

# Defining key habitats for low density populations of Eurasian badgers in Mediterranean environments

Eloy Revilla \*, Francisco Palomares, Miguel Delibes

Department of Applied Biology, Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas, Avenida de María Luisa s/n, 41013 Seville, Spain

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## Abstract

Populations of Eurasian badgers (*Meles meles*) living in Mediterranean ecosystems are of conservation concern. Deciduous forests are considered the main habitats of these badger populations in mountains, but key habitats for badgers have not been distinguished in Mediterranean lowlands. We provide a quantitative analysis of the overall habitat selection and preferences of Eurasian badgers in a Mediterranean area (Doñana, SW Spain). Data on 17 radiomarked animals in a rabbit-based population and three animals from another population with no single staple food were analysed by compositional analysis for determining selection and preference order, and Jacobs' index for absolute preference/avoidance. Results indicate that, in the rabbit-based area, badgers preferred well-preserved Mediterranean scrubland at every level of the analysis. In the area where badgers had no staple food there was no clear pattern. Rabbit abundance explained a significant amount of variance of the Jacobs' index in the rabbit-based area at all levels of the analysis. It is concluded that badgers are selecting those habitat types which hold key resources, such as food or shelter. Thus, not only deciduous forest and associated pastures, but also scrubland holding healthy rabbit populations are key habitats for Mediterranean badgers living in the Iberian peninsula. © 2000 Elsevier Science Ltd. All rights reserved.

**Keywords:** Badger conservation; Habitat selection; Mediterranean areas; *Meles meles*; Doñana

## 1. Introduction

Habitat selection is one of the most poorly understood ecological processes (Krebs, 1994), but its study has become a necessary tool in conservation biology and wildlife management (Caughley and Sinclair, 1994; Noss and Csuti, 1997; Pulliam and Dunning, 1997). The basic assumption in habitat selection theory is that individuals select those types of habitat where the return in fitness is maximised. Habitat selection applies at different scales, varying from the spatial position of every individual to species distribution (Johnson, 1980; Morris, 1987; Orians and Wittenberger, 1991; Morris, 1992). Many variables can influence the individual decision of selecting between available habitats, from physiological limitations, to ecological constraints (e.g. predation pressure, refuge); but among them, trophic resources are the most frequently quoted (Krebs, 1994). The knowledge of

these factors is basic for the correct understanding of habitat choice processes (Morris, 1987) and for the implementation of effective strategies in conservation and/or management of species and landscapes (Kaiser, 1997).

The Eurasian badger (*Meles meles*) is a medium sized carnivore distributed all over temperate Eurasia (Long and Killingley, 1983). It occupies mainly Eurosiberian deciduous woods, but also boreal forest, Mediterranean landscapes, mountainous areas and steppes, among others (Long and Killingley 1983; Lüps and Wandeler 1993). However, it is generally considered as a forest-dwelling species (Long and Killingley, 1983; Corbet and Harris, 1991).

Badger populations inhabiting Mediterranean ecosystems are of conservation concern (Griffiths and Thomas, 1997). In Spain, the status of the Eurasian badger is listed as insufficiently known, i.e. it is suspected to be endangered, vulnerable or rare (Blanco and González, 1992), but the sparse information indicates that in some areas badger populations are declining (Virgós, 1994). Reduction and fragmentation of key habitats are considered to be among the most important causes of the decline of badger populations (Virgós, 2000). Badgers inhabiting

\* Corresponding author at current address Department of Ecological Modelling, UFZ Centre for Environmental Research, Leipzig-Halle, PO Box 2, D-04301 Leipzig, Germany. Fax: +34-95-462-1125.

E-mail address: revilla@ebd.csic.es (E. Revilla).

Mediterranean environments can be expected to be very vulnerable to these factors due to their low densities (Revilla et al., 1999), low fecundity (Neal and Cheeseman, 1996; Revilla et al., 1999), wide ranging behaviour (Rodríguez et al., 1995; Revilla, 1998) and high susceptibility to human-caused mortality (Blanco and González, 1992). In order to understand fragmentation processes a clear definition of the pattern of habitat selection is needed (Saunders et al., 1991). Thus, as a first step in the conservation of this species in Mediterranean environments, it is necessary to identify key habitats and the factors underlying habitat preferences of Mediterranean badgers.

The primary aim of our study was to provide a quantitative analysis of the overall habitat selection and preferences of radio-marked Eurasian badgers in a Mediterranean landscape, in order to detect the key habitats, if any, that should be the target of conservation efforts.

