Universidade de Aveiro Departamento de Biologia
2014

Tamira Íris Vandenbussche Leandro Cruz

Roe deer reintroduction in central Portugal: pre-release phase

Reintrodução do corço no centro de Portugal: fase de viabilidade

DECLARAÇÃO

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Aplicada, no ramo de Ecologia, Biodiversidade e Gestão de Ecossistemas, realizada sob a orientação científica do Doutor Carlos Manuel Martins Santos Fonseca, Professor auxiliar com agregação do Departamento de Biologia da Universidade de Aveiro e coorientação da Doutora Rita Maria Tinoco da Silva Torres, investigadora de Pós-Doutoramento do Centro de Estudos do Ambiente e do Mar, da Universidade de Aveiro.

Aos meus avós, Beatriz e David.

o júri

presidente

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agradecimentos

Ao meu orientador Professor Carlos Fonseca, pela confiança depositada que permitiu que eu fizesse parte do projecto e de outros, e pela concretização da tese, apesar das dificuldades impostas pela vida.

À minha co-orientadora Rita Torres, pela partilha de conhecimentos, amizade, apoio e trabalho nas diferentes etapas do Mestrado, principalmente pela ajuda na estruturação e espírito-crítico ao longo da escrita e revisão da tese.

Ao Gonçalo Brotas, Lígia Mendes e Cindy Loureiro, da Associação de Conservação do Habitat do Lobo Ibérico, pelas oportunidades dadas e pelo belo passeio até terras de “nuestros hermanos”.

À minha família, pelo apoio incondicional ao longo de toda a vida académica e pessoal. Pelo carinho, amizade, amor e paciência eternos: avó Beatriz, avô David, mãe, pai, Zé, tio David, Bela e Vicente. Sem vós nada disto seria possível e não fazia sentido. Aos tios-avós Olga e Alcino, por todo o apoio e preocupação sempre demonstrados. À D. Lurdes, por toda a hospitalidade, apoio e animação cruciais nesta fase.

Ao Bruno, a quem devo agradecer mais que ninguém só por me aturar há tanto tempo. Por ser o pilar que (quase) tudo sustenta e apoia, principalmente quando tudo correu mal. Por partilhar e sobreviver comigo a momentos únicos e incondicionais dos nossos mestrados e das nossas vidas, meu melhor amigo e parceiro de aventuras! Por todas as desavenças que nos fizeram crescer. Por em mim depositar a confiança, paciência e o amor que me levaram até aqui. (Sem ti não sei se tinha chegado até ao fim. Obrigada!)

À Gabriela, “Queen Gabe”, por ser minha a irmã querida e reinar com estilo e esplendor. Por ser tão benevolente e paciente e sorrir constante e incontrolavelmente. Por, apesar de eu ser uma “criatura”, gostar de mim e preocupar-se tanto comigo ao longo da vida e do Mestrado.

À Lucília Ferreiro, pela constante preocupação e enorme amizade, que perduram e nunca esmoreceram há já 20 anos. Pela disponibilidade e apoio nos momentos difíceis, crucial nesta etapa académica.

À Carla Pereira, que apesar de ter estado longe estes três anos sempre foi um dos meus pilares, com uma grande amizade, carinho, enormes sorrisos, abraços e ajuda na tese, sempre pronta para dar. Por me entender só com um olhar. Por estar comigo em episódios nossos, tão importantes! Por ser fofa e continuar a dizer que é normal.

Ao João Carvalho, pela incrível disponibilidade para tudo e também ajuda no campo. Pela amizade e momentos de riso constantes. Pelo apoio e preocupação ao longo de todo o Mestrado. Pela ajuda nos raciocínios e explicações delirantes e na análise e tratamento de dados, sem ele esta tese estaria muito mais pobre.

Aos meus amigos e colegas de curso Sara Marques e Eduardo Mendes, pela amizade, disponibilidade e preciosa ajuda no trabalho de campo. Pelos nossos encontros para “tertúlias de desafogos”, belos jantares, concertos e noites de diversão. Ao Tony Fernandes, David Miguéis, Ana Margarida Borges e Ana Macedo pela amizade, apoio e belos jantares e noites em grupo.

Ao Joaquim Pedro Ferreira, por toda a ajuda prestada ao longo do Mestrado e pelos conhecimentos transmitidos sobre fotografia e vídeo. Pela amizade, apoio e boa disposição sempre presentes.

Ao João Santos e à Tânia Barros, que apesar de mais distantes estiveram sempre presentes. Pela ajuda e preocupação sempre demonstradas. Pela partilha artística e musical, crucial em determinados momentos. Pela amizade crescente e importante.

Às minhas queridas “Mulheres” bailarinas e ao Claudinei, pelas noites de pirataria, licores e bolaria. Pela força, alegria, energia e união em momentos únicos, essencial para manter o espírito leve e animado durante todo o Mestrado e durante a escrita da tese.

palavras-chave

Reintrodução, corço, lobo-Ibérico, Portugal, modelação de habitat, conservação, gestão

resumo

A reintrodução de espécies é cada vez mais uma parte importante dos programas de recuperação de espécies e das iniciativas de restauração de *habitats* a nível mundial. Apesar de o corço (*Capreolus capreolus*) ter sido reintroduzido em Portugal no passado, com uma identificação *a priori* dos locais adequados para a reintrodução, o sucesso deste projeto pode melhorar em grande parte. Este estudo é focado na primeira fase do processo de reintrodução – a fase de viabilidade –, onde a área de estudo (Serras da Freita, Arada e Montemuro) foi caracterizada e avaliada em termos de adequabilidade, de forma a implementar o processo de reintrodução e definir núcleos de reintrodução no centro de Portugal. Para isso, foram utilizados modelos empíricos e de conhecimento especializado (Analytical Hierarchy Process acoplado com GIS), e foram identificados três núcleos de reintrodução adequados para a ocorrência de corço e para a sua futura expansão natural (Manuscrito I). As variáveis utilizadas no modelo incluíram: uso de solo, rede hidrográfica, rede de estradas, áreas urbanas, e o relevo. De seguida, foi implementado um modelo de uso de habitat preditivo simples (GLM) à escala da Península Ibérica, onde a presença e a ausência de dados foram usados na análise. O modelo foi baseado em variáveis climáticas, topográficas, de perturbação humana e de estrutura de habitat. Neste estudo, o modelo foi utilizado para prever a distribuição e extensão atual do habitat que seria adequado para a reintrodução do corço (Manuscrito II). O modelo final do GLM foi muito preciso, revelando um poder discriminatório elevado. A ocorrência e distribuição do corço estava intimamente relacionada com a distância a áreas de perturbação, corpos de água, matos, manchas florestais e fatores topográficos. Os resultados são discutidos numa perspetiva ecológica, destacando a relevância de previsões precisas na conservação e gestão da espécie. As metodologias utilizadas no Manuscrito I (AHP) e II (GLM) foram escolhidas porque são comumente usadas, facilmente replicadas, e relativamente intuitivas de entender. Isto é de especial relevância na comunicação de resultados a proprietários privados, que serão fundamentais para a gestão das populações de corço. Por fim, as metas e ações futuras são discutidas em relação à promoção das condições ecológicas e sociais que sustentam a sobrevivência do corço e do lobo-Ibérico no centro de Portugal. Este estudo demonstra que a reintrodução do corço no centro de Portugal é viável e que a área de estudo tem condições ecológicas e ambientais adequadas para o sucesso do projeto de reintrodução. Numa perspetiva mais ampla, este estudo pode também contribuir para a conservação do lobo-Ibérico e, assim, para a restauração dos ecossistemas no centro de Portugal.

keywords

Reintroduction, roe deer, Iberian wolf, habitat modelling, conservation, management

abstract

Species reintroduction is increasingly becoming an important part of species recovery programs and habitat restoration initiatives worldwide. Roe deer (*Capreolus capreolus*) have been reintroduced to Portugal in the past, but the *a priori* identification of suitable sites for reintroduction can greatly improve the success of such programmes. This study is focused on the first phase of the reintroduction process - the viability phase -, where our study area (Freita, Arada and Montemuro mountains) was characterized and evaluated in terms of suitability to implement the reintroduction process and define reintroduction nuclei in central Portugal. For this, we have used empirical models and expert knowledge (Analytical Hierarchy Process coupled with GIS), and we have identified three reintroduction nuclei suitable for roe deer occurrence and future natural expansion (Manuscript I). The variables used in the model included land use, hydrographic network, asphalted roads, population/villages, and relief. Then, we implemented a simple predictive habitat-use model (GLM) at the Iberian Peninsula scale, where both presence and absence data was used. The model was based on climatic, topographic and environmental variables. Here the model was used to predict the current extent of roe deer habitat that would be suitable for roe deer reintroduction (Manuscript II). GLM model was very accurate, showing a high discriminatory power. Roe deer occurrence and distribution was closely related with distance to perturbation areas, water bodies, shrubs, forest patches and topographic factors. The results are discussed from an ecological perspective, highlighting the relevance of accurate predictions in roe deer conservation and management. The methodologies used in Manuscript I (AHP) and II (GLM) were chosen because they are commonly used, easily replicated, and relatively intuitive to understand. This is especially important in communicating the results to private landowners who will be critical to the management of roe deer. Finally, future goals and actions are discussed in relation to the promotion of the ecological and social conditions that would support the survival of roe deer and Iberian wolf in central Portugal. Our study shows that reintroducing roe deer in central Portugal is feasible and the study area has ecological and environmental suitable conditions for the success of the reintroduction project. In a wider perspective, this study can also contribute to the Iberian wolf conservation and, therefore, to central Portugal ecosystem restoration.

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CHAPTER I

Introduction

1. INTRODUCTION

1.1. Background of the thesis

Human activities have caused degradation of the habitats and ecosystem services and ultimately contributed to the loss of biodiversity. In this scenario, species reintroduction is increasingly becoming an important part of species recovery programs and habitat restoration initiatives worldwide (Armstrong and Seddon 2008). As a valuable tool in wildlife management, nowadays animal reintroductions have three primary aims: i) to solve human–animal conflicts, ii) to restock game populations, and iii) conservation proposes (Fischer and Lindenmayer 2000). In general terms, reintroductions try to re-establish and/or support, in suitable habitats, extinct populations or ones in which the effective population is low. Reintroduction is a complex process and is particularly problematic and contentious in the case of large mammals, whose social, economic and ecological impacts – both perceived and real – are complex and often contradictory. Therefore, reintroduction programs are difficult processes and require a long-term compromise of all institutions involved to be successful.

In order to increase reintroduction programs success, the International Union for Conservation of Nature (IUCN) has published *Reintroduction Guidelines* (IUCN 1998) and more recently *Guidelines for Reintroductions and Other Conservation Translocations* (IUCN/SSC 2013) to provide guidance in reintroduction programs that are globally accepted, although are not a legal obligation. These guidelines may increase the success rate of reintroduction programs and prevent inappropriate reintroductions and their adverse effects.

Although a native species in Portugal and with a restricted distribution area in some core populations in the north of the country, in the past four decades, the abundance and distribution of the roe deer (*Capreolus capreolus*) has increased. This species plays an important ecological role as a key-element of the Iberian wolf's (*Canis lupus signatus*) diet and in vegetation composition and dynamics. The Iberian wolf is classified as an Endangered species in Portugal (Cabral et al. 2005) which has been suffering a dramatic decrease in its numbers and distribution, particularly during the 20th century (Bessa-Gomes and Petrucci-Fonseca 2003, Cabral et al. 2005).

Large wild preys, such as roe deer, are very low in central Portugal in areas inhabited by wolf. This work is based on the premise that the natural prey of the wolf is a major missing element in the species' ecology. The importance of increasing Iberian wolf's wild prey to ease human-predator conflicts has been suggested by several studies (Cuesta et al. 1991, Meriggi and Lovari 1996, Vos 2000, Barja 2009, Meriggi et al. 2011) since it might enable an increase in the diversity of food available, reduce wolf attacks on livestock and, as a result, reduce wildlife-human conflicts.

In order to increase the success of a reintroduction program, it is essential to understand the factors that affect roe deer distribution, and thus assess the suitable release areas that overlap roe deer ecological requirements. The use of Geographical Information Systems (GIS) as a complement to the study allows a strong, multi-criteria method that offers the possibility of analysing large geographical data sets, therefore being of a huge applicability in identifying potential reintroduction sites. Species distribution models (SDMs) are recognised as extremely effective tools providing valuable and quantitative information by displaying the most important conditions and resources required by the individuals in a given spatial context (Guisan and Thuiller 2005). Consequently, habitat suitability models are important tools in conservation planning and game management (Pearce and Ferrier 2000). The combined use of population modelling and GIS have been widely used in assessing landscape suitability for different species (*e.g.* Cianfrani et al. (2013); Doswald et al. (2007); Nolet and Baveco (1996), Macdonald et al. (2000); Olsson and Rogers (2009); Pearce and Lindenmayer (1998); South et al. (2000); Telesco et al. (2007); Thatcher et al. (2006)).

This study examines the relationship between habitat requirements of roe deer and the interaction between environmental factors, which may influence the success of the reintroduction of this species in central Portugal. This thesis will be focused on the first phase of the reintroduction process, the viability phase, where the area will be characterized and evaluated in terms of suitability to implement the reintroduction process (based on suitability criteria for roe deer) and define reintroduction nuclei.

1.2. Reintroductions: a tool for species and ecosystem recovery

The reintroduction of a species allows i) the re-establishment of populations long-extinct in a certain place and/or ii) the reinforcement of a weakened effective population. It can enhance the long-term survival of a species by establishing additional viable populations or bolstering existing populations. However, the ultimate goal of reintroduction projects should be not just to conserve the reintroduced species, but also to restore the diversity

and functioning of the ecosystem, promoting its stability and correct functioning, recreating opportunities and conditions so far lost – ecosystem restoration (Macdonald et al. 2000).
The first step in any reintroduction program, is to seek and understand the main reason for the species extinction or decrease in the study area (Gurnell et al. 2008). Regarding all the possible impacts that reintroducing a species on an ecosystem can have, reintroduction process should be made with extreme rigor and based in a strong scientific component (Hodder and Bullock 1997), and an assessment of the study area to fulfil the species ecological requirements is fundamental. This might be accomplished by creating habitat suitability models, which can be generated through a conceptual approach, and which rely on knowledge of the species ecological requirements (Dettki et al. 2003, Yamada et al. 2003, Rüger et al. 2005), or from population data and the correlation between the occurrence of the species and environmental variables (gathered in the field or derived by GIS) that can influence the distribution of the species (Hirzel et al. 2002, Carter et al. 2006).

As mentioned before, reintroduction programs are complex procedures that require many important choices and all this choices may affect the outcome of the program (Fischer and Lindenmayer 2000, Jule et al. 2008). There are essentially five important steps/decisions which need to be considered before releasing the animals into the wild: a) the origin of the source animals (Jule et al. 2008); b) the number of animals to be released (Komers and Curman 2000, Deredec and Courchamp 2007); c) the age and sex structure of the released group (Saltz et al. 2000, Sarrazin and Legendre 2000); d) the location of the release site (Seddon and Ismail 2002); and e) when to stop the reintroduction program.

In order to increase the success of reintroduction, the International Union for Conservation of Nature (IUCN) published the "*Guidelines for Reintroductions and Other Conservation Translocations"*, a set of standard criteria for reintroduction programs, which are agreed and recognized internationally. According to them, **reintroduction** is an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct by natural or anthropic factors.

The reintroduction projects are based in three phases: i) the pre-reintroduction phase or the viability phase; ii) the release phase and the iii) the post-reintroduction phase. In this thesis, I will only focus on the pre-reintroduction phase.

1.2.1. Reintroductions outcome

The outcome (*e.g.* success, failure) of the majority of the reintroduction initiatives are generally overestimated as most authors may be more likely to publish their results if they are able to report a "success" (Fischer and Lindenmayer 2000). This fact, combined with the large number of "uncertain" results obtained from extensive assessments of the literature, makes it difficult to draw deductions about the importance of reintroductions as a conservation tool.

According to these authors, there is a range of factors influencing reintroduction success. These can be ecological, such as: i) habitat quality (Burgman and Lindenmayer 1998); ii) genetics (Jimenez et al. 1994, Pray et al. 1994); iii) or competition (Burgman and Lindenmayer 1998). In addition, a number of non-ecological factors may affect reintroduction success, including: i) public relations and education (Maguire and Servheen 1992, Reading and Kellert 1993); ii) good team management (Clark and Westrum 1989); iii) social factors (Reading et al. 1997); iv) legal considerations and litigation costs (Morris 1986, Minckley 1995); and v) long-term commitment to the reintroduction project (Rahbek 1993).

The effectiveness of reintroductions, both ecologically and as a persuasive tool for conservation purposes, could be enhanced through a more uniform and rigorous methodology in the design and in reporting the success of the reintroductions. According to Fischer and Lindenmayer (2000), two important examples of such approaches can be: i) a clearer definition of success; and ii) the publication of results. The creation of a sustainable self-sustaining population is a key measure of success from an ecological viewpoint, however, some authors assumed a reintroduction as successful if the initial signs of ecological success were observed (Fischer and Lindenmayer 2000). However, the time-scale over which reintroductions prove to be successful is important, since even if initially the population can show signs of success then the population can decline. Therefore, such programs should include a long-term monitoring period. Furthermore, the majority of the literature about reintroductions is not generally accessible to wildlife managers and conservation biologists (Fischer and Lindenmayer 2000). It is necessary to have a more complete documentation of past experiences in the generally accessible literature (Stanley Price 1991, Minckley 1995), so that future wildlife managers can learn from past mistakes and feedback on the feasibility, preparation and introduction methods used previously can be provided, in order to avoid its future extinction (Fischer and Lindenmayer 2000).

One of the most notorious reintroduction projects in the conservation history is the reintroduction of the gray wolves to Yellowstone National Park (YNP) in the 20th century. After 70 years of wolf absence, gray wolves were restored to YNP in 1995-1996 with the release of 31 wolves captured in western Canada (Bangs and Fritts 1996). Since then a lot of research on trophic cascades has been done to analyse the effects of this predator on the ecosystem (Ripple and Beschta 2003). Several studies indicate that wolf reintroduction in YNP allowed the species and, consequently, the ecosystem recovery over time, arguing that wolf reintroductions had several large scale effects: i) it acted as management measure needed to help understanding trophic dynamics and spatially variable plant community growth patterns (Ripple and Beschta 2007) and to insure the restoration of riparian species and preservation of biodiversity (Ripple and Beschta 2003, 2006); ii) the predation risk that reintroducing wolf may bring, may have deep effects on ecosystems structure and is a key component of innate biodiversity (Ripple and Beschta 2004); iii) wolf also act as a climate change buffer, illustrating the importance of restoring and maintaining unbroken food chains when faced with large-scale environmental perturbations (Wilmers and Getz 2005); and iv) wolves can change seasonal elk distribution and habitat selection, demonstrating its importance in re-establishing ecosystem processes (Mao et al. 2005).

Another example of a reintroduction project was the roe deer reintroduction in Israel and Jordan in the Ramat Hanadiv Park, on Mount Carmel near Zichron Yaacov (Lovari et al. 2008). The first release of six females and two males took place in February 1997, a second release of a male and a female took place in March 1998, and a third release of four animals was completed in 1999. However there is incomplete information on the success of this project, so this reintroduction is not yet marked on the distribution maps. Another example of roe deer reintroduction was in a dry Mediterranean region in Israel, providing an opportunity to study the bottleneck effect of water requirements on a mesic-adapted species (Wallach et al. 2007). The results indicated that in a dry Mediterranean environment, availability of free water is both a physiological constraint and a behavioural constraint for roe deer, demonstrating the importance of physiological and behavioural feasibility studies for reintroduction programs.

