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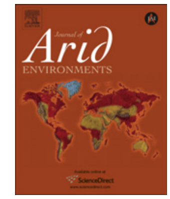

Habitat selection by European badgers in Mediterranean semi-arid ecosystems

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ABSTRACT

We studied the habitat selection patterns of badgers *Meles meles* (Linnaeus, 1758) in Mediterranean semi-arid ecosystems. Fifty-seven plots were sampled in two semi-arid regions of Spain. In each plot, badger latrines were located along 2.6 km transects. The number of badger latrines per km was used as a surrogate of badger abundance and as an index of habitat selection by badgers. For each plot, a series of environmental variables were measured at two spatial scales. These variables were related to land use and vegetation formation parameters that are considered potentially important for habitat requirements (i.e., food and shelter). The habitat selection model was carried out using generalised linear models (GLM) and an information-theoretic approach. Results indicated that badgers prefer fruit orchards, and shrub and rock-covered areas, which provide additional trophic and shelter resources, and avoid intensively cultivated fields and human settlements. We conclude that badger conservation in semi-arid environments of the Iberian Peninsula requires the existence of fruit orchards and the limitation of human development. Policies restraining agriculture intensification would encourage traditional or new non-intensive agricultural practices and increase shrub-patch availability, which would benefit this species.

1. Introduction

Habitat selection models are a useful tool in conservation biology and wildlife management (Caughley and Sinclair, 1994). They identify the processes involved in habitat choice by using statistical methods to relate species distribution to the spatial distribution of environmental factors (Guisan and Zimmermann, 2000). As habitat selection can occur at different scales, habitat selection models should include a multiscale approach varying from individuals to total species distribution (Johnson, 1980). Although many variables such as climatic conditions, ecological interactions or soil characteristics can influence habitat selection, vegetation (which represents shelter and trophic resources) is the most frequently discussed (Cody, 1985). Knowledge of how these variables affect habitat selection at different scales should be the first step in designing conservation strategies (Caughley and Sinclair, 1994).

The European badger, *Meles meles*, is widely distributed across the western Palaearctic region (Del Cerro et al., 2010) where it is mainly associated with deciduous woodlands and pastures (Kruuk, 1989; Feore and Montgomery, 1999). However, their versatile ecological requirements also allow them to occur in boreal forests, Mediterranean landscapes and steppes (Neal and Cheeseman, 1996). The southern limit of its distribution range runs along the border between semi-arid and hot-arid climate regions. Hence, aridity can be considered a limiting factor of badger distribution. This species reaches the southwestern limit of its distribution range in the Iberian Peninsula (Del Cerro et al., 2010). In this region, the highest badger densities and occurrences have been found in temperate areas in landscapes composed of a mosaic of deciduous forests and pastures (Virgós and Casanovas, 1999b). It is scarce in drier landscapes, which are dominant in most of the Iberian Peninsula (Revilla et al., 1999; Virgós and Casanovas, 1999a, b) probably due to reduced food availability (Rodriguez and Delibes, 1992; Virgós et al., 2004; Barea-Azcón et al., 2010) and fragmentation of key habitats, particularly in intensively cultivated areas (Virgós, 2001, 2002). In southeastern and central Spain, badgers occur in semi-arid regions where trophic resources, climate, and landscape pattern are extreme for the species. Nevertheless, little is known about badger distribution, abundance and habitat selection in semi-arid environments. Rodriguez and Delibes (1992) proposed that badgers can only reach high abundance in these regions by

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using productive patches devoted to orchards and other forms of cultivated land. Barea-Azcón et al. (2010) recently outlined a similar proposal. Therefore, badger distribution and abundance in semi-arid regions seem to be highly dependent on farming practices.

A large proportion of the farmland in semi-arid regions in Spain has a high environmental value as a semi-natural habitat subjected to extensive management practices (Blondel and Aronson, 1999; Reidsma et al., 2006). However, in the last few decades, the European Union's Common Agricultural Policy (CAP) has impacted the ecology of these agricultural systems, by promoting the specialisation and intensification of areas of high potential productivity and the abandonment of less productive and marginal lands (Oñate et al., 2007; Stoate et al., 2009). This process, far from disappearing, is likely to continue according to most land use predictions (Petit et al., 2001; Reidsma et al., 2006). As a consequence, low intensity agricultural practices and semi-natural vegetation have decreased, producing a loss of habitat heterogeneity (Berger et al., 2006; Stoate et al., 2009). Badgers inhabiting semi-arid environments in the Iberian Peninsula may be highly vulnerable to these changes, as they prefer heterogeneous habitats and those characterised by traditional agricultural practices (e.g., Kruuk, 1989; Feore and Montgomery, 1999; Virgós and Casanovas, 1999a; Rosalino et al., 2004), and are susceptible to habitat loss and fragmentation in intensive agricultural landscapes (Virgós, 2001, 2002).

