Habitat Selection in a Low-Density Badger Meles meles Population: A Comparison of Radio-Tracking and Latrine Surveys

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Indirect methods such as faecal counts have been widely used for assessing the abundance and habitat preferences of many mammal species, although their reliability has been long debated. We tested the validity of this method for the Eurasian badger *Meles meles* in a low-density population in northern Italy by comparing results obtained from radio-tracking and latrine distribution. The pattern of habitat use extrapolated from each method was strikingly similar, with badgers selecting for patches of woodland and avoiding agricultural and urban areas. Latrines were mainly sited in the centre of activity of all individuals along man-made linear features. Although our data need to be validated over a wider range of social groups, evidence suggests that latrines might be used to broadly infer habitat preferences of badgers at the landscape level in low-density areas.

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Landscapes consist of a dynamic (both in space and time) mosaic of heterogeneous elements named 'patches' (Wiens 1976) which, offering different resources, can be of different value for animals in terms of the use that can be made of them.

The understanding of how animals interact with landscapes is a main tool for wildlife management and conservation in fragmented habitats (Noss & Csuti 1997), but it is hindered by the difficulty of quantifying all the biotic and abiotic parameters that can affect habitat selection by different species or even by individuals of the same species (Gough & Rushton 2000), and of interpreting how they perceive the surrounding environment (i.e. adopting an 'organism-centred' point of view; Wiens 1989).

In studying nocturnal and elusive animals such as carnivores, two main methods have been adopted to investigate their pattern of landscape-use, namely radio-tracking and faecal counts. In the first meth-od, the observed number of radio-locations occurring in each habitat type is compared with habitat availability. The relative amount of time spent by an animal in the available habitat types is believed to represent its preference for each particular habitat or, put another way, to reflect the relative value of each habitat to the animal. Radio-tracking is time-consuming, but it is a powerful tool in obtaining sound information about the natural behaviour of wildlife (White & Garrott 1990).

Faecal counts are based on the same assumption as radio-tracking, i.e. that the intensity of marking activity, as measured by the proportion of faeces deposited by animals in the available habitats, is an index of their relative preference for each habitat type. This indirect sampling method has been widely used for assessing the abundance and habitat preferences of many mammal species (Putnam 1984, Kohn & Wayne 1997, Gese 2001), although its reli-

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ability has been the subject of long-term debate, particularly in relation to the otter *Lutra lutra* (Kruuk et al. 1986, Mason & Macdonald 1987, Kruuk & Conroy 1987, Conroy & French 1987). The main objection raised by opponents to this sampling method is that faeces have a communication function and, additionally, that the site of deposition may depend on the presence of vegetation, prominent points or specific landmarks, rather than reflect patterns of habitat use (Kruuk et al. 1986). On the other hand, for many carnivores, scat counts are often the only effective, non-invasive and low-cost method of deriving an estimate of their relative abundance at different times or in different habitats (Davison et al. 2002, Sadlier et al. 2004).

Eurasian badgers *Meles meles* are social mustelids which form spatial groups of up to 27 individuals (Rogers et al. 1997) sharing a communal home range. Badgers deposit their faeces, as well as urine and anal and subcaudal gland secretions, into a number of shallow pits or 'latrines' (Kruuk 1978, Kruuk et al. 1984, Roper et al. 1993).

The use by badgers of restricted sites for defecation (Böhm et al. 2008), rather than simply defecating randomly while foraging, and their well-documented role in intra- and inter-group communication (e.g. Gorman et al. 1984, Palphramand & White 2007) could suggest a lack of correlation between marking activity and habitat selection. According to the hypothesis of Kruuk et al. (1986), specific sites of deposition, such as linear features (e.g. ditches and fences; Roper et al. 1986, Stewart et al. 2002) and the cover of the canopy of close-standing trees, particularly conifers (Kruuk 1978, Stewart et al. 2002), have been reported to be strongly associated with latrines.

However, research on high-density badger populations has shown that woodland seems to be selected for in the positioning of latrines, whilst arable land is generally avoided (Brown 1993, Hutchings et al. 2001).

As reported for other areas of Mediterranean Europe (Revilla & Palomares 2002, Rosalino et al. 2004, Loureiro et al. 2007), badgers on the floodplain of the River Po in northern Italy form social groups composed of a few individuals (one male and 1-3 females) which share the same main sett (Remonti et al. 2006b). Mean sett density (0.21 setts/km^2; Remonti et al. 2006a) falls in the range of available data for continental Europe (0.04-0.65 setts/km^2), and is distinctly lower than in Great Britain (0.11-4.55 setts/km^2; Kowalczyk et al. 2000).

