucho Marx

Chapter 2

SPACE AND HABITAT SELECTION BY FEMALE EUROPEAN WILD CATS (*FELIS SILVESTRIS SILVESTRIS*)

Sarmento, P., Cruz, J., Tarroso, P. & Fonseca, C. (2006). Space and habitat selection by female European wildcats (*Felis silvestris silvestris*). *Wildlife Biology in Practice* 2(2). 79-89

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 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.

Keywords: *Felis silvestris*; Habitat selection; Home range; *Quercus pyrenaica* forests; *Quercus rotundifolia* and *Arbutus unedo* forests; Space use.

INTRODUCTION

In Europe, the wildcat (*Felis silvestris silvestris*) presents a rather fragmented geographic distribution, ranging from the Iberian Peninsula to the eastern part of the continent (Stahl & Leger, 1992). Globally, this feline is included in Category 5C of the *Global Cat Species Vulnerability Rankings* (Nowell & Jackson, 1996) and it represents a Least Concern (LC) species according to the IUCN Red List (IUCN, 2006).

However, in Portugal the wildcat is a Vulnerable (V) species according to the Portuguese Red Data Book (Cabral et al., 2005). Furthermore, in some European countries the wildcat became extinct and in most cases, changes and trends in distribution are poorly documented (Stahl & Artois, 1991).

The major threats to the wildcat include habitat destruction and population fragmentation (Stahl & Artois, 1991; Biró et al., 2004), poaching (Stahl & Leger, 1992), vulnerability to pathologies (Artois & Remond, 1994; McOrist et al., 1991) and hybridization with domestic cats (Randi & Ragni, 1991; Oliveira et al., 2005. 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 (Palomares, 2001). 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 (Powell & Mitchel, 1998). The Serra da Malcata Nature Reserve (SMNR) is a mountainous area in the eastern centre of Portugal. This area presents a stable wildcat population (Sarmento & Cruz, 1998), which constitutes a priority in terms of conservation considering the above-mentioned status in agreement with the Portuguese Red Data Book (Cabral et al., 2005).

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 (Stahl et al., 1988; Ferreras et al., 1997). 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. 5) is a 200 Km2 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.

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 trapnights. 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 (Swihar & Slade, 1993).

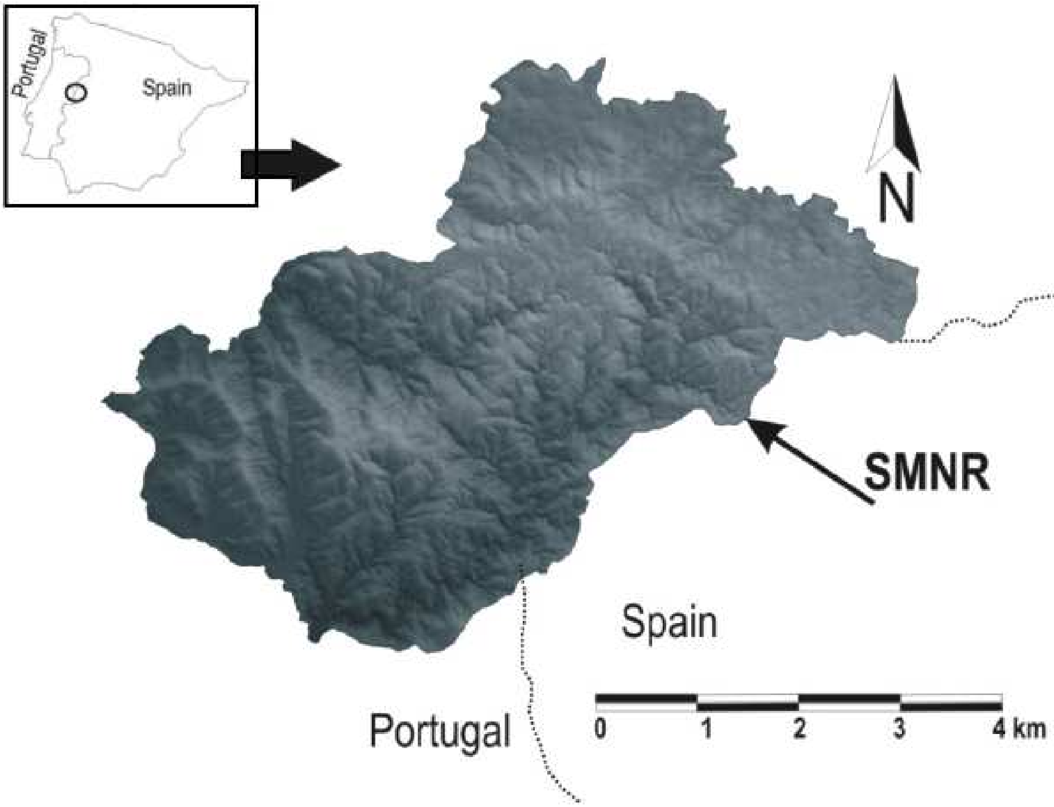

Fig. 5. Map of Serra da Malcata Nature Reserve in central-eastern Portugal.

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 2). In order to locate wildcats during all light and dark hours, an equal number of locations were 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 2).

The independent fixes were used to analyse home-range size and overlap (Kenward & Hodder, 1996). Home range size was estimated by the Kernel method (Worton, 1989) 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 (1945), 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 3). 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. 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).

		N.º of locations		
Season	**Sample sizes 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

Habitat selection analysis

We used an Euclidean distance-based approach to investigate seasonal habitat selection of wildcats (Conner & Plowman, 2001). We examined habitat selection at two spatial scales according to Johnson's (Johnson, 1980) 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 (Perkins &

Conner, 2004; Benson & Chamberlain, 2007). Distance from random points or wildcat 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 & Chamberlain (2007), 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 (Conner et al., 2003). 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.

TABLE 3. 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

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 (Conner & Plowman, 2001; Benson & Chamberlain, 2007). 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 km2 (fixed-kernel 95%), with an individual-weight average of 2.89 ± 1.01 km2 (mean; SE) (Table 3).

The lowest value was reported for spring 1999 (0.89 km2) 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 4).

TABLE 4. 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 km2 (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 5 and 6) 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.

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 6). 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 (Stahl et al., 1988). 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. (Stahl et al., 1988) (1.8±0.5 km^2; n=7; 0.67) and slightly larger than those obtained by Monterroso et al. (2005) for a Mediterranean ecosystem in Portugal (2.23 km2; 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. (1988) was conducted in continuous areas of broad-leaved forest, thus with higher quality habitat, and the report of Monterroso et al. (2005) 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 (Cruz, 2002), and constitute the major prey type for this species (Sarmento, 1996). With respect to shelter, these forests offer tree cavities located high above ground, which can be used as dens (Stahl & Artois, 1991). 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 (Stahl & Leger, 1992), 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 (Heptner & Sludskii, 1972). 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 (Klar, 2005).

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.

TABLE 5. Total area (km2) 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

Habitat type	km^2	%	2nd order Rank[a]	t [b]	P	3rd order 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

Habitat type rankings and results of univariate t–tests for second and third order habitat selection by female wildcats. [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 6. 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

Habitat type rankings and results of univariate t–tests for second and third order habitat selection by female wildcats. [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).

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* (Cruz, 2002). 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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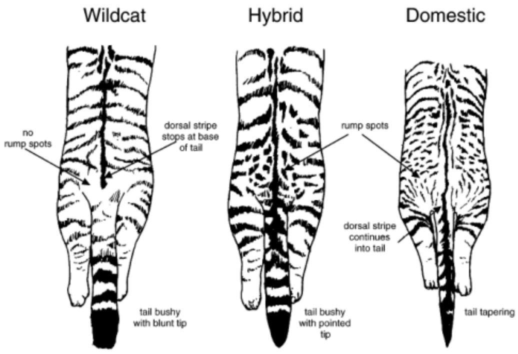
Adapt or perish, now as ever, is nature's inexorable imperative.

H. G. Wells



Kitchener et al. 2005

Chapter 3

Spatial colonization by feral domestic cats *Felis catus* of former wildcat *Felis silvestris silvestris* home ranges.

Sarmento, P., Cruz, J., Eira, C. & Fonseca, C. (2009). Colonization by feral domestic cats of former wildcat home-ranges. *Acta Theriologica* 54(1): 31-38.

ABSTRACT:

Presently, wildcat (*Felis silvestris silvestris*) populations are fragmented and rapidly declining in most of Europe. Although habitat destruction possibly constitutes the most serious threat to wildcat survival, hybridisation with feral domestic cats is also a critical problem. As genetic studies increase, the detection of hybrids is becoming more frequent, probably as a result of an earlier expansion of domestic cats into wild areas. However, the mechanisms that allow domestic cats to colonise former wild cat home ranges are yet unclear. The present paper describes the decrease of typical phenotypic wildcats and the increase of phenotypic domestic cats in a remote wild area of Portugal (Serra da Malcata). A field survey using box-traps and radio-tracking between 1998 and 2001 revealed that wildcats were widespread in the study area and no domestic cats were present. A second survey using camera traps between 2005 and 2007 revealed only one wildcat whereas four typical domestic phenotype individuals were photographed. The present study clearly emphasizes the need for urgent measures aimed at preserving wildcat populations. These measures should include a national census of the species and an extensive monitoring of genetic integrity of wildcat populations, followed by the elaboration of a wildcat conservation action plan.

Key words: competition, camera-trapping, action plan, regression

INTRODUCTION

Originally wildcat *Felis silvestris silvestris* Schreber 1777 populations were spread throughout Europe, except for Scandinavia and north-eastern Europe (Mitchell-Jones et al., 1999). With the exception of some areas in Central Europe (Klar et al., 2008), populations are presently fragmented and rapidly declining as a result of habitat destruction and fragmentation (Stahl & Artois, 1991), human persecution (Stahl & Leger, 1992), proliferation of viral diseases (Leutenegger et al., 1999) and hybridisation with domestic cats (Beaumont et al., 2001; Randi et al., 2001; Pierpaoli et al., 2003, Oliveira et al., 2007). Globally this felid is included in Category 5C of the *Global Cat Species Vulnerability Rankings* (Nowell & Jackson, 1996), representing a Least Concern (LC) species according to the IUCN Red List (IUCN, 2006). However, the Portuguese Red Data Book (Queiroz et al., 2006) lists the wildcat as a Vulnerable (VU) species. Generally, changes and trends in distribution of wildcat populations are poorly documented, particularly in the Mediterranean area (Stahl & Artois, 1991).

According to the Council of Europe (Stahl & Artois, 1991), the aims and priorities of the long-term, effective conservation and management of wildcats include: 1) regular monitoring of their population densities and distribution; 2) research on hybridisation and its effect; 3) studies on the loss and destruction of habitats and 4) evaluation of mortality due to illegal hunting and road kills.

Although habitat destruction may be the most important threat to wildcat survival, hybridisation with feral domestic cats is also a critical problem. Several genetic studies conducted in Europe indicate the introgression of domestic genes into wildcat populations, particularly in Hungary and Scotland (Beaumont et al., 2001; Daniels et al*.,* 2001, Pierpaoli et al., 2003). In Portugal a study on hybridisation was conducted using animals from several areas of the country (Oliveira et al., 2007). The study of genetic variation at 12 autosomal microsatellites of 34 wild and 64 domestic cats detected the presence of four hybrids (12% of the free-ranging individuals). These were distributed across all sampled areas (north, centre and south Portugal), suggesting that hybridisation is a major concern when dealing with wildcat conservation in Portugal. Even though this study failed to detect a constant and generalized gene flow between sympatric populations of wildcats and domestic cats, migration rates documented an effective negative impact on the wildcat's genetic composition caused by hybridisation.

Studies describing the process that allows domestic cats to occupy wildcat territories are lacking. In addition migration is probably favoured by a decrease in competition owing to a decline in wildcat numbers. In turn, this decline could be a direct result of habitat destruction and fragmentation, human-caused mortality and diseases.

In this paper, two surveys describe the decrease of typical phenotypic wildcats and the increase of phenotypic domestic cats in a remote wild area of Portugal, located in the Nature Reserve of Serra da Malcata.

STUDY AREA

Serra da Malcata (Figure 6) is a 200 km^2 mountainous area located in Portugal near the Spanish border between 40º08´50´´ - 40º19´40´´ N and 6º54´10´´ - 7º09´14´´ W. The climate is typical 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 *Quercus rotundifolia* and *Q. pyrenaica* woodlands constitute 15% of Serra da Malcata, whereas 30% of the area 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, originally constituted to help preserve the Iberian lynx *Lynx pardinus*, although recent surveys indicate its possible extinction in the area (Sarmento, unpubl. data). Inside the Nature Reserve human occupation is low and only three farms exist in its periphery. Outside the Reserve, in the northern area, there are four villages harbouring a total population of about 1000 people (Figure 6).

MATERIAL AND METHODS

THE 1998-2001 SURVEY

The wildcat population was assessed continuously from 1998 to 2001 by trapping and radio-tracking (Sarmento et al., 2006). From April 1998 to September 2001 60 home-made box-traps (1.8 x 0.7 x 0.70 m), baited with live pigeons inside protection cages, were placed in the field accounting for a total of 1560 trap-nights during 6 trapping sessions (Table 7). Traps were placed in a grid arrangement spaced 0.3 to 0.5 km apart on trails and trail intersections. Each trapping session lasted at least 15 days. A buffer area of half a wildcat's medium home-range diameter (600 m) (Sarmento *et al.* 2006) was calculated around the box-traps to represent the total surveyed area by that set of box-traps (Karanth & Nichols, 1998; Carbone et al., 2001) (Figure 6). The effectively sampled area comprises the minimum convex polygon (MCP) enclosed by the trap locations on the perimeter (57.38 km^2) and the above-mentioned buffer area adding up to 82.45 km^2 (Sarmento et al., 2006).

THE 2005-2007 SURVEY

From July 2005 to February 2007 the distribution of wild carnivores in Serra da Malcata was assessed using camera-trapping techniques (Jones & Raphael, 1993; Karanth & Nichols, 1998; Moruzzi et al., 2002; Jackson et al*.,* 2006; Kauffman et al., 2007). The use of camera traps to detect elusive mammals, such as carnivorans, has proved to be highly efficient (Cutler & Swann, 1999). The technique has the advantage of being cost-effective and providing positive species identification. Another advantage is the low disturbance in detecting cryptic animals with inconspicuous habits (Zielinsky et al., 1995). Four distinct camera devices were used: 1) CamTracker® analogue system; 2) DeerCam® analogue system; 3) Bushnell 1® digital camera; 4) GameSpy ® digital camera. Each camera was set at a 20 cm height (average) 2 to 4 metres away from the lure (Swann et al., 2004). The scent station consisted of a wooden stake with a piece of cork-tree (*Quercus suber*) bark attached at 40-50 cm above the ground. The lure (domestic cat urine) was sprayed on the bark and replaced every seven days.

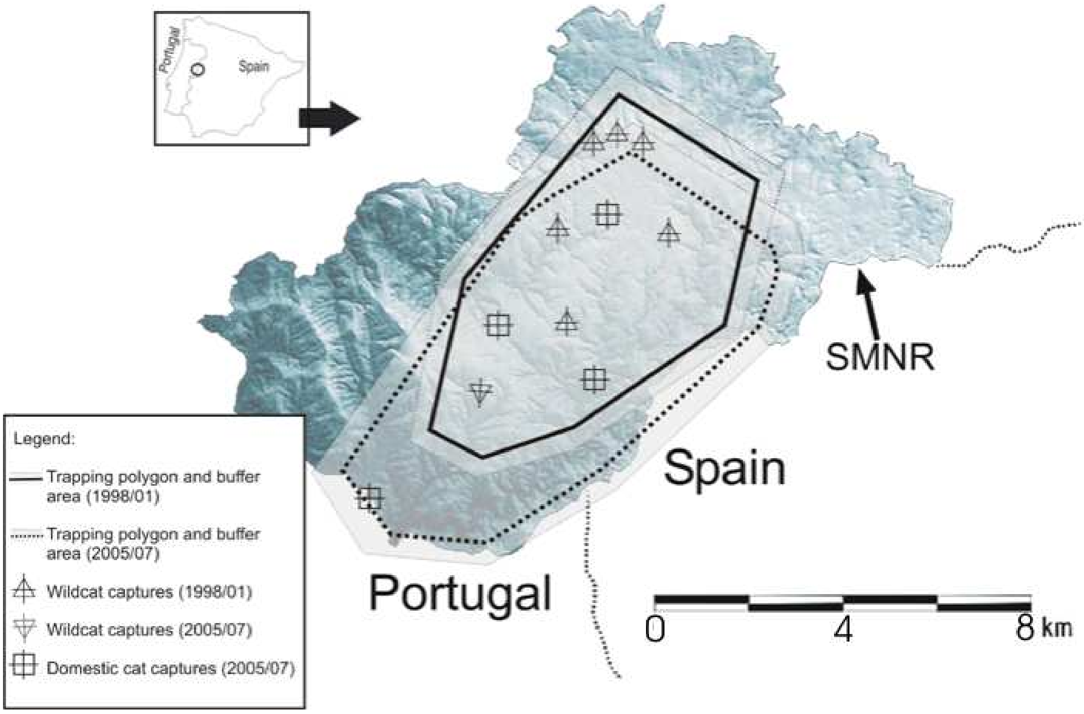


FIG. 6. Trapping polygon and buffer area and geographic locations of domestic cat and wildcat captures, during both field surveys (1998/2001 and 2005/2007) conducted in Serra da Malcata Nature Reserve (SMNR).

Cameras were placed in the field according to the same methodological process described for box-traps. Similarly the area sampled by camera-traps (Figure 6) was also calculated in the same manner. We conducted seven trapping sessions using 186 trapping stations, performing a total of 6127 camera-nights (Table 7).

Individual cats were identified according to their distinct pelage patterns. Quality, individual orientation and framing of each photograph were considered, in order to detect distinct markings useful for individual identification, based on the guidelines of Heilbrun et al. (2003) modified by Jackson et al. (2006).

TABLE 7. Trapping effort for wildcat surveys and results in Serra da Malcata Nature Reserve. n, number of captured individuals.