The Mediterranean area is also one of the regions most threatened by global warming (Parmesan and Yohe, 2003). According to current predictions, most of its semi-arid landscapes could become more arid and extend northward, reducing overall habitat quality for badgers.

In this work, we studied the habitat selection patterns of European badgers in Mediterranean semi-arid habitats. We hypothesised that badger abundance would be positively correlated to the presence of natural vegetation, cultivated fruit orchards and rock blocks cover, which in combination provide trophic and shelter resources.

2. Methods

2.1. Study area

This study was carried out in two regions in the Iberian Peninsula (Spain) where agriculture is the main human activity and hunting and extractive activities are of minor relevance.

The northern study area was located in the southeastern Madrid region (40°09'N, 3°15'O), with an average annual temperature of 13.7 °C and an average annual precipitation of 410 mm. It is covered by xeric vegetation such as *Stipa tenacissima* L. (28%) with small patches of sclerophyllous holm oak forest dominated by *Quercus ilex* and *Quercus coccifera* (9%) and cultivated pine forest (*Pinus halepensis*) (6%). These patches are included in an agricultural matrix of intensive and monospecific olive tree (*Olea europaea*) plantations (18%) and non-irrigated crops, mainly cereal crops (25%). In this area, we did not find orchards of fruiting tree species that are known to be preferred by badgers in semi-arid landscapes (Rodriguez and Delibes, 1992).

The southern study area was located in the southeastern Andalusian region (37°00'N, 2°20'O), with an average annual temperature of 16.6 °C and an average annual precipitation of 310 mm. Its vegetation is comprised of xeric species such as *S. tenacissima* L. (56%) and a mosaic of small orchards with various fruit trees (mainly orange, lemon and almond trees) (9%), olive plantations (7%) and irrigated crops (12%). Forests are very scarce, and there is only one cultivated pine forest (*P. halepensis*) in the area (8%).

2.2. Survey procedure

This study was conducted in autumn 2007 and spring 2008, coinciding with the periods of high faecal marking rates in this species (Pigozzi, 1990; Virgós et al., Unpublished results), which maximises the probability of detection. We sampled 28 and 29 plots of 3 × 3 km in the northern and southern study areas, respectively. Plots were separated by a minimum distance of 2 km to mitigate spatial autocorrelation (Guisan and Zimmermann, 2000). The survey covered an area of approximately 1400 km^2 and 1700 km^2 in the northern and southern study areas, respectively.

Badger abundance was recorded using a modification of the methodology proposed by Tuyttens et al. (2001). In each plot, we sampled a 2.6 km × 5 m linear transect. The transects were walked following linear features such as hill slopes, gulches, natural narrow paths and ecotone edges among different habitat patches, as badgers tend to dig at such places (Kruuk, 1989). The number of badger latrines was recorded for each transect because this variable correlates better with badger density than the amount of faeces (Tuyttens et al., 2001; Mangas et al., Unpublished results). Thus, the number of latrines per kilometre of surveyed transect (hereafter latrine/km) was used as an index of badger abundance. Moreover, latrine distribution reflects the pattern of badger home range use, and marking such activity can be used as an index of habitat selection by badgers in low density populations (Balestrieri et al., 2009).

2.3. Environmental variables

A series of environmental variables related to land use and vegetation formation were measured in each plot at two spatial scales (Table 1). These variables can potentially influence food and shelter availability for badgers, as they have been identified as the main components of badger habitat quality (Kruuk, 1989). At the microhabitat scale (e.g. transect scale), the environmental variables were measured in field surveys. Linear transects were divided into 200 m segments. The percent cover of eight environmental variables was visually estimated every 200 m along each transect, following protocols similar to those previously used for this species (Virgós and Casanovas, 1999a).

At the macrohabitat scale, we used ArcMap 9.2 GIS (ESRI© 2006) and a recent 1:50,000 vegetation/land use map (Spanish Ministry of the Environment and Rural and Marine Environments: www.marm.es) to obtain the land cover of 10 environmental variables within a 9 km^2 buffer zone around each transect. We considered 9 km^2 to reflect habitat selection at a level similar to the mean probable home range (Johnson, 1980) of this species in areas of low habitat suitability. This area is larger than the home ranges defined for Mediterranean ecosystems in previous studies (Revilla and Palomares, 2002; Rosalino et al., 2004), because resources are scarcer and more dispersed in semi-arid environments. Thus, according to the resource dispersion hypothesis (RDH: Kruuk, 1989), badgers will move longer distances, cover larger daily ranges and defend larger territories.

2.4. Statistical analyses

All variables were standardised to an average of zero and a standard deviation of one to increase the comparability of the effects of variables, and latrines per kilometre (latrine/km) were log-transformed to attain normality of data.

We used generalised linear models (GLMs) to determine habitat selection patterns of European badgers. Prior to building the models, a Pearson correlation analysis was carried out for the total set of environmental variables and loglatrine/km to avoid multicolinearity