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Distribution, characteristics and use of shelters by the Eurasian badger *Meles meles* along an altitudinal gradient in the Western Carpathians, S Poland

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Abstract. We studied the location of Eurasian badger (*Meles meles*) setts in relation to various environmental factors, and attempted to assess the role of competition with other burrowing carnivores and the importance of human activity on their sett selection in the Western Carpathians (southern Poland). Excavated dens (53 %), caves and rock crevices (43 %), and burrows under buildings (4 %), were used by badgers as permanent shelters. Setts were located mostly in foothills (< 680 m a.s.l.), but selection for den location within the lower montane zone (680-980 m a.s.l.) was also observed. Excavated setts were recorded only up to 640 m a.s.l., while setts in rock crevices occurred up to 1050 m a.s.l. Badger shelters were mainly situated in forests or covered by dense bushes. Badgers avoided northern slopes in all altitudinal zones, and located their burrows mostly on SE or W slopes in foothills, and S or E slopes in montane zones. Setts were placed further from human settlements and main roads, but closer to meadows with high earthworm biomass, when compared with random points. Within badger territories, 1-12 setts were recorded. Badgers occupying territories which included both foothills and montane zones used burrows at various altitudes, but their main setts used for overwintering, were located exclusively above 800 m a.s.l. We conclude that sett location by badgers in mountains is shaped not only by the availability of cover and geological factors influencing digging, but also by human pressure and distance to foraging areas.

Key words: burrow, resting sites, habitat selection, mountains, wildlife management

Introduction

Carnivorous mammals use a wide variety of shelters, from provisional lairs adapted as a temporary refuge (Zalewski 1997a, Hwang et al. 2007, Podgórski et al. 2008), through burrows used seasonally for protection of offspring (Mela & Weber 1992, Jędrzejewski et al. 2001, Kowalczyk & Zalewski 2011) or wintering (Friebe et al. 2001), to extensive underground systems utilised throughout the entire year (Kowalczyk et al. 2004). Their availability heavily influences animal density and distribution, the size and configuration of home ranges and foraging behavior (Weber 1989, Doncaster & Woodroffe 1993, Lucherini et al. 1995, Zalewski 1997b). Among carnivores, the Eurasian badger *Meles meles* is known as a species that creates large and complex excavated setts (Roper 2010). However, it can also adapt numerous natural and anthropogenic shelters as refuges (Revilla et al. 2001, Kowalczyk et al. 2004, Pavlačík et al. 2004, Prigioni & Deflorian 2005), or even sleep just on the ground (Hancox 1990, Loureiro et al. 2007). The key factors determining shelter choice are geology and soil types, which influence digging, as well as availability of cover, which makes burrows less conspicuous (Dunwell & Killingley 1969, Kruuk 1978, Harris 1984, Neal & Roper 1991). Sett occupancy may be affected by competition from

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other burrowing carnivores (Theuerkauf et al. 2003, Macdonald et al. 2004, Kowalczyk et al. 2008), and by human activity (Skinner et al. 1991, Jenkinson & Wheater 1998, Sadlier & Montgomery 2004).

Most studies on selection and utilisation of shelters by Eurasian badgers have focused on lowland populations, while data from montane environments are scarce (Neal & Cheeseman 1996, Roper 2010). In mountains, along with the elevation gradient, there are large differences in climatic conditions, soil types, availability of cover and human pressure (Körner 2003, Jones et al. 2006). Strong altitudinal changes in environmental conditions may require, on a local scale, adaptations similar to those observed on a biogeographical scale (Virgós 2001, Huck et al. 2008).

In our study we aimed to analyse the distribution, characteristics and utilisation of shelters by Eurasian badgers in the Western Carpathians (southern Poland). We studied the influence of altitude, slope aspect, forest structure and climate, and attempted to assess the role of competition with other burrowing carnivores and the importance of human activity on sett selection by badgers. We hypothesised that: (1) at higher altitudes, badgers will tend to use shelters other than excavated setts, due to geological conditions which prevent digging; (2) to minimise effects of the harsh climate, setts will be mainly established on slopes with higher insolation; (3) badgers will build setts in places providing better cover, located further from human settlements and public roads, but closer to the best foraging grounds.