Methods		Stations	Sampled area	Trap-nights	Domestic cat			Wildcat		
					n	**Positive stations (%)**	**n/100 trap-nights**	**n**	**Positive stations (%)**	**n/100 trap-nights**
1998/2001	box-trapping	60	82.32 km^2	1560	0	0	-	8	13.33	0.51
2005/2007	camera-trapping	186	98.76 km^2	6127	4	3.22	0.065	1	1.61	0.02

STATISTICAL ANALYSIS

Geostatistical analysis was performed using X-tools and Geoprocessing extensions in ArcView 3.2. The area covered by wildcats was calculated using the Inverse Distance Weighted Interpolation (IDW) (Liszka, 1984; Kliskey et al., 2000) using wildcats capture locations. The IDW method is based on the assumption that the interpolating surface should be influenced most by nearby points and less by more distant points. Spatial interpolation provided grid surfaces across the study area representing wildcat abundance.

RESULTS

From 1998 to 2001 eight typical phenotypic wildcats (6 females and 2 males) were captured, representing a capture success of 0.51 individuals/100 trap-nights, which is equal to 1 capture per 195 trap-nights. These data correspond to a trapping rate of 0.13 males/100 trap-nights and 0.38 females/100 trap-nights (1 male capture for every 780 trap-nights and 1 female capture per 260 trap-nights). Four of these individuals were recaptured on six occasions. With respect to the trapping area, it was possible to estimate an average of 9.70 captures/100 km^2 (2.42 male captures/100 km^2 and 7.27 females/100 km^2). An area of 39.65 km^2 (IDW interpolation) was occupied by the wildcats (Figure 2). No domestic cats were captured during this period.

During the 2005-2007 survey nine domestic cat photographs were taken as a result of six events. These photographs identified four individuals, representing a capture success of 0.07 individuals/100 trap-nights, which is equivalent to one domestic-cat capture per 1021.17 trap-nights and 4.05 captures/100 km^2. These animals exhibited typical domestic phenotypes, being tabby and white (n=2), black (n=1) and tabby (n=1). Using the IDW interpolation we obtained an area of 17.23 km^2 (Figure 7), which included 5.34 km^2 (31%) overlapping former wildcat home ranges. Only one individual presented pelage characteristics compatible with that of a wildcat, corresponding to a capture success of 0.02 individuals/100 trap-nights (1 capture for every 6127 trap-nights). This animal was detected in three occasions (0.5% of all carnivore events) in only 1% of the total trapping stations (Table 7) corresponding to a total area of 6.19 km^2 (IDW method). These results thus emphasise a significant decline in wildcat numbers in Serra da Malcata (Figure 8) with an 85% decrease of the area previously inhabited by wildcats (Figure 7).

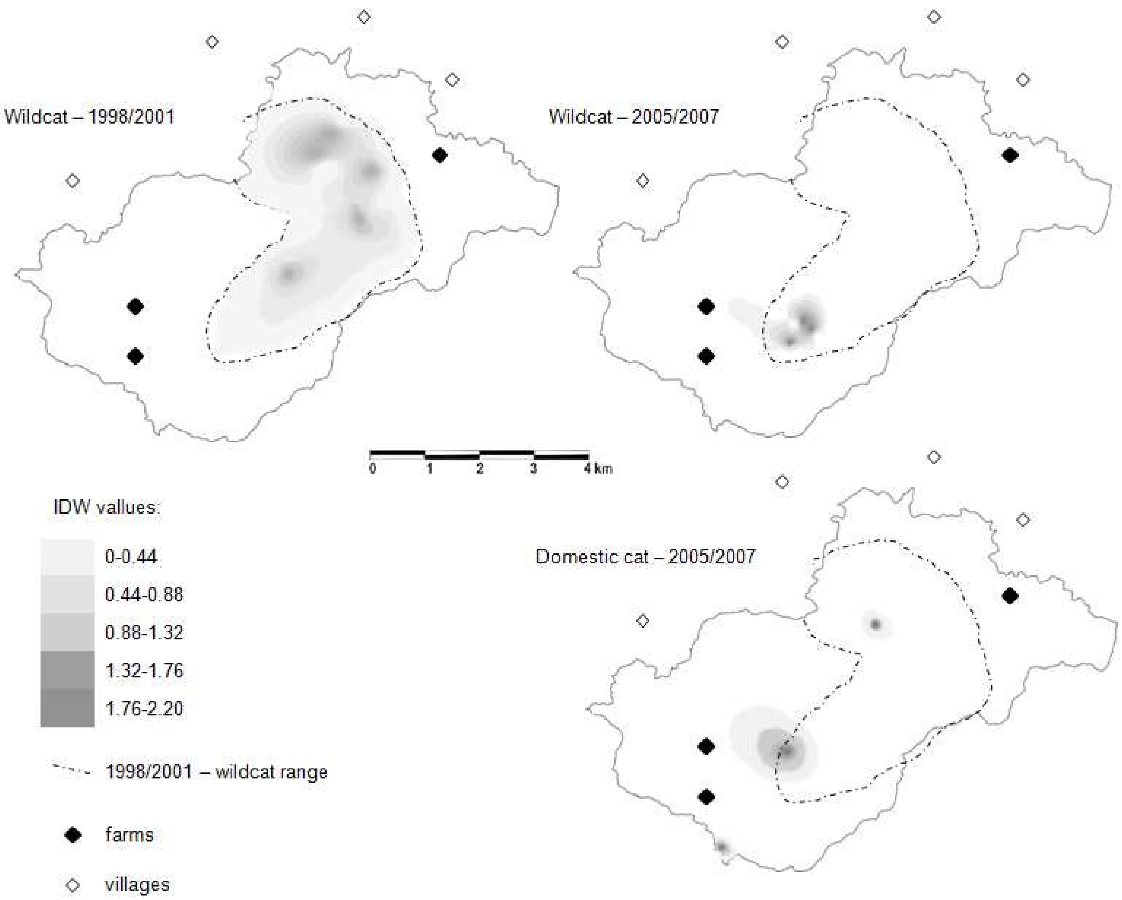


Fig. 7. Areas used by wild and domestic cats in the 1998/2001 and 2005/2007 surveys using the IDW interpolation (in 1998/2001 no domestic cats were detected).

DISCUSSION

Despite the different methods used during the 1998-2001 and 2005-2007 surveys, the data obtained show that the area was formerly used by wildcats and that feral domestic cats have replaced them in Serra da Malcata. A recent study, comparing several methods used to assess the presence of carnivores in large-scale study areas, demonstrated that camera-trapping and box-trapping detect wildcats with a similar probability (Bárea-Azcón et al., 2007). Therefore, had wildcat population density remained unchanged wildcats would have been recorded at similar levels in both study periods. Likewise, if domestic cats had been present during the 1998-2001, they would have been successfully trapped.

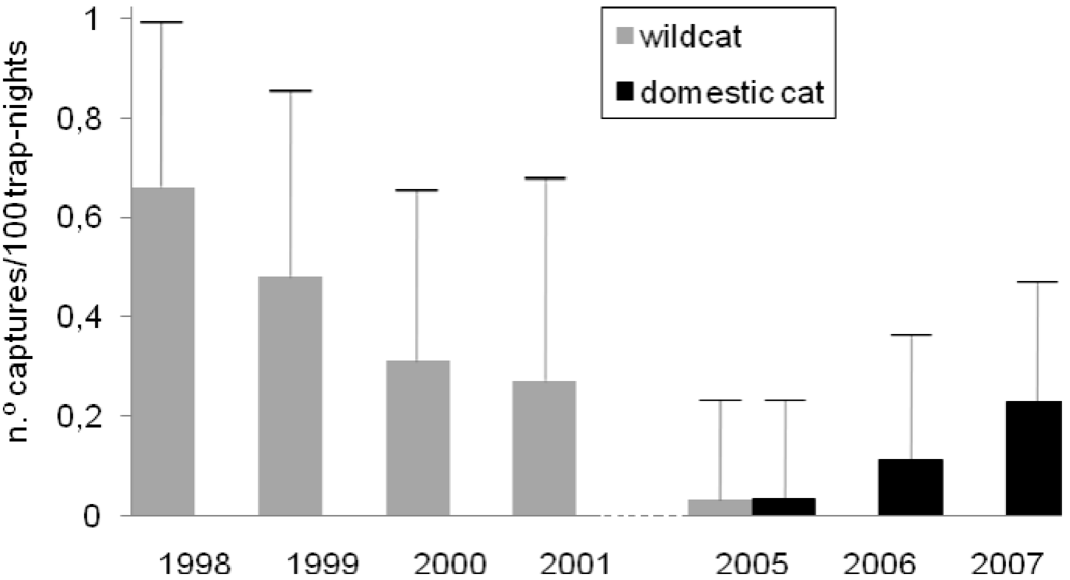


Fig. 8. Temporal changes of capture success per trapping unit (+ standard deviation) of wild and domestic cats in Serra da Malcata Nature Reserve from 1998/99 till 2005/07.

Over the last decade the highest wildcat population densities in the Mediterranean area of the Iberian Peninsula were recorded in the Guadiana Natural Park (Sarmento et al., 2004), followed by those in Serra da Malcata between 1998 and 2001 (present study). Furthermore, the 1998-2001 wildcat population density in Serra da Malcata was found to be similar to that observed in Toledo mountains (Spain: 0.48 individuals/100 trap-nights) that are known to present a suitable habitat for wildcats (Guzmán et al. 2002). Considering the similar wildcat population densities in both areas, Serra da Malcata constituted an important area for this felid during that period, both in terms of abundance and conservation. Thus, a dramatic decrease in wildcat population recorded in this study is puzzling.

A clear cause for the observed considerable decline of the wildcat population has not yet been established, even though the commonly described threats, particularly habitat destruction, human persecution and typical feline diseases are present in Serra da Malcata. Sarmento et al. (2006) concluded that wildcats selected Quercus pyrenaica forests and Quercus rotundifolia and Arbutus unedo forests and avoided Erica spp. and Cistus ladanifer scrubland and pine stands. The selected habitat types, which provided wildcats with shelter and food resources such as small mammals, have considerably declined since 2001, particularly in the northern range of Malcata. This decline was brought about by a EU-funded national forestry policy, which largely promoted the conversion of autochthonous forests and agriculture areas into pine stands. Inside the Nature Reserve a total area of 1797 hectares of pine stands were installed, which corresponds to a total loss of 20% of potential wildcat habitat. Simultaneously, human persecution could also be a serious problem. From 1995 to 2001, poachers shot two out of eight wildcats fitted with radio-collars (Sarmento et al., 2006).

Another critical threat could be the feline leukemia virus (FeLV) spread by domestic cats. A clinical analysis of 14 domestic cats inhabiting the peripheral areas of the Reserve indicated the presence of FeLV virus in 36% of the sample (Sarmento, unpubl. data), which is clearly an indicator of a potential threat to wildcats. According to Leutenegger et al. (1999) the increasing occurrence of domestic cats represents an actual threat to the wildcat considering the potential cross-transmission of viral infections such as those caused by the feline viral rhinotracheitis virus (feline herpesvirus, FHV), the feline panleucopaenia virus (feline parvovirus, FPV), the feline leukemia virus (FeLV) and the feline immunodeficiency virus (FIV).

The above-mentioned threat factors probably played a crucial role on the rapid reduction of the wildcat population, which led to decreased competition allowing domestic individuals to colonise former wildcat home-ranges. Several farms and villages located in the Nature Reserve borders represent continuous sources of domestic cats (Figure 2). These animals may become completely wild or semi-free ranging, continuing to use human settlements and conducting exploratory visits to the Nature Reserve. These cats may have a significant advantage over wild animals since supplementary feeding by humans does not reduce their hunting motivation and causes that their numbers are not influenced by changes in prey populations (Coleman et al., 1997). The severe impact of domestic cats on wildlife populations is well documented (Patronek, 1998; Crooks & Soulé, 1999; Molsher et al., 1999; Slater, 2002).

Our results are concordant with the general trend of wildcat declines across Europe, which is documented in Scotland (Kitchener et al., 2005), Hungary (Heltai et al., 2006), Russia (Puzachenko, 1993) and France (Stahl & Artois, 1991). In terms of conservation the European wildcat should be a crucial target for Portuguese governmental authorities, considering its status of Vulnerable species according to the Portuguese Red Data Book (Queiróz et al., 2005) and the substantial evidence of population decline over the last 10 years (Sarmento et al., 2006). In fact, the above-mentioned studies clearly emphasise the need for urgent measures for preserving wildcat populations. These measures should include a continuous and non-invasive national survey on the species, and an extensive monitoring of genetic integrity of wildcat populations using dead animals and hair snares (Oliveira et al., 2007).

The identification of priority population nuclei is fundamental for the elaboration of a wildcat conservation action plan using IUCN guidelines. This action plan should include wildcat priority areas (Heltai et al., 2006), where populations should be stabilised and increased by means of protective management. Management guidelines should focus on habitat protection and restoration, particularly scrublands dominated by *Quercus* spp. (Sarmento et al., 2006). It is noteworthy that the severely dry summers registered over the last three years have led authorities to use shrub removal as one of the major actions against forest fires thus forsaking the already reported importance of Mediterranean scrublands to the conservation of the wildcat (Lozano et al., 2003) and other wild carnivores (Mangas et al., 2008), including the endangered Iberian Lynx (Sarmento, unpubl. data). Specifically in the Serra da Malcata Nature Reserve it is necessary to follow the conservation guidelines established in the Official Management Plan (Ministries Council Resolution n. 80/2005, 2005), which emphasises the reforestation with autochthonous tree species of most of the presently unsuitable areas, particularly those submitted to forest fires or covered by pine stands. It is also necessary to resume the application of conservation measures for wild rabbit restoration (interrupted in 2006), which consisted in the creation of grazing areas, construction of artificial warrens and rabbit restocking. These conservation measures are fundamental to the future reintroduction of the Iberian lynx and simultaneously, they provide wildcats with extremely adequate conditions (Sarmento et al., 2006). Although food support for wildcats in this area is primarily constituted by small mammals in spring and summer, rabbits could have a crucial role in their diet (Sarmento, 1996) and so, the increase of this prey population could favour wildcat recovery. Furthermore apart from habitat protection and restoration, other important management guidelines should focus on domestic cat eradication inside the protected area, prey enhancement and active protective measures against human-induced mortality. Priority research should focus on genetic introgression, habitat suitability and diseases. As a fallback position captive breeding and population reinforcement should also be considered, particularly in those areas where future actions will accomplish a significant decrease or elimination of threats to the wildcat population.

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A fox is a wolf who sends flowers.
Ruth Brown

Chapter 4

Evaluation of Camera Trapping for Estimating Red Fox Abundance

Sarmento, P., Cruz, J., Eira, C. & Fonseca, C. (2009). Evaluation of camera trapping for estimating red fox abundance. *Journal of Wildlife Management* 73(7): 1207-1212.

ABSTRACT

The nature reserve Serra da Malcata, Portugal, was recently considered a site for Iberian lynx (*Lynx pardinus*) reintroduction. Because of potential disease risk posed by red foxes (*Vulpes vulpes*) in the area, a reliable estimate of fox abundance was critical for a dependable reintroduction program. We adapted camera-trapping techniques for estimating red fox abundance in the reserve. From July 2005 to August 2007, we conducted 7 camera-trapping sessions, allowing for individual identification of foxes by physical characteristics. We estimated abundance using the heterogeneity (M_h) model of the software program CAPTURE. Estimated density ranged from 0.91 6 0.12 foxes/km2 to 0.74 6 0.02 foxes/ km2. By estimating red fox density, it is possible to define the number of foxes that must be sampled to assess the presence of potential fox transmitted diseases that may affect lynx reintroduction.

KEY WORDS camera trap, capture–mark–recapture, density estimate, Program CAPTURE, red fox, *Vulpes vulpes*.

INTRODUCTION

Serra da Malcata, a nature reserve located in central-eastern Portugal, is a potential site for Iberian lynx (*Lynx pardinus*) reintroduction (International Union for Conservation of Nature and Natural Resources [IUCN] 2005). The IUCN (1998) guidelines establish a checklist of activities for carnivore reintroduction programs, including a feasibility study (habitat and potential threats). The risk of disease transmission between wild species and reintroduced animals represents an issue of concern.

Red foxes (*Vulpes vulpes*) could have negative effects on the success of Iberian lynx reintroduction. The red fox is one of the most abundant wild carnivores in Europe, with high densities across the Iberian Peninsula (Lloyd, 1980). The potential role of the red fox in the etiology and dissemination of diseases, such as rabies (Chautan et al., 2000), mange (Baker et al., 2000), and bovine tuberculosis (Martín-Atance et al., 2005), led to implementation of predator-control campaigns aimed at reducing fox abundance, particularly in France and Germany (Baker et al., 2001; Macdonald & Baker, 2004). Therefore, a reliable estimate of fox abundance was important for any subsequent disease risk analysis. The most commonly used methods for estimating fox densities include scent stations (Travaini et al., 1996), capture–mark– recapture (Montgomery 1987), and night counts, tracks, and scat counts (Webbon et al., 2004), although these methodologies have been questioned considering the biased results from several studies (e.g., Mortelliti & Boitani, 2008). Recently, remote photography methods have been used to study canid populations (Larrucea et al., 2007; Trolle et al., 2007). Remote photography has been demonstrated as particularly useful for species that are individually identifiable and, along with appropriate mark–recapture experimental design and analysis, allows for population density estimates, while providing information on ranging behavior, activity patterns, and patterns of dispersal and migration (Karanth & Nichols, 1998).

We used camera-trapping techniques to estimate red fox abundance and density in a potential Iberian lynx reintroduction area. Assessing the status of the red fox population will produce baseline information, which was needed for the establishment of sampling protocols in future disease surveys. Our objectives were to 1) access abundance and distribution of foxes in Serra da Malcata Nature Reserve using camera trapping, and 2) evaluate the adequacy of this technique as a tool for subsequent surveys.

STUDY AREA

The 200-km^2 Serra da Malcata (Fig. 9) was located in Portugal near the Spanish border (40º08´95´´N–40º19´94´´N, 6º54´91´´W–7º09´91´´W). The climate was Mediterranean, characterized by cold, wet winters and warm, dry summers. Vegetation was dominated by dense scrub of brooms (*Cytisus* spp.), halimiums (*Halimium* spp.), cistus (*Cistus* spp.), heaths (*Erica* spp.), carquesia (*Chamaespartium tridentatum*), and strawberry trees (*Arbutus unedo*), covering 43% of the area. Scattered woodlands of holm oaks (*Quercus rotundifolia*) and Pyrenean oaks trees (*Quercus pyrenaica*) constituted 15%of the area. The area was 30% covered by industrial plantations of *Pinus* spp., eucalyptus (*Eucalyptus globulus*), and Douglas firs (*Pseudotsuga menziesii*), and 12% was cropland. Approximately 60% was protected in the Serra da Malcata Nature Reserve.