## 2. Methods

### 2.1. Study area

The study took place in the Doñana region (SW Spain, 37° 9' N, 6° 26' W). The core of this region is protected by Doñana National Park, which is surrounded by Doñana Natural Park (Fernández-Delgado, 1997). Doñana is a subhumid Mediterranean area (i.e. characterised by long-dry summers), with an average annual rainfall of 500–600 mm. Soils are sandy, except in marshlands, where they are clayey. Most of the study was carried out in the Coto del Rey area (northern border between both protected areas), where we considered seven different types of habitat, characterised by vegetation composition and structure: (1) *Lentiscus* scrubland (LS), dominated by *Pistacia lentiscus*, and *Halimium halimifolium*; (2) dehesa (DH), also called Mediterranean savannah, formed by rich pasturelands with scattered cork oaks (*Quercus suber*), and wild olive trees (*Olea europaea*); (3) ash stands (AS), situated along small streams and dominated by *Fraxinus angustifolia*, *Populus alba* and *Rubus* spp.; (4) pasturelands (PS), located at the ecotone between marshland and other types of habitat, especially LS; (5) marshland (MA), with several vegetation types that are flooded during the winter and dry in summer; (6) high density pine plantations (PI) of *Pinus pinea*; and (7) *Eucalyptus* sp. plantations (EU). The *Lentiscus* scrubland is divided into two large patches by ash stands, having dense pine plantations at the north, marshland and pasturelands at the south and west and dehesa to the east (see Fig. 1 in Palomares et al., 1996a).

Additionally, we had three marked badgers in the Reserva Biológica (hereafter Reserva), 8 km to the south

of Coto del Rey. Reserva forms the core of the National park. Here we distinguished six types of habitat: (1) Mediterranean dry scrubland (DS), dominated by xerophytic species; (2) hygrophytic scrubland (HS), characterised by *Erica* spp.; (3) Sabine stands (SA), dominated by *Juniperus phoenicea*; (4 and 5) pine plantations, considered as dense (DP) when uncleared, and as open (OP), when cleared; and (6) wetlands (WT), formed by small natural ephemeral pools and associated vegetation.

In the Reserva there is an important landscape shift from the east, close to the marsh and dominated by a matrix of HS, to the west, where a transition to DS occurs (Rogers and Myers, 1979). Both types of pine plantations are included in the scrub matrix as large patches, as well as SA and WT which are at small focal locations (for a sketch of the Reserva, see Fig. 1 in Ferreras et al., 1997; for more information on vegetation types at both Coto del Rey and Reserva, see Allier et al., 1974; Peinado and Rivas-Martinez, 1987).

A habitat availability map was generated for Coto del Rey from a raster-based 50 m resolution map obtained from the Andalusian System for Environmental Information (SINAMBA; Moreira and Fernández-Palacios, 1995) using IDRISI Geographical Information System (GIS) (Eastman, 1995). We did not use this information in the case of the Reserva, since it did not allow discrimination between the habitats considered (especially between pine plantations). In this case, we used the ecological map of the Reserva (Allier et al., 1974), which was updated with field information and latter digitised. Habitat types were assigned to the animal locations (see below) in accordance to these maps.

### 2.2. Doñana badgers and radiotracking

In Coto del Rey, badgers live in territorial groups (on average 3.22 individuals without yearlings), while in the Reserva they form pairs (Rodríguez et al., 1995; Revilla, 1998), the density in Coto del Rey being higher than in the Reserva (0.67 and 0.23 badgers/km<sup>2</sup>, respectively; Revilla et al., 1999). In Coto del Rey, the diet of badgers is very diverse, but European rabbits (*Oryctolagus cuniculus*) are the most important trophic resource, accounting for 53% of the food (Fedriani et al., 1998; Revilla, 1998). In the Reserva rabbits only represent 15% of the food during the period of study (Revilla, 1998), a consequence of lower rabbit abundance (rabbit density was 20 times less in the Reserva than in Coto del Rey; Revilla, 1998).

We used radiotracking in order to obtain information on the spatial position of individual badgers. Animals were captured, sexed, weighed, marked with a transponder and tagged with radio-collars (A. Wagener, Herwarthstr., Köln, Germany). In total, between 1993 and 1997, we captured and marked 24 individuals in Coto del Rey, 21 of which were established in five different

territories (being more than 80% of the total number of badgers estimated to be present; Revilla, 1998). Three of the animals changed their initial territory (by dispersal and re-establishment or by range expansion-fission), and thus their tracking interval was split into two distinct periods, and for analytical purposes considered as new individuals (following Geffen et al., 1992).

