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Badger *Meles meles* sett site selection in low density Mediterranean areas of central Spain

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We studied the habitat selection of badgers *Meles meles* (Linnaeus, 1758) in a mountainous area of central Spain through badger sett location, in relation to a series of variables related to the micro and macrohabitat structure considered potentially important for habitat requirements (food and shelter) were choosen.

The analysis was carried out using the Savage index (W) for use/availability data. Badgers in this area prefer mid-elevation mountain areas, where both dehesas (open woods with pastures) and pine forests prevail. Lower elevation areas were avoided. Badgers are associated with watercourses, but we found, no significant differences for distance to villages or for roughness. Badgers preferred trees and rock covered areas, which provided shelter places.

Badger conservation in Mediterranean mountains requires mosaic habitats (dehesas). The low density that has been found could be due both to human factors (eg persecution and habitat loss) and to a probable low suitability value of Mediterranean environments for the badger.

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Introduction

The European badger *Meles meles* (Linnaeus, 1758) is a widely distributed mustelid with versatile ecological requirements (Neal 1986). It has been well studied throughout Occidental Europe, especially in the United Kingdom and The Netherlands (Kruuk 1989). Information is available about its distribution and status (Wiertz and Vink 1986, Cresswell *et al.* 1989, Griffiths and Thomas 1993, Reason *et al.* 1993, Smal 1993); aspects related to behavioural plasticity in different environmental conditions (Kruuk 1989); diet (Kruuk 1989, Roper 1994); and sett distribution in relation to habitat characteristics (Zejda and Nesvadbova 1983, Thornton 1988, Skinner *et al.* 1991a, b).

Several studies have demonstrated the sensitivity of this species to human disturbance (Wiertz and Vink 1986, Skinner *et al.* 1991a, b, Zee *et al.* 1992, Reason *et al.* 1993). All were conducted in central Europe where conditions are especially favourable for this species (Griffiths and Thomas 1993). The Mediterranean region is at the southwest limit of the badger's distribution area (Griffiths and Thomas 1993) and, therefore, populations may be more affected by small changes in ecological conditions (Brown 1984). Mediterranean environments are predominantly very dry and the badger is more scarce in xeric environments than rainy areas (Griffiths and Thomas 1993). However, our knowledge of its ecology and conservation from the Mediterranean area is very limited (Pigozzi 1988, Virgós *et al.* 1993, Martín *et al.* 1995, Rodríguez *et al.* 1996). An understanding of the areas selected by badgers for setts is useful in determining the species ecological requirements (Thornton 1988, Skinner *et al.* 1991a, b, O'Corry-Cröwe *et al.* 1993) and is, therefore, potentially useful in management decisions.

In this study, we analyzed factors affecting badger sett distribution in a mountainous area of central Spain and have provided some recommendations for conservation.

Material and methods

Study area

The study area was located in the Alto Manzanares Regional Park and its surroundings (41°40' N, 4°10' E), on the southern slope of the Guadarrama mountains (central Spain), covering a total area of 65.000 ha.

This natural area is characterized by its severe altitudinal gradient and by its localized dense human population. As a consequence of the pronounced orography, all vegetation types characteristic of central Spain can be found. The low-elevation level was covered by holm-oak forest (*Quercus ilex*) and its serial succession formations (eg *Cistus, Retama*). The holm oak forests is between 600 to 900 metres above sea level (a.s.l.) and is the most typical Mediterranean habitat and the most inhabited by people. Between 900 - 1200 m a.s.l. are the dehesas, they are used as feeding pastures for cattle and are dominated by Pyrenaean oak (*Quercus pyrenaica*) and ash trees (*Fraxinus angustifolia*). They are characterized by open formations with little scrub and higher moisture than in the Mediterranean holm-oak forests. At higher elevation there is a strip in which oak forest has been replaced by pine forest (eg *Pinus sylvestris*). These are between 1200 - 1700 m a.s.l. and have different degrees of scrub coverage depending on the predominant type of land use. This is colder and wetter level and the snow is common. The highest elevation (1700 - 2100 m a.s.l.) are not forested and have a typical high mountain climate. These were not included because badger do not occur here.

Further information about climate and vegetation types of the study area can be found in Rivas-Martínez (1982).

Survey procedures

Field work was carried out between 1989 and 1991, from October to April. The survey consisted of a search for badger setts, using a procedure similar to other studies (Thornton 1988, Cresswell *et al.* 1989, O´Corry-Cröwe *et al.* 1993). Sampling was carried out by four people with experience in locating and identifying of setts. Badger setts were not classified according to conventional criteria (see Thornton 1988) because of problems in applying these in our study area, where the use of the badger setts is erratic (eg is not possible define main setts or outliers, see also Skinner *et al.* 1991a).

