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Original Investigation

Effects of agro-forestry activities, cattle-raising practices and food-related factors in badger sett location and use in Portugal

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ABSTRACT

Mediterranean landscapes in Europe are characterized by a mixed matrix of agriculture, agro-forestry or cattle-farming areas, which have influenced native communities for centuries. Recently, new changes were imposed on these agro-forestry landscapes due to novel management options that provide new challenges for wildlife. From a conservation perspective, there is an urgent need to assess what are the impacts and ecological responses of local wildlife populations to those changes. In the present study, we assessed the influence of human-caused disturbances (*e.g.* agroforestry practices, cattle-breeding activities and game management), together with food/water and landscape-related factors, on sett site selection by European badgers. We also tested the role of these factors, together with climatic variability, on sett use. We detected that areas further away from water sources, but close to game species feeding structures, have a higher probability of hosting a European badger sett. Moreover, sett use was promoted by low disturbance: setts with lower cattle presence and without understory removal activities were more often in use. Thus, our study shows that, in our study area, agro-forestry and cattle breeding activities constrain badger sett use, while food and water availability influence their distribution. Although badgers have been adapting to anthropogenic activities for centuries, they respond differently depending on the type and intensity of management. Thus, to ensure biodiversity persistence and sustainable human exploitation of the landscape, we need to identify trade-offs between wildlife ecological adaptations and anthropogenic agriculture, forestry and cattle production.

Introduction

Cork (*Quercus suber*) and/or holm (*Q. ilex*, *Q. rotundifolia*) woodlands are savannah-type agro-forestry-pastoral systems, termed "montado" in Portugal or "dehesas" in Spain (Bugalho et al., 2011). Agricultural, forestry and cattle-breeding practices and management changes, together with the recent introduction of other anthropogenically-managed activities, such as commercial and recreational hunting (Casanova and Memoli, 2001), have impacts on the diverse wildlife community that inhabits these forest systems (Bugalho et al., 2011). These impacts may lead to alterations in population patterns and processes (*e.g.* decreasing abundance – Pita et al., 2009; local extinctions – Cabezas-Díaz et al., 2009; dependence on anthropogenic resources – Rosalino et al., 2005a). The degree of impact depends on the magnitude of the driver of change and also on species resilience. Species that are capable of persisting in these human-shaped forest ecosystems are already resilient to landscape humanisation, but recent alterations impose new challenges to which they must respond.

Among species that have managed to survive in agriculture landscapes, carnivores are particularly important since they are key players in ecosystem structure and functioning due to their ecological role (*e.g.* population regulators, pest controllers, seed dispersers; Correia, 2001; Herrera, 1989; Jaksić and Delibes, 1987) and their sensitivity to human activities (*e.g.* direct persecution, hunting; Muñoz-Igualada et al., 2008). Particularly important are those with large-scale patterns of distribution and abundance, such as red fox (*Vulpes vulpes*), stone-marten (*Martes foina*) or the European badger (*Meles meles*).

The European badger is one of the most common mesocarnivores living in southwestern Mediterranean cork/holm oak woodlands (Rosalino et al., 2005c). The ecological pattern and role of this carnivore is anchored in its social structure, with group size and composition varying according to available resources (Kowalczyk et al., 2003; Revilla and Palomares, 2002). In

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western Mediterranean environments, badgers live in small groups (3–4 adults and 3–4 cubs; Rosalino et al., 2004) and in low abundance; these being regulated by the availability of sites to build their communal dens, commonly known as setts (Rosalino et al., 2005b). Unlike most mustelid species and other carnivores, badgers build their own setts, which often comprise several entrances connected by a complex tunnel system (Roper, 1992), and their location is strongly influenced by physiographic factors (*e.g.* altimetry, geology; Rosalino et al., 2005b), proximity to feeding grounds (Good et al., 2001), habitat shelter characteristics (Virgós and Casanovas, 1999) or intensity and type of anthropic disturbance (*e.g.* human settlements, roads – Jepsen et al., 2005). In addition, sett use also varies greatly with the type of sett (main *vs* secondary – Loureiro et al., 2007), sett ectoparasitic load (Butler and Roper, 1996) or human disturbance (*e.g.* poaching activities, degree of public access – Jenkinson and Wheater, 1998).

Despite the species' sensitivity to disturbance, in Mediterranean areas badgers occupy areas where the landscape matrix consists of agricultural fields and/or agro-forestry systems but, to our knowledge, the influence of land management practices on badger sett location and use is seldom evaluated (but see Virgós and Casanovas, 1999), in spite of the large number of studies targeting several ecological facets of its southern populations (see Roper, 2010 for a review).