In the Mediterranean habitats of Spain, France and Italy, some reintroductions have also already been performed (Gerard et al. 1997, Perco et al. 1997, Maillard et al. 1999, Calenge et al. 2005). Particularly in the Iberian Peninsula, the purpose of the reintroductions was to increase the numbers of the species and thus contribute to its recovery or, for instance, to link roe deer populations between protected areas (Rosell et al. 1996). Particularly in Portugal, roe deer populations located south of the Douro River result from reintroductions, which aimed to increase the density of the species for hunting purposes (south) or as a natural prey for the endangered Iberian wolf populations (central) (Mattioli et al. 1995, Vingada et al. 1997). In central (namely *Lousã* moutain, *São Macário* mount and *Gardunha* mountains) and south of Portugal, reintroductions were performed with animals translocated from Chizé and Trois-Fontane (France), Spain and a few animals from the well-known and growing nuclei north of the Douro river, northeast of Portugal (Vingada et al. 2010).

1.3. Roe deer reintroduction in central Portugal: pre-release activities

The Wildlife Research Unit, from Biology Department & CESAM (Aveiro University) has been developed, since 2011, the project "Roe deer reintroduction in central Portugal", which main goal is to plan and implement a successful reintroduction plan for the roe deer in Freita, Arada and Montemuro mountains. The project is based on the premise that the reintroduction of roe deer in selected areas of the distribution area of the Iberian wolf would foster the availability of wild prey and its consequent predation, reducing predation on domestic prey, which is the main cause for wolf-man conflicts in the area. The reintroduction will therefore help the Iberian wolf populations' recovery and, consequently, play a key role in the ecological restoration of Freita, Arada and Montemuro mountains ecosystems. The primary objective of the first phase of the project (Figure 1.1) was to characterize and evaluate the areas of the Freita, Arada and Montemuro mountains in terms of suitability for the reintroduction project implementation (based on criteria of suitability of the roe deer) and define reintroduction sites. With the definition of the main areas with potential for the reintroduction of the roe deer, it will be possible to implement management actions to achieve the proposed objectives and, above all, make an important contribution to the conservation of the roe deer and, consequently, the Iberian wolf in Portugal.

Nowadays, the roe deer is one of the most widely distributed mammals in Europe, living in almost all its natural habitats (Andersen et al. 1998, Machado 2007) and in fact the key for its success is its ecological and behavioural plasticity. Its distribution currently ranges from the Mediterranean scrublands of Portugal, on the southwest of its distributional range, to the boreal forests of central Norway, on the northwest of its distributional range (Apollonio et al. 2010). The increased distribution and geographical range of this species in the last four decades is the result of socio-economic changes (*e.g.* rural exodus with consequent vegetation re-naturalization), and a general lack of predators associated with protectionist policy, adopted by the countries of Central and Eastern Europe since the mid 1960's (Danilkin and Hewison 1996).

In Portugal, roe deer is located on the edge of its south-western distribution range (Holt and Keitt 2005) and is considered a species with a Least Concern (LC) conservation status. In the 80’s, roe deer populations have suffered a large decrease and its expansion was very limited, mainly due to the mismanagement of their populations, habitat fragmentation and illegal hunting (Cabral et al. 1987). However, in the past decades, roe deer distribution and density have increased (Vingada et al. 2010), mainly due to changes in land-use practices and rural exodus, which has led to the re-naturalization of the habitats, but also due to stricter hunting and management policies. Nevertheless, in Portugal, comparing to central and northern Europe populations and despite this population increase, roe deer densities have remained low (Vingada et al. 2010).

Roe deer populations are native of the north of the country, north of the Douro River, and have always persisted in a few patches. Their natural populations are confined to the north of the Douro River, particularly in the *Peneda, Soajo, Gerês, Amarela, Cabreira, Marão, Alvão, Montesinho, Coroa* and *Nogueira* mountains (Mathias et al. 1999, Ferreira 2002, Salazar 2009, Vingada et al. 2010).The populations that currently inhabit in the south of the Douro river, are the result of reintroduction programs performed during the 90’s but the populations on the border are mostly the result of roe deer natural dispersion from Spanish populations (Salazar 2009). The reintroductions that were done in central Portugal aimed not only to return to this area the original ungulate distribution but also to contribute for the conservation of the Iberian wolf (Salazar 2009). The reintroductions performed in the south of Portugal were due to hunting purposes and were mainly in closed hunting grounds (Vingada et al. 2010). In Portugal, roe deer is listed as a game species and can be hunted by different hunting processes (*e.g.* sit and wait hunting, stalking, battue, drive hunting and spear hunting) according to management hunting plans. However, due to its low abundance and the lack of monitoring in most places (between 3,000 and 5,000 animals throughout all Portugal, according to Vingada et al. (2010), roe deer hunting is still very residual.

The principal effort in planning a reintroduction should be the desired performance of the species in terms of its population performance, behaviour and/or its ecological roles after reintroduction (IUCN/SSC 2013). Therefore and first of all, a **feasibility study and background research** (IUCN 1998, IUCN/SSC 2013) should be made of the taxonomic status of individuals to be reintroduced. Feasibility assessment should cover the full range of relevant biological and non-biological factors (IUCN/SSC 2013). An investigation of historical information about the loss and fate of individuals from the reintroduction area, as well as molecular genetic studies, should be undertaken in case of doubt as to individuals' taxonomic status. Detailed studies should be made of the status and biology of wild populations including its biotic and abiotic habitat needs, its interspecific relationships and critical dependencies (*e.g.* descriptions of habitat preferences, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases). Overall, a firm knowledge of the natural history of the species in question is crucial to the entire reintroduction scheme.

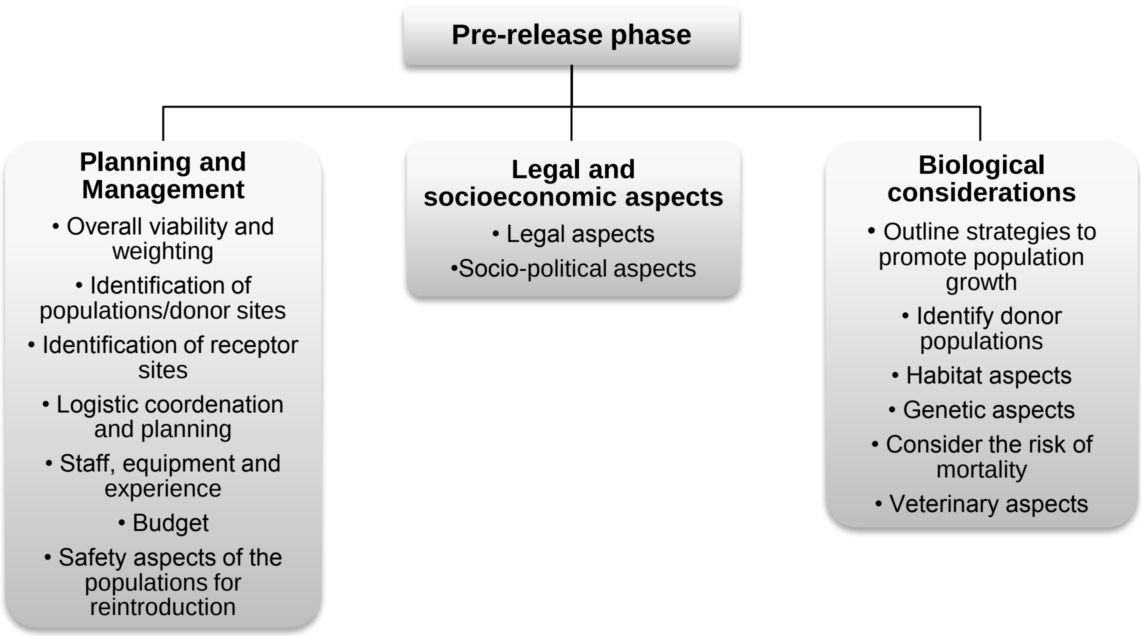


Figure 1.1: Structure of the guidelines for the pre-reintroduction phase (adapted from Torres et al. (2012a)).

During and prior to the development of the reintroduction project, thorough research should be conducted regarding **previous reintroductions** of the same or similar species and wide-ranging contacts with people who have relevant expertise in the area.

In our study area, roe deer have already been reintroduced at *São Macário* mount, in São Pedro do Sul, Viseu (Vingada et al. 1997). This reintroduction process did not aim to conserve the species *per se*, but was based on the premise of creating a stable population in order to promote the conservation of the Iberian wolf. On January 10, 1997, at *São Macário* mount (Arada mountain) ten animals were released: four adult males (two with telemetry collars), a juvenile male, three adult females (two with telemetry collars) and two juvenile females. Of the four animals marked with telemetry collars it was only possible to locate three of them, one male and two females. However, after a certain period of time the location of the animals was lost and their fate became uncertain, therefore, and once again, there was no rigorous tool to measure the success of the reintroduction.

The **choice of the release site** (IUCN 1998, IUCN/SSC 2013) is also an important factor when considering a reintroduction. The release site should be within the historic range of the species. The reintroduction area should assure long-term protection (whether formal or otherwise). Furthermore, it should be made an **evaluation of the release site** (IUCN 1998, IUCN/SSC 2013), and reintroductions should only take place, ideally, when all the ecological requirements of the species (*e.g.* habitat, food availability) are present, and can be maintained in the future. To analyse the viability of the reintroduction, a previous study should be done to assess if the reintroduction sites have the ecological characteristics needed to fulfil the species ecological requirements. There should be an identification and elimination, or reduction to a sufficient level of the previous causes of decline (*e.g.* disease; over-hunting; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programs; and competition with domestic livestock). In addition, habitat suitability should include assurance that the release of organisms, and their subsequent movements, is compatible with permitted land-uses in the affected areas.

The **source population** (IUCN 1998, IUCN/SSC 2013) should come from a population as close as wild as possible. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics (*e.g.* morphology, physiology, behaviour, and habitat preference) to the original sub-population. In Portugal, on May 8, 2001, the Ministry for Agricultural, Rural and Fishing Development approved the Decree n. º 466/2001 which identifies the cinegetic species/subspecies with which is allowed to make reintroductions and establishes particular standards to roe deer reintroductions, in order to protect the genetic similarity between the origin and receptor populations (Salazar 2009). This Decree states that north of Portugal reintroductions with animals from other sources are not allowed.

According to Lovari et al. (2008), the main threat to roe deer in Europe is the increased mixing of various genetic stocks as a result of translocations. This may be a particular threat to genetically distinct peripheral populations, such as those in northern Portugal (Randi et al. 2004, Lorenzini and Lovari 2006). According to Lorenzini et al. (2002) and Lovari et al. (2008), to protect remnant and genetically distinct peripheral populations in Portugal, the following measures should be taken in place: i) conduct research to determine the genetic structure of the roe deer; ii) map extant populations of the roe deer, with indications of their distinct genetic; iii) prohibit translocations of roe deer from northern stocks to central and southern Portugal, and *vice versa*; iv) facilitate the expansion of remaining populations by reducing poaching and eliminating feral dogs; and v) establish a reintroduction plan for central/south Portugal. As it was unknown the genetic structure of roe deer in Portugal, and according to the Decree conservative directions, based on Randi et al. (2004) it was initiated a study to characterize the Portuguese roe deer genetic structure (Torres et al. 2013b), whose results will soon be published.

A crucial part of such project, and that can never be excluded from the assessment of the reintroduction program are the **socio-economic requirements** (IUCN 1998). Reintroduction projects are generally long-term projects and so it is necessary to ensure financial and political support in the long term. Socio-economic studies should be conducted to assess the impacts, costs and benefits of the reintroduction program in local populations. It is necessary to have a thorough and detailed assessment of the attitudes of the local population in relation to the proposed project (Annex X), to ensure protection in the long term of the reintroduced population, especially if the cause of the species' decline was related to human factors (*e.g.* poaching). The program should be fully understood, accepted and supported by local communities, particularly by rural landowners and hunters.

1.3.1. Choosing potential reintroduction sites for roe deer

1.3.1.1. Factors affecting roe deer distribution

Roe deer ecology has been widely studied however most of these studies come mainly from northern and central Europe ecosystems (Apollonio et al. 2010). In southern Europe its ecology is relatively unknown despite its huge importance since it's located it is its western geographical distribution limit. In Mediterranean habitats, due to specific ecological requirements, the process of colonization by a species may be delayed (Acevedo et al. 2005). For example in Spain, Gortázar et al. (2000) described that, in general, the Mediterranean environments of the Iberian Mountains have low densities of roe deer in contrast to higher densities in the more Atlantic environments in the north, in the Pyrenean Mountains. That probably happens because in the Pyrenean Mountains roe deer has better opportunities to expand, where other competing wild ungulates are rare, and where habitat availability offers more chances (Virgós and Tellería 1998, Acevedo et al. 2005).

Climatic and ecological factors and human activity are limiting factors that have been described and which affect species distribution and dispersal process. In particular, climatic factors influence roe deer distribution, density and, thus, its dispersal (Aragón et al. 1995, Latham et al. 1997). Therefore, in the same way, in the Iberian Peninsula the hot and dry summer could a limiting factor for the species.

In order to select favourable areas for a successful roe deer reintroduction, it is necessary to carry out a prior and correct assessment of the habitat characteristics where the reintroduction of the animals is intended. Such an analysis should focus on a thorough and careful review of all the ecological requirements necessary for the existence and survival of roe deer. Similarly, it is important to keep in mind throughout the process, that the reintroduction of roe deer in these areas has the main objective of promoting wild prey for a sub-fragile Iberian wolf population south of the Douro river.

Therefore, selection criteria should be taken into account, such as: i) food availability – selecting areas with diverse habitat as well as provide food, cover and water; and areas with patches of deciduous and mixed forests with a developed understory, where small gaps occur and in proximity to water lines; ii) habitat/refuge – selecting areas that provide coverage both horizontally (protection from predators) and vertical (protection against adverse weather conditions) to the roe deer; and iii) tranquillity/minimal human disturbance – selecting areas with low human disturbance (*e.g.* away from main roads and urban areas).

Habitat | Refuge

Habitat can be evaluated with regard to both cover and feeding quality (Jepsen and Topping 2004). There are direct (food, refuge and water) and indirect soil factors (soil's moisture, fertility and stoniness), subjected to spatial and temporal variation, which can influence habitat use (Rueda et al. 2008). Roe deer has an high ecological plasticity and populations are heavily affected by abiotic (Acevedo et al. 2005) and biotic (Focardi et al. 2006) factors. This species uses a wide variety of environments preferably occupying mosaic habitats, characterized by the presence of wooded areas with herbaceous or shrub layer, where vegetation is characterized by an interchange of open areas and forests, with a variable density and height (Linnell et al. 1998), alternating with cultivated fields, both in mountain and in lowland zones (Andersen et al. 1998, Stubbe 1999). Such areas are characterized by having a high density of transition habitat (ecotone) between open areas, which they use for feeding and refuge (Saïd and Servanty 2005). However, typically, it is considered an animal of deciduous woods, being found in oak, broadleaf and mixed forests, which offer shelter, food and tranquillity. Therefore, roe deer distribution can be directed influenced by the arrangement of the varied patches of the landscape pattern (Torres 2011). In many parts of central and northern Europe, roe deer are linked with human modified landscapes and with the presence of agricultural fields, largely determined by the great diversity and abundance of food items associated with these areas (showing perhaps an opportunistic behaviour (Oliveira and Carmo 2000)), often using the ecotone between forests and agricultural areas (Andrén 1994, Panzacchi et al. 2009).

In the Iberian Peninsula, roe deer occurs in the woods and scrublands of the Mediterranean ecosystem (Blanco 1998, Mathias et al. 1999), completely different from the well-studied populations of central and northern Europe (Carvalho et al. 2008). In regions under Mediterranean climate, food and water availability are subjected to spatial and temporal variations and habitat selection needs to be interpreted within a seasonal context (Rueda et al. 2008). In the Mediterranean, in low population densities, it is expected that non-dependent density factors can model population's dynamics. Climatic conditions, for instance, namely rainfall, can act as limiting factor, since roe deer depends on primary production (Aragón et al. 1995). Also, habitat use in winter and summer can be related to topographical and soil cover features (Palmer and Truscott 2003).

According to Torres et al. (2011), roe deer distribution in Portugal is positively associated with areas of high density of shrubs, especially *Erica* sp. and thorny shrubs. Furthermore, the presence of the red deer (*Cervus elaphus*) has a negative effect on its distribution. At a broader scale, the distribution of the species is negatively associated with spatial heterogeneity and positively associated with distance to agricultural fields. Additionally, the roe deer uses areas away from areas with human disturbance (roads and settlements).

In a dry Mediterranean environment, availability of water is a physiological and a behavioural constraint for roe deer (Wallach et al. 2007). Therefore, the distance to water sources is a factor that should also be taken into account, when analysing the habitat use by roe deer. Usually, in south Europe (in forests and xeric shrublands) the limiting factors are related with hot and dry seasons (Virgós and Tellería 1998). Since the time of birth, lactation and reproduction in roe deer occur during the summer (Sempéré et al. 1998), the lack on water sources can create several limitations to this species survival. Thereby, the habitat/refuge for the roe deer can be assessed not only from the land use data, but also from the proximity to favourable habitats for refuge and distance to water sources. It is a key factor for roe deer distribution, and on the assessment of the presence of suitable habitats that provide food, shelter and tranquillity for the species and therefore should be assessed in any habitat suitability study.

Predation – Recovery plans for large carnivores such as the Iberian wolf should take into account the environmental productivity when predicting their impact on prey (Melis et al. 2009). Studies carried out on a local scale showed that the percentage of predation on roe deer is inversely dependent on the density: higher at lower prey densities (Jedrzejewska and Jedrzejewski 1998). In several studies it was observed that in less productive environments there was a higher limitation by predation. Changes in environmental productivity caused by climate change can lead to changes in roe deer abundance. The discussion around recovering large predators should take into account the fact that the expected effect on roe deer numbers depends on the environmental productivity. According to Melis et al. (2009), in the most productive areas, limitation can reach 20 to 40% less of population density which is free of predators. In less productive areas, the impact of the predator can reach a level considered by managers as devastating to local roe deer populations.

Furthermore, predation is expected to have a great effect in marginal populations comparing to other locations closer to their central distribution (Hoffmann and Blows

1994). However, the factors that shape roe deer distribution in the mosaic Mediterranean landscapes are not well known (Torres et al. 2011). There is still a debate focusing on the extent of predation as a limiting factor, and on whether predation works in a controlling density-dependent method on ungulate populations (Aanes et al. 1998).

Roe deer is one of the most wide distributed ungulates and often occur at high densities, which imply that this species is the most abundant and widespread of all potential ungulate prey for large carnivores in Europe (Okarma 1995). For example for the wolf, the availability of wild prey like roe deer is likely to be crucial for their successful conservation in Europe, and most of the areas that wolves are recolonizing (mainly in western and southern Europe) will support higher populations of roe deer, especially in the more fragmented, human-dominated landscapes (Aanes et al. 1998). An example of how roe deer is important for predator recover comes from Norway, where lynx (*Lynx lynx*) were found in areas with higher roe deer densities even though those correspond to areas with higher human presence as well (Basille et al. 2009).