Variables 1–5 and 8 (see Table 1) were quantified on 1 : 50.000 topographical maps onto which the locations of setts were plotted. The remaining variables: habitat type, landscape use and tree, shrub, rock and pasture cover were measured in the field by visual estimation within circular-plots of 25 m radius around each sett. The selection of this sampling unit is a convention based in procedures used

Table 1. Description of the topographic (1–5), habitat, land use and soil types (6–8) and vegetation structure variables (9–12) used in this study.

Variable	Measure
1. Elevation	Height above sea level in each point
2. Roughness	Number of 50 m height level curves included in 500 m radius around each point in the topographical map
3. Distance to water	Minimum distance (in metres) from each point to the nearest watercourse
4. Distance to village	Minimum distance (in metres) from each point to the nearest village
5. Distance to road	Minimum distance (in metres) from each point to the nearest road (any road type)
6. Habitat	Habitat type: holm oak forest, dehesa – a typical landscape with woods and pastures – and pine forest in each point
7. Land use	Type of land use: cattle, forestry, recreative and game in each point
8. Soil type	Type of soil (soil taxonomy classification) in each point: leptosols, cambisols, others – regosols, fluvisols, etc
9. Tree cover	Tree canopy cover in 25 metres radius around each point
10. Shrub cover	Shrub cover in 25 metres radius around each point
11. Rock cover	Rock cover in 25 metres radius around each point
12. Pasture cover	Herb cover in 25 metres radius around each point

elsewhere (eg in vegetation and wildlife-habitat studies, see review in Morrison *et al.* 1992). The choosed 25 m radius may be useful because is a measure of small-scale habitat features, and we assume that the badger select their sites for badger setts according with small-scales characteristics. However, it is possible that the species select their setts sites at other scales (see Doncaster and Woodroffe 1993) and, therefore, that the obtained results were wrongs. The problem of the scale in habitat selection studies has been largely discussed (eg Morris 1987, Wiens 1989, Kotliar and Wiens 1990). Thus, the different life processes can be viewed in a hierarchical manner (Wiens 1989). The decisions at any level may be simultaneously affected by factors associated to levels below and above in the hierarchy (Kotliar and Wiens 1990). In general, it is recommended choose the scale according to relevant questions of the study, however, because studies about the perceptual cues used by animals in their decision-making activities are scarce in the literature (but see Ims 1995, and references therein), may be reasonable use conventional methods and scales, as the cicular plot method to estimate vegetation structure variables.

All variables were considered related to food or/and shelter for badgers, in accordance with previous studies (Thornton 1988, Skinner *et al.* 1991a, b, O'Corry-Cröwe *et al.* 1993). Availability of the first set of variables and soil type were quantified using 100 random points over the topographical and soil maps (1 : 50.000). For the second group, the availability was determined by carrying out 546 transects of 500 m scattered around the study area, in which values of each variable were estimated within circular-plots of 25 m radius spaced at 125 m intervals.

Data analyses

We used a chi-square goodness-of-fit test to determine whether or not badgers used the variables considered in proportion to availability. The Savage selectivity index (Manly *et al.* 1993) was used to measure between intervals or classes for each variable. The Savage selectivity index (Wi) is obtained from the expression: U_i/P_i where U_i is defined as the proportion of used units and P_i as the proportion of available units. Selection was considered positive when Wi was significantly higher than one and negative when the value is significantly lower than one. The statistical significance of the indices was tested by comparing the statistic $(Wi-1)^2$/standard error $(Wi)^2$ with the corresponding critical value of a chi-square distribution with one degree of freedom (Manly *et al.* 1993). We estimated standard error of Wi on the null hypothesis that there was no selection, so that the standard error (SE) of Wi was approximated by the square root of $(1-P_i)/(u+X\ P_i)$, where u+ is the number of samples with sett presence for this interval or class, and P_i is the proportion of available units within this interval or class. Statistical significance of these chi-square values was fixed at $p < 0.05$, but in order to avoid type I errors, Bonferroni sequential corrections were applied (Rice 1989).

Results

We found a total of 26 badger setts (0.04 setts/km^2). The distribution of the badger setts in the different habitats was as follows: 4 (holm-oak), 10 (dehesas), 12 (pine forest).

These badger setts rarely have been used along all year, rather its use is erratic and any seasonal trend were found during the study period (more infornation on badger sett location and other charcteristics can be seen in Table 2).