Study Area

Studies were conducted in the western-most part of the Polish Carpathians (49°41′ N, 19°01′ E) (Fig. 1). The study area (1039 km^2) lies between 245 and 1557 m above sea level (a.s.l.). There are three main climatic zones: (1) semi-warm (foothills), (2) semi-cool (lower montane) and (3) cool (upper montane), which were determined on the basis of various features of the local climate (Table 1). Soils, mainly podzolic, in the upper elevations, are acidic and poor in nutrients. In the middle elevations brown acidic soils predominate, while in the foothills, especially on the rocks rich in carbonates, typical brown soils occur.

The current vegetation within the study area has largely been shaped by human activity. The overall forest cover is 46 %, but is dependent on altitude. The foothills are heavily deforested (forest cover 26 %), and patches of broadleaved and mixed forest occur mainly along watercourses and at hill summits. Forest cover in mountain areas is 91 %. Middle elevations are covered by coniferous and mixed forests, with the two dominant species being Norway spruce *Picea abies* and beech *Fagus sylvatica*; while the upper elevations are dominated solely by Norway spruce (Wilczek 2006). The human population density is on average 150 individuals per km^2, rising to 300 individuals per km^2 in the foothills.

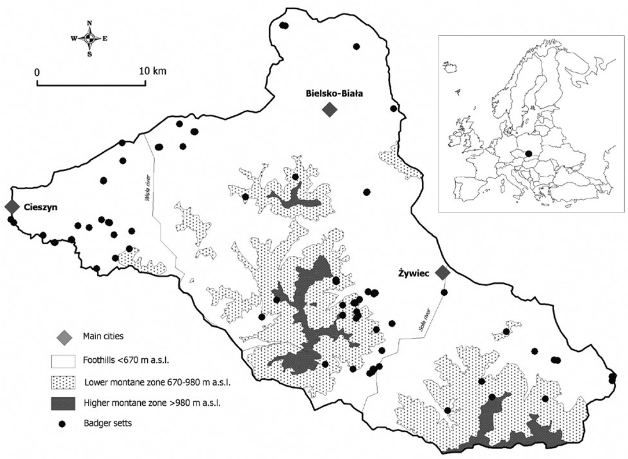

Fig. 1. *Distribution of badger setts recorded in a studied portion of the Western Carpathians in relation to altitude zones.*

In the Western Carpathians, badgers co-exist with three large predators: brown bear *Ursus arctos*, wolf *Canis lupus*, lynx *Lynx lynx*; and numerous small carnivores: otter *Lutra lutra*, fox *Vulpes vulpes*, raccoon dog *Nyctereutes procyonoides*, pine marten *Martes foina*, beech marten *M. martes*, common polecat *Mustela putorius*, stoat *M. erminea* and weasel *M. nivalis* (Pucek & Raczyński 1983, Niedziałkowska et al. 2006, Nowak et al. 2008). However, only the presence of wolves, foxes and racoon dogs seems likely to be important for the local badger population, because of the potential risk of predation (Nowak et al. 2005) or competition for burrows (Kowalczyk et al. 2008) presented by these species. In Poland, badgers are game species readily harvested by local hunters (Mysłajek 2009). Within the study area, hunters can hunt badgers through the entire year, as Polish law allows year-round hunting in areas inhabited by capercaillie *Tetrao urogallus*.

Material and Methods

A survey of Eurasian badger setts in the Western Carpathians was conducted in 2002-2010. We discovered badger shelters during long-distance snow-tracking of animals and radio-telemetry. Additionally, we checked information on sett location obtained from local foresters, hunters and naturalists. We anticipate that by using multiple methods to detect badger shelters we were able to minimise

Table 1. *Characteristics of climatic zones in the Western Carpathians (after Hess 1965).*

Parameter	Climatic zone		
	Foothills	Lower montane	Upper montane
Altitudes (m a.s.l.)	< 670	670-980	> 980
Mean annual temperature (°C)	6-8	4	2
Length of the vegetation season (days)	200-220	170	140
Annual precipitation (mm)	800-1000	1400	1600