METHODS

From July 2005 to August 2007, we studied distribution of red fox using camera-trapping techniques (Jones & Raphael, 1993; Karanth & Nichols, 1998, Moruzzi et al., 2002; Jackson et al., 2005). We used 4 camera types: 1) CamTrakker® (CamTrak South, Watkinsville, GA) analog system (n 5 14); 2) DeerCam® (Non Typical, Inc., Park Falls, WI) analog system; 3) Bushnell 1® (Bushnell Outdoor Products, Overland Park, KS) digital camera; and 4) GameSpy® (EBSCO Industries, Inc., EastBirmingham, AL) digital camera. We placed cameras approximately 20 cm aboveground and 2–4 m from the lure, domestic cat urine sprayed on a piece of cork tree (*Quercus suber*) bark, attached to a wooden stake at a 40–50-cm height (Swann et al., 2004), and dog dry food. We programmed cameras to take a photograph every 30 seconds. We arranged cameras so that lateral views of foxes were photographed, thus detecting most diagnostic features. We used time stamps in our photos to record the time and day the photo was taken.

Our assumptions were 1) the population was closed, and 2) all animals inhabiting the study area had equal probability of being detected. We achieved the first premise with a 7-day trapping period and the second premise by arranging cameras in a trapping grid. Distance between cameras should be, at most, the diameter of the smallest home range described for the species. Thus, we placed cameras every 300–500 m, according to Cruz & Sarmento (1998). We calculated a buffer area of half a fox's medium home-range diameter (600 m; Cruz & Sarmento, 1998) around cameras to represent the total surveyed area by that set of box traps (Karanth & Nichols, 1998; Carbone et al., 2001; Fig. 1). The effectively sampled area comprised the minimum convex polygon enclosed by the camera locations on the perimeter plus the above-mentioned buffer area (Cruz & Sarmento, 1998).

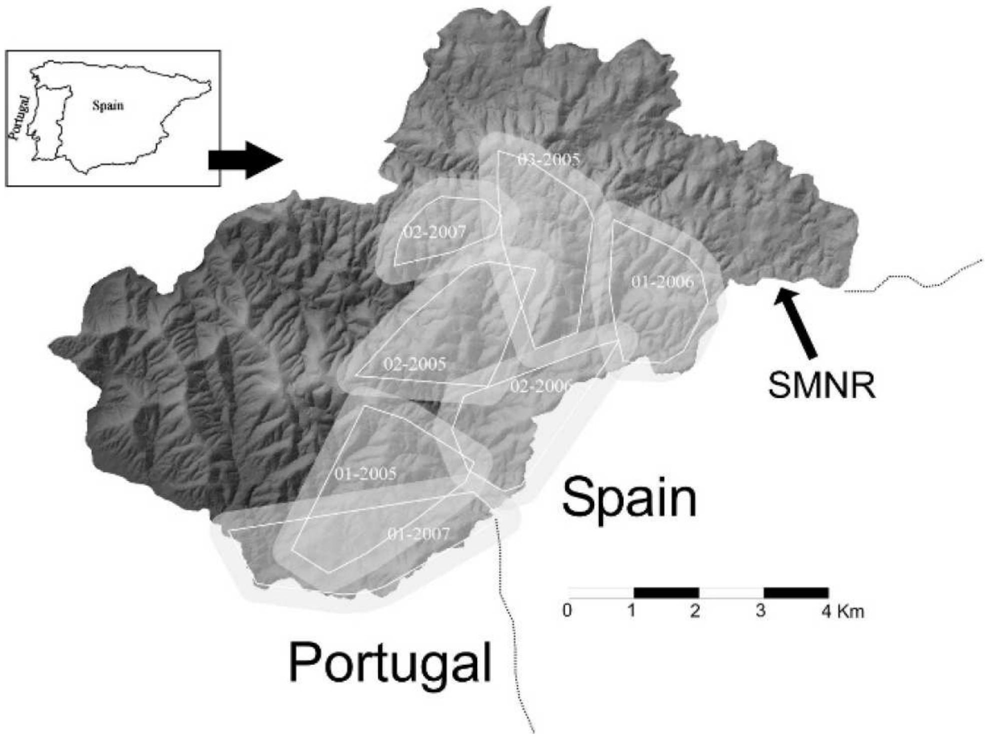

Fig. 9. Study area location, trapping polygons, and buffer areas for 7 camera-trapping campaigns conducted in Serra da Malcata Nature Reserve (SMNR; Portugal) for estimating red fox density, 2005–2007.

To cover the study area, we divided the study into 7 trapping sessions during spring, summer, and autumn, with an average duration of 38 days (Table 8; Fig. 9). Some trapping areas overlapped between sessions (Fig. 9), which might have allowed a single animal to be detected in one area. However, we considered multiple detections irrelevant because we based density estimates on individually identified foxes. We defined a capture as detection of an individually identified fox in a 24-hour interval in one trapping station regardless of the number of photos taken. For example, a fox visits a station on one occasion, where it is photographed 10 times during 7 minutes; this corresponds to one capture.

TABLE 8. Camera trapping periods and efforts during 7 trapping campaigns in Serra da Malcata Nature Reserve, Portugal, 2005-2007. [a] – total number of photographs taken during campaigns; [b] the detection of an individually identified fox in a 24-hour interval in a single trapping station; [c] individually identified foxes.

Campaign	Sampling period	Trapping area (MPC) (km^2)	Trapping polygon and buffer area (km^2)	Trap stations	Camera-nights	Photos[a]	Captures[b]	Individuals[c]
01-2005	06 Jun-16 Aug 2005	8.92	16.09	30	1030	44	20	7
02-2005	06 Sep-11 Oct 2005	8.61	15.37	30	850	47	28	8
03-2005	20 Oct-06 Dec 2005	8.90	16.08	29	1163	155	70	12
01-2006	16 Jun-20 Jul 2006	7.02	13.03	30	950	71	34	7
02-2006	08 Sep-20 Oct 2006	8.02	15.11	22	824	71	26	7
01-2007	14 May-16 Jun 2007	11.33	20.18	23	728	94	35	7
02-2007	26 Jun-27 Jul 2007	3.17	7.65	22	582	100	27	6
Total				**186**	**6127**	**582**	**240**	
Average ±SE				26.57 ±3.70	875.29±178.6			

Individual Identification

We based individual identification of foxes on several physical characteristics (Table 9; Fig. 10). The most important features for identification were the skin patterns on the lower limbs, the body morphology, and the tail. Fox pelage tends to vary in the lower limbs, presenting light spots alternating with dark regions (Fig. 10). We based body morphology on estimated size and weight. From 1994 to 2001, we captured 125 foxes, which we measured, weighed, and photographed from different angles. These procedures allowed us to register several characteristics that helped in the photographic analyses. Adult foxes presented 3 morphologic types: small (Fig. 10K, L), medium (Fig. 2A, B, F–H), and large individuals (Fig. 10D, E). These 3 types, in combination with other characteristics, produced a general individual appearance (Table 2). Another important aspect was to obtain photographs of both flanks of the animal. Although we did not use 2 opposing cameras at each station, fox behavior allowed us to obtain several photographs of the same fox from various positions (Fig. 10). We examined each photograph for subject orientation, resolution, and framing to detect unique markings useful for identification. The identification process included the following items (adapted from Jackson et al. 2006): 1) initial capture: a photograph that we could not positively match with a previously photographed fox; 2) recapture: a photograph that we could positively match to a previously identified animal; 3) null capture: a photograph that we could not identify as an initial capture or recapture; 4) primary features: the most distinctive features (body areas) and, therefore, the most useful for identification, for each photograph; 5) secondary features: all useful marks other than primary features; and 6) initial capture or recapture determination: positive identification by comparison of the primary feature in each photograph and L2 secondary features. We estimated red fox abundance using Program CAPTURE (Rexstad and Burnham 1991), following Otis et al. (1978), White et al. (1982), and Karanth & Nichols (1998). This program tested 7 models, which differed in sources of variation assumed in capture probability. The null model (M_0), which is the simplest, assumes no variation between individuals or over time. More complex models include 1) the heterogeneity model (Mh), 2) the timevariation model (M_t), and 3) the behavior model (M_b), plus 3 combinations of these models (time and behavior; heterogeneity and behavior; time, behavior, and heterogeneity).

Fig. 10. Individual identification of red foxes in Serra da Malcata (Portugal), 2005–2007. (A and B) A medium fox captured in 2 sites and occasions (arrow indicates the lure station). (C) We used spot patterns in the left foreleg for individual identification. (D and E) A large-sized fox (note the large head in proportion to the body) photographed from both flanks in the same occasion. Circles indicate a distinctive pattern in the left foreleg. (F–H) A medium fox photographed in 3 sites and occasions. (I) We used patterns of the right hind leg as primary features for identification. We used morphological type and the tail (arrows) as secondary features. (K and L) A small fox photographed in 2 occasions exhibiting a characteristic right foreleg pattern (J). All photographs correspond to the same trapping campaign to avoid seasonal pelage variations.

The program identified the best-fitting model, then generated capture statistics for all adequately fitted models, along with a statistic for evaluating likelihood of population closure. Within 7 days, we generated a sufficient number of captures, thus maximizing the number of sampling occasions without violating population closure assumptions.

TABLE 9. Physical characteristics used for individual identifications of red foxes in 7 camera-trapping campaigns conducted in Serra da Malcata Nature Reserve, Portugal, 2005-2007.

Characteristics		
Morphologic type	Small	Adults of juvenile appearance, usually < 4 Kg. Thin neck and slender legs
	Medium	Elegant fox, usually < 7 Kg, with a medium sized head
	Large	Compact fox, usually > 7 Kg. Well developed shoulders. Broad head, with well-developed cheeks
Tail	Thin	
	Large	
	Markedly white tip	
	No white tip	
Foot	Presence of distinct spots	
Forearm	Presence of distinct spots	

RESULTS

From 2005 to 2007, we made 3.96 captures/100 trap-nights (1 fox capture/28.8 trap-nights; Table 8). Average time until first capture was 3.3 6 2.07 (SE) nights. We photographed foxes at 56% of trapping stations (*n*=5; 104 stations). On average, we obtained 1.3 ± 0.21 (SE) captures per trap (min. = 0; max. = 8). Falsely triggered images constituted 34% of all images and were mostly because of rain, wind, and extreme heat. We obtained 582 photographs useful for identification (Table 8), and we could not use 135 of them because quality of the photograph was low and orientation did not allow identification. Of 240 captures, we were unable to individually identify 26 animals (10% of the sample). We obtained an average of 2.4 photographs (SE = 0.65; min. 5 1, max. 5 11) for each capture event and an average of 10.6 photographs (SE = 7.28; min. = 2, max. = 28) for each individually identified fox. Other captured species included badgers (*Meles meles*), wildcats (*Felis silvestris*), stone martens (*Martes foina*), genets

(*Genetta genetta*), mongooses (*Herpestes ichneumon*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and boars (*Sus scrofa*).

We observed the torso and tail in 75% and 76% of the photographs, respectively. In 49% of photos, L3 limbs were visible, and we obtained front views of foxes' faces in 39% of cases. In 43% of captures (n = 103), we obtained photographs of the left and right flanks, which allowed relating physical characteristics with other photographs from distinct captures. Left and right flank photographs were available for 98% of identified individuals, which, combined with other physical characteristics, allowed us to identify the foxes. Lower limbs (Fig. 10B, D, E, I, J) and tip of the tail (Fig. 10F, G) were the most reliable body parts for individual identification.

The M_0 and the M_h were considered the best-fitting models for all trapping campaigns using the 7-day sampling period (Table 10). Although the M_0 model obtained higher ranks, we selected the Mh model because capture probabilities should vary between individuals (Table 10). The CAPTURE test for closure supported the assumption of population closure (i.e., no emigration, immigration, birth, or deaths) during all 7 campaigns, as did the most robust test of Stanley and Burnham (1999; Table 10).

We sampled an area of 98.15 km^2, corresponding to juxtaposition of all trapping areas and respective buffer areas. We recorded capture probabilities that ranged from 0.433 to 0.712 for the 7 trapping campaigns (Table 10). Using the M_h model, population estimates ranged from 6 to 12 individuals, considering areas separately (Table 9).

Estimated density ranged from 0.40 ± 0.02 foxes/km^2 to 0.91 ± 0.12 foxes/km^2 (±SE). We observed differences in fox density (analysis of variance [ANOVA] $F_{6,179}$ = 4.10; P = 0.043) and fox detection (ANOVA $F_{6,179}$ = 3.52; P = 0.003) across sampling areas but no differences between seasons (ANOVA $F_{2,179}$ = 5.82; P = 0.072). We obtained an average density of 0.61 foxes/km^2 (95% CI = 0.54–0.69 foxes/km^2) in the Serra da Malcata, which corresponds to a population of 53–67 foxes (excluding cubs), assuming a stable density during the 2005 to 2007 period. Using the same criteria, M0 model estimated a lower fox density (0.56/km^2, 95% CI = 0.49–0.63 foxes/km^2), corresponding to an adult population of 48–62 individuals.

DISCUSSION

Our density estimates (0.54–0.69 foxes/km2; average 5 0.61 foxes/km^2) were lower than estimates obtained in areas of maximum density in Europe (3.30 foxes/km^2; Lloyd, 1980). However, average fox abundance in Serra da Malcata agreed with values obtained in some English rural areas (0.64 foxes/km^2; Heydon et al., 2000) and in a sand dune region in Portugal (0.63 foxes/km2; Eira, 2003).

We successfully identified foxes by their physical characteristics; however, photo orientation proved to be the most variable factor. The most useful photos for individual identification were those showing animals with one entirely visible flank, complete tail, and lower limbs. To obtain good quality photos showing morphologic features that can be used for individual identification, the bait should be surrounded with rocks or vegetation thus forcing the animal to approach laterally. It is also important to remove from the ground any objects that may affect visibility of lower limbs.

The closed capture–recapture M_0 model was the best fitting model to the capture-history data, followed by the M_h model. Small sample size could be the primary reason for our inability to select a more sophisticated model. Results obtained using the Mh model indicated the presence of more individuals than that obtained with the M_0 model.

This disparity may be explained by different responses and sensitivity of individuals to captures. In fact, different fox behaviors toward cameras ranged from animals that we photographed only 1–2 times per visit to animals that lingered in the area. These differences in fox behavior indicate evidence for using the M_h model. Because of the lack of statistical differences in density values between seasons and to the density estimate obtained by CAPTURE, we conclude that the trapping period, number of cameras, and distance between cameras were suitable for our study purpose. Furthermore, the cumulative capture curves indicate that 35 days are sufficient for an adequate recapture number. These results emphasize that camera trapping is a viable tool for estimating red fox population size if a sufficient number of cameras are used, the distance between the cameras correlates with the spatial ecology of the species, and the length of the trapping period allows for a sufficient number of recaptures.

MANAGEMENT IMPLICATIONS

Camera trapping was a reliable method for assessing average fox density over large spatial scales and could be useful for monitoring changes in fox numbers in other areas. Determining red fox density could be useful for estimating the minimum sample size necessary to assess prevalence of diseases (Thrusfield, 2005) that could adversely affect lynx reintroduction. Ultimately, the use of camera-trap surveys along with adequate statistical models can produce valuable information on several important population characteristics, which are the basis for developing population models and for prognosis about population status.

TABLE 10. Results of population closure, estimated abundance, standard error, and capture probabilities of red foxes samples in Serra da Malcata Nature Reserve, Portugal, 2005-2007.

	Test for closure				**Model selection**				**Population density**				
	CAPTURE		**Stanley and Burnham (1999)**		**Rankings**				**Null model (M_o)**		**Heterogeneity model (M_h)**		
Campaign	*Z*	*P*	χ^2	*P*	M_o	M_h	M_b	M_t	**Capture probability**	**Abundance (SE) 95% CI**	**Capture probability**	**Abundance (SE) 95% CI**	**Estimated density (foxes/km^2)**
01-2005	1.494	0.06	1.455	0.956	1.00	0.92	0.53	0.13	0.582	7 ±1.78 (7-9)	0.433	7 ±2.58 (7-10)	0.53
02-2005	1.477	0.030	1.455	0.956	1.00	0.97	0.43	0.10	0.582	8 ±2.33 (8-10)	0.4121	8 ±2.77 (8-11)	0.62
03-2005	1.510	0.030	1.455	0.956	1.00	0.96	0.41	0.19	0.582	12 ±2.33 (8-10)	0.4121	12±0.31 (12-12)	0.75
01-2006	1.334	0.040	1.671	0.987	1.00	0.93	0.56	0.21	0.782	7 ±2.01 (7-9)	0.643	7 ±2.35 (7-9)	0.61
02-2006	1.141	0.040	1.772	0.985	1.00	0.91	0.56	0.17	0.799	7 ±1.41 (7-8)	0.785	7 ±1.35 (7-9)	0.53
01-2007	1.345	0.040	1.722	0.957	1.00	0.92	0.46	0.18	0.712	7 ±1.51 (7-9)	0.712	7 ±1.75 (7-9)	0.40
02-2007	1.375	0.040	1.712	0.977	1.00	0.94	0.56	0.19	0.712	6±1.50 (6-8)	0.712	6 ±1.76 (6-8)	0.91

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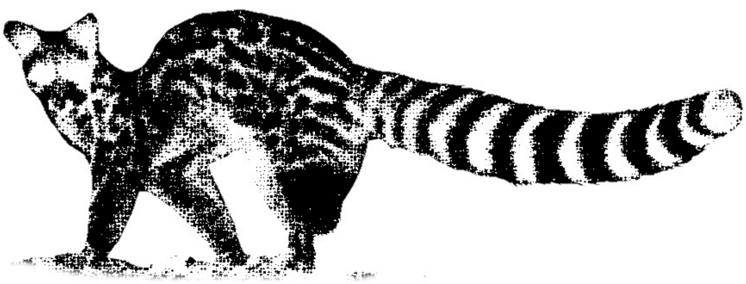
A person with a new idea is a crank until the idea succeeds.
Mark Twain



Chapter 6

Habitat selection and abundance of common genets *Genetta genetta* using camera capture-mark-recapture data

Sarmento, P., Cruz, J., Eira, C. & Fonseca, C. (2010). Habitat selection and abundance of common genets *Genetta genetta* using camera capture-mark-recapture data. *European Journal of Wildlife Research* 73(7): 1207-1212.