Roe deer reintroduction has started in several areas in Europe and should be encouraged in predator recovery areas (Boitani 1992), such as Freita, Arada and Montemuro mountains, in central Portugal. However, predator recovery in Europe is expected to be restricted by social acceptance of wolf attacks on domestic livestock rather than habitat availability (Linnell et al. 1996).

The roe deer plays a key role in the food chain in which it is inserted, constituting one of the natural prey of endangered predators such as the Iberian wolf and the Iberian lynx (*Lynx pardinus*) (Cabral et al. 2005). In the Iberian Peninsula, the Iberian wolf is considered his greatest predator in areas where they co-inhabit, because apparently the roe deer only integrates the fox (*Vulpes vulpes*) diet by necrophagy and fawns predation. However, feral dogs (*Canis lupus familiaris*) are considered as their probable direct predators. The fawns, although hard to detect, are easy and sensible preys to any predator attack in general, like the fox, feral dogs and the golden-eagle *Aquila chrysaetos* (Cabral et al. 2005).

Food availability

Roe deer is a ruminant herbivore and as a small species it requires more energy per unit body weight (20-30 Kg), therefore can only satisfy its requirements on food of relatively high quality compared to large herbivores (Duncan et al. 1998). Their tolerance to secondary metabolites (*e.g.* tannins, a well-known mechanism against herbivory) allows roe deer to use food resources not usually eaten by potential competitors like other ungulate species (wild and domestic) (Duncan et al. 1998).

The roe deer has a broad food spectrum, consuming a large variety of species, from which takes all its tissues (Blanco 1998, Faria 1999, Carvalho 2007): flowers, fruits, seeds, leaves, arks, stems and roots (Duncan et al. 1998). The positive preference of roe deer for patches rich in shrubs is probably linked to the quality of the site, since there is a greater opportunity to select better food among a greater number of plant species (Torres et al. 2011). Roe deer is a concentrate selector, using high selective feeding strategies, allowing it to maintain high energy requirements and high parental investment (Tixier et al. 1997, Blanco 1998, Carvalho 2007). Roe deer is considered generalist but at any other time they can also be highly selective (Duncan et al. 1998). It is considered a browser preferably by feeding on small portions of several shrubs like *Rubus* spp., *Pterospartum tridentatum*, *Erica* sp. and sprouts of broadleaf trees like *Castanea sativa*, *Fraxinus angustifolia* and several oak *Quercu*s spp. species, namely the young parts with high nutritional value (Tixier and Duncan 1996) .

Habitat and, to a lesser extent, season, are the main causes of differences on roe deer food resources (Tixier and Duncan 1996), implying that availability is a key determinant of roe deer diet (Duncan et al. 1998). Cornelis et al. (1999) showed that there is relatively little seasonal variation in roe deer diet composition, which is more closely correlated to the habitat than to the season. However, other studies showed that the diet of the roe deer varies also with seasons, switching of food items according to their availability (Duncan et al. 1998, Faria 1999). Winter is the limiting time in the diet of herbivores, and their feeding spectrum decreases, showing less and varied food due to a natural decrease in the availability of vegetation. This usually causes a decrease in the number of items present in the diet and in the consumption of leaves and *Erica* sp., which have a low nutritional value (Faria 1999). However, pine needles are also available and constitute an important source of protein, water, sugars and minerals. In spring, where food availability is high, most plants are available, having green leaves, sprouts and flowers, and some also fruits. At this time, the availability of the plants is not a limiting factor to the roe deer diet. According to Verheyden et al. (2011) faecal nitrogen broadly follows seasonal and spatial variations of food quality at the population level, with higher values in spring, and in individuals living in an area with richer food resources when compared to those in forests. Summers in Mediterranean ecosystems are hot and dry, therefore productivity is more restricted, with lower availability of food resources, which is also reflected in the reduction of food resources in the ground layer (Blondel and Aronson

1995). However, in this time there is an increase in the availability of fleshy fruits, which are important water and sugars sources. At the end of this time, the first nuts begin to appear, including acorns and chestnuts. Therefore, there is a reduction in the quality of the vegetative parts of the plants but, on the other hand, there is an increase in the availability of fruits. In autumn, most plants have dry leaves, although there are still some plants with green leaves (*e.g. Rubus* sp.). At this time the availability of vegetative parts of the plants is reduced in terms of quality, but is offset by the availability of dried fruits rich in starch and minerals, which are an important source of energy. According to Faria (1999), throughout the year at *Lousã* mountain and *Montesinho* Natural Park, the most consumed items by roe deer were young leaves and sprouts of *Rubus* spp., *Castanea sativa, Pterospartum tridentatum* and several oak *Quercu*s spp. species. The presence of leaves and sprouts of the genus *Quercus* sp. in the roe deer diet is very important, mainly due to the high content of nitrogen compounds, which are responsible for the huge attractiveness and consequent consumption (Maizeret et al. 1991). Species like *Calluna vulgaris*, *Erica* sp., *Erica australis*, *Erica arborea*, *Ulex minor*, *Ulex europaeus* and L*onicera periclymenum*, although less important, constituted a small part of the diet. There were also some traces of *Fraxinus angustifolia*, *Acacia melanoxylon*, grass, *Pinus* sp. and some pteridophytes. The presence of water/moisture is the major determinant of primary productivity in Mediterranean habitats (Blondel and Aronson 1995, Virgós and Tellería 1998), therefore are essential elements in roe deer diet and habitat, essentially obtaining water from the consumed plants (Danilkin and Hewison 1996, Faria 1999). Beyond that, and mostly in other European ecosystems, roe deer can also consume berries and fruits, chestnuts, acorns, cherries, strawberries, blackberries, blueberries, raspberries, cranberries and sometimes fungi, particularly mushrooms (Mathias et al. 1999). In many places in Europe, cereals of agricultural when invades, for example, agricultural fields, consuming beet *Beta vulgaris, Brassica napus*, *Medicago sativa* and mice *Zea mays* (Duncan et al. 1998, Hewison et al. 2001, San José 2002).

Form that, we can see that food availability is a key factor for roe deer distribution and on the assessment of the presence of suitable habitats that provide food for the species, and therefore should be inferred according to the land use in any habitat suitability study.

Disturbance

Like many other wild ungulates roe deer show cryptic behaviour and usually fear human presence (Hewison et al. 2001) which, when sensed, most frequently leads to escape

(Danilkin and Hewison 1996). Thus, as a shy and sensitive species to human disturbance, roe deer proximity to roads and human activities (*e.g.* urban areas; settlements) are important factors that influence roe deer habitat use (Torres et al. 2011, Torres et al. 2012b).

Proximity to roads and to human activities – Through fragmentation, roads can affect the quality and quantity of available habitats for wildlife. Therefore low road density is a key criterion of habitat security since roads increase vehicle collision mortality, which, in certain cases, can have significant effects on animal populations. In fact, death by collision with vehicles is widely recognized as a major cause of non-natural mortality for the roe deer (Bruinderink and Hazebroek 1996, Glista et al. 2009).

Therefore, as relevant disturbance variables, the following sub-variables should be used in a habitat suitability analysis: distances to: i) paved roads (*e.g.* highways, municipal roads) and ii) settlements; and iii) population density.

Death by capture (intentional or not) in traps, loops and/or through illegal hunting has been a cause of unnatural death of this ungulate. For this reason, this should be a sub-variable to be taken into account. However, given the difficulty of obtaining such data, that sub-variable could not be used in this study.

1.3.1.2. Factors affecting human acceptance

Ownership of the land

A large part of the land where the intention is to implement management measures, including the reintroduction of roe deer, is wastelands (*baldios*). Therefore, a great deal of time and effort must be devoted promoting the awareness, sensitizing and explaining local populations regarding the project in order to get them involved in an attempt to assume a partner role in this process, thus supporting its success.

Natura 2000 network areas

The study area includes the Natura 2000 network classified areas *Serras da Freita and Arada* (PTCON0047) and *Serra de Montemuro* (PTCON0025) sites. Thus, the planned actions should take into account their respective management plans. The management entity of these classified areas – the Institute for Nature and Forestry Conservation – is a partner in this project, and should take on an important role in the communication and dissemination of such actions, in line with ACHLI (Iberian wolf Habitat Conservation Association), which is also involved.

Game planning and management

Much of the implementation area of this project is a hunted area with different regimes. Thus, to ensure the success of the process it is essential to immediately proceed to the integration of all hunting area management entities involved. Therefore, it should i) increase the awareness of hunters and their local representatives to the exceptionality of this process and of the gains it could bring in terms of nature conservation and enhancement of natural heritage; ii) promote a game species that could be exploited in the long term, according to certain scientifically and technically supported rules; and iii) increase alertness during the reintroduction process and the following period, in order to reduce the possibility of illegal hunting.

1.3.1.3. Factors affecting habitat connectivity

The connectivity of a landscape is the degree to which a landscape enables or inhibits movement among resource patches, reflecting which landscape features are used preferentially and which are avoided (Coulon et al. 2008). It is determined by landscape features, but also by the movement skills and characteristics of the animals. The definition of population borders are therefore influenced by the way resource patches are connected to each other, and by individual’s movements within a landscape (Bowne and Bowers 2004). A reduced connectivity due to habitat fragmentation is expected to be a big threat for species survival (Lindenmayer and Possingham 1996), and is particularly true for species with highly specific habitat requirements and limited dispersal skills (Fahrig 1998).

Data on the dispersal behaviour of roe deer, and especially in Portugal – particularly via radio collar tracking – is scarce, so research often relies on expert knowledge and the presence or absence of roe deer in habitat areas in order to deduce favourable dispersal corridors. According to roe deer ecology, this species should avoid buildings and roads, move preferentially along valley bottoms and through the more wooded areas of the landscape, as a general rule and also during dispersal. Nevertheless, Coulon et al. (2008) results in south-western France suggested that they tend to avoid valley bottoms and possibly the more wooded areas. Furthermore, the avoidance of potential sources of disturbance may be a key factor in determining ranging behaviour of roe deer in human dominated landscapes. Coulon et al. (2004) suggested that in a fragmented woodland area roe deer dispersal is strongly linked to wooded structures and therefore gene flow within the roe deer population is influenced by the landscape's connectivity. Therefore, mainly three key factors affect corridor suitability – habitat, refuge and disturbance. Thus, cost to itinerant roe deer is dependent primarily on land cover (tree cover is preferable), terrain (steep slopes, wide rivers and lakes are circumvented), and human absence. Roads and urban landscapes present considerable barriers and hugely increase the mortality rate of dispersers.

1.3.1.4. Habitat suitability modelling

Reintroducing a species to an ecosystem generally has possible impacts that need to be evaluated *a priori* based on a rigorous scientific component (Hodder and Bullock 1997). The first steps of a reintroduction program should be part of the evaluation to explore potential short-term consequences of management plans and assess long-term viability (Seddon et al. 2007). That might be achieved by generating habitat suitability models, which can be created through a theoretical approach, and depend on the knowledge of the species ecological requirements (Dettki et al. 2003, Yamada et al. 2003, Rüger et al. 2005). Basically, habitat suitability models resume the conceptual knowledge of the habitat association of the species, based on several sources of information through the description of important environmental variables (Storch 2002). The combined use of population modelling and GIS have been widely used in several studies with the aim to assess landscape suitability for different species (Nolet and Baveco 1996, Pearce and Lindenmayer 1998, Macdonald et al. 2000, South et al. 2000, Thatcher et al. 2006, Doswald et al. 2007, Telesco et al. 2007, Olsson and Rogers 2009, Cianfrani et al. 2013).
In this thesis two analytical approaches (Manuscripts I and II) were performed. In the first approach it was applied an Analytical Hierarchy Process (AHP) coupled with GIS to develop a habitat suitability model, allowing the integration of empirical models and expert knowledge. The AHP method is based on three fundamental steps: i) definition of the objectives and the variables that are going to be considered in the analysis; ii) developing a matrix of pairwise factors comparison using a given scale and iii) the final weights definition. The final result is a habitat suitability map and a Habitat Suitability Index (HSI),

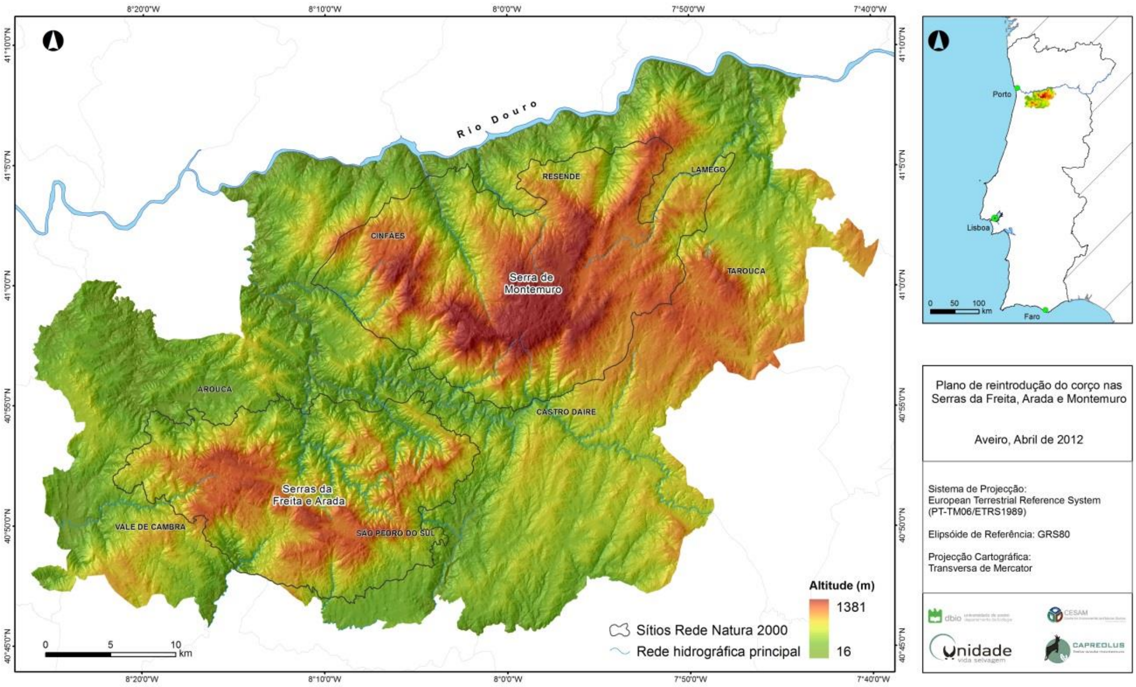
which quantitatively characterizes the capacity of an area to fulfil the ecological requirements of roe deer and is divided into three classes of suitability. In the second approach it was intended to develop an Iberian model for the species, exploring which is the suitability of the model to our study area. The model is able to show the suitability of our study area for roe deer, comparing with the environmental similarity of areas where the species now exists in the Iberian Peninsula.

1.3.1.5. Study area – Freita, Arada and Montemuro mountains

The continued destruction and degradation of natural habitats are a key priority concern in the environmental policy of the European Union (EU 2011). The main objective of the creation of Sites of Community Importance (SCI) is to ensure the conservation of classified habitats and prevent its damage, as well as significant disturbance of the species (EU 2011). Concerning the species, these are selected based on criteria that take into account: i) the representativeness of each one in a given site; ii) the size and density of a species population in a given site, in relation to its national quantitative; iii) the conservation status of the considered species on the site; and iv) the degree of isolation of a population in relation to its distribution area (EU 2011).

The study area (Figure 1.2) is inserted in two SCI from the list of sites defined in the Natura 2000 network Sectorial Plan, which are *Serra da Freita e Arada* (PTCON0047) and *Serra de Montemuro* (PTCON0025), being the latter also classified as a CORINE Biotope under the designation of *Serra de Montemuro/Bigorne*. The classification of these two places was based on the presence of a rich vertebrate community and in the existence of habitats and species with a high conservation value listed in the Annex I (Directive 92/43/CEE), among which the presence of the Iberian wolf population south of the Douro river stands out. Both are vital areas for the conservation of this subpopulation, which situation is very fragile due to its isolation and high fragmentation level. As such, it is important to ensure the maintenance of the communication of the individuals of this pack with the rest of the population. Between these two places, there is *Rio Paiva* (PTCON0059) site which is an important passing zone to the Iberian wolf, allowing the connection between the Freita, Arada and Montemuro mountains (west zone) packs and the Lapa, Trancoso and Leomil (east zone) packs.

In all the study area, the human population is dispersed through the valleys, in small villages with tens or a few hundred inhabitants, expressed by low population density (314 inhabitants/Km^2 (INE 2011)).



Fonte: Altimetria, Carta Militar de Portugal série M888. Carta Administrativa Oficial de Portugal (CAOP2011). Sistema Nacional de Informação de Recursos Hídricos (SNIRH).

Figure 1.2: Location of the study area in continental Portugal, with Natura 2000 network sites and altimetry (from Torres et al. (2012a)).

Freita and Arada

The Freita and Arada mountains (Figure 1.3) are characterized by being mid-mountain areas, with vigorous reliefs and rift zones, which together with the *Arestal* mountains comprise the *Gralheira* Massif, a region of medium altitudes (800 – 900m) and with steep slopes, reaching a maximum of 1102m in the central upland of Freita (ICN 2006b). These are areas are under the influence of the ocean, showing high levels of rainfall. They are located in the transition zone between the Atlantic and the Mediterranean biogeographical regions, being the repository of several rare species and in the limit of its distribution area (ICN 2006b). The *Paivô, Caima* and *Teixeira* rivers are some of the ones which constitute the hydrographic network of the zone.

In terms of flora and vegetation, the occurrence of permanent peat swamp communities and wet heaths assumes particular significance, since some of them are classified as priority habitats. Of equal importance are the woods dominated by the

English oak *Quercus robur* and/or the Pyrenean oak *Quercus pyrenaica* and the Holly *Ilex aquifolium*. Also worth mentioning are the *Ulex* sp. communities and the siliceous rocky slopes with chasmophytic vegetation (ICN 2006b). The shrub formations is the most common type of vegetation dominated by *Ulex* sp., the heather *Erica* sp. and the gorse *Pterospartum tridentatum*. In terms of dominant systems, the forest areas have bigger representativeness while there are few agricultural fields. The scrublands occupy more than half the area of the site and forest stands are dominated by Maritime pine *Pinus pinaster* and eucalyptus. In these areas, man still subsists on agriculture and pastoralism, with livestock cattle and small ruminants, and there is also some specialization in bovines for milk production. The wild boar *Sus scrofa* is present in the study area, another potential wild prey to the Iberian wolf.

Figure 1.3: Freita and Arada mountains landscape and vegetation cover.

