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Original Investigation

Factors affecting roe deer occurrence in a Mediterranean landscape, Northeastern Portugal

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ABSTRACT

The European roe deer population in Portugal is on the southwestern edge of its distribution. Understanding limiting factors that act on these populations enlightens both local aspects concerning their conservation and wider scale aspects of the species bioclimatic envelope, which is crucial for being better able to predict the impacts of environmental change. Accordingly, a survey was conducted to explore roe deer distribution in a 75,000 ha area located in Trás-os-Montes region, a Mediterranean landscape in the northeast of Portugal. Pellet-group counts were used to examine how roe deer distribution was related to habitat structure and composition, landscape structure, and human disturbance. The analysis considered two spatial scales: habitat patch and the wider landscape. At the patch scale, roe deer distribution was positively associated with high density of shrubs and with increasing distance from roads. At the landscape scale, roe deer distribution was negatively associated with spatial heterogeneity, namely mean shape index. Our findings suggest that landscape structure, vegetation composition and distance to roads are all important factors influencing roe deer distribution, highlighting the importance of multi-scale approaches.

Introduction

Understanding how species are distributed spatial and temporally is a central topic in ecology. Over the last two decades, discussions about the underlying mechanisms that influence species abundance and distribution have increased (Guisan and Thuiller 2005). Although a diversity of models is available, all try to statistically relate field observations to a set of environmental predictor variables, presumably reflecting potential key factors of the species niche. These models produce spatial predictions indicating the suitability of locations for a target species, community or biodiversity (Guisan and Thuiller 2005). Such research has become especially important against the backdrop of climate change and efforts to predict the consequences for species distributions (Copeland et al. 2010).

Animals can perceive their environment over a range of scales that might affect their final selection (Wiens et al. 1993; Rettie and Messier 2000) and many studies have shown different selective behaviours depending on the spatial scale used for analysis (Kie et al. 2002). This has led to the expansion from an early focus on local interactions to include broader scales (e.g. from home-range, to landscape, and biogeographic regions, etc.), underlying the importance of multiscale approaches (Cushman and McGarigal 2004). Failure to consider and select the most appropriate scale, or suite of scales, may jeopardize wildlife decision-making (Rotenberry et al. 2006).

The European roe deer (*Capreolus capreolus*) is the most abundant and widespread cervid species in Europe (Apollonio et al. 2010). Once considered a typical forest species, recent studies have demonstrated this species' ability to colonize a wide range of habitats and they can now be found in almost all European landscapes (Tellería and Virgós 1997; Hewison et al. 2001; Jepsen and Topping 2004). Two factors that play a critical part in shaping this species' distribution are food (Virgós and Telléria 1998) and cover (Mysterud and Østbye 1999; Borkowski 2004; Borkowski and Ukalska 2008). Several other factors can also affect its spatial distribution including, human disturbance (Aragón et al. 1995; Hewison et al. 2001), terrain characteristics (Mysterud and Østbye 1999), climatic factors (Brewka and Kossak 1994). In addition, the ongoing expansion of large carnivores, especially wolves, across Europe is leading to an increased interest in how predation may influence habitat use and distribution (Jędrzejewski et al. 1992; Ratikainen et al. 2007; Melis et al. 2009). Marginal populations can be expected to be prone to greater impacts of predation than in other locations

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close to their central distribution (Hoffmann and Blows 1994). It is unknown however, which factors shape roe deer distribution in the mosaic Mediterranean landscapes, such as those occurring in the north of Portugal. This population of roe deer is undoubtedly of high conservation and ecological interest since it: (i) occupies the edge of its southwestern distribution range (Holt and Keitt 2005); (ii) occurs at low densities and is thus relatively prone to extinction as a consequence of potential environmental changes (Lande 1993); (iii) occupies a Mediterranean ecosystem, completely different from the well studied populations of central and northern Europe (Carvalho et al. 2008) and (iv) constitutes the main wild prey for the endangered Iberian wolf *Canis lupus signatus* (Vos 2000). Most of the information of the effect of predators (e.g. *Eurasian lynx Lynx lynx*, fox *Vulpes vulpes* and/or by wolves *Canis lupus*) on this species comes from central and northern Europe (Okarma et al. 1997; Jędrzejewski et al. 2002; Molinari-Jobin et al. 2002; Odden et al. 2006; Panzacchi et al. 2008; Nilsen et al. 2009). In Mediterranean habitats, where wolf densities are high (Boitani 2000), the anti-predator strategies adopted by roe deer against wolf predation are scarce, particularly when compared with those adopted against lynx and foxes in central and northern European ecosystems. Consequently, studies on habitat use of roe deer are essential to understand the mechanisms involved in their distribution and abundance (Prevedello et al. 2010). Our study provides a novel opportunity to analyse roe deer populations at the edge of its range, where densities are low and predation risk can be assumed to be relatively high.

Generally, we expect roe deer to be particularly sensitive to human activity, avoiding these areas (e.g. settlements, roads). Roe deer are very timid, showing cryptic behaviour and generally fear human presence (Hewison et al. 2001). We also hypothesized that roe deer distribution is directed influenced by the arrangement of the varied patches of the landscape pattern.