Table 2. Sett characteristics (location and number of entrances) according to habitat types considered.

Habitat	Number of entrances (mean and range)	Sett location
Holm oak	2(2)	100% below rocks
Dehesa	8.2 (2–30)	94% below rocks 6% underground
Pine	2.5 (2–4)	100% below rocks

Topographical variables

The minimum distance to watercourses was the only variable with significant results in the goodness of fit test (see Table 3). The Savage index showed avoidance at elevations between 600–800 m a.s.l. There was a positive selection for places located less than 200 m from water, but no significant differences at other distances (see Table 3). The chi-square goodness of fit test showed no significant differences for slope, distance to villages and roads (Table 3).

Habitat type, land use and soil type

These variables presented significant values for the goodness of fit test (Table 3). For soil type, only the category "others" (eg regosols, fluvisols) were significant

Table 3. Chi-square values for each variable and category; number of badger setts (n); expected values (after its environmental availability) and Savage index in each category (W). ns – no significant differences, * – $p < 0.05$, ** – $p < 0.01$, *** p – < 0.001, "+" – significant positive selection, "–" – significant avoidance.

Variable	n	Expected value	Savage index (W)	χ^2
1	2	3	4	5
Elevation				7.6 (ns)
600–800	0	5.1	0	6.41 (–)
800–1000	9	7.7	1.16	0.28
1000–1200	7	4.9	1.43	1.11
1200–1400	7	3.3	2.10	4.57
>1400	3	4.9	0.61	0.91
Roughness				4.00 (ns)
1–2	7	10.4	0.40	1.79
3–4	5	5.7	0.21	0.07
5–10	12	6.9	0.27	5.06
>10	2	3.0	0.11	0.33
Distance to water				6.7 (*)
0–200	17	10.4	1.61	6.67 (+)
200–600	8	11.5	0.69	2.04
>600	1	4.1	0.24	2.81
Distance to village				2.71 (ns)
0–1000	4	6.3	0.64	1.05
1000–2000	7	6.4	1.09	0.06
2000–3000	10	6.4	1.55	2.63
>3000	5	6.9	0.72	0.73
Distance to road				3.84 (ns)
0–500	6	4.5	1.29	0.48
500–1500	11	7.5	1.47	2.34
1500–2500	4	5.9	0.67	0.81
>2500	5	8.1	0.61	3.01
Habitat				30.59 (***)
Holm oak	4	18.1	0.22	38.00 (–)
Dehesa	10	2.6	3.76	22.66 (+)
Pine	12	5.3	2.26	72.04 (+)
Land use				14.47 (**)
Cattle	10	4.8	2.10	7.04
Forestry	3	2.6	1.15	0.06
Recreative	11	6.9	1.59	3.31
Game	2	11.7	0.17	14.95 (–)

Table 3 – concluded.

1	2	3	4	5
Soil type				7.76 (*)
Leptosols	13	12.4	1.05	0.04
Cambisols	13	8.6	1.52	3.44
others	0	5.0	0	6.28 (–)
Tree cover				12.74 (**)
0–25	8	15.9	0.50	10.13 (–)
25–50	5	6.2	0.80	0.31
>50	13	3.9	3.36	25.36 (+)
Shrub cover				1.88 (ns)
0–25	13	13.6	0.96	0.05
25–50	2	4.9	0.39	2.13
>50	11	7.5	1.5	2.32
Rock cover				36.96 (***)
0–25	3	18.5	0.16	44.74 (–)
25–75	21	5.8	3.61	50.98 (+)
>75	2	1.7	1.17	0.05
Pasture cover				0.45 (ns)
0–25	21	19.3	1.09	0.59
>25	5	6.7	0.75	0.53

avoided. It is remarkable that no badger sett was located outside cambisols or leptosols, which are the most abundant soils in the study area.

All Savage indexes were significant for the habitat type. Holm-oak forest was avoided by badgers, but pine-forests and dehesas showed clear positive selection (Table 3).

With regard to land use, which is closely related to habitat type in this area, the Savage index showed badgers selected cattle grazing land and avoided areas occupied by game activities.

Vegetation structure

Badgers selected tree-cover and rock-cover (Table 3). For tree cover there was clear selection for wooded places (> 50% cover) and avoidance of more deforested areas (0 – 25%). For rock-cover, chi-square analysis indicated that badger selected places with 25 – 75% cover and avoided less rocky ground (0 – 25%). Pasture and shrub cover did not show significant selection from availability (Table 3).

Discussion

Badger sett density in our study area is very low compared with other surveys reported in the literature (see Smal 1993 and references therein). Following Neal (1986) this density would be categorised as "scarce" (3 – 7 setts/100 km^2).