Table 2. *Availability of slopes with various aspects and location of badger setts in foothills and montane zones of Western Carpathians (setts located on flat areas not included). Slope aspect assessment based on ASTER Global Digital Elevation Map (see Methods for further details).*

Slope aspect	Slopes		Setts		Ivlev's selectivity index
	Area (km^2)	%	*N*	%	
			Foothills		
NW	97.8	13.1	5	14.3	0.05
N	166.4	22.3	6	17.1	–0.16
NE	101.7	13.6	6	17.1	0.14
E	62.3	8.3	1	2.9	–0.51
SE	71.5	9.6	8	22.9	0.47
S	98.8	13.2	1	2.9	–0.68
SW	81.0	10.8	3	8.6	–0.13
W	68.0	9.1	5	14.3	0.25
Total	747.6	100.0	35	100.0	-
			Montane zones		
NW	39.3	13.5	2	7.1	–0.34
N	63.9	21.9	2	7.1	–0.57
NE	33.9	11.6	2	7.1	–0.26
E	22.6	7.8	4	14.3	0.33
SE	30.2	10.3	1	3.6	–0.51
S	47.0	16.1	11	39.3	0.54
SW	29.1	10.0	4	14.3	0.20
W	25.5	8.7	2	7.1	–0.11
Total	291.5	100.0	28	100.0	-

biases associated with detectability that might affect particular approaches (e.g. questionnaires).

Tracking of animals was conducted mostly in early spring, when tracks of badgers were still visible on snow cover, which in areas of high altitude sometimes lasted until the beginning of May. Five badgers (two adult females and three adult males), belonging to four family groups, were radio-tracked over the period 2005-2008. Animals were captured in snares or box traps equipped with alarm systems sending warning signals via a radio or GSM network, which limited the time an animal spent in a trap to a maximum of 40 minutes. Trapped badgers were immobilised by an intramuscular injection of *Ketaminum hydrochloricum* (Kreeger 1997, Bodin et al. 2006), sexed, aged (adult or yearling) according to tooth wear (Hancox 1988, Harris et al. 1992), weighted and fitted with radio-collars (L-2/ER1733, Andreas Wagener Telemetrien-Anlagen, Germany). The weight of the collar (120 g) constituted 0.7-1.3 % of the animal body mass, and was well below animal welfare guidelines advised for safe telemetry studies (Sikes & Gannon 2011). All permissions required by Polish law were obtained from the Ministry of Environment, and county authorities for protection of the environment. Studies were also approved by the ethical commission for use of animals in scientific experiments. We located the animals by triangulation on foot using a portable VHF receiver

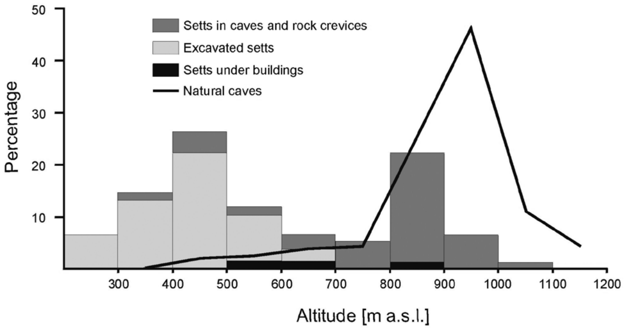

Fig. 2. *Percentage shares of excavated setts, setts in caves and rock crevices, and under buildings along an altitudinal gradient in the Western Carpathians, against availability of natural caves (data on caves from the unpublished database of the Caving Club in Bielsko-Biała).*

(HR-500 or FT-817, Yaesu, Japan) and a hand-held antenna (RA-14, Telonics, USA). Collared individuals were routinely monitored from their first emergence to their final return to setts. Fixes were taken every 15 min, but the final number of locations was limited by the mountain terrain which often hindered triangulation (see Appendix for detailed information). The resting locations of the animals were recorded between sunrise and sunset.

The location of every sett and its elevation was recorded using GPS (GPSmap 60CSx, Garmin, USA). For all setts (n = 77, temporary shelters not included in analysis), and for comparison also for 121 randomly selected points, we measured the straight-line distance to human settlements, public roads and meadows with high earthworm biomass.