Montemuro

The Montemuro area (Figure 1.4) is a mountainous region with steep slopes and medium altitudes (800 – 1000m), reaching the maximum at 1381m, although there are also extensive areas of high altitude plateaus (Vieira 2008). The SCI is dominated by the massif, whose platform is developed between 1200 and 1300m and belongs to the Mediterranean biogeographical region. The hydrographic network of the area is broad and rich, covering, for example, the *Paivô, Paiva, Bestança, Cabrum* and *Balsemão* rivers. It has areas in good condition, which maintain a high biological diversity, especially with regard to habitats. It has interesting peatlands and it is possible to observe important and well conserved *Quercus pyrenaica* stains (ICN 2006a). The territory is characterized by a predominantly forest use with a very significant representation of bushes. The shrub formations, from deforestation by human action (*e.g.* agriculture, grazing, fires), are the most common type of vegetation dominated by *Ulex* sp., heather *Erica* sp. and gorse. Therefore, the vegetation that characterizes these areas is essentially constituted by different types of scrublands, composed by: i) *Cytisus scoparius, Cytisus grandiflorus*; ii) *Ulex europaeus, Ulex minor, Ulex micranthus* and *Genista triacanthos*; and iii) *Erica australis, Erica arborea, Erica cinerea, Erica umbellate* and *Pterospartum tridentatum* (Paiva 2000). In the highest areas, where there is intensive and excessive grazing, herbaceous communities grow, where the *Nardus stricta* is dominant. There are also rocky communities, dominated by *Asplenium trichomanes* subs. *quadrivalens, Ceterach officinarum, Selaginella denticulata, Polypodium* spp. and *Chelanthes hispanica* (Paiva 2000). In some high parts of the mountain can exist small nuclei of *Betula alba* and some oaks. It is also noteworthy, as a landscape unit of Montemuro mountains, the presence of *lameiros*. *Lameiros* are semi-natural meadows kept by humans to provide pasture for livestock, and are usually flanked by hedges, consisting of different tree species, like the Pyrenean oak and the Narrow-leafed Ash *Fraxinus angustifolia*. The slopes facing the south and southwest, and almost all the northwest sector, have great development of the arboreal stratum. Here it is possible to observe extensive patches of planted pine *Pinus pinaster*, in pure stands or mixed with eucalyptus. There also still occur stains of indigenous vegetation, composed by *Quercus robur, Quercus pyrenaica* and also by considerable patches of *Castanea sativa*. In the agricultural use, the extensive livestock of native cattle and small ruminants predominates, with extensive use of vacant land. In this region, the agricultural practices are fully consistent with hostile terrain (steep slopes) and climate conditions, and there is a tendency to neglect. The wild boar *Sus scrofa* is also present in the study area.

Figure 1.4: Montemuro mountains landscape and vegetation cover.

1.3.2. General and specific aims

1.3.2.1. Motivation behind roe deer reintroduction

From an ecological point of view, roe deer plays an important role in the ecosystem function. This species plays a fundamental role in vegetation composition, structure and dynamics, from which it feeds, and plays another essential role as a seed disperser, contributing to the spread and colonization of wild plant species (Couvreur et al. 2004, Cabral et al. 2005, Carvalho 2007).

Although it is known some negative impacts of roe deer herbivory, namely damage to forestry in northern and central Europe (Cederlund et al. 1998), the impact of roe deer on vegetation might be minimized by the high diversity of plant species consumed. At low or medium densities can even promote the increase of the total biomass of vegetation, in the medium-long term, since while consuming only small part of plants, these are not permanently damaged and can thus be used for several times (Danilkin and Hewison 1996). In addition, this species is extremely important from the standpoint of conservation, constituting one of the natural preys of some European top predators, as the wolf, and particularly the Iberian wolf in Portugal (Cabral et al. 2005).

The grey wolf (*Canis lupus*) once inhabited a wide variety of habitats throughout most of the northern hemisphere (North American continent, Eurasia and Japan) (Mech and Boitani 2010). However, due to competition with humans for wild prey and feeding on livestock, by the end of the 19th century, the species was exterminated from all central and northern European countries and apparently only survived in the southern peninsulas (Iberia, Italy and the Balkans) and in eastern regions (Blanco et al. 1992, Boitani 2000). However, environmental awareness in the late 1960s brought for the wolf legal protection and together with socio-economic changes in agricultural areas (*e.g.* decrease of human density and subsequent increase of wild ungulates densities and distribution – Apollonio et al. (2010)), increased research, and favourable media coverage (Mech 1995), lead to an increase in wolf population numbers and distribution ranges in several European countries.

In Portugal, the subspecies *Canis lupus signatus* is considered an Endangered (EN) subspecies (Cabral et al. 2005) where its numbers and distribution also decreased radically during the 20th century (Bessa-Gomes and Petrucci-Fonseca 2003, Cabral et al. 2005) until it was legally protected in 1988 (Grilo et al. 2002). Presently, the Iberian wolf occurs in approximately 20% of its original range and its distribution has been greatly reduced through a combination of direct human persecution (*e.g.* killed illegally by shooting, poison or snares), deforestation and the loss of wild ungulate prey (Petrucci-Fonseca 1990, Bessa-Gomes and Petrucci-Fonseca 2003). The Iberian wolf populations in Portugal have retreated (Petrucci-Fonseca 1990) and have been decreasing (Grilo et al. 2002) from south to north and west to east of Portugal. On the south of the Douro river, it still remains a small population with two isolated nuclei: Leomil, Lapa and Trancoso packs (on the east part) and the Arada, Cinfães and Montemuro packs (on the west part) (Roque et al. 2011, Torres et al. 2013a).

According to the last Iberian wolf National Census, in 2002/03 (Pimenta et al. 2005), the subpopulation inhabiting south of the Douro river is composed by a reduced number of breeding groups, with no more than 9 packs (6 confirmed and 3 probable). In central Portugal, the Freita, Arada and Montemuro mountains, home between 30 to 50% of the actual subpopulation that occurs south of the Douro river (Pimenta et al. 2005). This subpopulation has a high level of fragmentation, low genetic diversity and is apparently isolated from the remaining Iberian population (Grilo et al. 2002, Pimenta et al. 2005, Godinho et al. 2007), highlighting its Endangered conservation status. In addition, its diet is highly dependent on the presence of domestic ungulates, which builds up 75% of their diet (Grilo et al. 2002). This has generated a huge amount of persecution from man and the conflicts with humans in this area are one of the main conservation problems and can jeopardize wolf population existence in the area, promoting some local extinctions.

Large wild prey, such as roe deer, is scarce in these areas inhabited by wolf. It is evident that the natural prey of the wolf is a major missing element in the species' ecology. Several studies have demonstrated the importance of increasing the abundance of wild prey with the aim of providing a greater food supply for this predator (Cuesta et al. 1991, Meriggi and Lovari 1996, Vos 2000, Barja 2009, Meriggi et al. 2011), in order to sustain populations and to reduce their impact on livestock, thereby reducing the conflicts with humans (*e.g.* the increase in the distribution/density of roe deer in Spain has probably been of great importance in helping wolf population recovery (Blanco et al. 1992)). Therefore, the viability of this subpopulation is not only threatened by human persecution, habitat loss, fragmentation, but also with the decreasing of wild prey availability (Roque et al. 2011, Torres et al. 2013a). Furthermore, with the abandonment of the rural areas, with consequent decreasing of the livestock production, this food source might decrease in a close future risking wolf survival.

Based on the previous, the wolf's conservation in this region depends on practical actions such as increasing wild prey availability (Oliveira and Carmo 2000). Therefore, the reintroduction of roe deer in selected areas of Iberian wolf range would allow the wolf a choice of natural prey, and, politically, such measures would show that wolf conservation is a dynamic process and not merely a passive protection defence. For this purpose, the reintroduction of roe deer to the Freita Arada and Montemuro mountains would improve the productivity of the region by providing, in due course, a surplus of wolf wild prey.

1.3.2.2. Reintroduction program objectives

The main aim of this project is to propose a strategy for the successful reintroduction of roe deer on the Freita, Arada and Montemuro mountains through an intensive monitoring program, specifically in the **pre-release**, **release** and **post-release** phases. Thus, according to Torres et al. (2012a) the fundamental objectives are:

- ✓ **To establish of a self-sustained wild population (*e.g.* viable and reproductive) of roe deer in central Portugal (Freita, Arada and Montemuro**

mountains); According to IUCN guidelines, the reintroduction project is a scheme of three phases: pre-release to i) determine the habitat suitability of Freita, Arada and Montemuro mountains for the ecological requirements of the roe deer; and ii) select the source of the animals and release site; release, which includes selecting the date and time of the release and post-release, monitoring to assess the success of the reintroduction project. Thus, is necessary to understand the factors that affect these parameters in order to improve the methods of release and management of the reintroduced populations.

- ✓ **Assess the impact of the roe deer reintroduction project in the Freita, Arada and Montemuro mountains in the context of the Iberian Iberian wolf conservation.** The aim is to reinforce some lost ecological interactions, particularly interspecific interactions which are essential to the maintenance of ecological complexity (*e.g.* predator-prey) at a regional scale. As an umbrella species, the Iberian wolf plays an important role in the structure and shape of ecosystems. Thus, scientific data about their diet are essential to understand the reintroduction project. In the medium to long term, it should be evaluated how the reintroduction of the roe deer will affect the composition of the Iberian wolf diet.

Therefore, the general objectives of this project are:

i) To enable and maximize the probability of survival of roe deer in the medium-long term;
ii) To re-establish a population of key-species (in an ecological and cultural sense);
iii) To keep/recover the natural biodiversity;
iv) To promote nature conservation, namely species with relevance in terms of conservation status;
v) To provide long-term economic benefits to the local economy;
vi) To encourage changes in cultural attitudes towards the environment and its conservation;
vii) To promote people’s environmental awareness.

1.4. Objectives and structure of the thesis

Aiming for the conservation of the Iberian wolf habitat in the Freita, Arada and Montemuro mountains, this work is part of the reintroduction project (Torres et al. 2012a). This study tries to assess whether the Freita, Arada and Montemuro mountains provide suitable ecological environment for the reintroduction of roe deer. We aim to answer this question: **are there environmentally suitable areas for the roe deer at Freita, Arada and Montemuro mountains?**

Therefore, the main objectives of this thesis are:

i) To review and incorporate human and roe deer needs into a weighted, multi-criteria, habitat-suitability model;
ii) To identify suitable habitats and define reintroduction nuclei;
iii) To develop an habitat model at two spatial scales (Iberian Peninsula and central Portugal), exploring the suitability of the model to our study area;
iv) To assess potential implications for conservation and management of roe deer and Iberian wolf in central Portugal.

The following is an outline of this **thesis structure:**

- **Chapter I** is an introduction which delivers a review of literature, providing a research background essential to understand the thesis. This chapter aims to give a theoretical overview of reintroduction processes, the reintroduction project in central Portugal and the pre-release activities (choosing reintroduction sites; factors affecting roe deer distribution, human acceptance and habitat connectivity; habitat suitability modelling; study area). It also elucidates the project goals and motivations, and outlines the thesis objectives and structure.
- **Chapter II (Manuscript I)** identifies possible areas for roe deer reintroduction in the Freita, Arada and Montemuro mountains. Using empirical models and expert knowledge (Analytical Hierarchy Process coupled with GIS), we identified three reintroduction nuclei suitable for roe deer occurrence. Some future goals and actions are also assigned.
- **Chapter III (Manuscript II)** describes the potential distribution of roe deer in the Iberian Peninsula with the aim of seeking potentially reintroduction sites. Using one method to model the current distribution of roe deer in an edge ecosystem, the Iberian Peninsula, we assessed the predictive performance of a generalized statistical model. The GLM model showed a high discriminatory power. Roe deer

occurrence and distribution was closely related with distance to perturbation areas, water bodies, shrubs, forest patches and topographic factors. The results are discussed from an ecological perspective, highlighting the relevance of accurate predictions in roe deer conservation and management.

- **Chapter IV** summarizes the main results and conclusions and highlights the consequences and applications of these results, as well as the research approach, to the future conservation of roe deer, Iberian wolf and their habitat, while proposing some directions for future work.
- **Chapter V** contains all the references used in the making of this thesis.
- **Chapter VI** contains all the annexes.

The thesis is organized as a series of independent, but related chapters. The manuscripts are "paper format" and **Manuscript I** has already been published in *Galemys* journal and **Manuscript II** is in preparation and is also going to be submitted to an international peer-reviewed journal.

CHAPTER II

Roe deer reintroduction in central Portugal: a tool for Iberian wolf conservation

Manuscript I

Chapter III – Manuscript I

Cruz T, Fonseca C, Carvalho J, Oliveira B, Torres RT (2014) Roe deer reintroduction in central Portugal: a tool for Iberian wolf conservation. *Galemys,* 26: x-xx.

2. ROE DEER REINTRODUCTION IN CENTRAL PORTUGAL: A TOOL FOR IBERIAN WOLF CONSERVATION

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Published in *Galemys.*

2.1. Abstract

Species reintroduction is an increasingly important tool for species recovery programs and habitat restoration initiatives worldwide. Roe deer *Capreolus capreolus* (Linnaeus, 1758) densities are very low in central west Portugal (the Freita, Arada, and Montemuro mountains). This area is inhabited by the endangered Iberian wolf *Canis lupus signatus* Cabrera, 1907, whose numbers have dramatically decreased since the 20th century. An important step in a roe deer reintroduction program is to establish suitable reintroduction sites. The aim of the study was to identify such sites in central Portugal. An Analytical Hierarchy Process (AHP) in combination with a GIS was applied to develop a habitat suitability model, which integrated empirical models and expert knowledge. The variables used in the model included land use, hydrographic network, asphalted roads, population/villages, and relief. Three reintroduction sites suitable for roe deer were identified as potential habitats for their future natural expansion. Those sites were considered as preliminary ones. Finally, future goals and actions are discussed in relation to the promotion of the ecological and social conditions that would favour the survival of roe deer and Iberian wolf in central Portugal.

Key words: *Canis lupus signatus, Capreolus capreolus*, habitat suitability, Portugal, reintroduction.

2.2. Resumen

La reintroducción de especies es una herramienta clave en programas de recuperación de especies y de restauración de hábitats. El corzo *Capreolus capreolus* (Linnaeus, 1758) se ha extinguido prácticamente de las sierras de Freita, Arada y Montemuro (centro de Portugal), ambas habitadas por el lobo ibérico *Canis lupus signatus* Cabrera, 1907. Tanto el número como la distribución de este carnívoro se han reducido drásticamente en Portugal durante el siglo XX. Uno de los aspectos clave en cualquier programa de reintroducción es establecer qué lugares son los más adecuados para introducir la especie. Los objetivos de este trabajo fueron identificar los lugares idóneos para reintroducir el corzo en el centro de Portugal (sierras de Freita, Arada y Montemuro). Para ello, desarrollamos un modelo de adecuación del hábitat aplicando un Proceso Analítico Jerárquico (AHP, en inglés) y técnicas de SIG. Las variables utilizadas en el modelo fueron: uso del suelo, red hidrográfica, carreteras asfaltadas y otras variables antropogénicas y topográficas. A partir de ese análisis, identificamos tres lugares de reintroducción idóneos que garantizan tanto el establecimiento como la dispersión del corzo. Finalmente, en este trabajo discutimos qué acciones pueden favorecer la supervivencia tanto del corzo como del lobo ibérico en el centro de Portugal.

Palabras clave: *Capreolus capreolus, Canis lupus signatus*, modelo de adecuación del hábitat, Portugal, reintroducción.

2.3. Introduction

Species reintroduction is increasingly becoming an important part of species recovery programmes and habitat restoration initiatives worldwide (Armstrong and Seddon 2008). Reintroductions can improve the long-term survival of a species by establishing additional viable populations or reinforcing existing ones. Many species of large carnivores have been persecuted for centuries, and that is one of the reasons why they are now facing serious threats and suffering substantial declines in their populations and geographic ranges around the world (Ripple et al. 2014). This has led to concern regarding their local extinction and the resulting implications for ecosystems A subspecies of the gray wolf (*Canis lupus* Linnaeus, 1758) called the Iberian wolf inhabits Portugal. According to the UICN, the Iberian wolf in Portugal is considered Endangered (EN), having suffered a significant decrease in its distribution and abundance in recent decades, partly due to direct persecution (Bessa-Gomes and Petrucci-Fonseca 2003). In central Portugal, south of the Douro river, there is a very isolated and fragmented population of Iberian wolf, more vulnerable to environmental and demographic stocasticity and local extinction. This population faces several problems that include scarce food resources (lack of wild prey and/or regression extensive livestock), the decrease in refuge areas, and habitat fragmentation and mortality caused by humans (*e.g.*, poaching, poisoning, road kill; see Cabral et al. (2005). Vos (2000) showed that in the areas north-west and south of the Douro river, wolves can exclusively feed on domestic prey, which has only been reported once (Cuesta et al. 1991). In the area south of the Douro river, an almost monospecific diet was found, with the domestic goat (*Capra hircus* Linnaeus, 1758) as the main prey. Several studies have demonstrated the importance of increasing the abundance of wild prey, in order to reduce the impact of wolf on livestock, thereby reducing conflicts with humans (Cuesta et al. 1991, Vos 2000, Barja 2009, Meriggi et al. 2011). Therefore, in due course, the reintroduction of roe deer in central Portugal would provide a source of wild prey for the Iberian wolf, decreasing wolf livestock predation, thus reducing conflicts with humans (Treves and Karanth 2003, Treves et al. 2004). Finding effective methods to decrease the damage to livestock is pivotal to improving tolerance among the local human population to the Iberian wolf and, consequently, its conservation. In 1997, roe deer were reintroduced into the present study area, at São Macário Mount, in São Pedro do Sul, Viseu (Vingada et al. 1997). This reintroduction process did not aim to conserve the species *per se*, but was also based on the premise of creating a stable population to promote the conservation of the Iberian wolf. In the process, ten animals were released in a forest area, four of them with telemetry collars. However, due to dispersal mechanisms, namely echo and shadow, it was impossible to implement the original plan and after a certain period of time the location of the animals was lost and their fate became uncertain.

Reintroducing a species to an ecosystem may have impacts that need to be evaluated *a priori* based on a rigorous scientific component (Hodder and Bullock 1997). The first steps in a reintroduction program should include the assessment of the potential short-term consequences of management plans and long-term viability (Seddon et al. 2007). This could be achieved by generating habitat suitability models, which can be created using a theoretical approach based on knowledge of the ecological requirements of the species (Dettki et al. 2003, Yamada et al. 2003, Rüger et al. 2005). Habitat suitability models summarize the conceptual knowledge of the habitat associated with the species through the description of important environmental variables based on several sources of information (Storch 2002). The combination of population modelling and Geographical Information Systems (GIS) has been widely used in several studies that assessed landscape suitability for different species (Thatcher et al. 2006, Doswald et al. 2007, Olsson and Rogers 2009).

This study is the first phase (the viability phase) of a project to reintroduce roe deer populations in central Portugal and attempts to determine the habitat suitability of the area for the species. Therefore, the main aims of the study were: (i) to review and incorporate human and roe deer needs into a weighted, multi-criteria, habitat-suitability model; and (ii) to identify suitable habitats for roe deer reintroduction. It was expected that well-developed tree cover areas with a high density of shrubs would be more suitable for roe deer, whereas areas close to roads and urban areas would be less suitable(Torres et al. 2011, Torres et al. 2012b).