The aim of the study was to find any key habitat for badgers, and thus we analysed the overall habitat preferences, without considering seasonal or annual variations. In order to avoid any bias due to this, we used data from 17 of the individuals (68% of estimated established population), for which we had gathered enough data to estimate their annual home ranges (at least with 80 independent locations; Revilla, 1998), and which had been tracked during at least two seasons. In total we used an average of  $254 \pm 50.4$  independent radio-locations per individual (range 86–874) between October 1994 and October 1997. Additionally, in the Reserva we marked three females in three different territories which were tracked between March and October 1997.

Badgers are nocturnal animals, and thus marked individuals were located by triangulation from two fixed stations (night) and homing to the resting place (day-time). In the analysis we used only independent locations (separated by at least 4 h during the active time, and by 1 day during the resting period; Revilla, 1998). Estimated location error of triangulation, calculated during an experimental trial, was 95% of the times < 245 m. As expected, there was a positive relationship between location error and maximum distance between transmitter position and stations of the bearings ( $r^2 = 0.46$ ,  $P < 0.0001$ , range of distances during the trial was between 50 and 2700 m). As 94% of field locations were taken < 1 km apart, location error should be always far below the stated limit (Revilla, 1998). In any case, special care was taken when animals were supposed to be at edges between habitat types. Then, one of the bearings was taken from the edge in order to ensure allocation of the animal to the right habitat type.

### 2.3. Analysis

We performed the analysis at two different scales. The upper level, hereafter territorial selection, uses territories as units of the analysis (Johnson, 1980), aiming to determine the key habitats in defining the spatial location of territories in the study area. Study area was defined by the minimum convex polygon encompassing radiolocations of all marked badgers (Tables 1 and 2), corresponding with 42 km<sup>2</sup> in Coto del Rey and 30 km<sup>2</sup> in the Reserva (calculated with 7281 and 350 independent radiolocation, respectively). Habitat availability was estimated as the proportion of every habitat inside the study area, while habitat use was considered as the

Table 1  
Percentages of habitat availability and use by badgers in Coto del Rey<sup>a,b</sup>

Habitat type	Territorial availability	Territory composition	Territory use	
			Resting	Activity
Lentiscus scrubland	12.8	52.0±11.09 16.9–83.8	83.0±4.00 4.8–100	69.1±4.13 29.4–95.7
Marshland	49.0	13.8±7.08 0.0–38.5	10.0±3.39 0.0–41.1	11.7±3.48 0.0–39.2
Pastureland	11.6	16.7±2.78 11.0–24.0	2.6±0.84 0.0–11.6	9.6±1.54 0.0–20.0
Ash stands	2.6	3.0±1.93 0.0–9.3	4.2±2.53 0.0–22.5	5.2±2.02 0.0–16.2
Dehesa	8.2	10.2±6.44 0.0–30.7	2.1±0.92 0.0–8.2	15.5±3.32 6.5–32.4
Eucalyptus plantations	1.1	1.4±0.89 0.0–4.4	0 <sup>c</sup>	0.5±0.29 0.0–1.9
Pine plantations	14.7	3.2±1.85 0.0–10.1	0 <sup>c</sup>	1.8±0.54 0.0–5.1

<sup>a</sup> Territorial availability represents the whole area covered by 17 radiomarked animals between 1994 and 1997. Territory composition represents five territories, being considered as the used fraction in territorial selection, and as the available fraction in intraterritorial selection.

<sup>b</sup> Data are presented as mean ± standard error and range. Note that mean percentages do not necessarily sum to 100%, since not all territories have all types of habitat.

<sup>c</sup> Not used by any of the marked individuals.

Table 2  
Percentages of habitat availability and use by badgers in the three territories in the Reserva during 1997<sup>a</sup>

Habitat type	Territorial availability	Territory composition	Territory use	
			Resting	Activity
Wetlands	3.3	5.4±3.58 0.9–12.5	1.3±1.33 0.0–4.0	2.1±1.45 0.0–4.9
Dry scrubland	10.4	8.6±4.48 0.0–15.0	11.6±3.85 7.5–15.2	11.6±2.20 9.4–13.8
Hygrophytic scrubland	44.8	32.8±14.46 10.7–60.0	34.3±24.6 0.0–82.0	42.4±17.2 9.4–67.2
Open pine plantations	26.2	31.3±7.22 21.9–45.5	29.1±14.5 14.0–58.2	27.9±1.47 26.2–30.8
Dense pine plantations	10.3	33.4±16.99 0.9–12.5	32.2±25.8 0–83.3	14.1±11.7 1.6–37.5
Sabine stands	5.0	15.2±8.89 0.0–30.8	0 0	8.6±8.6 0.0–17.2

<sup>a</sup> Territorial availability represents the percentage of each habitat type in the whole area covered by three radiomarked animals in 1997. For further details see legend of Table 1.

proportion of each habitat type inside each territory. Territories were defined as 95% fixed Kernel isoline, calculated using all independent radiolocations of all animals belonging to that territory (Seaman and Powell, 1996; Revilla, 1998).