ABSTRACT

Using camera-trapping techniques, the present study, conducted from 2005 to 2007, provides common genet abundance estimates in Serra da Malcata Nature Reserve (central-eastern Portugal). We estimated genet abundance using the software CAPTURE. It was possible to obtain a capture success of 1.49 captures/100 trap-nights. Considering the heterogeneity model (M_h), which presents higher biological significance, the estimated density varied between 0.50 (95% CI = 0.43–0.56 genets/km2) to 0.92 (95% CI = 0.87–0.97 genets/km2) genets/km2 with an average density value of 0.70 genets/km2 (95% CI = 0.58–0.82 genets/km2). These estimates emphasized this technique as a reliable method for assessing average genet density over large spatial scales and for monitoring future changes in genet numbers. In terms of habitat selection, genets selected *Quercus rotundifolia* and *Arbutus unedo* woodlands and avoided *Erica* spp. and *Cistus ladanifer* scrubland and Eucalyptus stands. Considering the landscape heterogeneity outside the reserve, our study emphasizes the importance of the protected area for small carnivore conservation.

Keywords: Camera trap . Capture-mark-recapture . Common genet . Density estimate . Genetta genetta .Program CAPTURE

INTRODUCTION

Studies of distribution and habitat selection patterns of freeranging species are critical for identifying areas and resources that influence the fitness of individuals and the viability of populations. Across their European geographic range, space use and habitat selection by common genets *Genetta genetta* have been extensively studied (Palomares & Delibes, 1994; Virgós & Casanovas, 1997; Virgós et al.,2001; Munuera & Llobet, 2004; Galantinho & Mira, 2009). However, there is a lack of published information regarding density and habitat relationships in Portugal, particularly with respect to central mountain areas. Although common genets are not threatened, being considered a rather common species in Mediterranean ecosystems, this species can act as an indicator of forest systems fitness (Virgós et al., 2001; Galantinho & Mira, 2009). In the south of Portugal, the occurrence of genets is positively related to the density of trees and shrubs in the dominant agro-silvo-pastoral system (montado), to soil organic matter, and to Shannon's index of vertical vegetation diversity and negatively related with the proportion of game-estate areas (Galantinho & Mira, 2009).

Across the Mediterranean basin, human dependence on wood throughout history for domestic firewood, ship and house building, charcoal, furniture, etc., was at the base of the systematic destruction of forests during the last thousand years (Torre, 1999). Furthermore, land clearance been responsible for forest destruction. Serra da Malcata, a nature reserve located in central-eastern Portugal, plays an especially important role as a refugium of both plant and animal species. As in other areas of the Mediterranean basin, during centuries, this area suffered uninterrupted forest clearing, burning, hunting and, finally, the intensive plantation of Pinus, Eucalyptus, and other exotic tree species.

However, once the area was defined as a nature reserve in 1980, the beginning of the recovery of Mediterranean forests was noted, as a consequence of the abandonment of traditional forest uses. This landscape evolution probably favors typical Mediterranean forest animals such as genets. Therefore, the density of this species and its association to certain habitats could be an adequate indicator of ecosystem fitness and vegetation evolution.

Recently, remote photography methods have been used to address a variety of questions in carnivore population studies (Larrucea et al., 2007; Trolle et al., 2007; Sarmento et al., 2009) including genet abundance estimates (Plá et al., 2001). This technology has been demonstrated as particularly useful for species that are individually identifiable. When used with appropriate mark-recapture experimental design and analysis, remote photography allows for relative abundance and population density estimates, while providing information on ranging behavior, activity patterns, and dispersal/migration (Karanth & Nichols, 1998).

Using camera-trapping techniques, the present study provides abundance estimates and habitat selection of common genets in a nature reserve with low human influence.

STUDY AREA

Serra da Malcata (Fig. 11) is a 200-km^2 mountainous area located in Portugal near the Spanish border (40°08′50″N– 40°19′40″N and 6°54′10″W–7°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 of the area is covered by abandoned industrial plantations of *Pinus* spp., *Eucalyptus globulus*, and *Pseudotsuga menziesii*, and the remaining 12% is cropland. Approximately 60% of Serra da Malcata is a protected area included in Serra da Malcata Nature Reserve. No human settlements exist inside of the protected area, and in most of the area, no human activities persist.

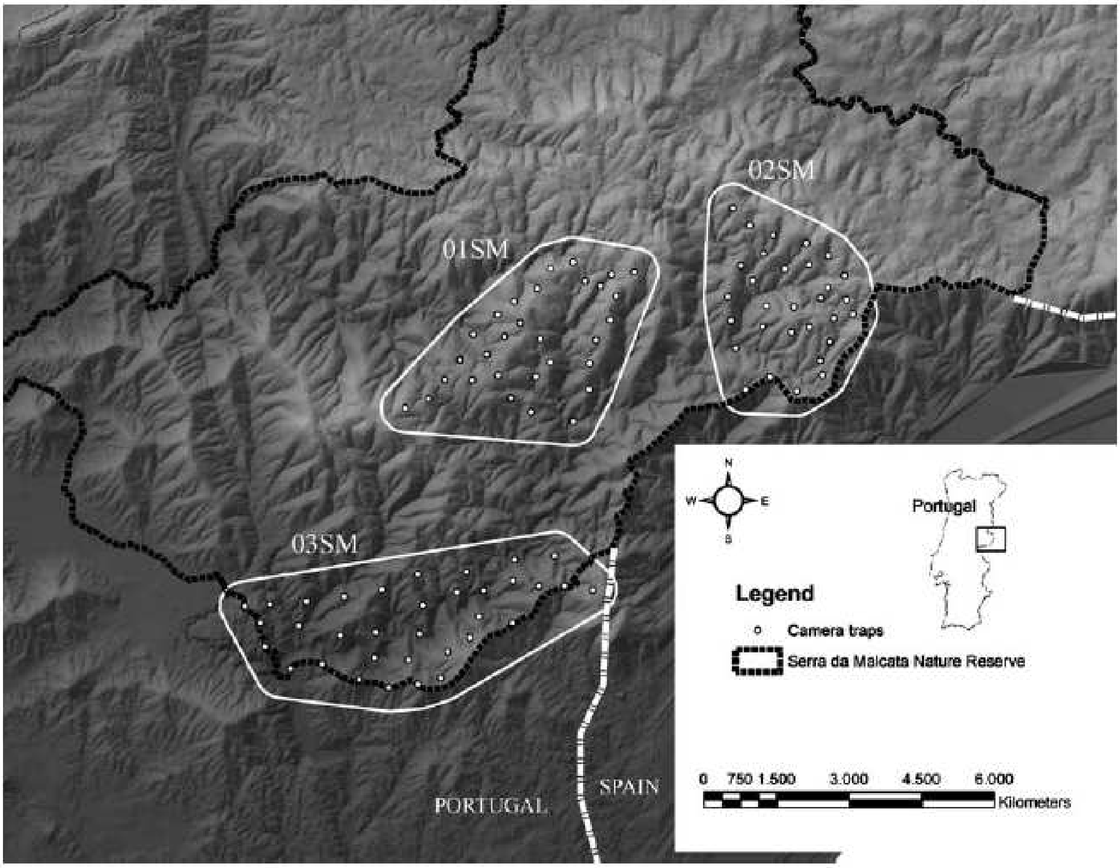


Fig. 11. Camera-trapping sites for common genet density estimates, within Serra da Malcata Nature Reserve, Portugal, showing trapping polygons and buffer areas.

MATERIALS AND METHODS

From October 2005 to November 2007, we studied the distribution of common genets in Serra da Malcata using camera-trapping techniques (Karanth & Nichols, 1998; Jackson et al., 2006). The rapid expansion of camera-trap surveys for elusive species has led to the widespread application of this technique, as camera technology improved and equipment costs decreased. Furthermore, this methodology produces a low disturbance effect while detecting cryptic animals with inconspicuous habits (Zielinski et al., 1995). We used four distinct camera devices: (1) CamTrakker® original 35 mm analog system, (2) DeerCam® analog system, (3) Bushnell 1® digital camera, and (4) GameSpy® digital camera. The cameras were placed 20 cm (average) above ground and distanced 2 to 4 m from the lure, according to the suggestions of Swann et al. (2004) for CamTrakker® and DeerCam®. With respect to the other two models, optimal distances were 2 to 3 m, according to the manufacturer. The lure consisted in domestic cat urine sprayed on a piece of cork-tree bark attached to a wooden stake at a 40–50-cm height.

Cameras were placed on the field according to two critical premises (Karanth and Nichols 1998): (1) The population of the target species should be considered a closed population; (2) All animals inhabiting the study area should have a probability of being detected. The first premise is achieved by shortening the trapping period and the second one by arranging the cameras in a trapping grid. The distance between cameras should be, at most, the diameter of a circle encompassing the smallest home range described for the target species in the study area. Thus, cameras were placed at an average distance of 472 m (SE = 122, min = 291, max = 680), according to Cruz (2002). Adjustments in camera distances were made according to vegetation features and accessibility. Due to the limitations in available cameras and in order to properly cover the entire study area, we divided the study in three trapping sessions (Table 11), with an average duration of 46 days (Fig. 1 and Table 1). A buffer area of half a genet's medium home-range diameter (600 m) (Cruz, 2002) was calculated around the cameras to represent the total surveyed area by that set of camera-traps (Karanth & Nichols, 1998; Carbone et al. 2001; Fig. 11). The effectively sampled area comprised the minimum convex polygon enclosed by the camera locations on the perimeter plus the above-mentioned buffer area (Cruz, 2002). In order to avoid biases caused by species-habitat associations, the number of cameras placed in the various habitat types was proportional to its availability.

TABLE 11. Camera-trapping periods and efforts during three trapping campaigns in Serra da Malcata Nature Reserve, Portugal, 2005–2007.

Area	Sampling period	Trap stations	Camera-nights	Photos	Captures	Individuals
01SM	10 Oct–06 Dec 2005	29	1,653	25	17	9
02SM	08 Sep–20 Oct. 2006	22	1,350	27	21	10
03SM	14 Oct–19 Nov 2007	23	828	29	19	9
Total		82	3,831	81	57	28
Average±SE		27.33(±3.78)	1,277 (±240.93)	27 (±1.15)	19 (±1.15)	9.33 (±1.20)

Individual identification

The individual identification of genets was based on their distinct pelage patterns (Fig. 12). Each photograph was examined for subject orientation, resolution, and framing to detect unique markings that might be useful for identification. The identification process included the following parameters (adapted from Jackson et al., 2006):

1. initial capture: a photograph that could not be positively matched with a previously photographed genet;
2. recapture: a photograph that could be positively matched to a previously identified animal;
3. null capture: a photograph that could not be identified as an initial capture or recaptured individual;
4. primary feature: the most distinctive feature (body areas) and, therefore, the most useful for identification, was designated for each photograph (Fig. 2);
5. secondary features: all useful marks other than primary features (Fig. 2);
6. initial capture/recapture determination: a positive identification was made by comparing the primary feature in each photograph and, at least, two secondary features.

We estimated genet abundance using the software program CAPTURE (Rexstad and Burnham 1991), following the procedures described by Otis et al. (1978), White et al. (1982), and Karanth and Nichols (1998). This program tests seven models, which differ in the sources of variation assumed in capture probability. The null model (M_o), which is considered the simplest, assumes no variation between individuals or over time. More complex models include the heterogeneity model (M_h), which assumes that individuals differ due to age, sex, ranging patterns, etc.; the time variation model (M_t), which considers the time effect on capture probabilities; the behavior model (M_b), which results from different responses to capture and recaptures, and three combinations of these models (time and behavior; heterogeneity and behavior; and time, behavior, and heterogeneity). The program identifies the best-fitting model to the data in question and then generates capture statistics for all adequately fitted models, along with a statistic test for evaluating the likelihood of population closure. Because this test is not considered statistically robust, we also employed the closure test of Stanley and Burnham (1999; CloseTest program). Each trapping campaign corresponded to 7-day sampling occasions (Jackson et al., 2006). In fact, within the 7-day period, it was possible to generate a sufficient number of captures, thus maximizing the number of sampling occasions without violating population closure assumptions.

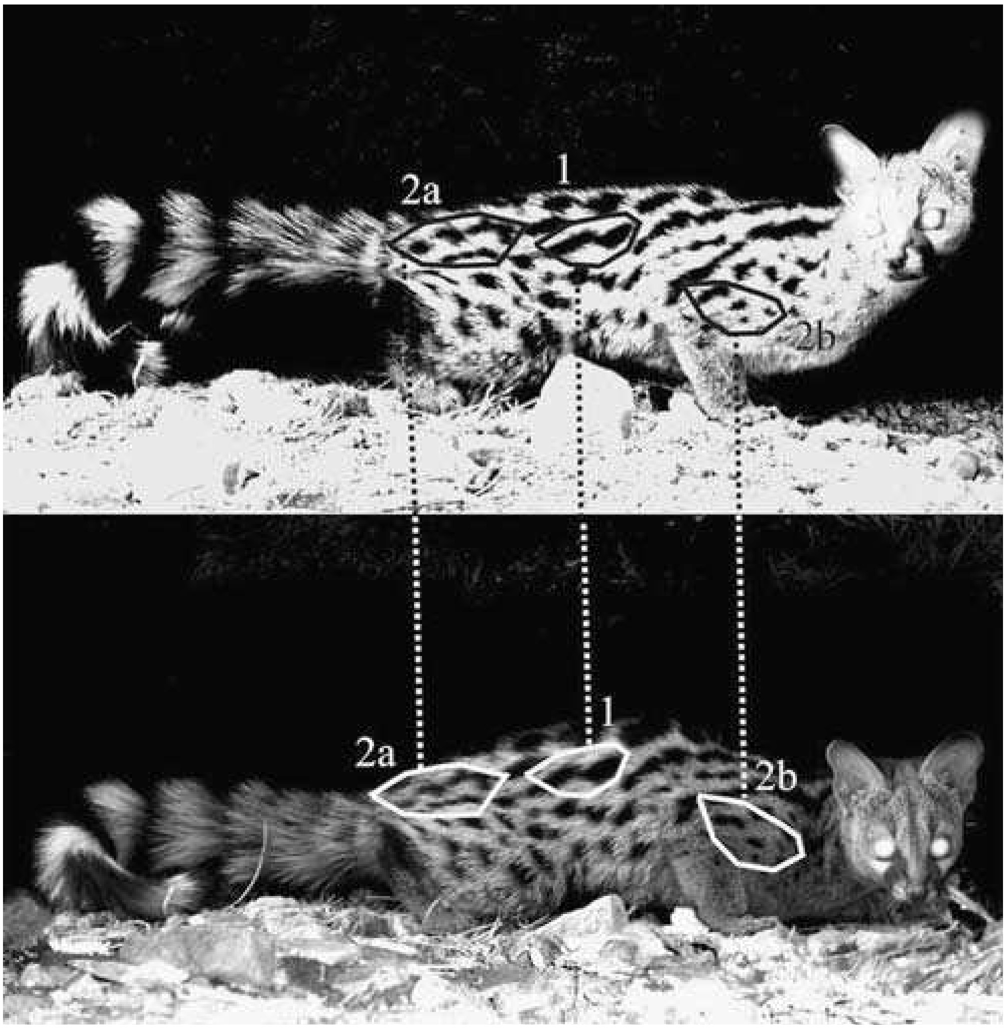


FIG. 12. Examples of pelage patterns used for a positive identification of a genet. 1 Primary feature; 2a and 2b secondary features (see text for details).

HABITAT CLASSIFICATION

A geographic information system (GIS) database was built for Serra da Malcata Nature Reserve using aerial photographs. We delineated nine habitat types within the study area (Table 12). We used aerial photographs and ground surveys to define habitat types and digitized each habitat patch using Arcview 3.2. The GIS land covers encompassed the trapping polygon and buffer area, and natural and human landscapes features were added (e.g., roads, habitat edges, and rivers).

HABITAT SELECTION ANALYSIS

We used a Euclidean distance-based approach to investigate habitat selection of genets (Conner & Plowman, 2001; Perkins & Conner, 2004; Benson & Chamberlain, 2007).

We compared distances from all genet locations and distances from all camera-traps locations in the trapping area to each of the nearest representative habitat type. Distance from camera-traps or genet locations within a certain habitat to that same habitat was considered to be zero. We calculated distances from random points and genet locations to each habitat type by using X-Tools and Geoprocessing extensions in Arcview 3.2. For each genet location, we created a vector of nine distance ratios (one for each type of habitat), which were defined as the mean distance of genet locations divided by the mean distance of random points throughout the trapping area.

STATISTICAL ANALYSES

We used multivariate analyses of variance (MANOVA) to test the null hypotheses that all habitats were equally used by genets. If the nine ratios means (number of habitats) differed from a vector of 1, which means that distances of genet locations to certain habitats were significantly different from those of random points to the same habitats, we used a univariate t test on each habitat type in order to determine which habitats were selected or avoided by genets. Distance ratios significantly lower than 1 indicate positive selection; whereas ratios, significantly higher than 1 indicate avoidance (Conner &Plowman, 2001; Benson & Chamberlain, 2007). Habitat types were then ranked in order of preference based on the magnitude and direction of the respective t statistics.

RESULTS

CAPTURE SUCCESS

From 2005 to 2007, we obtained a capture success of 1.49 genet captures/100 trap-nights (Table 11), which means that one genet was captured in every 67.21 nights of trapping. Genets were photographed in 41% of all trapping stations (n = 34). On average, we obtained 0.78 (SE = 0.14) captures per trap (min = 0; max = 5). Falsely triggered images constituted 36.19% of all images and were mostly caused by rain, wind, and extreme heat. Other captured species included badgers (*Meles meles*), wildcats (*Felis silvestris*), stone martens (*Martes foina*), foxes (*Vulpes vulpes*), mongooses (*Herpestes ichneumon*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and boars (*Sus scrofa*).

Cameras were positioned to photograph the lateral view of genets in order to detect the most diagnostic features. Consequently, it was possible to observe the torso and the tail in 81% and 46% of the photographs taken, respectively. In 30% of the photos, at least three limbs were visible, and front view photos (animal head facing the camera) were obtained in 39% of the cases. The flanks were the most reliable body part for individual identification (Fig. 12).