2.4. Material and methods

2.4.1. Study area

The study was conducted in central Portugal in two sites of the Natura 2000 Network (Figure 2.1). This area is a mountainous region with steep slopes and medium altitudes ranging from 800 to 1381 m.a.s.l. The climate is mainly Mediterranean, with a strong oceanic influence and high levels of rainfall. The vegetation is diverse and is mainly formed by different types of shrubs, such as common broom *Cytisus scoparius* and *Cytisus grandiflorus*, common gorse *Ulex europaeus*, dwarf gorse *Ulex minor* and *Ulex micranthus*, *Genista triacanthos*, *Erica australis*, tree heath *Erica arborea*, bell heather *Erica cinerea* and *Erica umbellata*, and gorse *Pterospartum tridentatum*. Tree species in the area are English oak *Quercus robur,* Pyrenean oak *Quercus pyrenaica*, sweet chestnut *Castanea sativa*, and Maritime pine *Pinus pinaster* in pure stands or mixed with the eucalyptus *Eucalyptus globulus.* Scattered pastures and agricultural fields are still found in the study area, which is crossed by several rivers and streams. The riparian vegetation is mainly ash *Fraxinus angustifolia* and birch *Betula alba*. The wild boar *Sus scrofa* Linnaeus, 1758, is the only wild ungulate in the study area. Subsistance agriculture and pastoralism are still practiced in which native cattle and small ruminants predominate along with the extensive use of uncultivated land. The human population is dispersed through the valleys in villages with population densities of approximately 314 inhabitants/km2 (INE 2011).

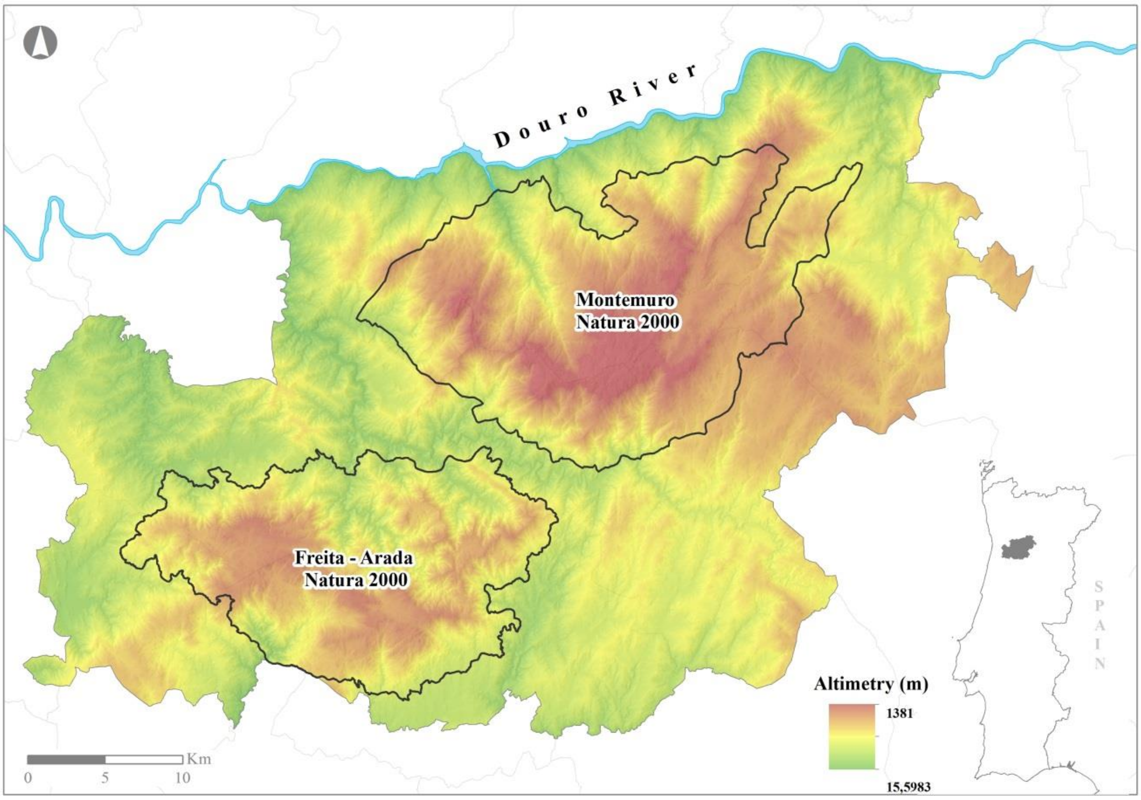

Figure 2.1: Location of the study area in continental Portugal.

2.4.2. Data collection

Field work was conducted between October 2011 and March 2012 using pellet group counting, a survey method that is frequently used to assess large ungulate habitat use (Telesco et al. 2007). Twenty triangular transects (1 km per side) were systematically placed to provide equal coverage of the different habitats in the surveyed area (Figure 2.2). This sampling design confirmed roe deer presence/absence in the study area. In total, 240 sampling plots (50 m x 2 m) were established and each of these transect sections was considered a sampling unit. In order to maximize spatial coverage and to mitigate sampling dependence, plots were spaced along the line every 200 m. Firstly, at each segment, roe deer presence was assessed by recording the number of pellets, and then the habitat variables that could potentially affect species distribution were recorded over a 10-m radius circle. Geographic information system software (*ArcGIS 10.0*) was used to derive several ecological descriptors known to be important for roe deer presence, which ranged from local scales (patch scales; 1.26-km buffer) to land scales (landscape scales; 12.6-km buffer) (*e.g.* macro-habitat, landscape structure variables, as well as human disturbance and topographic factors). The smallest buffer (1.26 km), termed the home range, was calculated based on home range values in Portugal reported by Carvalho et al. (2008), and in similar Mediterranean habitat types (Rosell et al. 1996, Lamberti et al. 2006). The largest buffer (12.6 km) represents a wider spatial scale and indicates how the surrounding landscape potentially affected roe deer occurrence.

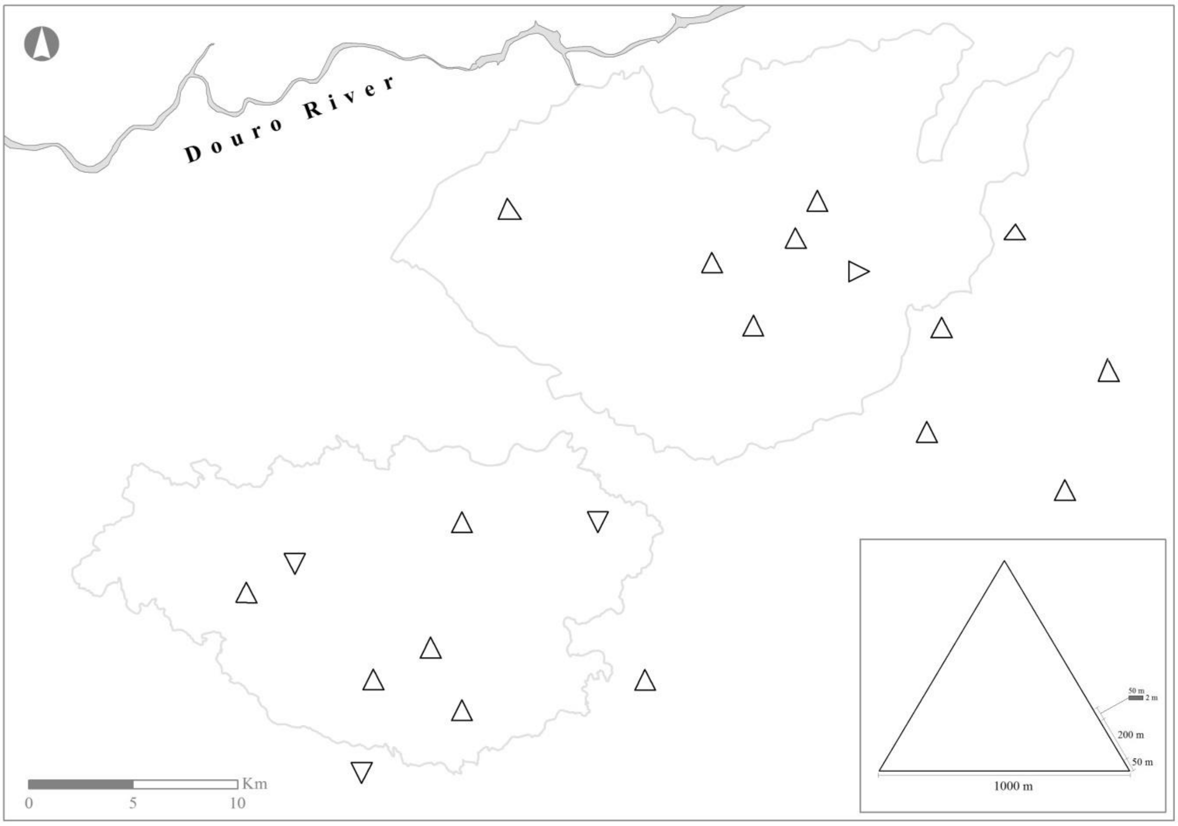

Figure 2.2: Triangular transects defined in the study area for field data collection.

2.4.3. Environmental variables selection

The environmental variables used were selected according to the ecological requirements of roe deer, as described in previous studies (San José et al. 1997, Virgós and Tellería 1998, Torres et al. 2011, Torres et al. 2012b). The variables were grouped according to three factors: i) habitat composition; ii) topography; and iii) human disturbance (Table 2.1). Habitat composition was represented by three general land use predictor variables divided into forest (including broadleaved and coniferous woodland, wetlands, and scrubland), agricultural fields (including herbaceous and woody crops, arable horticulture, and heterogeneous crops), and urban areas. Information was obtained from CORINE Land Use/Land Cover database (CLC06) with a spatial resolution (pixel width) of 250 meters.

Roe deer food resources are mainly affected by habitat and, to a lesser extent, by season (Tixier and Duncan 1996), which suggests that availability is a key determinant of diet (Duncan et al. 1998). Therefore, food availability was inferred from the presence of habitats that are well-suited to providing food for the species (Faria 1999, Torres et al. 2011). Topographic factors were represented by slope and relief. In a dry Mediterranean environment, the availability of free water is a physiological and behavioural constraint for roe deer (Wallach et al. 2007). Thus, distance to water sources is a factor that should also be taken into account when analysing roe deer habitat use. Consequently, measurements were made of the distance from the centre of the segment to the closest water body. Human disturbance was represented by road density, the asphalted road network, and urban areas (houses, buildings, and industrial areas). These factors can influence roe deer distribution as they may be considered analogous to predation risk. To analyse the different levels of disturbance relative to each segment, the distance to settlements and the distance from the centre of the segment to paved roads were measured.

Table 2.1: Comparison matrix with the relative weight assigned to the factors under analysis. (FA-Forest areas; AA-Agricultural areas; RD-Roads density; DAR-Distance to asphalted road network; DHN- Distance to Hydrographic network; DUA- Distance to urban areas; S-Slopes; RA-Relief Aspects).

Variables	FA	AA	RD	DAR	DHN	DUA	S	RA
FA	**1**	-	-	-	-	-	-	-
AA	1/7	**1**	-	-	-	-	-	-
RD	1/5	5	**1**	-	-	-	-	-
DAR	1/7	5	1/5	**1**	-	-	-	-
DHN	1/7	5	1/7	1/7	**1**	-	-	-
DUA	1/5	5	1	5	7	**1**	-	-
S	1/7	3	1/5	1/3	1/3	1/5	**1**	-
RA	1/9	1/5	1/9	1/9	5	1/9	1/9	**1**

2.4.4. Multi-criteria analysis: the AHP method

The weight of each criterion was obtained using the Analytical Hierarchy Process (AHP) (Saaty 2005). The criteria and weightings were employed in the GIS based on Multicriteria Decision Making (MCDM), which associate the environmental factors under analysis in a single assessment parameter (Chen et al. 2010). This methodological approach has been widely used in habitat suitability studies (Mardle et al. 2004, Li et al. 2009, Xiaofeng et al. 2011). Despite some subjectivity inherent to this method, it has proven to be a valuable option in the absence of presence data and contributes to reducing the subjectivity associated with heuristic methods. This method integrates data from different sources and correlates their respective weights. The AHP method is based on three fundamental steps: i) defining the objectives and variables to be considered in the analysis; ii) developing a pairwise comparison matrix of factors using a given scale; and iii) defining the final weights. A weighted linear combination was used since it is the most common procedure for multi-criteria evaluation. Factors (*e.g.* variables) are combined together by applying a weight to each one followed by the sum of the weights applied to each factor. The evaluation also included our field experience and knowledge of the study area, which was fundamental to developing the final model. The final output is a habitat suitability map generated according to the following equation:

$$S = \Sigma\,(wi\;xi)$$

where S is suitability, *wi* is the weight of factor *i, xi* is the criterion score of factor *i*.

In the present case, the result was a Habitat Suitability Index (HSI), which quantitatively characterizes the capacity of an area to fulfil the ecological requirements of roe deer.

The criteria weights were assigned according to Saaty's pairwise comparisons (Saaty and Vargas 2012) to reduce subjectivity. Firstly, a qualitative numerical scale was used to score each pairwise comparison between the chosen criteria. The relative preference between two variables under analysis was obtained by using a 9-point rating scale ranging from 1 (equal importance) to 9 (extreme importance) and reciprocal values (Table 2.2). All continuous variables were standardized (linear scaling and scale inversions) prior to map algebra operations to avoid the effect of different measurements scales and to simplify direct comparisons. The following equation was used:

$$xi = \frac{(Ri - Rmin)}{(Rmax - Rmin)}$$

where R_i is the raw score of factor *i.*

The comparison matrix was then completed in both directions (Table 2.1). Using the given values, the specific weights for each criterion were calculated to be used in the weighted linear combination (Table 2.3).

Table 2.2: Saaty's pairwise comparisons. The values vary between 1 and 9 (factor on vertical axes is more important than the factor on horizontal axes) or 1/3 and 1/9 (factor on vertical axes is less important than the factor on horizontal axes).

Degree of importance	Definition
1	Equal importance
3	Weak importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values
1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9	Reciprocal values

Table 2.3: Final factor weights to be applied. (FA-Forest areas; AA-Agricultural areas; RD-Roads density; DAR-Distance to asphalted road network; DHN- Distance to Hydrographic network; DUA- Distance to urban areas; S-Slopes; RA-Relief Aspects).

FA	AA	RD	DAR	DHN	DUA	S	RA
0.38	0.03	0.17	0.10	0.05	0.17	0.06	0.03

2.4.5. Data analysis

The final model representing habitat suitability in the study area was divided into three suitability classes by applying the Natural Breaks method, which is one of the most common procedures to classify quantitative data. The low number of classes provides more accurate and robust information (Hirzel et al. 2006). Class ranges are defined by comparing them to the distribution of the entire dataset thus making it possible to identify break points. Finally, the data available are divided to maximize the differences between the number of classes desired. Habitat evaluation and the selection of habitat patches with high suitability were performed by comparing highly suitable habitat patches and the species annual home range. Since no information was available on roe deer home ranges in the study area, home range values from Mediterranean habitats from other areas of the Iberian Peninsula were used (Rosell et al. 1996, Carvalho et al. 2008).

2.5. Results

The fieldwork showed that no sampling plot contained any evidence of the presence of roe deer. The network of transects covered the entire study area and was representative of its range. A final map representing the different degrees of suitability of potential reintroduction areas (Figure 2.3) was obtained by intersecting the three ecological variables considered relevant to the species: habitat/shelter, food availability, and disturbance. Three main classes of suitability were considered by grouping the scale values in the final map. Thus, white areas represent highly suitable areas, grey represents moderate suitability areas, and black represents low suitability. By dividing the suitability model into three quantitative parameters, approximately 18% of the study area was classified as highly suitable for roe deer. The remaining 82% were divided into moderate (38%) and low suitability (44%). Taking into account the ecological requirements of roe deer, three nuclei of reintroduction were selected by using the Habitat Suitability Index (HSI).

2.6. Discussion

2.6.1. Habitat suitability map: reintroduction nuclei

Based on knowledge of roe deer requirements, a habitat suitability model of the species was developed. Three reintroduction nuclei were selected by using the Habitat Suitability Index (HSI) and by fieldwork to confirm all the relevant variables in the model. The results showed that the study area contains suitable areas for roe deer occurrence and expansion. The Freita mountains contain areas that are suitable for roe deer reintroduction (*RCore 1*): the area exhibits continuity between habitats, which promotes the natural expansion of the species. This area has dense vegetation with large patches of highly suitable habitat, mainly consisting of well-developed tree cover (*Castanea sativa, Quercus* sp., *Betula* sp., *Pinus* sp., *Pseudotesuga menziezii*) and a dense shrub layer (*Pterospartum tridentatum*, *Erica* sp., *Ulex* sp. and *Cytisus* sp.).

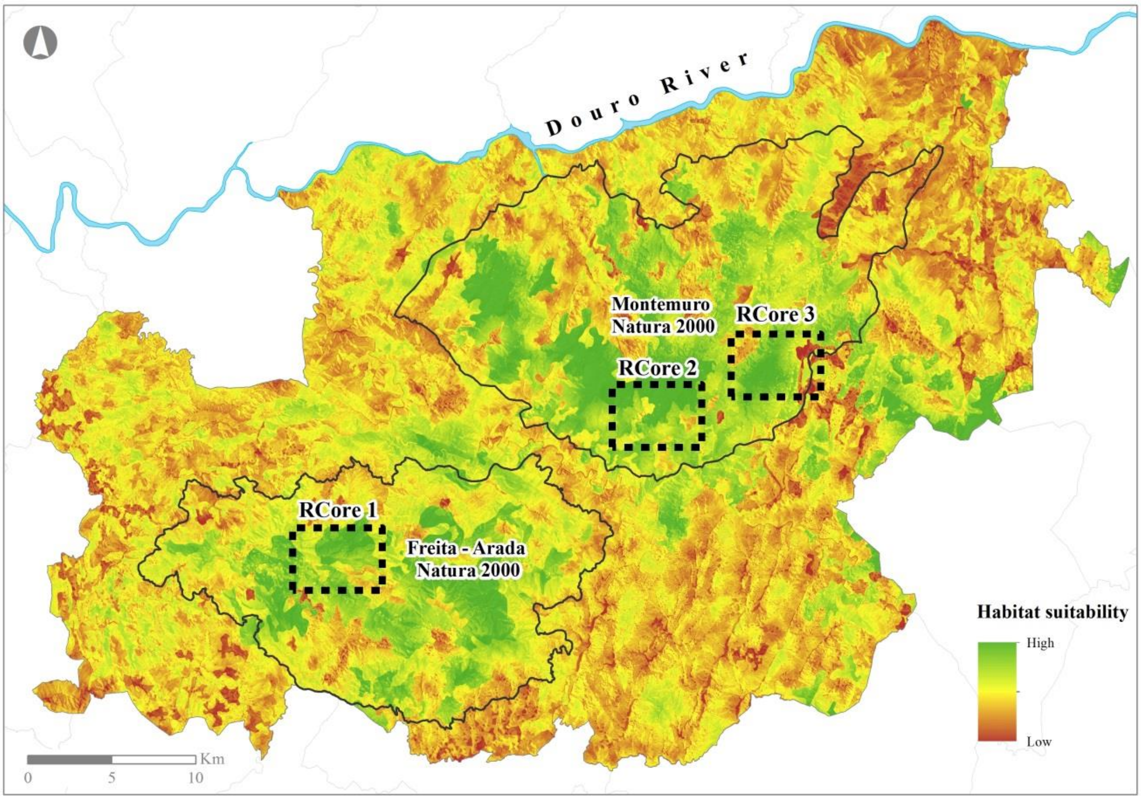

Figure 2.3. Habitat suitability model output with the potential reintroduction cores. Colours graded from red (unsuitable areas) to green (suitable areas).