Table 3. *Altitude and mean distance ± SE (range) of badger setts and randomly selected points to buildings, public roads and meadows with high earthworm biomass in the foothills and montane zones of the Western Carpathians.*

Location of setts or random points	Altitude [m a.s.l.]	Distance to buildings [m]	Distance to public road [m]	Distance to meadows with high earthworm biomass [m]
Setts foothills (n = 49)	438 ± 14.9 (252-666)	272 ± 19.8 (10-560)	334 ± 33.5 (20-1040)	80 ± 12.0 (2-330)
Setts mountains (n = 28)	856 ± 12.0 (684-1050)	1158 ± 84.6 (260-1940)	1386 ± 93.7 (580-2290)	1436 ± 112.0 (100-2370)
Setts total (n = 77)	590 ± 25.5 (252-1050)	594 ± 58.9 (10-1940)	717 ± 70.4 (2-2370)	523 ± 85.3 (2-2370)
Random points foothills (n = 89)	445 ± 11.4 (290-655)	227 ± 36.5 (0-1780)	277 ± 45.1 (0-2350)	127 ± 45.1 (0-1790)
Random points mountains (n = 32)	817 ± 22.8 (690-1150)	945 ± 118.3 (100-3290)	1388 ± 147.2 (80-3310)	1221 ± 147.5 (80-3200)
Random points total (n = 121)	543 ± 18.2 (290-1150)	417 ± 50.1 (0-3290)	571 ± 67.7 (0-3310)	416 ± 63.6 (0-3200)

Table 4. *Number and location of setts within territories of badgers studied with radio-telemetry in the Western Carpathians.*

Parameters	Badgers				
	M-2	F-1	M-1*	M-3*	F-2
Altitude within the territory (m. a.s.l.)					
Minimum	375	430	485	510	530
Maximum	590	660	930	920	840
Number of shelters	1	4	12	4	3
Location of shelters within the territory (m a.s.l.)					
Minimum	544	496	488	708	684
Maximum		541	879	886	834
Location of a wintering sett (m a.s.l.)	544	541	826	826	834
Location of setts with pups (m a.s.l.)	-	-	826	826	684/834

** M-1 and M-3 used the same family territory and overwintering sett.*

***Table 5.** Animals recorded at badger setts through direct observation or recording of signs (N – number of observations of a given species, % – percentage of sett controls where given species was recorded, number of controls: foothills 189, montane zones 237, total 426).*

Species	Foothills		Montane zones		Total	
	N	%	*N*	%	*N*	%
Red fox *Vulpes vulpes*	18	9.5	12	5.1	30	7.0
Marten *Martes sp.*	1	0.5	4	1.7	5	1.2
Domestic cat	1	0.5	1	0.4	3	0.7
Domestic dog	2	1.0	-	-	2	0.5
Wolf *Canis lupus*	-	-	2	0.8	2	0.5
Lynx *Lynx lynx*	-	-	1	0.4	1	0.2
Bank vole *Myodes glareolus*	-	-	1	0.4	1	0.2
Fire salamander *Salamandra salamandra*	1	0.5	-	-	1	0.2
Total	23	12.0	21	8.8	44	10.5

Biomass of earthworms was assessed based on 500 samples taken in the main habitats distributed within all altitude zones (for details see: Rożen & Mysłajek 2005, Mysłajek 2009). All measurements were made using MapInfo Professional software (Pitney Bowes Inc., CT, USA), based on topographic maps of 1 : 50000 scale. Setts were classified as main, secondary or temporary shelter, based mainly on evidence of use (Thornton 1988, Kowalczyk et al. 2000). Main setts were identified by the presence of offspring or from evidence of overwintering. Altogether, 82 shelters of badgers were discovered (32 main setts, 45 secondary setts and five temporary shelters; 54 in foothills and 28 in montane zones). We checked known setts during irregular visits performed within all seasons. In total, during 424 controls (189 in the foothills and 235 in the montane zones), we recorded signs of badgers and the presence of other species (e.g. tracks, faeces, beddings, hair, signs of foraging, parts of skeletons removed from setts). We also recorded evidence of human presence near burrows.