TABLE 12. Description of nine habitat types used to investigate habitat selection of genets in Serra da Malcata Nature Reserve (Portugal)

Habitat type	Description
Quercus pyrenaica forests	Northern areas or areas above 800 m (asl) dominated by Quercus pyrenaica with reduced or absent understory, which is mostly concentrated in the watercourses
Quercus rotundifolia and *Arbutus unedo* woodland	Medium succession Mediterranean woodland with disperse and well-developed individuals (>2 m high) and understory dominated by Cistus ladanifer
Cytisus spp. scrubland	Areas dominated by tall shrubs (≥1.5 m) of Cytisus striatus and Cytisus 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, Erica umbellata, and Cistus ladanifer, occupying the central and southern areas of SMNR
Well-developed pine stands	Over 30-year-old pine stands (Pinus pinaster, Pinus radiata, and Pinus pinea), with an average tree height >3.5 m and shrub understory
Less-developed pine stand	Pine stands of Pinus pinaster, Pinus radiata, and Pinus pinea, with an average tree height <3.5 m
Douglas fir stands	Over 30-year-old Douglas fir dense stands
Eucalyptus stands	Over 40-year-old Eucalyptus stands with an average tree height >5 m
Agriculture	Areas lacking forest cover used for crop production (generally corn and wheat)

Closure tests and model selection

The null model (M_o) and the heterogeneity model (M*h*) were considered the best-fitting models to our sampling data, for all trapping campaigns using the 7-day sampling occasions (Table 13). For the null model (Mo), we obtained a capture probability of 0.360 (SE = 0.025), which is slightly higher than that obtained for the heterogeneity model (M*h*; 0.297; SE = 0.013).

The CAPTURE test for closure supported the assumption of population closure (i.e., no emigration, immigration, births, or deaths) during all three campaigns, as did the most robust test of Stanley and Burnham (1999; Table 3).

TABLE 13. Results of population closure, estimated abundance, standard error, and capture probabilities of red foxes samples in Serra da Malcata Nature Reserve, Portugal, 2005-2007.

	Test for closure				Model selection				Population density			
	CAPTURE		Stanley and Burnham (1999)		Rankings				Null model (M_o)		Heterogeneity model (M_h)	
Campaign	*Z*	*P*	χ^2	*P*	M_o	M_h	M_b	M_t	**Capture probability**	**Abundance (SE) 95% CI**	**Capture probability**	**Abundance (SE) 95% CI**
01SM	1.712	0.450	1.445	0.966	1.00	0.98	0.25	0.62	0.381	9 ± 3.33 (9–11)	0.312	9 ± 4.77 (9–13)
02SM	1.543	0.540	1.422	0.961	1.00	0.96	0.25	0.60	0.344	10 ± 2.73 (10–13)	0.311	10 ± 3.59 (10–14)
03SM	1.447	0.340	1.533	0.931	1.00	0.97	0.29	0.56	0.323	9 ± 2.01 (9–11)	0.285	9 1.99 (9-11)

POPULATION SIZE AND DENSITY

Globally, a total area of 27.25 km^2 was sampled. Using the null model (M_o), the estimated density ranged from 0.50 (95% CI = 0.46–0.53 genets/km^2) to 0.92 (95% CI = 0.88–0.96 genets/km^2) genets/km2 (Table 14), which corresponds to an average density of 0.68 genets/km^2 (95% CI = 0.56– 0.80 genets/km^2). Assuming that genet density was stable in the areas sampled since 2005 until 2007, a total population of 27–39 adult individuals was estimated in those areas. Considering the heterogeneity model (M_h), the estimated density also varied between 0.50 (95% CI = 0.43–0.56 genets/km^2) and 0.92 (95% CI = 0.87– 0.97 genets/km^2) genets/km^2, and we obtained an average density of 0.70 genets/km^2 (95% CI = 0.58–0.82 genets/km^2) in the sampled area. This average density corresponds to a population of 29–40 genets (excluding cubs), which is slightly higher than the values obtained using the null model (M_o). Although the heterogeneity model (M_h) presents higher estimates with wider confidence intervals, no significant statistical differences were observed between population numbers estimated by both models (χ_5^2 = 7.851;P = 0.910). Also, no statistical differences were observed regarding the number of events per trapping area (ANOVA $F_{2,7}$ = 2.08; P = 0.079).

HABITAT SELECTION

Genets exhibited habitat selection considering the available habitats within the trapping areas (MANOVA: $F_{8,56}$ = 24.59, P<0.001; Table 15). Genets selected *Q. rotundifolia* and *A. unedo* woodlands and avoided *Erica* spp. and *Cistus ladanifer* scrubland and Eucalyptus stands (Table 15).

DISCUSSION

Camera trapping provides a statistically robust estimate grounded in mark/recapture analysis, which can be used to determine genet densities within a short period of time.

Although we successfully identified genets on account of their coat patterns, individual orientation proved to be the most variable factor. All camera systems worked properly and present a good efficiency for detecting animals. Only in 3% of the occasions we detected animal’s activity without photographic detection. The most useful photos for individual identification are those showing animals with one entirely visible flank. In order to obtain good quality photos that can be used for individual identification, the bait should be surrounded with rocks or vegetation thus forcing the animal to approach laterally. It is also important to remove from the ground any objects that may affect the visibility of lower limbs.

The closed capture-recapture null model (M_o) is the bestfitting model to the capture-history data, closely followed by the heterogeneity model (M_h). Small sample size could be the primary reason for our inability of selecting a more sophisticated model. The results obtained using the heterogeneity model (M_h) indicate a slightly higher genet density in the 02SM area when comparing to the null model

(M_o; Table 14), which can be explained by the assumption of different responses and sensitivity to captures. However, considering the models' biological significance, the heterogeneity model (M_h) is more suitable to represent genet behavior since this model incorporates variable probabilities of individuals' capture. The robust density estimate obtained by CAPTURE allows us to conclude that the trapping period, the number of cameras, and the distance between them were suitable for the study purpose. This is reinforced by the cumulative capture curves, which indicate that 40 days are sufficient for an adequate number of recaptures. These results emphasize that camera trapping is a viable tool for estimating genet population size if a sufficient number of cameras is used, the distance between them respect the spatial ecology of the species, and the length of the trapping period allows for a sufficient number of recaptures.

Considering habitat selection, our results emphasized the species association to Mediterranean woodlands dominated by broad-leaf trees (Virgós & Casanovas, 1997). Mediterranean woodlands are important to genets because they provide shelter and food resources such as small mammals, such as the wood mouse (*Apodemus sylvaticus*), which are particularly abundant and constitute the genet's main prey (Virgós et al., 1999; Cruz, 2002). With respect to shelter, tree cavities located high above ground can be used as dens. Parturition and early maternal care occur mostly in this type of cavities and so, the availability of secure dens is particularly important to increase cub survival and breeding success. Genets show preference for areas covered by dense shrubs and trees where they can find both food and protection against their own predators (Virgós et al., 2001).

TABLE 14. Genet density (individuals/km2) estimates for the study area, Serra da Malcata Nature Reserve, Portugal, 2005–2007

				Estimated density	
Area	Area surveyed (km^2)	Effectively sampled area (km^2)[a]	Mediterranean woodland (%)	Null mode (M_o)	Heterogeneity model (M_h)
01SM	8.90	16.08	17	0.50 (SE = 0.03)	0.50 (SE = 0.04)
02SM	7.02	13.03	34	0.62 (SE = 0.03)	0.68 (SE = 0.06)
03SM	11.33	20.18	45	0.92 (SE = 0.04)	0.92 (SE = 0.05)

[a] Trapping polygons plus buffer area

TABLE 15. Habitat type rankings and results of univariate t tests for habitat selection of nine habitat types by genets in Serra da Malcata Nature Reserve (Portugal), 2005–2007.

Habitat type	Rank[a]	t[b]	*P*
Quercus rotundifolia and *Arbutus unedo* woodland	1	−16.03	<0.001
Well-developed pine stands	2	−4.39	0.071
Douglas fir stands	3	−2.01	0.067
Quercus pyrenaica forests	4	−1.42	0.092
Cytisus spp. scrubland	5	1.78	0.073
Less-developed pine stands	6	2.60	0.274
Agriculture	7	7.24	0.352
Eucalyptus stands	8	9.81	<0.001
Erica spp. and *Cistus ladanifer* scrubland	9	10.55	<0.001

Regarding density values, our results (M_h, 0.70 genets/ km^2, 95% CI = 0.58–0.82 genets/km^2) can only be compared with estimates obtained by other methodologies, since other data sets on genet capture-mark-recapture using camera-trapping are not available. A density of 0.98 genets/km^2 was estimated for an area of northeastern Spain using radio-telemetry techniques (Munuera & Llobet, 2004). Whereas the latter density value is higher than the average density obtained in the present study, it is similar to the density values estimated for sampling area 03SM. A study area with a higher percentage of suitable habitats may account for the higher genet density estimated by Munuera & Llobet (2004). In Serra da Malcata, although suitable habitat patches are significant, they are highly fragmented as a result of forestry activities that have replaced Mediterranean woodlands by intensive pine tree plantations over the last decades. Carnivore richness is positively associated with Mediterranean woodlands, which provide the appropriate shelter considered a key element for carnivore conservation in the Mediterranean region (Mangas et al., 2008). On the other hand, a density of 0.33 individuals/ km2 was estimated in Doñana National Park also using radio-telemetry (Palomares & Delibes, 1994). This lower density can be related with the potential intraguild predation by the Iberian lynx (Palomares et al., 1996).

During the 2 years of our study, we did not observe any relevant habitat disturbance (e.g., forest fires and deforestation), so, we can clearly assume that genet density was rather constant. On the other hand, outside the reserve, the landscape presents an even higher degree of spatial heterogeneity and very low Mediterranean woodland cover.

Favorable habitats are fragmented, and landscape is dominated by Eucalyptus stands and Erica spp. and C. ladanifer scrubland, which are significantly avoided by genets. According to Virgós & García (2002) these fragmentation processes are known to affect the spatial distribution of genets and so the nature reserve could act as a crucial refugium for this species.

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"-You didn´t think is going to be that easy? Did you?
"-You know, for a second there…yeah..I kinda did!"

Quentin Tarentino - Kill Bill, Vol. I

Chapter 7

Modeling the occupancy of sympatric carnivorans in a Mediterranean ecosystem

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ABSTRACT

Site occupancy provides a reasonable estimate of population status and trends, and it also provides an unbiased, cost-effective alternative method for large-scale, multispecies monitoring programs. In this study, we used camera-trapping data to determine carnivoran occupancy and associated environmental factors in Serra da Malcata Nature Reserve, Portugal. The study was intended as a precursor of further long-term multispecies monitoring programs. We estimated carnivoran species occupancy using a likelihood-based method, using the software PRESENCE. The major conclusions of the study were: 1) fox occupancy tends to be independent of environmental factors, 2) stone marten occupancy is related with habitat variables, landscape structure and preys, 3) common genet occupancy is related to broad leaf formations and preys, and 4) mongoose occupancy is higher in extensive areas of shrub habitats. Methodologically, we demonstrated the importance of modelling detection probabilities for species with low or variable detection rates. In the future, monitoring programs could benefit from incorporating estimates of detection probabilities into their design and analysis.

Key words: camera-trapping, Iberian carnivores, occupancy rate, software Presence, site occupancy.

INTRODUCTION

Documenting and monitoring biological diversity is critical to conservation (Manley et al., 2005). In Europe, a significant amount of importance has recently been given to this subject (e.g. European Mammal Assessment- EMA) and in Portugal, several large-scale monitoring programs have been established to document specific taxonomic groups (e.g., National Atlas of Breeding Birds, National Atlas of Amphibians and Reptiles). However, monitoring programs often focus on ecological indicators or on species that raise public awareness, such as large carnivores. In terms of monitoring efforts, relatively little attention has been given to small and medium sized carnivores (Gese, 2001), which often play fundamental roles in natural processes and in the ecological equilibrium by influencing prey species that, in turn, can have a significant effect on other system components (Gittleman, 1993). In fact, much remains to be studied about the role of carnivores in different environments, especially in heterogeneous landscapes (Crooks, 2002).

Monitoring programs are crucial to obtain information that can provide reliable estimates of biological variation and changes in trends over space and time (Yoccoz et al., 2001). Despite the significant amount of indirect and direct surveying methods currently available to sample carnivoran presence and document species occurrence (e.g. scat counting transects, scent stations, captures) (Long, 2006), results are frequently presented in terms of abundance indices and they do not provide reliable monitoring data (Conroy, 1996). Although studies that produce these indices are relatively easy to plan and implement, the relation between estimates and the sampled populations is often unknown (Bailey et al., 2004). Among current monitoring methods, camera-trapping has proven to be successful in determining absolute abundances of carnivore species in relatively small areas (Sarmento et al., 2009a). The camera-trapping technique has been developed within a robust capture recapture statistical framework and is applicable where individual conspecifics can be identified (Sarmento et al., 2009b). However, for some Iberian carnivorans positive individual identification is not possible (e.g. mongooses *Herpestes ichneumon*; stone martens *Martes foina*). In this case, occupancy surveys are usually applied based on the detection of a species at a particular site (MacKenzie et al., 2002; Linkie et al., 2007).

Although methods used for assessing detection probabilities or site occupancy are relatively recent having yet received little attention (MacKenzie et al., 2002), site occupancy is considered to provide a reasonable estimate of population status and trends, and it also provides an unbiased, cost-effective alternative method for large-scale, multispecies monitoring programs when conspecifics cannot be identified (Bailey et al*.,* 2004; Linkie et al., 2007).

The occupancy method is based on the premise that changes in the proportion of the occupied area of a species (w) may be correlated with changes in its population size (Royle & Nichols, 2003). However, during surveys to record the presence of a species over several sites, not all species or individuals will be detected. Detection/non detection surveys therefore present a new technique for assessing the status of carnivoran populations by detecting changes in their occupancy estimates. In Portugal, data on population trends of most carnivoran species, or standardized methods to collect these data, are far from established. Therefore, it is of fundamental importance to develop systematic assessment methods to fully assess both conservation status and ecological requirements of mammalian carnivores.

Serra da Malcata, a Nature Reserve created in 1980, is currently in a process of recovering natural habitats as a consequence of the abandonment of traditional forest uses and progressive human impact decrease for the last three decades. This process can create a significant effect on carnivore species, which constitute a conservation concern in the Nature Reserve context (Sarmento et al., 2009b). Reliable data on these species occupancy could be an adequate indicator of ecosystem fitness and vegetation evolution. In the present study, we used camera-trapping data to determine carnivoran site occupancy and related environmental factors in Serra da Malcata Nature Reserve, Portugal, as a foundation for future long-term multispecies monitoring programs, which is a critical issue for a more effective management of the protected area.

STUDY AREA

The 200 km2 Serra da Malcata (Fig. 13) is a Nature Reserve located in Portugal near the Spanish border (40º08´50´´ N - 40º19´40´´ N and 6º 54´10´´ W - 7º 09´14´´ W). The climate is Mediterranean, characterized by mild cold wet winters and warm dry summers. Vegetation is highly fragmented and dominated by dense scrub 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 the area. The area is covered by industrial plantations (30%) of *Pinus* spp., *Eucalyptus globulus* and *Pseudotsuga menziesii* and 12% is cropland.

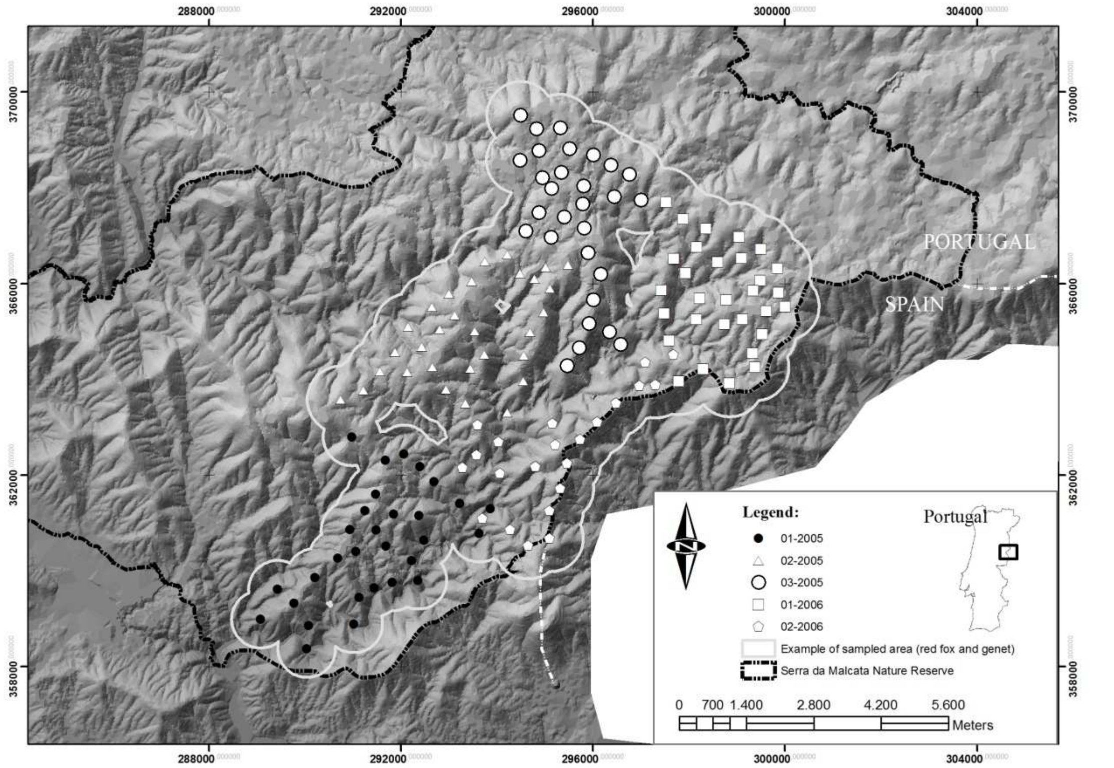

FIG. 13. Study area location and camera trapping sites in 5 camera-trapping campaigns conducted in Serra da Malcata Nature Reserve (SMNR; Portugal), 2005-2006.