Tree cover with sparse shrubs can provide rest areas for roe deer, while dense shrubs can offer protection (Torres et al. 2011). This type of vegetation not only provides shelter and cover from predators, but also provides highly nutritious food (Duncan et al. 1998).According to Torres et al. (2011), roe deer distribution in Portugal is positively associated with areas of high shrub density, especially *Erica* sp. and thorny shrubs. The positive preference of roe deer for patches rich in shrubs is probably linked to the quality of the site, since they have more opportunities to select better food from the great number of plant species (Torres et al. 2011). The results also suggest two other reintroduction nuclei in the Montemuro mountains: *RCore 2* and *RCore 3*. *RCore 2* is located along a river valley with an extensive oak forest and broadleaf and deciduous trees that offer the species cover, food, shelter, and safety. The valley contains pastures which contrast and function as an ecotone and are extremely important for roe deer. The shrub layer is rich and varied, contributing to the species food requirements. Finally, *RCore 3* is an area of woody vegetation mainly consisting of oaks, chestnut trees, and some broadleaf trees. It is characterized by transitional habitats (ecotones), which are very important for this species, alternating with fields mainly composed of grasses, oak trees, and bushes. In addition, the digestive adaptability of roe deer would favour their successful colonization of these heterogeneous landscapes (Serrano et al. 2012).

Human disturbance is relatively low in all reintroduction nuclei. This is of importance because, like many other wild ungulates, roe deer usually fear human presence, particularly in Portugal (Torres et al. 2011, Torres et al. 2014). The low suitability areas were mainly urban areas with a relatively well-developed asphalted road network, or sloping areas without a shrub layer or tree vegetation. As mentioned, this can limit roe deer expansion and distribution, and thus these areas were not selected by the model nor were they close to any potential reintroduction nuclei. The areas contiguous to reintroduction nuclei with moderate suitability may play an important role in habitat connectivity and act as wildlife corridors from which roe deer can eventually expand.

2.6.2. Methodology

A strong, multi-criteria method was applied based on the complementary use of a GIS. This approach can report many of the inconsistent criteria leading site suitability and can offer an accurate evaluation of the overall viability of the reintroduction process. The choice of the method is often subject to the model's objective, the species, and the data available (Manel et al. 1999) and there are several techniques which include expert opinion in habitat suitability models (Carver 1991, Pereira and Duckstein 1993, Pearce et al. 2001, Store and Kangas 2001). The model could not be validated with presence data because these were unavailable. Although we are aware of the importance of model validation, we choose not to replace absent data with data from another area because of the difficulty of finding other regions with a similar environment. Furthermore, such projections always entail uncertainties, such as asymmetrical transferability due to environmental causes, which are specific to differences between geographical regions (Fielding and Haworth 1995), or biotic causes, which are intrinsic to each species being modelled (Randin et al. 2006). Nevertheless, by using AHP as an heuristic method, the final suitability map output shows that the environmental variables for the analysis were sensibly and correctly selected. According to Ananda and Herath (2003), the success of this method is strongly determined by the way the decision problem is structured and by the weighting method, and therefore by the way the pairwise comparisons are conducted.

Similar to other methods, there are always some uncertainties associated with this modelling approach (South et al. 2000). However, the main benefits of this method are related to the possibility of integrating empirical models and expert knowledge and of considering the habitat factors on different scales (Store and Jokimäki 2003). Store and Kangas (2001) showed that while GISs include tools for managing and producing georeferenced information at the different scales needed (*e.g.* in habitat suitability assessment), multicriteria methods offer tools for modelling expert knowledge. This study attempts to prove that expert knowledge (even when no other data is available) (Doswald et al. 2007, Cianfrani et al. 2013) can be used in order to generate a habitat suitability model; however, the model needs to be validated after the species reintroduction. The model can be validated by using indirect records of species presence or by using data obtained from the animals using GPS.

2.6.3. Future actions and goals

Future steps in this project include releasing animals at the selected reintroduction sites. Some animals will be fitted with GPS collars and the information obtained by this method will be related to other ecological issues related to the project. Although studies with telemetry (GPS) in roe deer are common in the rest of Europe, in Portugal this technique has not been used for this species (but see Carvalho et al. (2008)). The information obtained will not only be used to improve potential habitat models and predict population expansion, but will also be of use to develop an adaptive management plan crucial to such reintroduction initiatives (Sarrazin and Barbault 1996). It is also intended to increase the availability of suitable habitat for roe deer through a set of management measures (*e.g.*, controlling poaching; defining boundaries at reintroduction areas regarding hunting activities; and conserving the mosaic vegetation type which provides suitable habitat for the species). The factors that can negatively affect the viability of roe deer populations should be mitigated. These factors should be analysed and measured on a case-by–case basis. It is also important to increase public awareness through local campaigns on the problem of Iberian wolf conservation and the importance of the roe deer reintroduction program.

2.7. Conclusions

The availability of suitable habitat is a prerequisite to ensure the success of any reintroduction project and to ensure the persistence of the reintroduced population. Thus, studies on habitat suitability for a species must be conducted as part of a reintroduction process. This study defined several suitable areas for the reintroduction of the roe deer.

The results illustrate an approach that contributes to the planning of roe deer reintroduction in central Portugal with the aim of evaluating species habitat suitability and assessing the implications of the results in relation to developing tools for biodiversity conservation.

Conservation actions will be implemented to increase the probability of achieving the proposed objectives. Above all, this project is attempting to make an important contribution to the conservation of roe deer and, consequently, the Iberian wolf in Portugal.

Like any reintroduction project, it also has a strong social dimension. The next steps in the project should focus on education and environmental awareness, thereby sensitizing local populations to the issue of the reintroduction of roe deer and conservation of the Iberian wolf.

Acknowledgements

We are grateful to all the people who provided valuable assistance in the field. Likewise, Associação de Conservação do Habitat do Lobo Ibérico (ACHLI) provided invaluable support.

CHAPTER III

Predicting habitat suitability for roe deer in the Iberian Peninsula: implications for conservation and management

Manuscript II (In prep.)

Chapter III – Manuscript II

Cruz T, Carvalho, J, Fonseca C, Torres R.T. (In prep.) Predicting habitat suitability for roe deer in the Iberian Peninsula: implications for conservation and management.

3. PREDICTING HABITAT SUITABILITY FOR ROE DEER IN THE IBERIAN PENINSULA: IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

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(In prep.)

3.1. Abstract

Due to species distribution models (SDMs) recent advances in the last decades, they have become increasingly applied to wildlife management actions. This allowed the possible prediction of potential anthropogenic effects on patterns of biodiversity, at different spatial scales, and an approach to management and conservation issues, at a large-spatial scale. In Portugal, investigations on the factors that affect roe deer distribution have been based on small-scale studies or on local factors. The main objective of this study was to predict a habitat suitability model for roe deer in the Iberian Peninsula (large-scale modelling). We implemented one method to model the current distribution of roe deer in an edge ecosystem, the Iberian Peninsula, assessing the predictive performance of a generalized statistical model. Firstly we performed a trend surface analysis (TSA) to delimit the geographical background (GB) (RMS Error = 0.37), followed by an exploratory analysis to check assumptions and collinearity among explanatory variables and a GLM stepwise. GLM model was very accurate (AUC = 0.97 HL $\chi2$ = 843.90; p-value = 0.35). Roe deer occurrence and distribution was closely related with distance to perturbation areas, water bodies, shrubs, forest patches and topographic

factors (*e.g.* slope). The results are discussed from an ecological perspective, highlighting the relevance of accurate predictions in roe deer conservation and management.

Keywords: *Capreolus capreolus*, conservation, generalized linear models, Iberian Peninsula, management.

3.2. Introduction

In the last years, species distribution models (SDMs) and the importance of habitat suitability models as a tool for applied ecology studies has significantly increased (Guisan and Zimmermann 2000, Guisan and Thuiller 2005). With them it is possible to approach management and conservation issues on a large spatial scale, by modelling the response of the species to environmental gradients (Austin et al. 1990). More recently, they have been used i) to predict distribution patterns of population abundance at a large spatial scale (Boyce et al. 2001, Pearce and Ferrier 2001, Real et al. 2009); ii) to determine similarities and differences in the response to the environment between subspecies (Acevedo and Real 2011); iii) to determine potential overlapping and competition areas between exotic and native species (Acevedo et al. 2007, Acevedo et al. 2010), and iv) to assess the effects of geographical background extent on the predictive performance of SDMs, specifically on model calibration and discrimination, and on the propensity of the models to predict environmental potential when projected outside their training area (Acevedo et al. 2012).

In Portugal, roe deer is on the edge of its south-western distribution range. In the 80’s, roe deer populations have suffered a large decrease and its expansion was very limited, mainly due to the mismanagement of their populations, habitat fragmentation and illegal hunting (Cabral et al. 1987). However, in the past decades, roe deer distribution and density have increased (Vingada et al. 2010), mainly due to changes in land-use practices and rural exodus, which has led to the re-naturalization of the habitats, but also due to stricter hunting and management policies. Nevertheless, in Portugal, comparing to central and northern Europe populations and despite this population increase, roe deer densities have remained low (Vingada et al. 2010).

Traditionally, investigation on the factors that affect roe deer conservation in Portugal has been based on small-scale studies or on local factors such as habitat features (Torres et al. 2011, Torres et al. 2012b). However, as Ricklefs (1987) and Levin

(1992) pointed out, local populations are also likely affected by historical and environmental processes that act on a regional or continental scale. The study of regional-scale processes is, therefore, important to complement ecological studies carried out on more local scales (Vaughn and Taylor 2000). It has been stressed the importance of large-scale modelling of species distribution (Barbosa et al. 2010). Nevertheless, large-scale modelling may not act at smaller scales, which are precisely the scales on which it is important to develop conservation and management strategies. However, recently, Barbosa et al. (2010) showed that SDM calibrated for large scale and small spatial resolution are also locally informative and therefore useful for the management of the species.

In this study we describe the potential distribution of roe deer in the Iberian Peninsula with the aim of seeking potentially reintroduction sites. Thus, the two main goals of this study are: 1) to generate a potential distribution model for the species in the Iberian Peninsula highlighting areas that could potentially harbour this species, and 2) to identify those areas environmentally suitable for reintroduction in central Portugal. To do this, we used a species-specific procedure to delimit the geographical background (GB) based on the global surface-fitting procedure known as trend surface analysis (TSA) (Legendre and Legendre 2012). Therefore, the main objective of this study is to model the distribution of the roe deer at Iberian Peninsula scale, exploring the suitability of the model to our study area and using UTM 10 X 10-km squares as territorial units.

3.3. Methodology

3.3.1. Study area

The Iberian Peninsula is located at the extreme southwest of Europe and covers an area of about 580,000 Km^2, including the territories of Portugal, Spain and Andorra. The climate is heterogeneous, and has a marked peninsular character, since the isthmus that connects it with the rest of the continent is narrow and is crossed by the Pyrenees, which delays the biotic and abiotic exchanges with the nearby areas. These mountain systems form the north-east edge of the peninsula, separating it from the rest of Europe. The terrain of the Iberian Peninsula is largely mountainous and is the westernmost of the three major southern European peninsulas – the Iberian, Italian, and Balkan. It is bordered on the south-east and east by the Mediterranean Sea, and on the north, west, and southwest by the Atlantic Ocean. Its southern tip is very close to the northwest coast of Africa, separated from it by the Strait of Gibraltar.

3.3.2. Roe deer distribution data

The roe deer distribution data (UTM 10x10km) was recorded at Iberian Peninsula scale (Figure 3.1). The data from Spain were obtained from the atlas and from the red book of terrestrial mammals of Spain (Palomo et al. 2007) and the Portuguese data from Salazar (2009). At the Iberian Peninsula scale, the roe deer is present in 3061 UTM 10X10-km squares (from the 6196 considered).

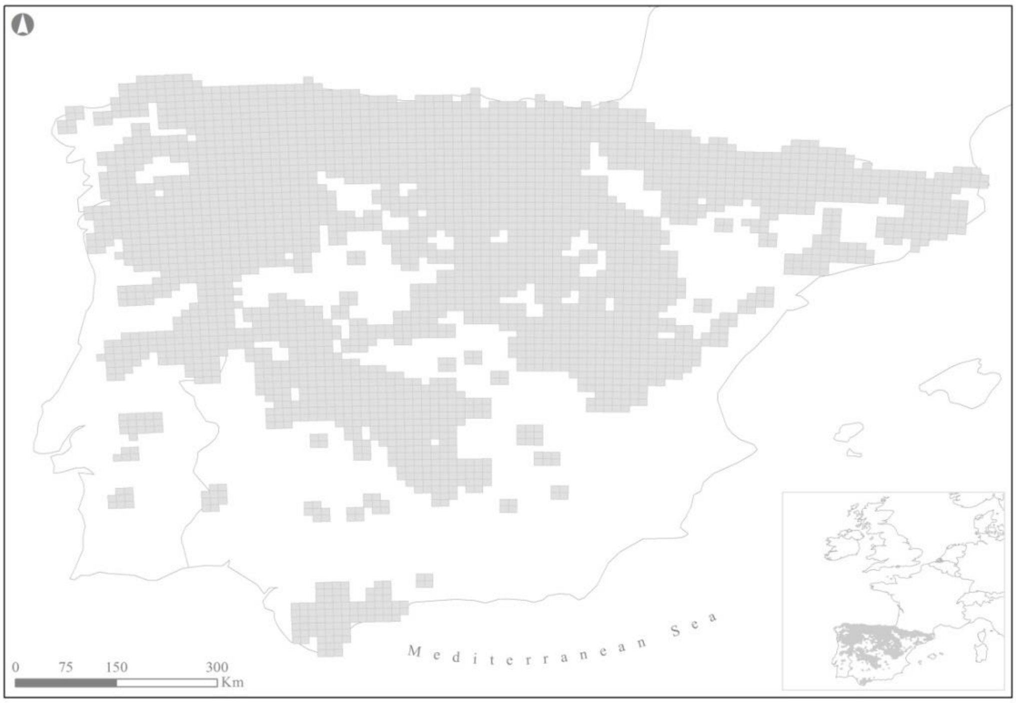

Figure 3.1: Roe deer distribution in the Iberian Peninsula (UTM 10X10-km).

3.3.3. Geographic background (GB) delimitation

SDM's discriminatory power can change according to variations in the geographical background extent of our study area (Barve et al. 2011, Acevedo et al. 2012). If too large, GB can limit the model ability to extract the fine-scale conditions that define species distribution (Lobo et al. 2010). While if too restricted (*i.e.* too small to entirely represent the ranges of the species) GB can underestimate the role of coarse-scale factors (*e.g.* climate) (Jiménez-Valverde et al. 2011, Sánchez-Fernández et al. 2011). In this study, and according to the methodology proposed by Acevedo et al. (2012) we used a species-specific procedure to delimit the geographical background (GB) based on the global surface-fitting procedure known as trend surface analysis (TSA) (Legendre and Legendre 2012). With the TSA, we can define the area that has the highest chance of being available to a species given its distribution, and avoid at the same time the addition of geographical areas that, due to their spatial inaccessibility, may be useless for an ecological model (Lobo et al. 2010). TSA fits a polynomial surface by least-squares regression of geographic coordinates. According to Legendre and Legendre (2012), this method is used to find general data tendencies, and the modulation of curvilinear structures is made through the addition of polynomial terms to the explanatory data. Consequently, trend surfaces are usually expressed as *nth* polynomials producing gradually changeable surfaces that describe the physical or geographical processes. We fitted several surfaces increasing the polynomial order and, consequently, the complexity. The root mean square (RMS) error of interpolation was used to determine the best value to use for the polynomial order.

3.3.4. Exploratory analysis and environmental predictors' selection

Commonly, the choice of the modelling method is more important to the authors than the correct selection of environmental predictors, although being critical to the performance of biodiversity models. A careful selection and grouping of variables can probable to lead to more strong predictive models and cause a better understanding of biodiversity–environment relations (Williams et al. 2012). In order to check for multicollinearity between predictors, preceding each analysis a Spearman's rank correlation test was performed. When the correlation coefficient exceeded 0.8, the variable with the lower biological significance was dropped (Jiménez-Valverde and Lobo 2006, Real et al. 2008).

The effects of ecological, climatic and human variables on abundance and distribution of roe deer have been described in several studies (*e.g.* Hewison et al. (2001) Acevedo and Cassinello (2009); Acevedo et al. (2006); Acevedo et al. (2011b); Torres et al. (2011); Torres et al. (2014)). Here we recorded variables that could account for roe deer distribution; for that we considered 36 environmental predictors (Table 3.1). We grouped the variables into four main macroenvironmental factors: 19 climate (CLI), 2 topography (TOP), 4 human disturbance (HUM) and 11 habitat structure (HAB).

Most of these variables are related to resources availability or to the physiological and ecological requirements of the species and the selection of the predictors was made based on availability at this scale and spatial resolutions required in this study, and in relation to their predictive potential according to previous studies (Acevedo et al. 2011a, Acevedo and Real 2011, Torres et al. 2011), and could be correlated with more local causal factors. The mean values for each predictor were summarized and mapped on the UTM 10x10km grid (Iberian and regional) and were estimated using *ArcGIS 10.2.1* software.

Climatic factors (CLI) – Strong evidence backs the idea that climate plays an important role in limiting species distributions (Jiménez-Valverde et al. 2011), for example through its effect on vegetation. In this study, 19 bioclimatic variables were selected and included in the model (Table 3.1). These variables were available at 30 arc-seconds ~ 1 Km^2) pixel width from the *Worldclim project database* (see Hijmans et al. (2005)), which is often used in ecological distribution modelling (Costa et al. 2008). The selected bioclimatic variables represent annual trends (mean annual temperature, annual precipitation), seasonality (standard deviation of monthly temperatures) and extreme or limiting environmental factors (temperature of the coldest and warmest month, and precipitation of the wettest and driest quarters [a quarter is a period of 3 months]).

Topographic factors (TOP) – Topography is the main factor that controls the distribution and patterns of vegetation in mountain areas (Titshall et al. 2000), thus influencing roe deer distribution through habitat requirements. Two topographic variables were extracted: altitude and slope.

Human disturbance factors (HUM) – Roe deer usually fears human presence (Hewison et al. 2001) which, when sensed, most frequently leads to escape (Danilkin and Hewison 1996) and previous studies have shown that roads and human activities (*e.g.* urban areas; settlements) are important factors that influence roe deer distribution (Torres et al. 2011, Torres et al. 2012b). Four variables were included for potential human disturbance on the distribution of the roe deer: distance to urban areas; distance to roads (highways); surface occupied by urban areas and total road extension.

Habitat structure factors (HAB) – Habitat structure-related variables were characterized from CORINE Land Use/Land Cover database (CLC06) with spatial resolution (pixel width) of 250 meters. We aggregated the habitats into 11 variables: forests (broad-leaved, coniferous and mixed); agricultural areas (arable land, permanent crops, pastures, heterogeneous agricultural areas); scrubland or herbaceous associations; wetlands; and water bodies.

Table 3.1: Ecogeographical predictors used in roe deer distribution modelling at Iberian Peninsula scale.