In this paper, we compare space-use by badgers as recorded by radio-tracking with patterns of habitat use extrapolated from analysis of latrine distribution in a flat, riverside protected area, where research on badger ecology has been carried out almost continuously since 2000.

Our aim was to check if, in low-density populations, latrine distribution reflects the pattern of use of their home range by badgers, i.e. if marking activity can be used as a broad index of habitat preference.

Material and methods

Study area
Our study area includes a Natural Reserve ('Garzaia di Valenza', in the southeastern Piedmont region of northwestern Italy) and its surroundings, covering 12.3 km^2 on the northern bank of the Po River. The entire study area is flat, and extensively covered by maize crops (22.0%), rice fields (38.0%), and poplar *Populus* sp. plantations (16.0%). Woods (6.8%) consist of willows *Salix cinerea* and *S. alba*, oak *Quercus robur*, poplars *Populus alba* (and various hybrids), and alder *Alnus glutinosa*, bordering an abandoned river meander and three naturalised artificial lakes (3.5%). Black locusts *Robinia pseudoacacia* are widespread along roads and man-made embankments. Gravel soils are covered with high herbaceous vegetation mainly formed by drought-resistant Graminaceae associated with black locust shrubs (1.6%). Alluvial silts are deposited close to the river during flooding (3.2%). Two villages and a few rural farms are scattered throughout the area (8.9%).

The climate is subcontinental temperate, with an average yearly temperature of 12.4°C and an average yearly precipitation of about 1,000 mm.

During the study period, one male and 2-3 female adult badgers shared five setts, dug in narrow wooded strips bordering marshlands or along embankments, inside the protected area. The average home-range size was 3.8 km^2 (100% MCP; Remonti et al. 2006b).

Habitat use recorded by radio-location
Between June 2000 and December 2003, the locations of one male and two female adult badgers belonging to the same social group were estimated by triangulation from a vehicle-mounted receiving system, usually standing < 500 m from the animals (see Remonti et al. 2006b for details). Once per week,

nocturnal locations were estimated every two hours between sunset and sunrise. The radio-tracking period varied from eight ($\male$) to 12 months ($\female_1$, $\female_2$). A total of 357 radio-locations was collected ($\male = 100$, $\female_{1 =} 124$, $\female_{2 =} 133$, respectively; Remonti et al. 2006b).

Fixes were transferred to a land-cover 1:10,000 digitalised map by a Geographic Information System (Arcview 3.1). The land-cover map was produced based on ground surveys. We defined six land-cover types: woodland (woods and high shrubs, WO), poplar plantations (PP), maize fields (MF), rice fields (RF), urban areas (villages and farms, UA) and 'others' (OT), the latter comprising habitats sparsely represented in the study area such as pastures, wheat-fields and gravelly riverbanks.

Home ranges were drawn by the Fixed Kernel (FK) estimator (Worton 1989, Seaman & Powell 1996) using Ranges 6.0, and range boundaries were overlaid on the land-cover map.

Selectivity in habitat use during nocturnal activity was assessed by two methods: compositional analysis and stepwise linear multiple regression. In compositional analysis (Aebischer et al. 1993), habitat preferences of individual badgers were analysed as the ratio of proportional use (the number of active radio locations within a habitat) against the proportional availability of each habitat type inside each home range (FK 95%). An $N \times N$ matrix of habitat types, where N is the number of habitat types ($N = 6$), was calculated for both habitat use and habitat availability. Zero proportions were replaced by 0.0001 (Aebischer & Robertson 1992). Habitat types were ranked in order of preference according to the value of the difference between the log-ratios of use and availability of each habitat type. We also obtained habitat preference at the group level, calculating, at each position in the matrix, the mean and standard error (SE) of all elements across the three badgers (Aebischer et al. 1993). For each element, statistical significance was determined by comparing the ratio mean*SE with t distribution with n-1 degrees of freedom, where n is the number of individuals used in the analysis.

In the second method, we assumed that within the overall home range of the badger group the percent cover of a selected habitat type would increase in the areas of concentrated use, which were drawn by FK using different contours (from 10% to 90% in 10% intervals and 95%). The variation in the percent cover of each habitat type was tested by means of a stepwise linear multiple regression, using Fisher's F-test to check the level of significance of

the model and to enter or remove the variables (SPSS 12.0.1, SPSS Inc., Chicago, USA). Before the analysis, all variables were tested for normality using Lilliefors' test. When necessary, data were transformed to achieve normality and homoscedasticity.