We calculated the badgers' selection of elevation zone, slope aspect and habitat at the sett location (temporary shelters were excluded from this analysis), using Ivlev's selectivity index, D (modified by Jacobs 1974): $D = (r - p)/(r + p - 2pr)$, where: r is the number of badger setts within a given zone, slope aspect or habitat as fraction of all setts, and p is the area covered by a given zone, slope aspect or habitat as fraction of the entire study area. We measured slope aspects using ArcGIS Desktop version 10 (ESRI, CA, USA), based on the ASTER Global Digital Elevation Map, with a resolution of 30 m, whereas areas of habitats were obtained from management plans of local forest districts and topographic maps. D ranges from –1 (the strongest negative selection) to +1 (the strongest positive selection), with 0 representing random utilisation. For statistical analysis we used the G test of independence and the non-parametric Mann-Whitney U test (Sokal & Rohlf 1995).

Results

Among 77 badger setts found in the Western Carpathians, 53 % constituted excavated dens, 43 % were burrows in small caves and rock crevices, and 4 % were dug below abandoned buildings. Most setts (64 %) were located within the foothills zone (< 670 m a.s.l.), 35 % were located in the lower montane zone (670-980 m a.s.l.), and only one sett was located in the upper montane zone (> 980 m a.s.l.). The selectivity index was –0.19, 0.32 and –0.73 for foothills, lower montane and upper montane zone, respectively. Additionally, as temporary shelters, badgers used piles of planks (two cases), bunkers originating from the Second World War (two cases) and ruins of a wooden hut (one case), all of them situated in the foothills.

Excavated setts occurred exclusively in foothills, up to 640 m a.s.l., mostly in the range 400-500 m a.s.l. Setts in small caves and rock crevices were recorded up to 1050 m a.s.l., most commonly within the 800-900 m a.s.l. range. The distribution of natural caves and that of badger setts located in caves and crevices were different (test G, $G = 14.969$, df = 2, $p = 0.001$). Although the highest number of both caves (75.8 %) and badger setts in caves and rock crevices was in the lower montane zone, in general badgers avoided caves in the upper montane zone despite their substantial availability (Fig. 2).

Badger setts were mostly situated in forests (83 %, Ivlev's selectivity index $D = 0.70$) and within bushes and high grass (12 %), but rarely in open areas (5 %). In the foothills the corresponding values were 79 %, 15 % and 6 % respectively, while in montane zones 97 % of setts were located in forests and 3 % in open areas (Table 2). Generally badgers preferred deciduous forests (D = 0.66) and avoided coniferous ones (D = –0.66).

In the foothills, badgers established setts mostly on the slopes of small hills (71 %) and less frequently in flat areas (29 %). All setts in montane zones were located on slopes. There was a difference in the slope exposure for setts located in foothills and montane zones (G test, G = 76.707, df = 7, p = 0.001). Badgers avoided northern slopes in all altitudinal zones, but strongly selected south-easterly and westerly slopes in foothills, and southerly and easterly slopes in montane zones (Table 2).

When compared with random points, badger setts were more distant to buildings (U = 3119.5, p = 0.0001) and public roads (U = 3398.0, p = 0.001), but closer to meadows with high earthworm biomass (U = 3139.5, p = 0.0001). However, calculations for separate data sets for foothills and montane zones showed that such a pattern was clear only for setts located in foothills (Table 3).

Within badger territories which were searched by radio-telemetry, we recorded between one and 12 setts. Badgers which occupied territories including both foothills and montane zones had setts at various altitudes, but their main setts used for wintering were located exclusively above 800 m a.s.l. in the lower montane zone (Table 4). Despite the fact that the project was conducted over a long time period, changes in the status of setts (e.g. between secondary and main setts) were never recorded.

We noticed the presence of hunting high seats near 8 % of badger setts in foothills, but no such constructions existed in montane zones. Badger setts were visited or utilised by a number of animals, mostly medium-sized or large carnivores, but relatively rarely. The large carnivores, lynx and wolf, were recorded at badger setts exclusively in mountains (Table 5).