At the finer level, hereafter intraterritorial selection, the aim was to detect the key habitats inside the territories, both during the periods of activity (night) and resting (daylight). Habitat availability was considered as the percentage of each type of habitat in the territory that each animal belonged to, and use as the percentage of independent radiolocations inside each habitat type (Tables 1 and 2). We considered only locations inside the territory isolines in order to reject excursions from the analysis. As badgers behave differently between the foraging and resting periods, we distinguished between both at the intraterritorial level (Palomares and Delibes, 1992). We considered it worthwhile to analyse habitat use during the resting period because in Doñana badgers use many different setts (on average 27 per territory; unpublished data), changing frequently from one to other.

We studied habitat selection using compositional analysis, which overcomes most of the problems found in studies of habitat selection, especially the non-independence of proportions and the use of individuals rather than radio-locations as the sample unit (Aebischer and Robertson, 1992; Aebischer et al., 1993). We replaced zero proportions with small values proportional to the round-off error (Tufto et al. 1996). We solved the significance of the matrix of differences with Wilk's  $\lambda$ , which transformed as  $-M \ln \lambda$  is compared with the  $\chi^2$  value with  $N-1$  degrees of freedom (where  $N$  is the number of habitat types considered). Preference order was obtained from the residual matrix following Aebischer et al. (1993), and statistical significance by comparing mean value and its standard deviation with  $t$ -distribution (with  $n-1$  degrees of freedom, where  $n$  is the number of territories or individuals used in the analysis).

In order to obtain an absolute preference value for each habitat, we also used Jacobs' (1974) preference index, calculated as

$$J = (r - p) / [(r + p) - 2rp]$$

where  $r$  is the used proportion and  $p$  the available proportion. It ranges between  $+1$  for maximum preference, and  $-1$  for maximum avoidance. Statistical significance was obtained comparing alternative hypotheses, where the null hypothesis corresponds with a Jacobs' index equal to zero (habitat used as available), comparing the obtained value with  $t$ -distribution (with  $n-1$  degrees of freedom, being  $n$  the number of territories or individuals used in the analysis).

We also aimed to relate habitat preferences with variables that indicate habitat quality, such as food or shelter (sensu Beutel et al., 1999). Food preferences may be reflected at the habitat resource scale, especially during activity, when trophic resources are influencing space use. Since rabbits are the key trophic resource for badgers in Coto del Rey (Fedriani et al., 1998; Revilla, 1998), we compared habitat preferences (value of

Jacobs' index) with the average rabbit density at every habitat (Palomares et al., unpublished data). Rabbit densities were estimated by line transect sampling carried out in the same habitats twice per year. We used the average of all density estimations for each habitat type during the study period. For a complete description of sampling methodology, density estimation procedures and seasonal rabbit densities, see Palomares et al. (unpublished data). On the other side, availability of refuges may be the key resource during the resting period. In Doñana rabbit warrens are used as temporal resting sites and as initial seeds in the construction on new setts (E. Revilla, unpublished data). In order to relate habitat preferences during the resting period with a measurement of the quality of each habitat type in offering protection, we used an index of the abundance of rabbit warrens, obtained for the same study area by intensive mapping of rabbit warrens in the same habitats, see Palomares et al. (unpublished data).