In the light of the lack of data regarding roe deer habitat use in a Mediterranean ecosystem, the main objectives of this study were: (i) to analyse roe deer occurrence in a Mediterranean landscape in the presence of a large range of factors, including a predator; (ii) to determine which ecological factors are relevant, at different spatial scales, for roe deer distribution, and (iii) to develop a model of roe deer distribution to improve future roe deer management.

Material and methods

Study area

The study was carried out in Montesinho Natural Park and Serra da Nogueira, Trás-os-Montes, northeast Portugal (6°30′–7°12′W and 41°43′–41°59′N), both sites are part of the European Union's Natura 2000 network, covering an area of 75,000 ha (Fig. 1). The terrain consists of rolling hills with elevation ranges from 438 to 1481 m. The climate is Mediterranean with the mean annual temperature varying between 3 °C in the coldest month and 21 °C in the warmest month and mean precipitation between 1000 and 1600 mm (Gonçalves 1980). In the study area, wolves have been present since historical times and densities have been calculated to be 1.6–3.1 wolves/100 km^2 (Moreira et al. 1997). Although comparisons are difficult because of variation in methods, these densities are relatively high in a European context, where the densities are generally <1 wolves/100 km^2, e.g. Finland or Croatia: 0.5–1 wolves/100 km^2 (Boitani 2000). Roe deer is a native species in the north of Portugal where populations have always persisted in a few patches in the study area. Due to its low abundance, hunting is very restricted, occurring in a few touristic hunting grounds only (Apollonio et al. 2010).

The vegetation is varied and characterised by *Quercus pyrenaica*, *Castanea sativa*, *Pinus sylvestris*, *Pinus pinaster*, and *Quercus rotundifolia*. Main understory species are *Erica australis*, *Pterospartum tridentatum* and *Halimium alyssoides*, *Cistus ladanifer* and *Lavandula sampaioana*. The area is crossed by a diversity of rivers and small streams and the associated vegetation is mainly *Alnus glutinosa*, *Fraxinus angustifolia*, *Populus nigra* and *Salix salviifolia*, which are strongly linked to mountain meadows. The area exhibits a mosaic of deciduous and coniferous forest, fragmented by small-cultivated fields. The area has a low population density of 9.5 people/km^2, living in small villages. A number of national roads, which provides connection between Portugal and Spain, cross the study area.

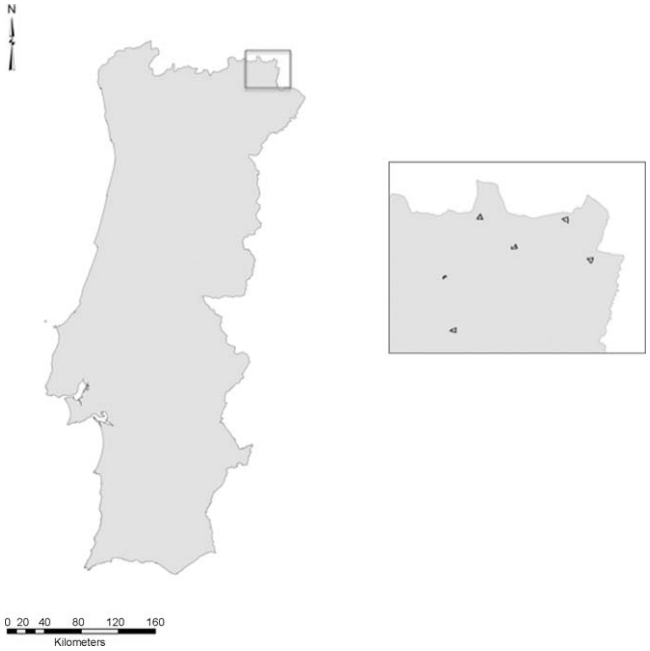

Fig. 1. Map of Portugal (left), highlighting where the field survey was done (Trás-os-Montes region, northeastern Portugal, right). On the right, there is the distribution of the sampling plots.

Data collection

Field work was conducted between October 2007 and August 2009 using pellet group counts. This technique is widely applied in studies of ungulate habitat use (e.g. Neff 1968; Tellería and Virgós 1997; Borkowski and Ukalska 2008) and provides a valid approach to allow an initial coarse scale assessment of habitat associations. A total of 120 segments (50 m × 2 m) were examined within our study area and the plots were visited five times throughout the field survey. Because of the low number of pellet groups detected in all segments, data was pooled across years to improve estimates. These segments were distributed along 6 transects, each one consisted of a 1 km × 1 km × 1 km triangle (3 km in total); which is an efficient field design (the start point and end point are on the same place). Transects were located with the help of technical staff from the Natural Park and were drawn on a 1:10,000 map scale, distributed to provide an adequate coverage of all the habitat types in the study area (Mayle et al. 1999). In order to maximize spatial coverage and to mitigate sampling dependence, segments were evenly spaced along the line. Each of these transect segments was considered a sampling unit. We used the number of roe deer pellet groups within each segment as our index of habitat use in order to focus our study on small scale habitat decisions of the species (Borkowski and Ukalska 2008). In the field, only roe deer pellet groups containing six or more individual pellets, and identified as being produced at the same defecation (similar size, shape, texture and colour), were recorded (Mayle et al. 2000). Pellet groups lying on the boundary