Factor	Code	Variable
Climate	*BIO 1*	Annual Mean Temperature (ºC x 10)
	BIO 2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
	BIO 3	Isothermality (BIO2/BIO7) (x 100)
	BIO 4	Temperature Seasonality (standard deviation x 100)
	BIO 5	Max Temperature of Warmest Month (ºC x 10)
	BIO 6	Min Temperature of Coldest Month (ºC x 10)
	BIO 7	Temperature Annual Range (BIO5-BIO6) (ºC x 10)
	BIO 8	Mean Temperature of Wettest Quarter (ºC x 10)
	BIO 9	Mean Temperature of Driest Quarter (ºC x 10)
	BIO 10	Mean Temperature of Warmest Quarter (ºC x 10)
	BIO 11	Mean Temperature of Coldest Quarter (ºC x 10)
	BIO 12	Annual Precipitation (mm)
	BIO 13	Precipitation of Wettest Month (mm)
	BIO 14	Precipitation of Driest Month (mm)
	BIO 15	Precipitation Seasonality (Coefficient of Variation)
	BIO 16	Precipitation of Wettest Quarter (mm)
	BIO 17	Precipitation of Driest Quarter (mm)
	BIO 18	Precipitation of Warmest Quarter (mm)
	BIO 19	Precipitation of Coldest Quarter (mm)
Topography	*Alt*	Mean altitude (m above sea level)
	Slp	Mean slope (º)
Human disturbance	*Urb*	Urban areas (%)
	DUrb	Distance to urban areas (m)
	DRoad	Distance to highway (m)
	ERoad	Roads total extension (m)
Habitat structure	*Fores*	Forest (%)
	CFor	Coniferous forest (%)
	BLFor	Broadleaved Forest (%)
	MixFor	Mixed Forest (%)
	Arab	Arable Land (%)
	Crop	Permanent crops (%)
	Past	Pastures (%)
	HAgr	Heterogeneous Agricultural Areas (%)
	Scrub	Scrubland and herbaceous associations (%)
	Wet	Wetlands (%)
	ERiver	Main water lines extension (m)

3.3.5. Modelling – GLM stepwise

For modelling purposes we used 6196 records of roe deer presence divided into training (70%) and test (30%) datasets. In our modelling approach we wanted to fully characterize the range of environmental conditions at our spatial context, which was provided by a random set of points from the study area. Presence records were used to establish the favourable conditions for the species occurrence while absence data were used to establish the conditions where the species does not occur.

Multiple regression or general linear models (GLMs) are used to cover the range of methods for analyzing one continuous response variable and multiple explanatory variables, used for example, for analyzing binary response data (Dobson 2002). One of the most common one is logistic regression which is used to model relationships between the response variable and several explanatory variables, which may be categorical or continuous (Dobson 2002). We performed GLM using stepwise variable selection which is a common implemented approach in distribution modelling (Araújo et al. 2005, Barbosa et al. 2009). In this procedure the variables with additional contribution to the model are added at each step. If at each step of stepwise, any effect in the model is negligible, then the least significant of these effects is removed. Correlation between variables affects the coefficients but not the model predictive performance. The most parsimonious model was selected based on Akaike's Information Criterion (Akaike 1974).

3.3.6. Model calibration and discrimination

The ability of a model to distinguish between the presence of the species (positive instance) and the absence of the species (negative instance) is called discrimination capacity (Jiménez-Valverde et al. 2013). Usually, this measure is the only parameter assessed in SDMs however calibration also provides useful information about the model performance. In this study, sensitivity (the percentage of correctly predicted presences to the total number of presences), specificity (the percentage of correctly predicted absences to the total number of absences, in percentage) (Acevedo et al. 2012) and the area under the curve (AUC) of the receiver operating characteristic plot (ROC) were calculated to account for the discrimination power of the models on each evaluation data set. Calibration plots were used to quantify the agreement between estimated probabilities of occurrence and observed proportions of presences, followed by a Hosmer-Lemeshow statistic test (HL), for fit of the regression model. The test assesses whether or not the observed event rates match expected event rates in subgroups of the model population.

Models for which expected and observed event rates in subgroups are similar are called well calibrated (Hosmer and Lemeshow 2000).

3.4. Results

3.4.1. Exploratory analysis

The results of the Spearman's rank correlation test indicated that the correlation coefficient between two variables exceeded 0.8 in some cases, and then the variable with the lower biological significance was dropped. Some variables were eliminated considering roe deer ecology. From the initial 36 variables, 14 were dropped (13 climatic and 1 topographic) and 22 were used in the following steps (*BIO 1, BIO 3, BIO4, BIO 8, BIO 12, BIO 15, Slp, Urb, DUrb, DRoad, ERoad, Fores, CFor, BLFor, MixFor, Arab, Crop, Past, HAgr, Scrub, Wet* and *ERiver.*

3.4.2. Geographical background

Following Acevedo *et al*. (2012), a TSA using known occurrences of the species was performed, in order to reduce the extent effects on the model predictive performance. The results provided evidence of broad-scale spatial trends in the distribution of roe deer (Figure 3.2). A root mean square error of 0.37 was obtained through the application of a third-order polynomial (Figure 3.2), which is the recommended for processes that occur at the same or higher range than the study region (Legendre and Legendre 2012). This area represents the geographical delimitation where the models was fitted and validated.

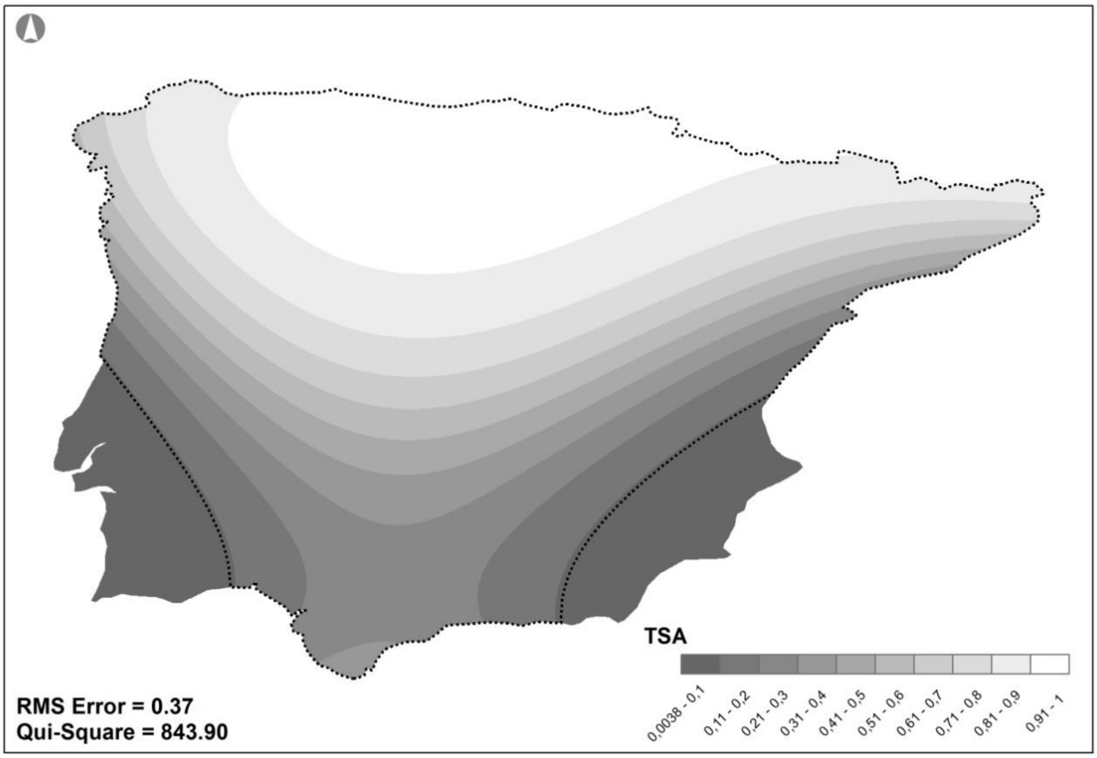

Figure 3.2: Trend surface analysis (TSA) using a third-degree polynomial for roe deer presences in the Iberian Peninsula.

3.4.3. GLM Stepwise

The most parsimonious GLM stepwise model has retained 20 variables (Table 3.2). From the initial set of 22 environmental variables, the following variables were dropped: *DRoad* and *CFor.* The variables *BIO 4, Slp, Urb, ERoad, Fores, BLFor, MixFor, Arab, Crop, Past, HAgr, Scrub, Wet* and *ERiver* had a positive effect in the occurrence probability of roe deer (Table 3.3), meaning that an increase in the measure units of these variables increases the species occurrence probability. For *BIO 1, BIO 3, BIO8, BIO12, BIO15* and *DUrb* the effects were negative (Table 3.3), meaning that an increase in the measure units of these variables decreases the species occurrence probability.

Table 3.2: Coefficients (*β*), standard deviation (*SD*) and the significance (*p*) for the regression model applied. Significance codes: "***" significant at 0.001, "**" significant at 0.01, "*" significant at 0.05.

	β	***SD***	**z value**	***p***
Constant	-4.728e+00	3.331e+00	-1.420	0.155712
Fores	2.362e-01	1.438e-02	16.423	< 2e-16 ***
MixFor	3.755e+03	1.683e+04	0.223	0.823410
BIO1	-2.456e-02	7.062e-03	-3.478	0.000506 ***
ERiver	6.677e-02	6.437e-03	10.374	< 2e-16 ***
BIO4	4.235e-04	1.719e-04	2.463	0.013777 *
ERoad	3.950e-02	7.226e-03	5.467	4.58e-08 ***
Scrub	1.495e-01	1.221e-02	12.241	< 2e-16 ***
BIO12	-1.951e-03	6.808e-04	-2.866	0.004160 **
DUrb	-7.999e-06	3.129e-06	-2.557	0.010572 *
HAgr	1.356e-01	1.232e-02	11.005	< 2e-16 ***
Arab	1.318e-01	1.212e-02	10.873	< 2e-16 ***
Crop	1.198e-01	1.245e-02	9.626	< 2e-16 ***
Past	1.957e-01	3.762e-02	5.203	1.96e-07 ***
Urb	1.281e-01	1.692e-02	7.571	3.71e-14 ***
BLFor	7.927e-02	1.468e-02	5.399	6.71e-08 ***
BIO3	-1.914e-01	5.707e-02	-3.354	0.000797 ***
BIO8	-9.924e-03	3.324e-03	-2.986	0.002830 **
BIO15	-3.187e-02	1.290e-02	-2.470	0.013502 *
Slp	1.431e-01	5.544e-02	2.582	0.009832 **
Wet	1.223e-01	5.725e-02	2.136	0.032715 *

The AUC (Figure 3.3) for GLM stepwise was 0.97, showing high discriminatory power. The calibration plot (Figure 3.4) and HL values revealed a perfect adjustment between predicted and observed values, and therefore the model is well calibrated.

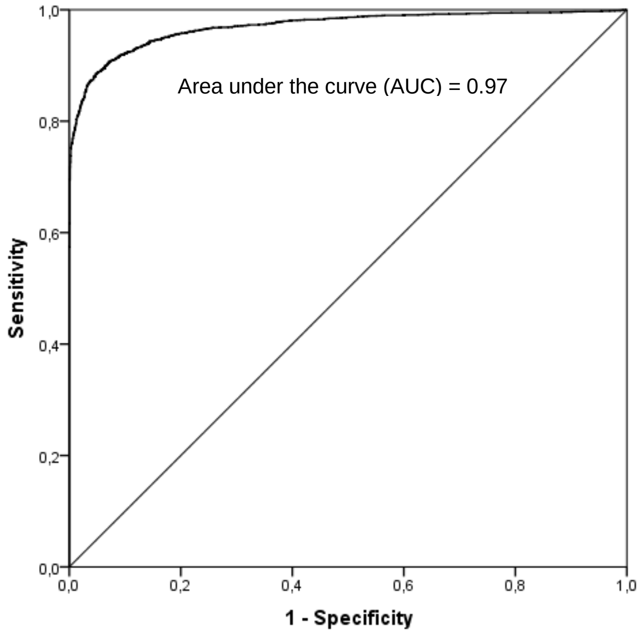

Figure 3.3: Receiver operating characteristic curve illustrating high discriminatory power.

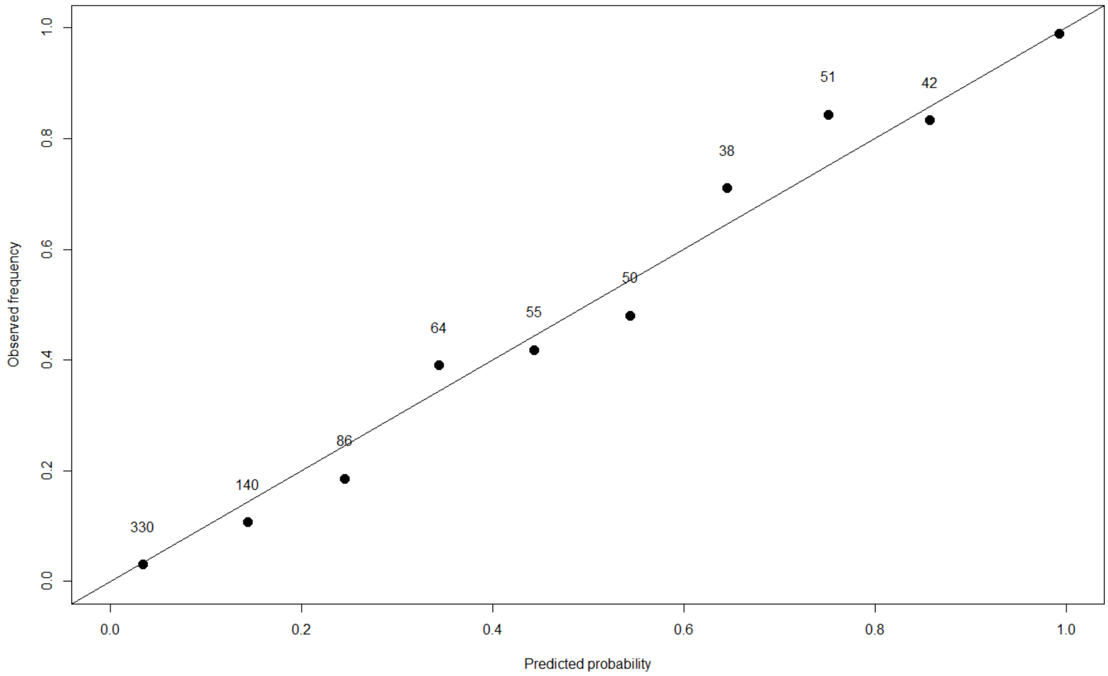

Figure 3.4: Calibration plot showing the adjustment between predictive/estimated probabilities (x-axis) and the observed proportion of positive cases (y-axis). HL ($\chi 2$= 843.90 and p-value=0.35).

3.5. Discussion

We performed an analysis of the factors determining habitat suitability on roe deer in Iberian Peninsula. According to the results it is possible to see that this species mainly occupies the central-north part of the Iberian Peninsula. This study shows that the proposed methodology is able to predict roe deer probability of occurrence with high accuracy identifying those environmental predictors that determine the presence/absence of the species. From an ecological point of view, the results are consistent with the known ecology of roe deer and are in agreement with previous studies in the area (Tellería and Virgós 1997, Virgós and Tellería 1998, Torres et al. 2011, Torres et al. 2012b, Valente et al. 2014). Generally, our results show that roe deer is affected by i) climate (*e.g.* positively affected by temperature seasonality and negatively affected by annual mean temperature, isothermality, mean temperature of wettest quarter and precipitation seasonality), ii) topographic (positively affected by slope) and habitat structure factors. Our study shows that roe deer occurs far from disturbance areas (*e.g.* villages and human settlements), agricultural fields and near of shrubs and forest patches. Roe deer often occurs in areas with gentle slopes preferentially exposed to south. The remaining variables exhibit modal effects, which makes it difficult to define patterns of selection. Torres et al. (2012) reported that well-developed tree cover areas with a high density of shrubs are more suitable for roe deer occurrence, whereas areas close to roads and urban areas are less suitable, using ranges away from areas with human disturbance (roads and settlements). Tree cover with sparse shrubs can provide rest areas for roe deer, while dense shrubs can offer protection. According to Torres et al. (2011), roe deer distribution in Portugal is positively associated with areas of high density of scrubland and thorny shrubs. The positive preference of roe deer for patches rich in shrubs is probably linked to the quality of the site, since there is a greater opportunity to select better food among a greater number of plant species. At a broader scale, the distribution of the species is negatively associated with spatial heterogeneity and positively associated with distance to agricultural fields. In central Spain, Tellería and Virgós (1997) described that in this region roe deer is more abundant in forest fragments near the mountains, in pine and oak woodlands and in forests with open water. The study concluded that agricultural areas seem to be sub-optimal for roe deer in comparison with forested, moist mountains. Virgós and Tellería (1998) also described roe deer preferences for forested areas and patches occupied by scrubland and thorny shrubs, with higher cover on pastures and moors. This type of vegetation is linked to moist soils in the Mediterranean zone, showing that roe deer prefer the moister, more productive patches. This supports the opinion that habitat constraints limit numbers and distribution of roe deer at the southern edge of its range.

The ROC curve, known as the AUC, has been widely used to estimate the predictive accuracy of distributional models derived from presence–absence species data even though some authors recommend caution when using it (see Lobo et al. 2008). Nevertheless, our final GLM model generated very acceptable geographical distribution hypothesis with very impressive high AUC scores (AUC = 0.97), which indicates a very good presence-absence prediction, and high discriminatory power of the model.

Our study showed that predictive models of species distribution based on climate, topographic and environmental variables can be used to delimit the potential distribution range on broad scales, and highlight areas that can potentially show high suitability for roe deer. When used as a base for biological management and conservation, SDM studies have had some critical responses, namely about the spatial scale and territorial units size frequently used in this type of studies. The main critic is that the majority of the processes studied at large spatial scales do not act at smaller scales, which are precisely those that management strategies and actions should be implemented on. The objective of a model should be to ask how much detail can be ignored without producing results that contradict specific sets of observations, on particular scales of interest (Levin 1992). Some studies have already showed new evidence about the utility of SDM as fundamental tools to face the current management challenges, reflecting at a population scale the results obtained through SDM generated as a large spatial scale. One of those examples is the study of Barbosa et al. (2010), who showed that SDM calibrated at a large scale and small spatial resolution are just as informative at a local scale, and therefore useful for species management. Also, Ferreres (2012) showed that the environmental suitability predictions modelled at a large scale are strictly related with roe deer abundance data from field samplings, giving new evidence about the utility of the models at the spatial scale required for population management.

Many studies showed that the habitat requirements of certain species are affected by factors measured on different scales (Edenius and Elmberg 1996, Wu and Smeins 2000, Store and Jokimäki 2003). In their modelling approach Wu and Smeins (2000) used multiple scales, but the different scales or variables measured on different scales were not combined; instead, their models were constructed separately on different scales, therefore not being as suitable as tools in large-scale landscape management or conservation biology. One important topic of future research and that should complement this study is the model transferability to a small spatial scale. The application of transferred models in management planning is considered of great utility. Large-scale GIS models can outline the main characteristics of the species' distribution areas. The approach followed in this study has contributed to the understanding of the most relevant factors affecting the current distributions of the roe deer in Iberia Peninsula.

Roe deer surveys can be used to elaborate distribution models based on presence probabilities that, when extrapolated to a finer resolution scale, allow a more detailed knowledge of the species' potential distribution. In this way, conservation and management planning might incorporate the identification of areas where roe deer populations could be more vulnerable to habitat destruction or fragmentation and areas which habitat is suitable for reintroductions.

Acknowledgments

We are grateful to Pelayo Acevedo for methodological support.