To obtain an absolute preference value for each habitat, we used Jacobs' preference index (Jacobs 1974) calculated as:

$$J = (r\text{-}p)/((r + p)\text{-}2rp),$$

where r is the used proportion and p the available proportion. J ranges between +1 for maximum preference and -1 for maximum avoidance.

Student's t-test with n-1 degrees of freedom (n being the number of available home ranges) was used to compare the mean value of J with the null hypothesis corresponding to $J = 0$ (habitat used as available).

Habitat use extrapolated from latrine distribution

Latrines were searched for throughout the whole study period, following badger paths and examining linear features such as field outlines and man-made embankments. Radio-tracking helped to focus on areas used by badgers. Latrines were georeferenced and overlaid on the land-cover map. Latrines located within a 5-m wide strip on each side of the border between two different habitat types were assigned to both habitats with a 0.5 score. The χ^2-test with Yates' correction for small samples (Yates 1934) and Bonferroni's confidence intervals for the proportion of use were used to compare the observed and expected frequencies. Jacobs' index was also applied, as done for radio-locations.

Results

Applying compositional analysis, habitat use by each badger differed significantly from random ($\male$: WO > PP > MF > UA > OT > RF, -Nln$\lambda = 19.7$, P = 0.0014, df = 5; $\female_1$: WO > OT > PP > RF > MF > UA, -Nln$\lambda = 21.0$, P < 0.001, df = 5; $\female_2$: WO > PP > OT > RF > MF > UA, -Nln$\lambda = 16.8$, P = 0.0047, df = 5). The mean*SE matrix ranked badger habitats as follows: WO > PP > OT > MF > RF > UA, with woodland being used significantly more than the remaining habitat types (P < 0.01).

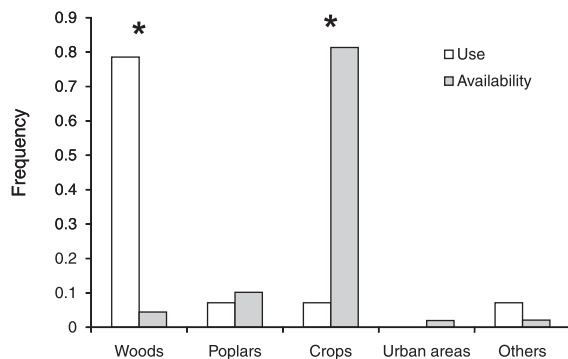A similar pattern emerged from the stepwise linear multiple regression method: moving from the

Figure 1. Habitat selection as assessed by badger latrine distribution (*P<0.001).

Figure 2. Home range (95% and 60%, Fixed Kernel estimator), setts and latrines of the badger group.

range boundaries towards the areas of concentrated use, the percentage cover of woods increased significantly ($R^2 = 0.91$, $F = 74.8$, $P < 0.0001$), whilst those of both maize and rice fields decreased ($R^2 = 0.74$, $F = 19.9$, $P = 0.0029$ and $R^2 = 0.73$, $F = 19.4$, $P = 0.0031$, respectively).

Using Jacob's preference index, woods were the only selected habitat ($J_{WO} = 0.94$, $t = 145.3$, $P < 0.0001$), whilst maize ($J_{MF} = -0.73$, $t = 6.8$, $P = 0.021$) and rice fields ($J_{RF} = -0.74$, $t = 6.08$, $P = 0.026$) were avoided.

A total of 14 latrines was found, with a mean of 5.3 pits each (SD = 4.9, range: 1-17). Latrines were not distributed according to habitat availability ($\chi^2 = 166.4$, $P < 0.0001$, df = 4); they were mainly sited inside woods or at their margins, whilst fields were avoided (Fig. 1).

Jacobs' index showed a similar pattern, but included urban areas among avoided habitats ($J_{WO} = 0.97$, $J_{OT} = 0.56$, $J_{PP} = -0.19$, $J_{MF} = -0.97$, $J_{RF} = -1$, $J_{UA} = -1$).

Most latrines were placed under tree cover (85.7%) and close to linear features (71.4%), and 11 latrines (79%) were situated inside the 60% isopleth (Fig. 2), which broadly corresponded to the area of overlap between the three home ranges.