METHODS

From July 2005 to October 2006, we assessed the occupancy rates of foxes (*Vulpes vulpes*), stone martens, common genets (*Genetta genetta*) and Egyptian mongooses using camera-trapping techniques (Karanth & Nichols, 1998) (Table 1). We used 4 camera types: 1) CamTrakker® analog system (CamTrak South, Watkinsville, Georgia) (n = 14); 2) DeerCam® analog system (Non Typical, Inc., Park Falls, Wisconsin) (n = 9); 3) Bushnell 1® digital camera (Bushnell OutdoorProducts, Overland Park, Kansas) (n = 4); and 4) GameSpy® digital camera (EBSCO Industries, Inc., East Birmingham, Alabama) (n = 1). We placed the cameras approximately 20 cm above ground and 2-4 m away from the lure, which was constituted by domestic cat urine sprayed on a piece of cork-tree bark attached to a wooden stake at a 40-50 cm height (Swann et al., 2004; Sarmento et al., 2009a) and also dry dog food. We programmed cameras to take a photograph every 30 seconds.

We assumed that the populations were closed and that all animals of the same species inhabiting the study areas had an equal probability of being detected. We achieved the first premise by establishing a 7-day trapping period and the second premise by arranging cameras in a trapping grid, with an average distance between cameras of 472 m (SE= 122, min =291, max=680) according to Sarmento et al. (2009a,b). Closed occupancy was verified for all species using the Robust-design models of MacKenzie et al. (2004), which indicated that the occupancy status for each species was constant throughout the study, allowing us to use the closed-occupancy models (MacKenzie et al., 2002) to test covariate effects. For calculating the effectively sampled area for each species a buffer area of half the species home-ranges diameters was calculated around the cameras to represent the total surveyed area by that set of camera-traps (Karanth & Nichols 1998; Fig. 13). Buffer area diameters were obtained from previous studies in our area and from studies performed in similar environments and available in the literature: 600 m for red foxes (Cruz & Sarmento, 1998), 550 m for stone martens (Genovesi et al., 1996), 600 m for genets (Cruz, 2002), and 450 m for Egyptian mongooses (Palomares & Delibes, 1990).

We defined capture as a detection of a given carnivore species in a site within a 24- hour interval, and the data was expressed in number of captures per 100 days of trapping.

Due to the restrictions posed by the number of available cameras and in order to properly cover the sampling area we divided the study into 5 trapping sessions, conducted in summer and autumn, with an average duration of 38 days (Table 16; Fig. 13). The summer-autumn period was selected because carnivore densities are higher and detection probabilities increase as a result of juvenile activity and dispersion (Cavallini & Santini, 1996; Genovesi et al., 1996; Zapata et al., 1997). We considered each trapping session as a 7-day period, which allowed us to generate a sufficient number of captures, thus maximizing the number of sampling occasions without violating population closure assumptions. Sampling area selection was based on: 1) representativeness of vegetation types, and 2) low human presence, which could avoid the loss of cameras.

TABLE 16. Camera trapping periods and efforts during 5 trapping campaigns for carnivorans in Serra da Malcata Nature Reserve, Portugal, 2005-2006.

				Sampled area (km^2)			
Campaign	Sampling period	Trap stations	Camera-days	Red fox	Stone marten	Genet	Egyptian mongoose
01-2005	06 Jun-16 Aug 2005	30	1030	16.41	15.29	16.41	11.87
02-2005	06 Sep-11 Oct 2005	30	850	17.15	14.17	17.15	12.73
03-2005	20 Oct-06 Dec 2005	29	1163	15.78	12.74	15.78	11.01
01-2006	16 Jun-20 Jul 2006	30	950	15.04	12.72	15.04	10.71
02-2006	08 Sep-20 Oct 2006	22	824	14.86	11.89	14.86	9.65
Total		141	4817	68.31	61.07	68.31	53.10
Average		28.20	963.40	15.85	14.07	15.85	11.19
SE		3.70	178.60	0.43	0.61	0.43	0.53

CARNIVORE OCCUPANCY

We estimated carnivore species occupancy (ψ) using a likelihood-based method (MacKenzie et al., 2002). The detection histories (H) of the targeted species were constructed for each camera-trap location (site) over 7-day consecutive sampling occasions using a standard 'X-matrix format' (Otis et al., 1978).

We produced detection histories for each camera-trap placed on the 5 trapping areas and we used the program PRESENCE v.2 software (Proteus Wildlife Research Consultants, New Zealand; http://www.proteus.co.nz) for defining occupancy with the single-season option (MacKenzie et al., 2006). The single-season occupancy model (MacKenzie et al., 2006) uses multiple surveys on a collection of survey sites to construct a likelihood estimate using a series of probabilistic arguments. False negative surveys can be corrected by estimating probability of detection, providing a more precise assessment of site occupancy values.

For each camera-trap location, we recorded factors (covariates) associated to habitat type, landscape diversity, feeding resources and competition (Table 17). All continuous covariates were standardized to z-scores prior to analysis, allowing model coefficients to be interpreted as the change in the log-odds ratio of occupancy relative to a 1-standard deviation change in the covariate from its mean (Cooch & White, 2005). We considered previous studies (Cruz & Sarmento, 1998, Sarmento et al., 2009b) and published studies on the natural history of each species to develop a set of predictor variables related with species ecological requirements (Palomares & Delibes ,1990; Cavalini & Lovari ,1991; Clevenger, 1994; Lucherini et al., 1995; Sacchi & Meriggi, 1995; Pandolfi et al., 1996; Genovesi et al,. 1997; Padial et al., 2002; Virgós et al., 2002; Carvalho & Gomes, 2004; Barrientos & Virgós, 2006; Mangas et al., 2008) (see Table 17). Variables were divided in four major groups: 1) HABITAT (vegetation cover types chosen because of their pertinence to the biology of the studied carnivores), 2) LANDSCAPE (variables related with the landscape complexity and composition), 3) FOOD (variables related with major food resources), and 4) COMPETITION (variables related with carnivore abundance) (Table 2).

A Geographic Information System (GIS) database was built for Serra da Malcata Nature Reserve using aerial photographs. Taking biological criteria into consideration, we defined 6 habitat types within the study area (Table 17) using both aerial photographs and ground surveys and then each habitat patch was digitized using Arcview 3.2. Habitat types covariates for each trapping location were measured using an Euclidean distance-based approach (Perkins & Conner, 2004; Benson & Chamberlain, 2007). We calculated distances from camera-traps to each habitat type by using X-Tools and Geoprocessing extensions in Arcview 3.2. These values were used as covariates to create candidate models for occupancy rate. Landscape covariates were measured in a 200-meter buffer plotted around the camera-trap (Mangas et al., 2008) (Table 17).

Food resource variables consisted in: 1) Distance to the vulture feeding camp (Dist. camp), 2) rabbit abundance (Rab. abundance), 3) Wood mouse (*Apodemus sylvaticus*) frequencies of photographic captures (Woo. captures) (Table 17). The Nature Reserve has a vulture feeding camp where carcasses of domestic animals are deposited on a weekly basis. Since carnivorans are able to pass through the fence, the feeding camp represents an important source of food. We assessed rabbit abundance by counting latrines (Calvete, 2006; Beja et al., 2007) in fixed 1km transects per each 2x2 km UTM quadrats, covering the entire nature reserve. Transects were designed in order to cover scrublands, which is the most suitable habitat for rabbits (Beja et al., 2007). We then used an index (number of latrines per km) to categorize rabbit abundance in each quadrat, which was used as a covariate for camera sites inside that quadrat. Wood mice are an important food item in the studied predators' diets in Mediterranean ecosystems (Padial et al., 2002; Carvalho & Gomes, 2004; Torre et al., 2005), and its abundance was inferred by using the camera-trapping detections in each camera site. This method was developed by Torre et al. (2005) as an alternative to live-trapping. Since we also used dog food as attractant bait to small mammal species, we obtained a significant amount of woodmouse photographic captures and we used this variable for models design. We defined a photographic encounter as a photographic series produced by the same individual or group of individuals when successive photographs were separated by less than five minutes (Hicks et al., 1998; Otani, 2001). We then converted these detections into the number of captured wood mice per camera site per 100 trap-nights.

The described covariates were extracted and imported into PRESENCE. We used a 2-step approach to analyze data. Firstly, we assessed the effect of seasonality and HABITAT on detection probabilities, while keeping site occupancy constant (i.e. ψ [.] ρ [*variable*]). Season when sampling took place could play a crucial role in the actual species occupancy of a given study site and thus we modelled Julian date (JULIAN), Julian date squared ($JULIAN^2$) and Julian date cubed ($JULIAN^3$) (Gompper and Hackett 2005). HABITAT can also affect detectability since it has a direct effect on foraging behaviour (Finley et al., 2005; O´Conell Jr., 2006). We constructed a set of 8 candidate models for each species with the following combination of factors: 1) we modelled species-specific detection probability as constant across sites and time or as varying according to season (JULIAN, $JULIAN^2$ and $JULIAN^3$), and HABITAT, and 2) we considered the possible interactive effects among season and HABITAT. Secondly, we used the best-fitting model for detecting probabilities and combined it with the candidate models representing biological hypotheses (Burnham and Anderson 2002). We modelled probability of occupancy as the dependent variable. A logistic regression analysis was then performed to determine the covariates that best explained overall carnivore occupancy (ψ) for each of the 7 trapping areas. A global model was produced that contained all potential covariates affecting occupancy, ψ (covariate). The potential covariates for occupancy were then allowed to vary, individually or combined. We started by testing habitat effects on occupancy, and then according to results (individually or combined) we added LANDSCAPE, FOOD and COMPETION variables, generating a total of 28 models for fox, 18 for marten, 18 for genet and 15 for mongooses. Finally, the simplest model, where occupancy and detection probability remained constant, ψ (.)ρ (.), was produced.

The ranking of candidate models, in the two-step analysis, was conducted using the Akaike Information Criterion (AIC) (Burnham and Anderson, 2002). Models with Δ AICc values ≤ 2 from the most parsimonious model were considered to be strongly supported, and their variables were considered the most determinant of species occurrence patterns. Akaike´s weights (ω) were used to further interpret the relative importance of each model´s independent variable. Δ AICc values were used to compute ωi, which is the weight of evidence in favour of a model being the best approximating model given the model set (Burnham & Anderson, 2002). Unless a single model had a ωi >0.9, other models were considered when drawing inferences about the data (Burnham & Anderson, 2002). A 90% confidence model set was created by summing all ωi until achieving 0.90. The relative importance of each variable was calculated by summing normalized ωi values for every model in which that variable was present (Anderson et al*.,* 2002).

The most parsimonious models for the observed data were used to estimate the final carnivore specific occupancy (and associated standard errors, S.E.s). A model averaging technique was applied to estimate occupancy when there were several top ranked candidate models, i.e. those with similar AIC weights that were greater than 0.010 (Linkie et al., 2007), where:

$$\hat{\theta}_A = \sum_{i=1}^{m} \omega_i \, \hat{\theta}_i$$

Where *ωi =* AIC individual model weight and θ_i individual occupancy estimate, with

$$SE\left(\hat{\theta}_A\right) = \sum_{i=1}^{m} \omega_i \sqrt{Var\ (\hat{\theta}_i | M_i + (\hat{\theta}_i - \hat{\theta}_A)^2}$$

TABLE 17. Covariates used to investigate carnivoran occupancy rates in Serra da Malcata Nature Reserve (Portugal), 2005-2006.

Covariate	Abbreviation	Description	Target species
HABITAT			
Pyrenean oak forests	Pyr. forests	Northern areas or areas above 800 meters dominated by *Quercus pyrenaica* with reduced or absent understorey.	fox, marten and genet
Mediterranean scrubland	Med. scrubland	Medium succession Mediterranean scrubland with disperse and well-developed individuals (> 2 meter high) and understorey dominated by *Cistus ladanifer*	fox, marten and genet
Dense scrubland	Den. scrubland	Areas dominated by tall shrubs (≥ 1.5 meters) of *Cytisus striatus, C. multiflorus*, *Erica australis, E. umbellata* and *C. Ladanifer*, and with disperse pine specimens (*Pinus pinaster, P. radiata* and *P. pinea*)	fox, marten and mongoose
Well-developed pine stands	Dev. pines	Over 30-year old pine stands, with an average tree height >3.5 meters and shrub understorey	fox, marten and genet
Douglas fir stands	Dou. stands	Over 30-year old Douglas fir dense stands	fox, marten and genet
Agriculture	Agr.	Areas lacking forest cover used for crop production (generally corn and wheat)	All
LANDSCAPE			
Shannon landscape diversity index	Sha. index	Measure of relative patch diversity inside a buffer area of 500 m radius around the camera trap; equals 0 when there is only one patch in the landscape and increases as the number of patch types or	All

		proportional distribution of patch types increases	
Patch size	Pat. size	Size (in hectares) of the habitat patch where the camera is located	All
Number of patches	Num. patches	Number of different patch types inside the 500 m buffer area	All
FOOD			
Distance to vulture feeding camp	Dist. camp	Distance (in meters) to the vulture feeding camp	All
Rabbit abundance	Rab. abundance	Number of rabbit latrines per 1km transects in each 2x2 km UTM square.	All
Wood mouse frequency of photographic captures	Wmo. captures	Number of woodmouse captures per 100 trap-nights	All
COMPETITION			
Red fox abundance	Rfx. abundance	Number of red fox captures per 100 trap-nights	Except fox
Stone marten abundance	Stm. abundance	Number of stone marten captures per 100 trap-nights	Genet
Genet abundance	Gen. abundance	Number of genet captures per 100 trap-nights	Marten
Egyptian mongoose abundance	Mon. abundance	Number of Egyptian mongoose captures per 100 trap-nights	Genet and marten

Finally, averaged site occupancy estimates of the top fitting models were used to generate occupancy maps by interpolating the data using the Inverse Distance Weighted Interpolation (IDW) (Liszka, 1984; Kliskey et al., 2000) (Fig. 14). The IDW method is based on the assumption that the interpolating surface should be influenced most by nearby points and less by more distant points. Spatial interpolation provided grid surfaces across the study area representing carnivore occupancy.

RESULTS

From June 2005 to October 2006, we performed 405 captures of the 4 carnivoran target species with a global capture success of 2.10 captures/100 trap-days (1 carnivoran capture/47.61 trap-days) (Table 18).

Average time until first capture was 2.50 (SE=2.37) days. We also performed one badger (*Meles meles*) and three wildcat (*Felis silvestris*) captures, which due to the low capture rate, were not incorporated in the model.

RED FOX

We found no effects of the tested variables on the detection probability (Table 19). So, this parameter was best modelled as a constant function. Red fox was detected in 73 sites, with naïve site occupancy of 0.53 (Table 20). A total of 3 models had Δ AIC ≤ 2 (Table 20). No single model emerged as the top ranking model, i.e. $\omega_i > 0.90$, so the averaged model occupancy value was chosen as the final estimate ($\hat{\psi}$ = 0.59, SE= 0.10) (Table 20), which corresponds to a difference of 6% on the naïve site occupancy. The occurrence model with the greatest support was ψ (.) ρ(.) (Table 20), suggesting that red fox occupancy could be independent of covariates. The second most parsimonious model was ψ (Dist camp) ρ(.) (Table 20), suggesting a relationship between distance to the vulture feeding camp and fox occupancy (Fig. 14). The only covariate that seemed to influence red fox occupancy was Dist. camp, with a 95% confidence interval of β coefficient that did not include 0 (Table 21). This covariate also ranked high in importance when summed AICc weights of models containing it over the entire set of candidate models (Table 22). The other covariate that appeared in the 3 best models (Den. scrubland) had a β coefficient with 95% confidence intervals overlapping 0, indicating that it is not a good predictor of red fox occupancy.

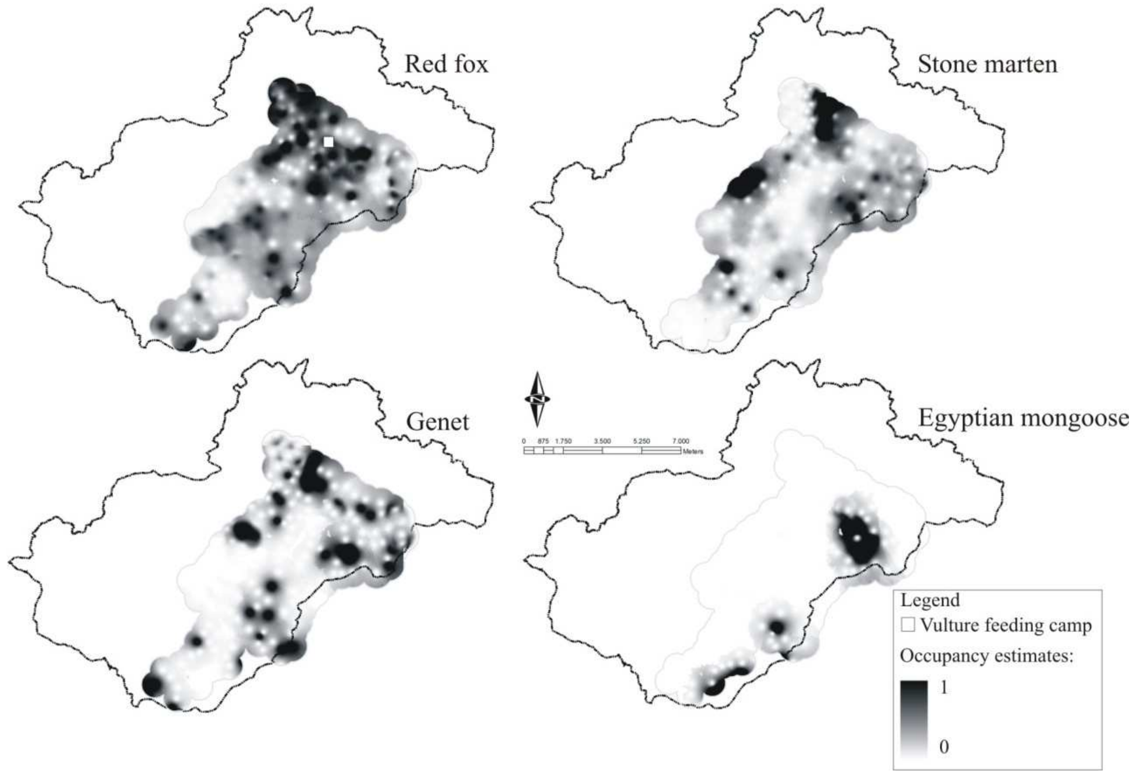

Fig. 14. Geographic distribution of averaged site occupancy estimates for carnivore species in Serra da Malcata Nature Reserve (Portugal), 2005-2006.