The objective of this study is to test if factors associated with human activities, such as agriculture, forestry, cattle breeding and game-feeding, influence badger sett location (sett *vs* non-sett sites) and levels of use (monthly use *vs* non-use), in an intensively managed agro-forestry farmstead. We tested four hypotheses, namely that badger sett locations will be determined by factors associated with: (1) food and water availability; (2) land cover; (3) disturbance; (4) or a combination of any of those. We hypothesize that badger setts will have a higher probability of being located in areas with less anthropogenic disturbance (*e.g.* low tree and cork harvesting, low understory clear-cutting, greater distance to rural houses, etc.), and greater access to basic resources (*e.g.* food, water and dense vegetation for refuge), when compared to non-sett sites. We also tested five hypotheses regarding factors determining sett use: (1) water availability; (2) land cover; (3) disturbance; (4) climate; (5) or a combination of any of those. We hypothesize that sett use throughout the year will decrease with increasing direct disturbance (*e.g.* understory clear-cutting, cattle presence) and changes in climatic conditions (*e.g.* higher precipitation, lower temperatures).

Material and methods

Study area

The study was conducted in central west Portugal, at the "Charneca do Infantado" (Fig. 1), part of "Companhia das Lezírias, S.A." (hereafter CL), the largest Portuguese agro-forestry farmstead, located *ca.* 30 km from Lisbon in Samora Correia and Alcochete counties. Charneca do Infantado comprises 10,000 ha of agro-forest farmland and is part of the LTsER Montado platform. The area is characterized by poor, sandy and sandy-loam soils with low permeability and a typical Mediterranean climate, with dry and hot summers (temperatures reaching 40 °C) and cold and rainy winters (up to 400 mm of rain).

Cork oak woodlands, with varying shrub densities, are the main land use type (6725 ha). Other forested areas include plantations of Maritime pine (*Pinus pinaster*; 971 ha), stone pine (*Pinus pinea*; 508 ha) and eucalyptus (*Eucalyptus globulus*; 476 ha). Agricultural activities are focused mainly on rice (630 ha), animal fodder (in irrigated areas – 460 ha), and olive (59 ha) and wine production (140 ha).

Another important economic activity in Charneca do Infantado is cattle production. This occurs on natural or permanent biodiverse pastures, many within and below cork oak trees, but patches of mixed forest with a dense shrub understory have been fenced for cattle exclusion at different time periods to improve tree regeneration and biodiversity preservation. The cattle are organized into herds that rotate among grazing plots during the wet season (from September/October until February/March depending on precipitation values). In the dry season herds are moved to

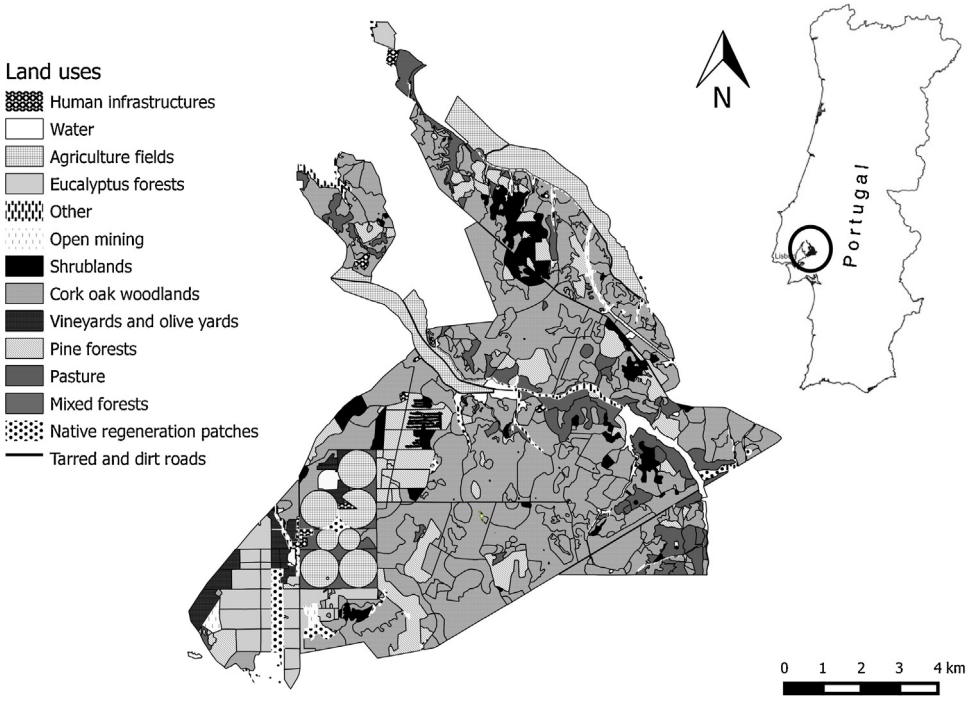

Fig. 1. Study area location and land cover composition.