In other European countries the badger is mainly an inhabitant of mosaic habitats, especially of deciduous woodland with pasture (Neal 1986, Wiertz and Vink 1986, Thornton 1988, Kruuk 1989). Its ability to adapt to very different habitats is well known (Roper 1994), and it can even live in arid, mountainous or farm habitats (Neal 1986, Kruuk 1989, Rodríguez and Delibes 1992). In the Sierra de Guadarrama it maintains a preference for habitats combining woodland and pasture (dehesas), and are much less abundant in holm-oak forests, where low environmental heterogeneity and xeric conditions prevail (Rivas-Martínez 1982). Higher elevation habitats (pine forest with scrub highland) were not as readily selected as the dehesas. Pine forests are poor habitat for badgers (but see Cresswell *et al.* 1989, O'Corry-Cröwe *et al.* 1993) because of their poor cover and low supply of trophic resources (Neal 1986). However, pine forests at lower altitudes appear to provide good conditions for badgers, because these have both well wooded and rocky shelter areas. In these areas, badger setts usually were located on the boundary between pine forest and either pastures or oak forest, allowing easy access to rich trophic habitat (see also Zejda and Nesvadbova 1983, O'Corry-Cröwe *et al.* 1993).

The habitat variables that seem most indicative of badger presence include: existence of woodland, rocky places, proximity to watercourses, and good soil. These variables agree with those cited by Neal and Roper (1991) for British badgers (good soils and tree cover). The need for good soils has been demonstrated in previous studies (Dunwell and Killingley 1969, Thornton 1988, Roper 1993). Badgers in the mountains of central Spain did not positively select the most important soil-types (cambisols and leptosols) but they did reject other types, which are less suitable for digging (Monturiol 1987). Clearly, soil diggability is a characteristic important when badgers looking for a place for a sett (Thornton 1988). However, the weak significance of this variable suggests that soil type is not particularly important in our study area. Alternatively, we may consider that the good soils are very abundant, and hence, do not show as selected.

The presence of rocks has not been previously suggested to be a key factor, perhaps because rocks are absent in many of the previously studied areas. Rocks could act as refuges in case of disturbance, besides permitting good thermic isolation. The choice of wooded places is also probably related to protection (see also Neal and Roper 1991). This function is also provided by dense scrub (Neal 1986) or hedgerows (O'Corry-Cröwe *et al.* 1993) elsewhere. Scrub and pasture areas do not seem to be favourable for sett construction. Scrub areas usually have poor soils (Monturiol 1987), while the pastures provide little protection and are periodically flooded. The selection of places near to watercourses can be related to their association with other important resources such as fruit-producing bushes and good soils (Neal 1986). It is interesting that the badger does not seem to be especially affected by the massive human presence in our study area. We did not find that badgers avoided roads or areas around villages or habitats with human presence. These findings contradict evidence from other countries (Wiertz and Vink 1986, Åaris-Sörensen 1987, Skinner *et al.* 1991a, b, Zee *et al.* 1992), but the low density found could be a consequence of the overall high human density in this area. In addition, human settlements were concentrated in the "a priori" optimal habitats for badgers (800 – 1200 m altitude). Conversely, game areas were avoided and it is possible that badgers were influenced by human persecution (see Cresswell *et al.* 1989, Reason *et al.* 1993), especially in low mountain areas. In summary, badger rarity in our study area appears to be attributed to the overall low quality of the environment (70 % of these mountains were xeric holm oak forests and associated shrub) and the increase of human settlements in the Sierra de Guadarrama will probably affect badger populations through habitar loss and direct persecution.

This selection pattern seems to coincide with results from more northerly areas (Roper 1993), suggesting that the environmental factors influencing badger sett location are the same in different regions. This is consistent with the hypothesis that the badger sett is a limiting resource with the maximal survival value (Neal and Roper 1991, Doncaster and Woodroffe 1993, Roper 1993) and, therefore, of critical conservation importance.

Badger conservation in Mediterranean areas requires the existence of man's traditional activities in the mountains (extensive livestock farming, see also Kruuk 1989) and the limitation of human development and game in low-lying mountain areas. Policies that encourage traditional agricultural practices would apparently benefit this species. Moreover, withdrawal of areas from use that have been used for agricultural purposes over the last 30 years would favour certain species that requires areas of dense scrub (Tellería and Sáez-Royuela 1984), but this would be detrimental for species such as the badger which are rarely found in this vegetation. Future studies should investigate the important impact that human activities can have on the ecology and abundance of the badger in Mediterranean areas.

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