STONE MARTEN

Stone marten detection probability was best modelled as a constant function with no linear effects of tested variables (Table 19). We detected the species in 46 sites (naïve site occupancy = 0.34) (Table 20; Fig. 14). Two candidate models had Δ AIC ≤ 2 (Table 20), indicating similar support for each of these models. Analyzing potential differences among the candidate models, where was varying with covariates, found low support for the constant model, which had a low AIC weight (ω_i =0.0001). Considering Δ AIC values, the most parsimonious model was ψ (Pyr. forests+Med. scrubland+Woo. capture) *ρ*(.), followed by ψ (Pyr. forests+Med. Scrubland+Den.pine+Sha. index+Woo. capture) *ρ*(.) (Table 20). The covariates Pyr. forests and Med. scrubland significantly influence occupancy negatively (i.e. the farther from these habitats the lower the probability of occupancy), whereas Sha. index and Woo. capture significantly influence occupancy positively (β coefficient 95% confidence interval did not overlapped 0) (Table 21). These covariates also ranked high in importance when summed AIC weights of models containing them over the entire set of candidate models (Table 22). The variable Dev. pines had a β coefficient with 95% confidence interval overlapping 0, which indicates that it is not a suitable marten occupancy predictor (Table 21). Considering that no single model achieved a ω_i>0.90, we used the averaged occupancy value of 0.42 (SE=0.13) as the final estimate (Table 20), which has a difference of 8% from the naïve estimate.

COMMON GENET

Common genets were detected in 34 sites (Table 19; Fig. 14), which corresponded to a naïve site occupancy of 0.25. We used ρ (.) for subsequent analysis since we detected no linear effects of the tested variables on this parameter (Table 18). Three of the candidate models presented Δ AIC ≤ 2 (Table 19), which indicates an identical support for these models These models accounted for 83% of the AICc weights among the analyzed candidates. Analyzing potential differences among candidate models found low support for the constant model, which had an AIC weighting (ω_i) of 0.0000. The most parsimonious model was ψ (Pyr. forests+Med scrubland+Sha. index+Woo. capture) ρ(.) (Table 19). Considering the analyzed factors, both Pyr. forests and Med. scrubland covariates influenced occupancy negatively (i.e the further from these habitats the lower the probability of occupancy), whereas Shan. index and Woo. capture influenced occupancy positively with 95% confidence intervals of β coefficients not overlapping 0 in the mentioned covariates (Table 20). These covariates also ranked high in importance when summed AIC weights of models containing them over the entire set of candidate models (Table 21). Since no single model achieved a >0.90, we used the averaged occupancy value of 0.27 (SE= 0.07) as the final estimate (Table 19), which is 2% higher than the naïve estimate.

EGYPTIAN MONGOOSE

The Egyptian mongoose was detected in 18 sites (naive site occupancy = 0.13) (Table 20; Fig. 14). As in other species, detection probability was best modelled as a constant function with no linear effects of the tested variables (Table 19). Only one model had Δ AIC ≤ 2 with ωi = 0.99 (Table 20). This model indicated that the habitat variable Den. scrubland and the landscape variable Pat. size are suitable predictors of Egyptian mongoose occupancy. We found low support for the constant model since it had a low AIC weighting (ω_i) =0.0004). Distance to Den. scrubland influenced occupancy negatively, and Pat. size influenced occupancy positively with 95% confidence intervals of β coefficients that did not include 0 (Table 21), indicating that these are suitable mongoose occupancy predictors.

TABLE 18. Number of captures, trapping success and number of occupied sites by carnivorans in Serra da Malcata Nature Reserve estimated during 5 camera-trapping campaigns, Portugal, 2005-2006.

	Photos	Captures	Number of captures 100 trap-days	Number of occupied sites	%
Red fox	388	178	3.90	73	53%
Stone marten	167	125	2.59	46	34%
Genet	56	65	1.35	34	25%
Egyptian mongoose	36	27	0.56	18	13%

TABLE 19. First step model selection analysis using the best approximating models for detection probabilities for carnivorans obtained during 5 camera-trapping campaigns in Serra da Malcata Nature Reserve, Portugal, 2005-2006. J – Julian days; see Table 2 for abbreviations.

Species	Model	-2log-likelihood	K	ΔAIC	Akaike weight
Red fox	ψ (.) *ρ*(.)	128.21	2	0.00	0.73
	ψ (.) *ρ*(J)	128.20	3	2.99	0.27
	ψ (.) *ρ*(J^2)	119.89	3	20.68	0.00
Stone marten	ψ (.) *ρ*(.)	135.01	2	0.00	0.73
	ψ (.) *ρ*(HABITAT)	135.00	3	2.02	0.26
	ψ (.) *ρ*(J)	134.56	3	21.55	0.00
Genet	ψ (.) *ρ*(.)	135.01	2	0.00	0.79
	ψ (.) *ρ*(HABITAT)	134.94	3	2.93	0.21
	ψ (.) *ρ*(J)	134.56	3	21.55	0.00
Egyptian mongoose	ψ (.) *ρ*(.)	155.01	2	0.00	1.00
	ψ (.) *ρ*(HABITAT)	154.56	3	21.55	0.00
	ψ (.) *ρ*(J)	154.56	3	21.55	0.00

TABLE 20. Model selection analysis (ΔAIC < 2) and parameter estimates of site occupancy ($\hat{\psi}$) for carnivorans obtained during 5 camera-trapping campaigns in Serra da Malcata Nature Reserve, Portugal, 2005-2006.

Species	Model	-2log-likelihood	K	ΔAIC	Akaike weight	Naïve occupancy	($\hat{\psi}$) (SE)	$\hat{\rho}$ (±SE)
Red fox								
RF01	ψ (.) ρ(.)	545.23	2.00	0.00	0.37		0.60 (0.05)	0.43 (0.03)
RF02	ψ (Dist camp) ρ(.)	543.53	3.00	0.31	0.28		0.60 (0.123)	0.42 (0.09)
RF03	ψ (Den. Scrubland+ Dist camp.) ρ(.)	543.62	4.00	0.39	0.27		0.57 (0.12)	0.43 (0.03)
	Model averaged				0.92	0.53	0.59 (0.10)	0.42 (0.03)
Stone marten								
SM01	ψ (Pyr. forests+Med. scrubland+Woo. capture) ρ(.)	403.87	5.00	0.00	0.50		0.42 (0.12)	0.34 (0.19)
SM02	ψ (Pyr. forests+Med. scrubland+ Dev. Pines+Sha index+Woo. capture) ρ(.)	401.97	6.00	0.10	0.42		0.42 (0.13)	0.35 (0.20)
	Model averaged				0.92	0.34	0.42 (0.13)	0.35 (0.20)
Genet								
GG01	ψ (Pyr. forests+Med. Scrubland+ Sha index+ Woo. capture) ρ(.)	306.72	6.00	0.00	0.48		0.30 (0.08)	0.38 (0.05)
GG02	ψ (Pyr. forests+Med. scrubland+Dev. pines+Sha. index+Woo. capture) ρ(.)	306.71	7.00	1.95	0.27		0.227 (0.06)	0.381 (0.05)
GG03	ψ (Pyr. forests+Med. srubland+Pat. size+Woo.	308.54	6.00	1.98	0.23		0.23 (0.07)	0.38 (0.04)

	capture) ρ(.)							
	Model avereged				0.99	0.25	0.27 (0.07)	0.38 (0.04)
Mongoose								
EM01	ψ (Den. srubland+Pat. size) ρ(.)	402.33	4.00	0.00	0.99	0.13	0.20 (0.18)	0.28 (0.13)

TABLE 21. Estimates of beta coefficients on the logit scale and standard error (SE) for covariates contained in the best models of carnivore occupancy in Serra da Malcata Nature Reserve, Portugal, 2005-2006. * indicates SEs that do not overlap 0. See Table 4 for model codes.

	Intercept	Pyr. forests	Med. scrubland	Den. scrubland	Dev. pines	Sha. index	Pat. size	Dist. Camp	Woo. capture
RF01	-0.347 (0.002)								
RF02	-0.341(0.003)							-0.064* (0.042)	
RF03	-0.285 (0.136)			-0.057 (0.028)				-0.061* (0.043)	
SM01	-0.334 (0.224)	-0.024* (0.004)	-0.047* (0.018)						0.024* (0.011)
SM02	-0.342 (0.244)	-0.026* (0.004)	-0.044* (0.021)		-0.058 (0.061)	0.764* (0.527)			0.027* (0.018)
GG01	-0.702 (0.055)	-0.893* (0.524)	-1.178* (0.556)			0.519* (0.371)			0.640* (0.177)
GG02	-0.593 (0.501)	-0.884* (0.523)	-1.032* (0.532)		-0.173 (0.244)	0.551* (0.344)			0.702*(0.182)
GG03	-0.783 (0.120)	-0.861* (0.126)	-1.167* (0.564)			0.512* (0.401)			0.643* (0.182)
EM01	-0.505 (0.469)			-0.035* (0.022)			0.005* (0.003)		

TABLE 22. Sum of AIC weights and covariate rank based on weight for all candidate models for carnivoran occupancy in Serra da Malcata Nature Reserve, Portugal, 2005-2006.

Species	Covariate	Sum AIC weights	Rank
Red fox	Dist camp	0.55	1
	Den. Scrubland	0.27	2
Stone marten	Pyr. Forest	0.92	2
	Med. scrubland	0.92	2
	Woo. captures	0.92	2
	Sha. Index	0.42	3
	Dev. Pines	0.42	4
Common genet	Pyr. Forest	0.99	2
	Med. scrubland	0.99	2
	Woo. captures	0.99	2
	Sha. Index	0.76	3
	Dev. Pines	0.27	4
	Pat. Size	0.23	5
Egyptian mongoose	Den. Scrubland	0.99	2
	Pat. Size	0.99	2

DISCUSSION

This study emphasizes the feasibility of rigorously assessing carnivoran populations in important conservation landscapes by estimating their detection probability and site occupancy. The detection/non-detection method therefore has a good potential for monitoring carnivoran populations in long-term studies, and has the ability to indicate that a clear understanding of carnivore ecology should examine relationships between species distribution patterns and habitat characteristics (Bailey et al., 2004). Contrary to other studies (Royle & Nichols, 2003; Bailey et al., 2004; Finley et al., 2005; O´Conell Jr. et al., 2006) we did not detect an effect of season on detectability, probably as a result of similarities between summer and autumn in carnivore densities, and also because of the inexistence of major disturbance factors during the two years of our study.

Inversely, the results obtained indicated that occupancy was not constant across space (Fig. 2). Behavioural factors, density, and local environmental factors could be the driving forces for these results. As observed by our models (Table 20), different species respond differently towards covariates, which influence occupancy (Manley et al., 2005). According to O´Conell Jr. et al. (2006) and as confirmed by our results, site occupancy surveys that incorporate detection probabilities provide a suitable basis for conducting effective biological inventories and subsequent monitoring. We believe that the proportion of sites occupied is useful as a state variable in a monitoring context, although some precautions should be taken into account, especially when regarding species with low detectability. Models do not produce valid site occupancy estimates when detection probabilities fall below 0.15 (O´Conell Jr. et al. 2006). Under this scenario, there is no way of distinguishing between where the species is poorly detected compared to true absence (MacKenzie et al., 2002). Considering these facts we decided to remove badgers and wildcats from our analyses.

RED FOX

Foxes were not always detected when present at a site, because the detection probabilities were lower than 1.0. The inclusion of covariates in the model selection analysis did not improve model precision, emphasizing the hypothesis of low interference of covariables in fox distribution. These results concur with most of the studies on fox ecology that classify the species as generalist not only in terms of habitat but also in terms of prey (Cavalini & Lovari, 1991; Lucherini et al., 1995; Virgós et al., 2002; Webbon et al., 2004). The variable Dist. camp seemed to influence fox occupancy (Fig. 14). The species scavenging habits (Cruz and Sarmento 1998) and the significant food source provided by the vulture feeding camp conditioned fox occupancy (Fig. 14). However, the geographic extension of this impact seems to be limited since the models that used this covariate had lower precision than the null model.

STONE MARTEN

The occupancy model for stone marten indicated that habitat variables, landscape structure and wood mouse frequency of photographic captures were the most important driving forces. These results indicate that a complex set of variables play a role in the occupancy of martens, and that the presence and diversity of forest habitats drive its patterns. Stone marten occupancy seems to be higher in areas presenting a patchy structure of Pyr. forests, Med. scrubland and Den. pine habitats. The first two habitat types present a rather fragmented pattern in the Nature Reserve, which contributed to a discontinuous distribution of martens (Fig. 14). This type of landscape probably contributes for a high density of wood mice, which constitute a fundamental prey item in stone marten´s diet (Barrientos and Virgós 2006). In fact, martens can easily find a variety of food sources and also safe shelter and breeding sites in a more diverse landscape (Sacchi & Meruggi, 1995). According to Barrientos and Virgós (2006) stone martens present a very complex pattern of food use, which can lead to higher occupancy rates in a more diverse landscape. Several authors refer frugivory as a relative specialization of this species and small mammals also constitute an important prey (reviewed in Clevenger 1994, Pandolfi et al. 1996). The understorey of Pyr. forests, Med. scrubland and Den. pine habitats is very rich in mushrooms and fruits such as berries. Mushrooms could represent a very suitable and abundant source of proteins and other resources for stone martens during cold winters, and can perhaps replace the relatively low availability of fleshy fruits during this season (Barrientos and Virgós 2006).

Another important fact is the lack of evidences regarding the effects of competition on marten´s occupancy (see Fig. 14 for occupancy estimates). Although Barrientos & Virgós (2006) reported the exclusive use of some key resources and sequential use of shared resources by martens and genets in order to reduce overall competition for food resources, we did not find any influence of genet trapping success in marten occupancy. In fact, these two species presented the most similar occupancy models, revealing a preference for similar landscapes.

GENET

The model averaging results for genet indicated that occupancy was driven by a complex conjugation of factors that included HABITAT, LANDSCAPE and FOOD covariates. Genet occupancy rates seem to be higher in areas where habitat types Pyr. forests and Med. scrubland are present in a patchy structure, where landscape diversity is high and small mammals are more abundant. These habitat types are important to genets because they provide shelter and food resources, such as small mammals, which are particularly abundant and constitute the major prey type for this species (Virgós et al., 1999). With respect to shelter, these forests offer tree cavities located high above ground, which can be used as dens. Parturition and early maternal care occur mostly in this type of cavities and so, the availability of secure dens is particularly important to increase cub survival and breeding success. This species presented a occupancy geographic distribution similar to that observed for stone martens (Fig. 14), which is translated by similar ecological requirements.

EGYPTIAN MONGOOSE

The model results for mongoose indicated that occupancy was affected by areas covered by Den. scrubland habitats. These results show the preference of this species for a rather homogeneous landscape, where vegetation thickness plays an important role. Palomares & Delibes (1990) demonstrated that mongooses prefer dense patches of vegetation and practically never use bare open areas. Patch size was an excellent predictor of mongoose occupancy. This association between patch size and occurrence has largely been shown for different carnivoran species (Virgós et al., 2002) and may be explained by large patches being able to maintain high-density populations of the species (Fahrig & Merriam, 1994) that should be less prone to extinction (Pimm et al., 1988).

Our study was conducted under specific conditions that differ from most of the potential study areas in Portugal. The human activity factor is almost absent since the area is far from human settlements, and hunting has been forbidden for more than 20 years. Therefore, extrapolating these results to other areas should be done with caution. Serra da Malcata is one of the few areas in Portugal with relatively contiguous autochthonous forest habitats. Biodiversity in this area is high and the conservation of carnivoran species should be taken into account. It is fundamental to preserve and expand habitat types such as Pyr. forests and Med. scrubland. These typical vegetation formations of the Mediterranean region are a reservoir of several unique species (Mangas et al., 2008) and its conservation should be considered a priority in the context of the Nature Reserve management.

In our study, the apparent lack of correlation between carnivore and rabbit distribution is noteworthy. Although rabbits constitute of the most important prey species in the Iberian Peninsula (Calvete, 2006), it seems that carnivorans distribution is more related with other feeding resources. In fact, the general low density of rabbits could be insufficient to shape the predators use of space.

Methodologically, we demonstrated the importance of modelling detection probabilities for species with low or variable detection rates. This is quite visible for species such as stone martens and mongooses, for which we observed a difference of 8 and 7% between naïve site occupancy and average model estimates. In the future, monitoring programs could benefit from incorporating estimates of detection probabilities into their design and analysis because of the potential differences in site occupancy estimates when detectability is considered, as previously emphasized by Smith et al. (2007). Our study could also be used as a precursor of future large scale monitoring efforts, using occupancy for estimating the status of carnivore populations, particularly by adding environmental variables that can shape occupancy patterns.

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“..E o Vale, o rio e as três cabras continuam, e irão continuar lá em baixo, acima de tudo, por cima de todos. Nós é que não.”
João Paulo Sotto Mayor. O vale das três cabras

Chapter 8

General discussion and conclusions

THE ADVANTAGES OF CAMERA TRAPPING

Camera trapping is being used for wildlife studies since the early XXth century (Chapman, 1927), but in the last 20 years or so, camera traps have become more accessible and much more inexpensive (Rowcliffe & Carbone, 2008). As a result, they become a conventional instrument in conservation and ecology, with uses ranging from species inventories (Silveiraet al., 2003; Kauffman et al., 2008, conservation assessments (Silver, et al., 2004), the discovery of new species (Rovero, et al., 2008), abundance estimation (Azlan & Sharma, 2003), and population dynamics (Karanth et al., 2006). This sudden increase in the use of camera traps is reflected in 50% annual growth over the past decade in the number of published papers that either directly address camera trapping methods or use them as a research tool (Rowcliffe & Carbone, 2008) (Fig. 15).