### 3. Results

#### 3.1. Territorial selection

The location of territories in Coto del Rey was significantly different from availability ( $-M \ln \lambda = 40.72$ ,  $P < 0.001$ , d.f. = 6,  $n = 5$ ). This difference was due to a preference for lentiscus scrubland and pastureland over the rest of habitat types in the compositional preference order (Table 3). Using Jacobs' preference index, lentiscus scrubland was the only preferred habitat type, while marshland and pine plantations were avoided and the remainder used as available (Fig. 1). The location of the three territories of the Reserva was also significantly different from availability ( $-M \ln \lambda = 18.79$ ,  $P < 0.005$ ,

Table 3  
Compositional preference order for territorial and intraterritorial habitat selection of badgers in Coto del Rey and the Reserva<sup>a</sup>

Scale of analysis	Compositional preference order <sup>b</sup>
<i>Territorial selection</i>	
Coto Del Rey	LS > PS > > > EU > AS > DH > MA > PI
Reserva	OP > WT > DP > HS > SA > DS
<i>Intraterritorial selection</i>	
<i>Coto Del Rey</i>	
Resting	LS > > > AS > > > MA > > > PI > EU > PS > DH
Activity	LS > > > PS = DH > AS > MA > > > PI > EU
<i>Reserva</i>	
Resting	DP > OP > HS > WT > DS > SA
Activity	HS > DP > OP > WT > SA > DS

<sup>a</sup> LS: Lentiscus scrubland, PS: pastureland, EU: eucalyptus plantations, AS: ash stands, DH: Mediterranean savannah, MA: marshland, PI: pine plantations, OP: open pine plantations, DP: dense pine plantations, WT: wetlands and associated vegetation, HS: hygrophytic scrubland, DS: dry scrubland, SA: sabine stands.

<sup>b</sup> > > > Indicate significant difference between groups ( $P < 0.05$ ).

d.f. = 5,  $n = 3$ ). Open pine plantations and wetlands were the most preferred habitats (Table 3).

### 3.2. Intraterritorial selection

#### 3.2.1. Resting

Individual badgers in Coto del Rey did not use available habitats inside their territories in a random fashion ( $-N\ln\lambda = 47.52$ ,  $P < 0.001$ , d.f. = 6,  $n = 17$ ). Lentiscus scrubland was the most preferred habitat (holding up to 83% of locations; Table 1), respectively for compositional order and Jacobs' index, followed at distance by ash stands, which was used as available (Tables 1 and 3 and Fig. 1). Pine and eucalyptus plantations were never used during diurnal resting, while marshland, pastureland, and dehesa were used sporadically. In the Reserva, intraterritorial selection during resting was also significantly different from availability ( $-N\ln\lambda = 28.65$ ,  $P < 0.001$ , d.f. = 5,  $n = 3$ ). There was not a clear overall preference for any of the habitats (Fig. 1). In two of the territories the most used habitat was dense pine plantation (with proportion of locations of 58 and 83%, respectively), while in the other was hygrophytic scrubland (with 82% of use; Table 2).

#### 3.2.2. Activity

In Coto del Rey, selection was again significantly different from availability ( $-N\ln\lambda = 48.08$ ,  $P < 0.001$ , d.f. = 6,  $n = 17$ ). This difference was due to the significant overuse of lentiscus scrubland (with almost 70% of locations; Table 1), while other habitat types, except ash stands, were avoided (Fig. 1 and Tables 1 and 3). In the Reserva, selection was again different from availability ( $-N\ln\lambda = 27.38$ ,  $P < 0.001$ , d.f. = 5,  $n = 3$ ). Two of the animals had hygrophytic scrubland as the most used habitat (holding 67 and 50% of locations), while the third preferred dense pine plantations (with 38% of locations; Table 2).

### 3.3. Habitat preferences and ecological correlates in Coto del Rey

Habitat selection in Coto del Rey showed a clear deviation from availability, due to a strong preference for lentiscus scrubland at every scale of the analysis. At the population level, absolute rabbit abundance in every habitat type was correlated with their Jacobs' preference index, explaining about 50% of the variance (Fig. 2). At the individual level, and during the activity period, rabbit abundance explained an even greater amount of the habitat preference variance (Fig. 2). During the resting period, we can expect the presence of refuges to be the limiting factor conditioning habitat preferences. In this case, we found that the abundance of rabbit warrens, as indicators of availability of potential refuges, explained the strong preference of badgers for lentiscus scrubland and, on a lesser extent, for ash stands (Fig. 2).