CHAPTER IV

Conclusions and perspectives

4. CONCLUSIONS AND PERSPECTIVES

This chapter will focus on the main results from this thesis and represents a link between them and some management measures and future directions. The discussion of the results of the Manuscripts I and II is not detailed, since that task has already been achieved independently in each corresponding chapter.

4.1. Highlights and major conclusions

In this study, we have shown the value of GIS as a tool for assessing the availability of suitable release sites for roe deer reintroduction. First, GIS not only allows investigation of a large area, in this case the Iberian Peninsula, but also a smaller area like central Portugal (Freita, Arada and Montemuro, our study area for roe deer reintroduction). Secondly, the output of GIS offers a simple and immediate visualization of the areas that may be suitable. Thirdly, since GIS can simultaneously consider a multitude of factors that determine the suitability of a site, it can be a far superior way of investigating an area to traditional map-based surveys; these often require a considerable amount of time and effort. GIS has many advantages, however there are always some arguments to consider (*e.g.* as a decision-support system: some authors argue that current GIS technologies do not offer sufficient decision support capabilities (Jankowski 1995)). Finally, it is important to point out that whatever the quality of the GIS output is, those sites identified as suitable must always be investigated by further expert field surveys, so that particular features of the site can be identified and evaluated. Perhaps the value of GIS is that it leads the investigator quickly and easily to a stage where field studies can be considered.

Most of the earlier habitat suitability models have been mainly constructed on a single scale and therefore they are not as suitable as tools in large-scale landscape management or conservation biology. In our approach, variables on different scales were used in both of the main phases of suitability modeling. Firstly, to construct the empirical models for case study species (Chapter II), and secondly, to calculate the suitability indices for the species to cover the entire case study area. The suitability models for roe deer were constructed in such a way that they included factors for all the needed scales (Chapter III).

Among others utilities, habitat suitability models are potent techniques which have been central to: refine species distribution maps, prioritizing areas for habitat restoration and species reintroduction (Wikramanayake et al. 2004). GLM identifies habitat using both presence and absence locations, as was made in Manuscript II. Another method that has kept popularity due to its simplicity is the expert-based modeling technique, or Analytic Hierarchy Process (AHP), which allows habitat modeling when empirical data are not available (Hurley et al. 2009). This approach can be inexpensive but can introduce uncertainty from the expert's perception or memory of the species or landscape in question. Results for expert-based habitat modeling generally improve when paired with literature review and when long-term local experts are used. We choose both AHP and GLM because they are commonly used, easily replicated, and relatively intuitive to understand. This is especially important in communicating the results to private landowners who will be critical to the management of roe deer.

Although the research field of modeling expert knowledge has recently been pointed out in many studies (see, *e.g.* Alho and Kangas (1997); Kangas et al. (2000)) there still exists some incompletely solved crucial problems. From the perspective of this study, the most essential of these were how to effectively utilize the knowledge of many experts, how to treat the differences between the data available and the data needed in the models, how to take account of the sensitivities of the results to the changes of the coefficients, and how to handle the interdependencies between decision variables.

The integrated habitat suitability index approach, as produced in this study, is based on the combined use of empirical evaluation models and models based on expertise in the GIS environment. GIS was used to produce the data needed in the models, as a platform to execute the models and in presenting the results of the analysis. This study showed that several GIS-based approaches and GLM techniques are immediately available for habitat suitability evaluation of roe deer as in this particular study. The biggest advantages of the method are connected to the possibilities to consider habitat factors on different scales, to combine habitat suitability evaluations for several species, and to integrate empirical models and the knowledge of experts.

4.2. Implications for conservation and management of roe deer and Iberian wolf

The main advantage of reintroducing roe deer to central Portugal would be to replace a species that is of uttermost importance for the conservation of a top predator that until recently was part of the native fauna of Portugal (and central Portugal more specifically), and should still be so.

An advantage of the models developed in this study is that they can be used and tested in the near future, as the roe deer population grow after the reintroduction. The model can be used in practice when selecting sites for reintroduction. Furthermore, it is already being in use by the roe deer reintroduction program for strategic planning (Torres et al 2012a).

In our study area, it is intended to increase the availability of suitable habitat for the roe deer through some management measures:

i) poaching control;

ii) definition of boundaries at reintroduction areas regarding hunting activities;

iii) reduction in the construction of roads and buildings that are physical insurmountable barriers and can cause population isolation;

iv) creation of systems to minimize the impact of forests fires and reforestation of burned areas with autochthonous vegetation;

v) to value the mosaic vegetation type which provides real suitable habitat for the species;

vi) to value traditional agricultural and cattle use techniques regarding the removal of the shrub layer, instead of mechanical methods;

vii) creation of clearings with seed;

(viii) silvopastoral management, with special regard to fires, cutting and paring control, as well as over-grazing;

ix) creation of new water sources (ponds) and their conservation;

x) monitoring domestic and wild ungulates health status.

Nevertheless, the factors that can negatively affect the viability of the roe deer populations should be mitigated. As a simple example, fires set by shepherds or private individuals, without the supervision of responsible entities, are one of the most important factors that may adversely affect roe deer populations, namely through habitat (and consequently the vegetation cover) destruction, which is the most important resource for this species, which uses it as a place of selective foraging and refuge. All of these factors should be analysed and measured case by case. Furthermore, it is important to increase public awareness through local campaigns and through the problem of the Iberian wolf conservation and the importance of the roe deer reintroduction program.

4.3. Future perspectives

This study reveals therefore that at the same time as potential suitable sites can be identified on a large spatial scale, a feasibility study should assess the sites and their surrounding region at a finer spatial scale. It is certainly possible to investigate areas of interest more closely using a GIS approach, and therefore we recommend that more detailed investigations should be carried out in future. Specific land-use characteristics, that may facilitate or constrain movement, may then be considered more closely. Therefore, future work should test the transferability of the model to our particular study area. Having this in mind, our future analysis will also explore the connectivity of our study area with areas currently occupied by roe deer.

4.3.1. People attitudes towards roe deer reintroduction in central Portugal

This study has considered only the biological feasibility of reintroducing roe deer to central Portugal, and concludes that it would be feasible. However, a feasibility study must also consider the desirability of reintroduction of a species within the wider, ecological and socio-economic, aspects of ecosystem protection and restoration. Such issues require a separate but complimentary investigation to this study. Nevertheless, within this project we have already started with some fundamental steps as reintroduction programs should be fully acknowledged by the local communities and is important to understand their acceptance to reintroduction. During my thesis, I made a questionnaire to distribute to the population prior to the release of the animals (Annex I) however, due to logistic constrains, the process was delayed and it was never accomplished.

In order to get a general idea of people attitudes towards roe deer reintroduction in the Freita, Arada, and Montemuro mountain ranges, the questionnaire was made of 64 simple questions and was called “People attitudes towards roe deer reintroduction in central Portugal” (Annex I). Although it hadn’t been put in practice, the purpose is to survey the attitudes of people most directly affected by the reintroduction and who, in the present, are more directly affected by the wolf damages, closer to the reintroduction areas.

Some personal data is collected and four categories of questions are tested: i) foreknowledge; ii) attitudes and opinion towards roe deer and wolf; iii) opinion about the reintroduction project and nature conservation; and iv) attitudes and opinion about game management. The statements are made based on the response that best describes their opinion, according to the following scale: 1 = Strongly Disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly Agree. Using the questionnaire it is intended to sample three main target groups: the local populations, the general public and the hunters, in order to test the following assumptions:

a) The high damage level that accompanies the presence of the wolf will result in locals being more positive towards roe deer, more supportive of the present policy of roe deer reintroduction.
b) Due to the long absence of roe deer, local populations and general public will know less about roe deer, than hunters.
c) Because the roe deer is a game species, hunters will have a greater knowledge, will consider it more useful, and will have a more positive attitude towards the roe deer and its reintroduction, and the present policy of roe deer expansion, than the local population.
d) Attitude towards roe deer is a key variable to predict support of the present policy of roe deer expansion.

The aim of the study is therefore to provide baseline data on peoples' attitude towards roe deer, identify key factors influencing attitude and knowledge gaps, and assess peoples' support of the present roe deer reintroduction in central Portugal. Future works should concern about having this type of assessment since these results should help to: i) encourage and facilitate communication between roe deer managers, hunters and locals – the first step to initiate public involvement in wildlife management; and ii) develop public information that focus on the concerns, misbeliefs and key issues of the various interest groups.

4.4. Final conclusions

Our study has showed that reintroducing roe deer in central Portugal is feasible and the study area has ecological and environmental suitable conditions for the success of the reintroduction project. Taking a wider perspective, the roe deer reintroduction project can also act as a flagship species for the Iberian wolf conservation and such reintroduction project would promote not only this endangered predator conservation but would also contribute to central Portugal ecosystem restoration. Among the many challenges ahead for roe deer reintroduction projects, and Iberian wolf conservation, building a better understanding of the main drawbacks for roe deer colonizing and expansion in central Portugal is essential for wolf conservation. As a final conclusion we stress that predictive models must be used with caution in conservation, they are a complement for expert knowledge, rather than a replacement. Expert knowledge can identify areas of potential model weakness and suggest possible refinements, further explanatory variables, or identify geographical barriers not considered by the model. As a final remark, we believe that our results illustrate an approach that could contribute specifically to planning the reintroduction of roe deer in central Portugal. More generally, we suggest that the combination of field survey and GIS-based population modeling is a potent tool for exploring wildlife management strategies in general.

CHAPTER V

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CHAPTER VI

Annexes

6. ANNEXES

6.1. Annex I

Reintrodução do corço (*Capreolus capreolus*) no centro de Portugal (serras da Freita, Arada e Montemuro)

[Inquérito]

Este inquérito, que se insere no projecto de reintrodução do corço nas serras da Freita, Arada e Montemuro, tem como objectivo principal providenciar uma base de dados sobre a atitude das pessoas locais e dos principais interessados relativamente à reintrodução do corço. Pretende-se também identificar os factores-chave que influenciam tais atitudes e/ou falhas no conhecimento, e avaliar o apoio das pessoas na actual gestão da espécie. Os resultados devem-nos ajudar a encorajar e facilitar a comunicação entre gestores de populações de corço, caçadores e pessoas locais – que é o primeiro passo para iniciar um envolvimento público na gestão da vida selvagem.
Os dados utilizados neste estudo são anónimos e totalmente confidenciais, sendo apenas utilizados para fins académicos e de análises estatísticas.
(Para qualquer dúvida ou questão sobre o assunto não hesitar em contactar: rita.torres@ua.pt e cfonseca@ua.pt).

Local: ______________________ Data: ___/___/______

GRUPO A (dados pessoais)

A.1. Sexo: Feminino □ Masculino □
A.2. Idade ____
A.3. Estatuto: Trabalhador(a) □ Estudante □
Reformado(a) □ Desempregado(a) □
A.4. Educação: Analfabeto □ Primária □ 9º ano □ Secundária □ Universitária □ Outra □: _____________
A.5. Actividade/Profissão: Pastor □ Agricultor □ Outra □: ____________________
A.6. Freguesia ________________ Concelho ________________ Distrito ________________
A.7. Possui gado doméstico? Sim □ Não □
A.8. Se sim, qual e número? Cabras □ ____ Ovelhas □ ____ Vacas □ ____
A.9. É caçador/ pertence a algum clube de caça local? Sim □ Não □
Se sim, qual? ____
A.10. Pertence a alguma organização/entidade directa ou indirectamente ligada à conservação da Natureza? Sim □ Não □
A.11. Se sim, qual? ____

GRUPO B (pré-conhecimento)

B.1. Conhece o animal que se apresenta nas imagens acima? Sim □ Não □

B.2. Alguma vez o avistou na sua zona? Sim □ Não □

B.3. Em que local ou locais já viu corços? Pinhal □ Montado □ Eucaliptal □ Carvalhal □ Souto □
Outro tipo de floresta □ Matos/Manchas arbustivas □ Culturas agrícolas □ Junto a habitações, estradas ou caminhos □ Outra(s) □: ____

B.4. Quando foi a primeira vez que avistou a espécie na sua zona? ______________________________

B.5. Achas que o corço na sua zona é: Muito comum □ Comum □ Pouco comum □ Raro □

B.6. Em termos legais acha que é permitido caçar corço? Sim □ Não □

B.7. Acha que o corço é uma espécie introduzida em Portugal? Sim □ Não □

B.8. O lobo é predador do corço. Sim □ Não □

B.9. Considera o corço uma espécie prejudicial? Sim □ Não □

B.10. Considera que, de uma maneira geral e em Portugal, os corços:
Têm aumentado □ Têm diminuído □ Têm-se mantido relativamente constantes □

B.11. Tendo em conta a resposta anterior indique as possíveis causas para que isso tenha ocorrido. ____

B.12. Considera que os lobos têm aumentado na sua região? Sim □ Não □

B.13. Se sim, porquê? ____

B.14. Os lobos preferem alimentar-se de: Animais selvagens (ex: corço; javali) □ Animais domésticos □

B.15. Os ataques de lobo a gado doméstico na sua zona são:
Muito comuns □ Comuns □ Pouco comuns □ Raros □

B.16. As populações de lobo em Portugal: Têm aumentado □ Têm diminuído □ Têm-se mantido relativamente constantes □

B.17. Acha que quanto maior for a disponibilidade de presas selvagens (ex: corço; javali), mais facilmente o lobo se alimenta destas do que de gado doméstico? Sim □ Não □

B.18. Acha que a presença de um grande predador como o lobo ajuda no controlo de espécies problemáticas como o javali? Sim □ Não □

B.19. Acha que o número de cães assilvestrados na sua região: Têm aumentado □ Têm diminuído □ Têm-se mantido relativamente constantes □

B.20. Quantos lobos acha que existem na: Arada/Freita: ______ Montemuro: ______ Cinfães: _______

GRUPO C (atitudes e opinião relativamente ao corço/lobo)

Tendo em conta as seguintes questões responda de acordo com a sua opinião sendo que: 1 = Discordo fortemente; 2 = Discordo; 3 = Neutro; 4 = Concordo; 5 = Concordo fortemente.

C.1. Se as pastagens fossem adequadas, seria capaz de "doar" parte como habitat para o corço?
1 □ 2 □ 3 □ 4 □ 5 □

C.2. Se houvesse corços a pastar nos seus terrenos, expulsava-os de lá? 1 □ 2 □ 3 □ 4 □ 5 □

C.3. Se visse um corço ferido, contactaria o ICNF para ajudar a salvá-lo/ reportar a situação?
1 □ 2 □ 3 □ 4 □ 5 □

C.4. É importante manter corços em Portugal para que as gerações futuras possam disfrutar deles.
1 □ 2 □ 3 □ 4 □ 5 □

C.5. É importante ter populações de corços em Portugal. 1 □ 2 □ 3 □ 4 □ 5 □

C.6. O que acha de ter corços na Arada, Freita e Montemuro? 1 □ 2 □ 3 □ 4 □ 5 □

C.7. Mesmo que eu possa ou não possa ver um corço, é importante para mim que eles existam em Portugal.
1 □ 2 □ 3 □ 4 □ 5 □

C.8. O lobo é um símbolo de Natureza intacta. 1 □ 2 □ 3 □ 4 □ 5 □

C.9. Não é necessário haver corços em Portugal porque já existem populações de corço abundantes noutros países Europeus. 1 □ 2 □ 3 □ 4 □ 5 □

C.10. Ter corço na Freita, Arada e Montemuro poderá fazer aumentar o turismo. 1 □ 2 □ 3 □ 4 □ 5 □

C.11. Seria realmente entusiasmante ver um corço no seu estado selvagem. 1 □ 2 □ 3 □ 4 □ 5 □

C.12. É importante ter populações de lobo em Portugal. 1 □ 2 □ 3 □ 4 □ 5 □

C.13. Se visse um lobo ferido, contactaria o ICNF para ajudar a salvá-lo/ reportar a situação?
1 □ 2 □ 3 □ 4 □ 5 □

C.14. Ter uma população estável de lobo na Freita, Arada e Montemuro pode ser um factor importante para o turismo. 1 □ 2 □ 3 □ 4 □ 5 □

C.15. Os cães assilvestrados causam prejuízos no gado doméstico. 1 □ 2 □ 3 □ 4 □ 5 □

C.16. A presença de lobo na Arada, Freita e Montemuro é importante, pois controla as populações de cães assilvestrados. 1 □ 2 □ 3 □ 4 □ 5 □

C.17. Concordo com a actual lei de protecção do lobo, visto ser uma espécie com estatuto de conservação "Em Perigo". 1 □ 2 □ 3 □ 4 □ 5 □

GRUPO D (atitudes e opinião sobre reintrodução e conservação)

Tendo em conta as seguintes questões responda de acordo com a sua opinião sendo que: 1 = Discordo fortemente; 2 = Discordo; 3 = Neutro; 4 = Concordo; 5 = Concordo fortemente.

D.1. Concorda com a conservação do corço na Arada, Freita e Montemuro?
1 □ 2 □ 3 □ 4 □ 5 □

D.2. Concorda com o estabelecimento de uma área especial protegida para o corço?
1 □ 2 □ 3 □ 4 □ 5 □

D.3. Concorda com o investimento de mais fundos para a conservação do corço? 1 □ 2 □ 3 □ 4 □ 5 □

D.4. Concorda que as pessoas locais participem na conservação do corço?
1 □ 2 □ 3 □ 4 □ 5 □

D.5. Acha que pode beneficiar da conversação do corço? 1 □ 2 □ 3 □ 4 □ 5 □

D.6. Concorda com a reintrodução de corço na Arada, Freita e Montemuro. 1 □ 2 □ 3 □ 4 □ 5 □

D.7. A reintrodução do corço é um bom método para salvaguardar as populações de gado doméstico na sua região. 1 □ 2 □ 3 □ 4 □ 5 □

D.8. Se os corços fossem reintroduzidos na Arada, Freita e Montemuro eu provavelmente ia lá tentar observá-los. 1 □ 2 □ 3 □ 4 □ 5 □

D.9. Com a reintrodução do corço os hábitos alimentares/comportamentais do lobo irão alterar-se.
1 □ 2 □ 3 □ 4 □ 5 □

D.10. Após a reintrodução do corço, o lobo deixará de se alimentar tanto de gado doméstico.
1 □ 2 □ 3 □ 4 □ 5 □

D.11. Os corços devem ser conservados pois têm o direito de existir. 1 □ 2 □ 3 □ 4 □ 5 □

D.12. O número de corços deveria aumentar. 1 □ 2 □ 3 □ 4 □ 5 □

D.13. O corço deveria existir apenas em partes restritas de Portugal. 1 □ 2 □ 3 □ 4 □ 5 □

D.14. Concordo com o aumento do número de corços na minha região. 1 □ 2 □ 3 □ 4 □ 5 □

GRUPO E (atitudes e opinião sobre gestão de caça)

Tendo em conta as seguintes questões responda de acordo com a sua opinião sendo que: 1 = Discordo fortemente; 2 = Discordo; 3 = Neutro; 4 = Concordo; 5 = Concordo fortemente.

E.1. Se os corços forem caçados, a caça deve ser restrita a áreas específicas. 1 □ 2 □ 3 □ 4 □ 5 □

E.2. Os corços deveriam poder ser caçados numa determinada época do ano. 1 □ 2 □ 3 □ 4 □ 5 □

E.3. Os corços deveriam poder ser caçados durante todo o ano em Portugal. 1 □ 2 □ 3 □ 4 □ 5 □

OBRIGADO PELA SUA COLABORAÇÃO!