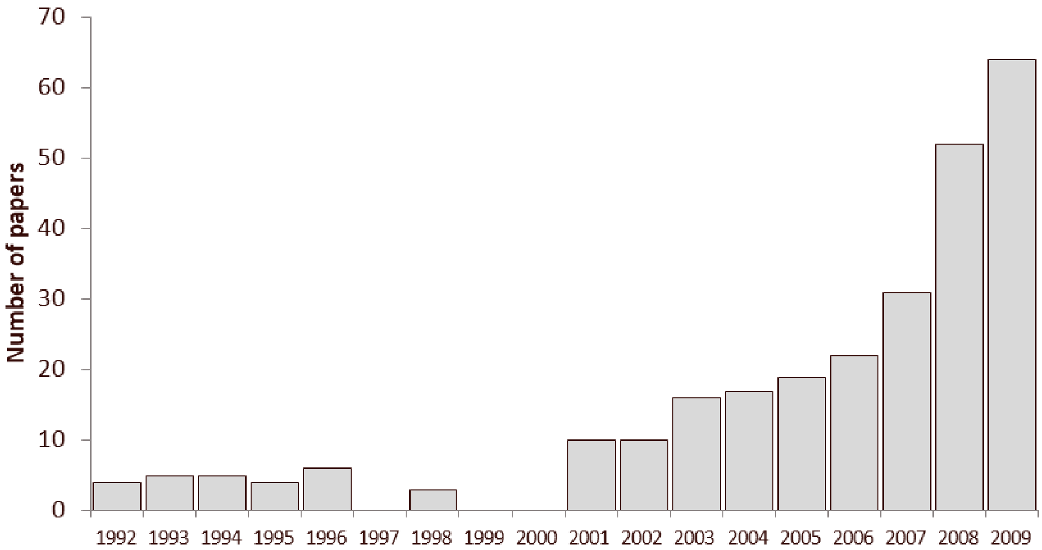

Fig. 15. Annual publications investigating or using camera trapping methods, extracted by Web of Science topic search on 'camera trap' (adapted from Rowclif & Carbone, 2008).

Camera trapping was the base-line method for the current thesis, and the advantages of this method were quite notorious. It was used for assessing fox and genet absolute density, for detecting dramatic changes in wildcat distribution and abundance, and to assess carnivore populations by estimating detection probability and site occupancy. The method was low-cost and easy to apply, and allowed to obtain a significant amount of information. In future studies the generalized use of camera-trapping, with adequate statistical models, can produce critical knowledge for diagnosis about population status, which is the base for more efficient conservation practices, particularly in protected areas.

Finally, the current increase of camera traps applications and methodologies, is leading to a massive spreading out in the number of areas where camera traps are used in Portugal. This is generating a significant amount of information that have never been completely analysed. Considering this remarkable but uncoordinated expansion in camera trapping studies, there is enormous future potential, but also a need for greater integration and consensus. Particularly one useful step would be a national data structure for camera trapping studies, such as those that are happening in some other areas of ecological research.

THE IMPORTANTE OF SERRA DA MALCATA FOR CARNIVORE CONSERVATION

As demonstrated by this thesis, Malcata could be one of the most important areas in Portugal for conserving carnivores. This fact is sustained by the following reasons:

1. In 80% of the area hunting was prohibited in the mid 1970s and so species have a higher degree of protection than in other areas;
2. Human disturbance is extremely low. There are no villages inside the reserve and no permanent residents;
3. Most of the area still presents a significant coverage of important habitats for conserving carnivores, particularly Mediterranean woodlands and Pyrenean oak forests (Fig. 16);
4. The conservation projects specifically direct for Iberian lynx, that were applied in the last 15 years, made a substantiall contribute for recovering habitas and preys increasing carrying capacity for carnivores (Sarmento et al.,2003);
5. Carnivores are monitored in this area since 1991 (Abreu, 1991), and so extensive knowledge is available.

In the contex of carnivore conservation is fundamental to apply the specific recommendations of the Malcata Management Plan (Sarmento, 2005):

1. To develop and apply a monitoring methodology in order to detect if the population is decreasing, increasing or stable. Such estimates are vital to measure the success or failure of management strategies;
2. To protect and increase the area covered by priority habitats for carnivores;
3. To continue the management strategy for increasing habitat suitability and prey density for the Iberian lynx (Sarmento et al.,2003)(Fig. 17);
4. To support scientific research related to carnivores particularly in topics such as habitat selection, diseases and population dynamics;
5. To develop a specific conservation strategy for wildcat.

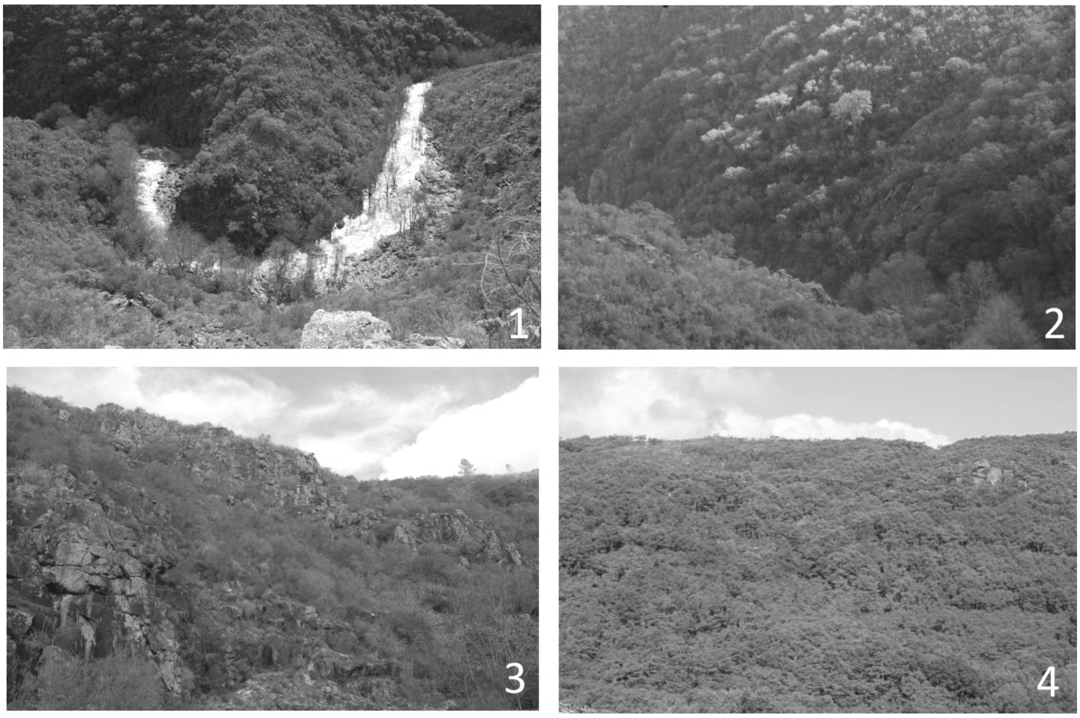

FIG. 16. Critical habitats for carnivore conservation in Serra da Malcata. 1), 2) and 3) Mediterranean woodlands of south and central Malcata; 4) Pyrenean oak forest of the northern range.

FIG. 17. Example of management actions (opening pasture lands in scrubland areas) conducted in Serra da Malcata for increasing prey species densities.

THE IMPORTANCE OF SYSTEMATIC MONITORING CARNIVORES IN PROTECTED AREAS: MALCATA HAS A FORERUNNER

Documentation and monitoring of biological diversity will be a leading conservation challenge in the 21st century (Wilson, 1992). However, in the Portuguese context of nature conservation, monitoring programs, particularly for carnivores, are not a priority. Carnivore species are nocturnal, cryptic, and elusive, which makes them difficult to inventory or monitor (Hoffmann, 1996). As a group, carnivores are characterized by wide differences in body size, morphology, and life history strategies that often require species-specific sampling methods (Jones et al., 1996). However, carnivores often play essential roles in the functioning of ecosystems: carnivores can influence prey species that, in turn, can have a cascading effect on other system components (Crooks & Soule, 1999). Indeed, much remains to be learned about how carnivores function in different environments, especially in human-dominated landscapes (Andre, 1994; Crooks 2002).

One of the major objectives of this thesis was to use simple and efficient field and analysis methods for monitoring carnivores as a precursor to establishing long-term multispecies monitoring programs in areas relevant for conservation. In order to fully apply the National Conservation Strategy for Biodiversity monitorization should be considered a vital element. The monitoring process should ideally contribute to the scientific advice for the application of conservation actions; and provide alerts to those responsible for undertaking such actions. This is a basic approach for managing protected areas, places were conservation should be a priority and were knowledge on key species is critical for the decision making process. The Management Plan for Serra da Malcata Nature Reserve (Sarmento, 2005), by establishing priorities in terms of research and monitoring, proposes a global assessment of carnivore species in a 5-year interval. In fact the plan refers the necessity of:

1. *Developing monitoring schemes to take account of threats and impacts on biodiversity.*
2. *Developing thresholds for conservation action in relation to species, population and habitat change.*

Based on the specific conservation objectives for Serra da Malcata, three general objectives for monitoring of terrestrial animals were defined (Holthausen et al., 2005):

1. *Improve the knowledge of the effects of ongoing management activities on priority species;*
2. *Provide a more complete understanding of species and system dynamics in order to facilitate adaptive management;*
3. *Improve the knowledge of the status of a broad array of species and the ecological conditions that support them.*

Using these objectives, and also the experience obtained with this thesis, four primary monitoring questions for carnivore species and their associated habitats were constructed. These questions are broad-spectrum in nature, but are practical for resource management in the Nature Reserve, and could be used in the future for managing carnivores and other species:

1. **Are conservation objectives being achieved for species and associated habitats with outcomes expected in plans?** This question is directed to species and associated habitats that are identified as being of priority conservation in the Malcata Management Plan, and for which specific outcomes are settled (e.g. wildcat). These outcomes may be quite general (e.g., the diversity of carnivore species) or very specific (e.g., increase in 20% the wildcat population).
2. **Are species and associated habitats responding to specific management activities and the effects of those activities as anticipated in plans?** As with question 1, this question is directed at those species and habitats, which are identified as being of concern or interest in the Management Plan, and for which specific outcomes are stated or implied.
3. **What are the status and trends of species of concern and interest for which there are not specific anticipated outcomes in the Management plan?** This question addresses species that are identified to be of concern or interest, but for which no specific outcomes are stated. These might include species that can negatively affect conservation plans (e.g. red fox as disease transmitter to Iberian lynx), and some species that are noted to be of special interest but are not the subject of individual outcomes (e.g. genet as an indicator of authoctones forests conservation).
4. **What are the mechanisms affecting species responses to changes in ecological conditions?** This question looks at actual mechanisms that by altering habitats can have a profound effect on carnivorans status. As an example, we could ask what effects of changes in land use have on reproductive and/or survival rates of a species. This is quite important in the context of the Nature Reserve and the surrounding Natura 2000 area, since the important changes in land use are occuring, particularly the constant decline of Pyrenean oak forests.

In this context monitoring should contribute to our understanding of the dynamics of targets species and of how management practices may be altered to improve the prospects of the population of interest. In resume, an optimal and professional management of the Nature Reserve demands a well structured monitoring scheme that should be applied in regular time intervals (Fig. 18).

Currently the monitoring programs for terrestrial wildlife and habitats in protected areas do not offer all the information essential for adaptive management, and to make this situation even worst the vast majority of the areas doesn´t have a monitoring routine or even adaptative management. Inadequacies in monitoring programs are long-standing, the subsequent problems with monitoring programs are well-known:

1. Conservation responsibles see monitoring as another new program which will necessitate more funds, more time, and more people and resources which are already allocated to other tasks;

2. Monitoring requirements frequently are not based on well-estalish objectives, do not concentrate on key management questions or do not address key issues;
3. There is no motivation for doing monitoring, and little or no apparent risk for not doing it;
4. Monitoring is not recognized as an integral part of nature conservation;
5. There is a lack of interdisciplinary approach in monitoring activities resulting in duplication of efforts and redundant or inconsistent data (Holthausen, et al., 2005).
6. Monitoring techniques, and methodologies can vary extensively resulting in contradictory conclusions;
7. Effective teamwork within ICNB and with other agencies, partners and public is not evident;
8. Appropriate scientific methods frequently are not used.

There are clearly no quick or simple paths to implement an effective monitoring routine in protected areas, and it takes a major commitment to it improve. Using the considerable experience of SMNR in terms of monitoring terrestrial animals and also the results of the current thesis, the following list of recommendations was elaborated for improving the monitoring process in protected areas:

1. Implement a National monitoring strategy that integrate habitat and population monitoring;
2. Ensure that all monitoring contributes to adaptive management by exploring both the causes for trends and alternative scenarios that could reverse unfavorable trends (Holthausen et al., 2005);
3. Use ecological principles and risk assessment to prioritize and design monitoring activities;
4. Provide adequate staffing, skills, and funding structures to accomplish monitoring objectives;
5. Use partnerships and interagency coordination to accomplish monitoring objectives;
6. Create national data bases with open access;
7. Implement in all protected areas monitoring programs with well establish objectives, methods and key results fundamental for adaptative management;
8. Ensure that individuals and teams responsible for monitoring have appropriate skills.

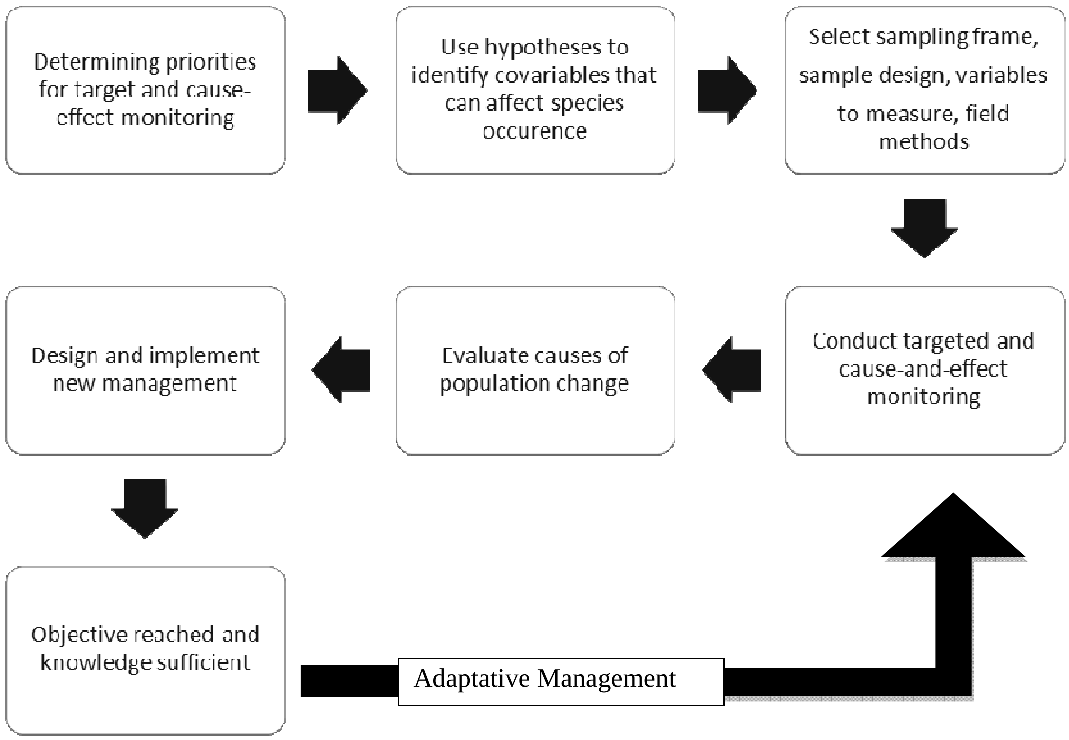

FIG. 18. Proposed monitoring scheme for carnivores in Serra da Malcata Nature Reserve (adapted from Holthausen et al., 2005).

Following these recommendations would allow ICNB, in conjunction with partners and collaborators, to identify appropriate monitoring questions and designs for natural resources and collect data needed for adaptive management over the long-term. We cannot make sensible plans about biodiversity conservation until we know how many species we have, and where they are. Despite considerable efforst for some groups (e.g. National Atlas for breeding birds), in the absence of a national monitoring scheme, in general we do not know these basic facts. Clearly, is time for a radical agenda for landscape level conservation of carnivores, and other wildlife too.

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GLOSSARY

Biodiversity hotspot. A biogeographic region with a significant reservoir of biodiversity that is under threat from humans (Myers, 1988)

Conservation biology. The scientific study of the nature and status of Earth's biodiversity with the aim of protecting species, their habitats, and ecosystems from excessive rates of extinction. It is an interdisciplinary subject drawing on sciences, economics, and the practice of natural resource management (Wilcox et al., 1980).

Flagship species. A species chosen to represent an environmental cause, such as an ecosystem in need of conservation. These species are chosen for their vulnerability, attractiveness or distinctiveness in order to engender support and acknowledgment from the public at large. Thus, the concept of a flagship species holds that by giving publicity to a few key species, the support given to those species will successfully leverage conservation of entire ecosystems and all species contained therein (Cunninghan and Cunningham, 2009).

Habitat. An ecological or environmental area that is inhabited by a particular species of animal, plant or other type of organism. It is the natural environment in which an organism lives, or the physical environment that surrounds (influences and is utilized by) a species population (Abercrombie et al., 1966).

Home range. The area where an animal lives and travels in. It is closely related to, but not identical with, the concept of "territory". Associated with the concept of a home range is the concept of a utilization distribution, which takes the form of a two dimensional probability density function that represents the probability of finding an animal in a defined area within its home range (Burt, 1943).

Indicator species. An indicator species is any biological species that defines a trait or characteristic of the environment. For example, a species may delineate an ecoregion or indicate an environmental condition such as a disease outbreak, pollution, species competition or climate change. Indicator species can be among the most sensitive species in a region, and sometimes act as an early warning to monitoring biologists (Reed, 1990).

Keystone species. A keystone species is a species that has a disproportionate effect on its environment relative to its biomass. Such species affect many other organisms in an ecosystem and help to determine the types and numbers of various other species in a community (Payne, 1995).

Mediterranean scrubland. The vegetation characteristic of the Mediterranean-Iberoatlantic phyto-geographic super-province, which occupies most of the western half of the Iberian Peninsula. The outstanding components are holm oaks (*Quercus rotundifolia*), cork oaks (*Quercus suber*) among trees, *Phillyrea spp., Arbutus unedo, Pistacia lentiscus* among the shrubs, and some *Cistaceae, Erica* spp., *Rhamnus spp.* among the scrubs (Delibes et al., 2000).

Natura 2000 network. Natura 2000 is an ecological network of protected areas in the territory of the European Union. In May 1992, governments of the European Union adopted legislation designed to protect the most seriously threatened habitats and species across Europe. This legislation is called the Habitats Directive and complements the Birds Directive adopted in 1979. These two Directives are the basis of the creation of the Natura 2000 network.

Umbrella species. Species selected for making conservation related decisions, typically because protecting these species indirectly protects the many other species that make up the ecological community of its habitat (Roberge & Angelstam, 2004).

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Stat rosa pristina nomine, nomina nuda tenemus