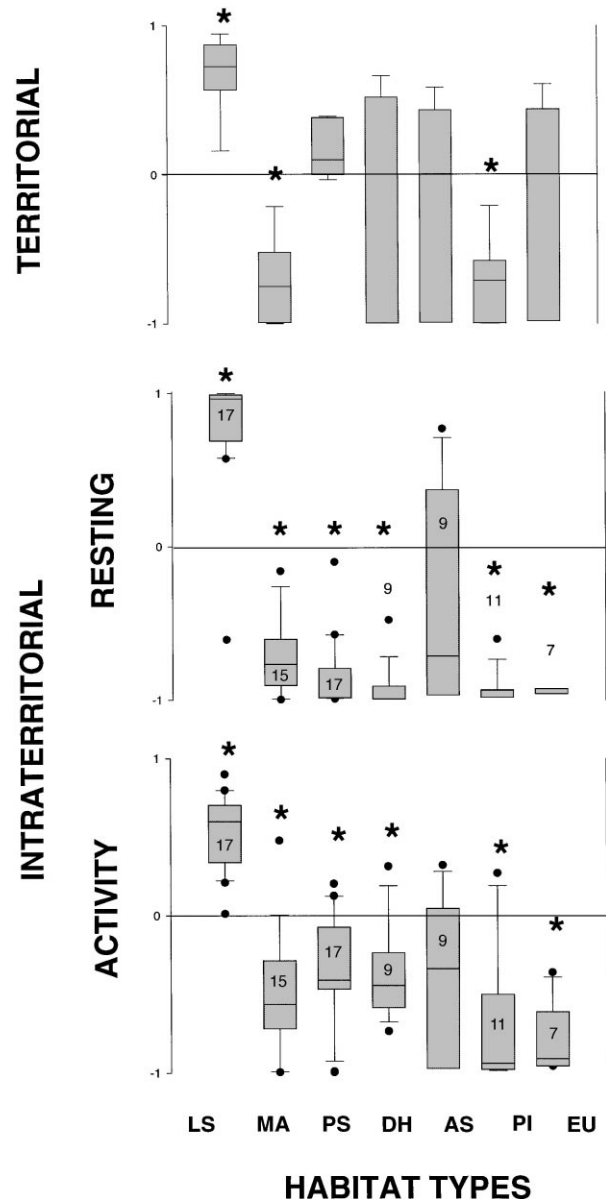


Fig. 1. Jacobs' index for each habitat used by badgers in Coto del Rey at the territorial (for five Eurasian badger territories), and intraterritorial (resting and activity periods, numbers inside boxes indicate the sample size of marked animals used in calculations) scales. Positive and negative values indicate preference and avoidance, respectively; boxes indicate the 25–75th percentile range and contain the median line; bars represent the 10th and 90th percentile values; closed dots represent points outside these values. LS: Lentiscus scrubland, PS: pastureland, EU: eucalyptus plantations, AS: ash stands, DH: Mediterranean savannah, MA: marshland, PI: pine plantations; \* mean is significantly different from zero ( $P < 0.05$ ).

## 4. Discussion

Numerous studies carried out in temperate Europe show a strong preference of badgers for deciduous woods on a regional scale (e.g. Macdonald et al., 1996; Reason et al., 1993; Thornton, 1988). Traditional human use of these areas in Central Europe has transformed the landscape