Discussion

The pattern of habitat use drawn from latrine distribution was essentially identical to that obtained by radio-telemetry. In the agricultural landscape which formed the badgers' environment, the small available wooded areas were strongly selected for by badgers, both for nocturnal activities and for marking.
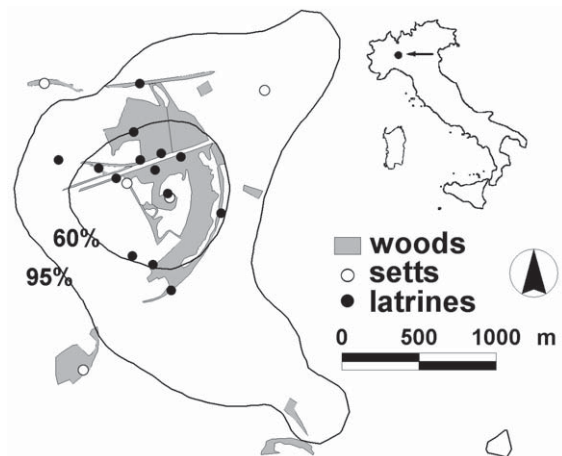
The preference of badgers for woods might ensue from their selection of suitable sett-sites: setts require slope, cover and seclusion, and woods often represent an optimal solution in rural areas (Thornton 1988, Revilla et al. 2001, Jepsen et al. 2005) such as the Po River plain (Balestrieri & Remonti 2000, Balestrieri et al., 2006, Remonti et al. 2006a).

Nonetheless, in the interval between two consecutive fixes (two hours), badgers proved able to cover a distance equal to their range maximum width (Remonti et al. 2006b) suggesting that the large amount of time spent by them in the wooded surroundings of their main sett was not only a consequence of its location.

Trophic resource availability and distribution have been most frequently quoted among the several parameters and ecological constraints which can influence animals' selection of a particular habitat (Krebs 1994). Wherever available, earthworms (Oligochaeta) are the staple food of badgers, and their abundance and distribution determines badger home-range size and numbers (review in Johnson et al. 2000). In our study area, badger presence in woods was likely to be related to foraging activities since the availability of earthworms, which along with maize form the bulk of badger diet, was highest under the tree canopy and lowest in cultivated fields (Balestrieri et al. 2004). Accordingly, in the central boreal region where coniferous forests are widespread, Brøseth et al. (1997) reported selection by badgers for the small patches of deciduous forest offering the highest earthworm biomass.

Finally, in heavily managed areas the need of badgers for seclusion cannot be excluded as a factor determining selection for woods, even if their nocturnal habits limit the chance of human interference.

Latrine distribution confirmed that badgers select for both linear elements in the landscape and cover, as has been highlighted by previous studies (Kruuk 1978, Roper et al. 1986, Feore & Montgomery 1999, Delahay et al. 2007). The chance of faeces being discovered by conspecifics is enhanced by the siting of latrines next to linear features, which are likely to channel badger movements (Stewart et al. 2002). Man-made linear features are widespread in rural areas, as low banks criss-cross the fields (particularly rice-fields). Tracks showed that these banks were often used by badgers as travelling routes but were, nonetheless, avoided for marking. As suggested by Stewart et al. (2002), the lack of vegetation characterising field banks could explain the preference of badgers for marking sites inside wooded areas, the canopy of trees reducing the washing away of faeces by rain. Both Stewart et al. (2002) and Kruuk (1978) found a positive association with conifers, whose dense canopy is likely to protect faeces from rain during all seasons, whilst deciduous trees are likely to offer less effective protection, particularly in winter. Incidentally, in our study area the two largest and most enduring latrines were dug under shrubs or scattered oak woods and, moreover, in clayey, moist soils which retain water from heavy rain for days, suggesting that the protection of scent marks was not the factor inducing badgers to mark in those particular spots.

Marking activity took place in the centre of activity of all individuals, confirming that the strong correspondence between the data from radio-tracking and surveys for latrines was not a casual by-product of badger choice for the most effective sites for scent mark deposition.

Questioning the validity of faeces counts in assessing habitat selection by otters, Kruuk & Conroy (1987) asserted that faeces do not indicate importance of sites for activities other than marking, quoting bridges for otters and lamp-posts for domestic dogs. These examples may lead to some misunderstanding, confusing the selection for habitats with selection for marking sites. Our results suggest that these two levels of selection must be clearly distinguished. Among available marking sites (linear elements), badgers selected those which crossed the habitat (woods) where all the members of the group were most active and scent-messages had the highest probability of being shared.

The small sample size of our study does not allow us to infer general conclusions about the validity of using latrine surveys to assess habitat selection in badgers. A similar pattern seemed to emerge in a hilly area of northern Italy (Balestrieri et al. 2006), although the surveys in that study were not precise enough to allow reliable comparison with radio-tracking data. However, in southern Portugal, surveys for badger signs have outlined a pattern of habitat selection consistent with that drawn through radio-telemetry (Rosalino et al. 2008).

Although radio-tracking allows the best insight into carnivore territorial behaviour at a small-scale level, available evidence suggests that latrine distribution might be used to broadly determine the habitat selection of badgers at the landscape level in low-density populations.

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