Discussion

In European mountains, badgers have been observed up to 1700 m a.s.l. (Mitchell-Jones et al. 1999), but they prefer to utilise setts below 1000 m a.s.l. (Matyáštík & Bičík 1999, Bičík et al. 2000, Dykyy 2002, Marassi & Biancardi 2002, Bartmańska & Nadolska 2003). A significant obstacle for animals living in mountains is a thin and stony soil layer at higher elevations, which prevents them from digging a proper sett. In such conditions they are forced to utilise alternative shelters. In mountains the alternative to excavated setts are small caves and rock crevices (Virgós & Casanovas 1999, Dykyy 2002, Prigioni & Deflorian 2005, this study). Badgers also easily adapt a huge variety of man-made structures as shelters. Setts were recorded inside sewage pipes, railway embankments, barns, stables and houses, both occupied and abandoned, and under concrete constructions (Balestrieri & Remonti 2000, Revilla et al. 2001, Pavlačík et al. 2004, Weber & Ferrari 2005, this study). In our opinion, the availability of alternatives to excavated setts helps badgers to utilise sub-optimal areas, such as the higher mountain locations.

Badgers can minimise the influence of unfavourable climatic conditions in mountains by locating setts on slopes of a particular aspect. In regions with a temperate climate, badgers prefer southern slopes, which are warmer and have a shorter period of snow cover (Matyáštík & Bičík 1999, Bičík et al. 2000, Dykyy 2002, Weber & Ferrari 2005, this study). In regions with a Mediterranean climate there is no such relationship (Virgós & Casanovas 1999, Marassi & Biancardi 2002) or even a preference towards northern slopes may be shown (Revilla et al. 2001). Similarly, in the Caucasian Mountains badgers choose northern slopes, which are far cooler during the hot summers typical of this region (Neal & Cheeseman 1996).

In most European mountain ranges, foothills are heavily deforested, which might encourage badgers to select elevated, but more forested areas, which provide good cover for their burrows. On the other hand, badgers feed mostly on fruits and earthworms (Goszczyński et al. 2000, Mysłajek 2009). In mountains these resources are most abundant in foothills and their availability substantially decreases with altitude. This is mostly a result of human activity, as the availability of fruit is directly connected with the presence of orchards, and earthworm biomass is highest in pastures and cultivated meadows (Rożen & Mysłajek 2005, Mysłajek 2009). This is the most likely reason that badgers occupying setts at higher altitudes preferred to forage in foothills, which in return influenced the size and shape of their territories (Mysłajek 2009).

In Poland badgers are a game species, but due to difficult access, hunters rarely kill them at higher altitudes, instead focusing on lowlands and foothills, where they often install high seats adjacent to badger setts in order to facilitate hunting. Regular disturbance and culls can also force badgers to avoid foothills in favour of montane zones. In the Polish Carpathians, montane zones are inhabited by three large carnivores: wolves, lynx and brown bears, which can occasionally kill badgers (Nowak et al. 2005, 2011) or use their setts to rear pups, as was recorded for wolves in Polish lowlands (Theuerkauf et al. 2003). The risk of predation is considered to be a factor affecting the spatial structure of some populations of badgers (Sidorovich et al. 2011). However, studies on mortality of a local population in the Western Carpathians have shown that hunters are a more important factor in badger mortality than wolves (Mysłajek 2009), and the presence of predators did not deter badgers from choosing setts in montane zones (this study), thus the risk of predation is not as significant in this population as in other regions (Sidorovich et al. 2011).

We conclude that badger sett location in mountains is influenced not only by geological factors limiting the possibilities for digging and the availability of suitable cover, but is also substantially affected by human pressure and the distance to foraging areas.

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Appendix. *Characteristics of radio-tracked badgers. F – female, M – male.*

Animal	Age	Weight (kg)	Tracking days	*N* of radio locations
F1	ad.	10.8	8	35
F2	ad.	9.5	11	30
M1	ad.	14.0	37	108
M2	ad.	9.5	21	93
M3	ad.	16.5	76	214
Mean		12.1	30.6	96.0
± SE		± 1.38	± 12.43	± 33.28