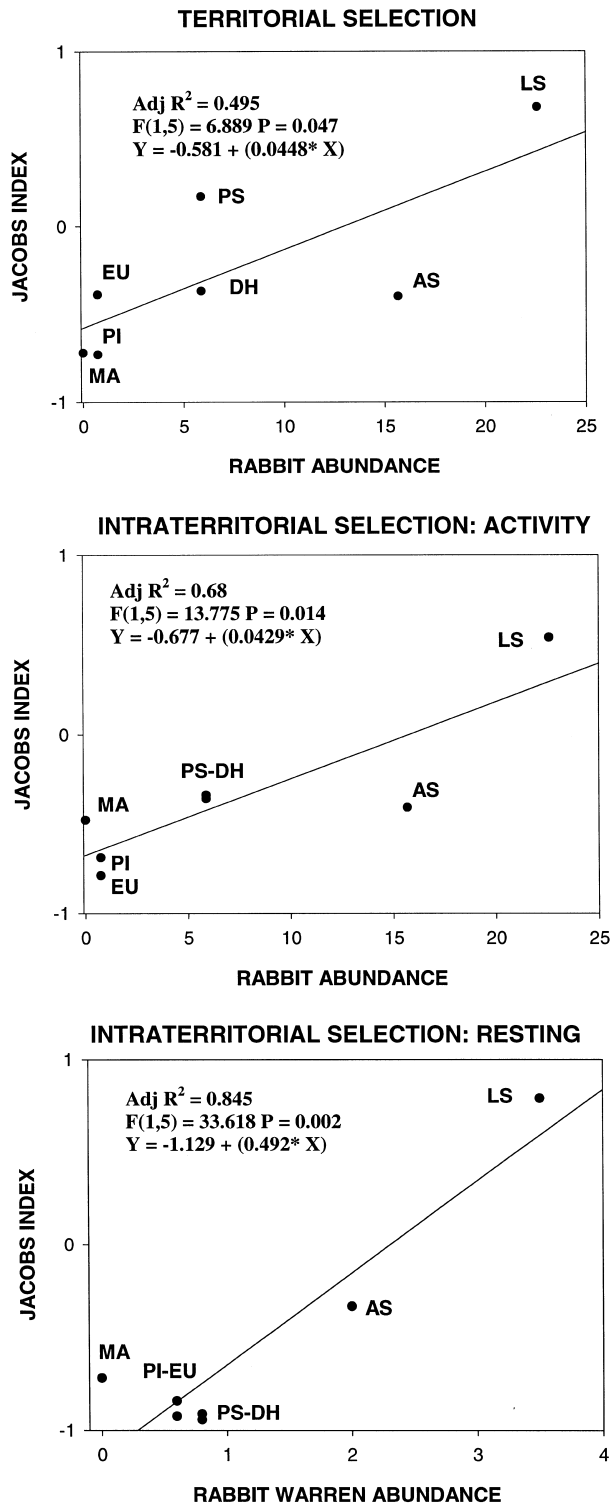


Fig. 2. Relationship between Jacobs' index for each habitat type and different predictors of preference for rabbit abundance (rabbits/ha) or rabbit warren abundance (warrens/transect of 100 m long). See legend of Fig. 1 for interpretation of habitat codes.

into a mosaic of pastures delimited by hedgerows, and small woodlots, which is even more productive for badgers than pristine woodlands, because the abundance of pastures increases the overall biomass of their staple

food, namely earthworms (Kruuk, 1989). At the intra-territorial level, badgers living in these landscapes select broadleaf woods and associated pastures during foraging (Kruuk, 1978; Kruuk et al., 1979; Harris, 1982; Hofer, 1988; Shepherdson, 1990). These habitat preferences are also shown in other areas such as alpine mountains and boreal forest (Seiler et al., 1995; Graff et al., 1996; Broseth et al., 1997). Recently, Virgós and Casanovas (1999) have shown, on a regional scale in Mediterranean central Spain, that the best predictors of badger distribution and abundance were also deciduous woods and pastures situated in mountains, while Mediterranean scrubland and holm oaks (*Quercus ilex*) affected it negatively. Their results are interpreted as a multimodal distribution of the species, with maximum abundance in deciduous woodlands (mountains), and minimum in Mediterranean areas. By means of this source-sink model, Mediterranean areas are considered suboptimal for badgers and the persistence of the species dependent on the proximity of mountainous areas (Virgós and Casanovas, 1999).

On the contrary, in Coto del Rey there is a clear pattern of habitat preference, dominated by lentiscus scrubland at every scale of the analysis, and despite analysis design, in which we did not consider seasonal variations in habitat preferences. Lentiscus scrubland is not an ecological analogue of Eurosiberian deciduous woodlands, nor of their associated pastures, as ash stands and pastureland could be considered (where Doñana badgers do forage for earthworms; Revilla, 1998). To our knowledge, this is the first time that a habitat other than deciduous woodland or associated pastures is reported as the most important habitat type for badgers.

At the level of individuals during the diurnal resting, we can expect that the existence of refuges affects badgers (e.g. Creswell et al., 1990; Reason et al., 1993). Thus, badger distribution is constrained by the availability of diggable soil where burrows can be built (Dunwell and Killingley, 1969). In Doñana the majority of the soils are loose sands (Siljeström et al., 1994), and most of the setts begin by the enlargement of pre-existing rabbit warrens (Revilla, 1998). The strong relation between Jacobs' index and the abundance of rabbit warrens in each habitat type show the influence (at least at this level) of refuge availability on habitat preferences. Lentiscus scrubland holds also the highest vegetation cover in Coto del Rey (Palomares et al., unpublished data), which together with the large amount of rabbit warrens can properly explain the selection pattern. Anyway, the influence of trophic availability on resting selection patterns can not be ruled out, as we can expect a strong correlation between rabbit abundance and warren density (Parer and Wood, 1986; Palomares et al., 1996b). In the Reserva, rabbit warrens are very scarce and scattered over most of the habitat types (E. Revilla, personal observations), and the densest vegetation types are

found in dense pine plantations and in hygrophytic scrubland. These habitats were the most used types by the marked animals. Badgers seem to need cover, but the generality of this assertion may be challenged by habitat preferences in open ecosystems, such as steppes. Thus, the relationship between cover preferences and human disturbance and/or predation pressure should be studied.

In Coto del Rey, rabbits were the key trophic resource during all the study period (Revilla, 1998), and a significant amount of variance in their habitat preferences can be explained only with the abundance of the key trophic resource (Fig. 2). On the other hand, in the Reserva, and with the obvious limitation in sample size, which precludes any firm conclusion, there was no clear pattern. This could be interpreted as a use similar to availability or as a more dynamic system of selection, where preferences would change towards the habitat containing the trophic resources used in every moment. In this way, and with no superabundant resources at a large scale, preferences should be different between territories, individuals, and periods of time, corresponding with local availability.

At the broader scale of selection, there should be new factors influencing habitat selection, besides the ones affecting intraterritorial level, as for example landscape structure and availability, the skill of dispersing individuals for finding empty places to settle, or the vacancies of previously defined territories (Morris, 1992). In Coto del Rey, there is a projection of the influence of individual preferences for resources to the upper level of selection, and thus at least part of the variance in the habitat preferences can again be explained by the key trophic resource allocation. In the Reserva we can explain the significant compositional result at every level with the landscape shift occurring from east to west of the area, which results in territories differing in the matrix that contain other habitats, and thus each territory is more a representative of a different landscape unit, than a different re-sample from the same landscape.

Eurasian badgers have to satisfy several needs within the habitats they have available. Key resources, when located at a specific vegetation or habitat type, give to it an additional value, and so we can talk about key habitat types also for species with such a broad spectrum of use. In central Europe, deciduous woodlands and pasturelands are basic for the maintenance of healthy badger populations, as is well-preserved scrubland in rabbit-based Mediterranean populations.

#### 4.1. Conservation of badgers in Mediterranean areas

Eurasian badger occupies all the Iberian Peninsula, including the southernmost Mediterranean parts (Delibes, 1981); where Mediterranean scrubland historically was removed from large areas for increasing the area used

for agriculture and livestock. This human use fragmented and reduced the area of the habitat suitable for badgers until the 1960s, producing the present landscape configuration. Together with this, habitat quality has been drastically reduced because rabbit populations have crashed during recent decades. This decrease (in Doñana region actual densities are estimated to be 5% of those in the 1950s; Delibes et al., 1999) is directly related to disease (catastrophic appearance of myxomatosis and of rabbit haemorrhagic disease; Rogers et al., 1994; Villafuerte et al., 1994) and to changes in land use. Disappearance of low-intensity traditional activities (mostly producing small-scale clearings inside scrubland, which favoured habitat productivity and rabbit abundance) has further reduced the carrying capacity of Mediterranean areas (Moreno and Villafuerte, 1995). Thus we may reasonably expect that during the last few decades badger distribution and density have been reduced by a diminution in the availability and quality of Mediterranean scrubland. Coto del Rey and Reserva are a good example of the difference in badger abundances between areas with high rabbit densities and those with low ones (badger density is 3.5 times larger in the first; Revilla et al., 1999). Lower densities may in turn facilitate the extinction of badgers in areas of fragmented Mediterranean landscapes where they are under high human-induced mortality (Virgós, 1994).

Nowadays, the European Union's Common Agricultural Policy promotes intensive farming systems (such as under-plastic strawberry cultures in southwest Andalusia), or by providing grant aid to extensive farming over large areas (which concentrates the originally small-scale traditional system in very large fields). Remnants of well-preserved Mediterranean scrubland that were formerly interspersed between small farms have been eliminated by the concentration of landholdings. However, the greatest threat to the key habitat of Mediterranean badgers in Spain and Portugal is the substitution of scrubland for conifer and eucalyptus plantations for timber and wood pulp production. The shrub layer is virtually absent in eucalyptus plantations and in most of the pine plantations, being periodically removed. Actually, this forestry policy is related to the incorrect application of the European afforestation programme, the main aim of which is to improve environmental quality and to increase biodiversity (Díaz et al., 1998) by financing the conversion of old fields into forested areas. However, many scrubland patches are classified as unproductive fields, and thus replaced with plantations (Delibes et al., 1999).

All these problems related to the conservation of well-preserved Mediterranean scrubland holding healthy rabbit populations also affect other species, such as the Iberian lynx (*Lynx pardinus*) (Delibes et al., 1999). In the actual fragmented landscape, remnants of high quality Mediterranean scrubland, together with deciduous

forest and associated pastures in the mountains (Virgós and Casanovas, 1999; Virgós, 2000), must be preserved as a first step in the conservation of low density populations of Mediterranean badgers.

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