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Den site selection of the European badger, *Meles meles* and the red fox, *Vulpes vulpes* in Hungary

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Abstract. The European badger (*Meles meles*) and the red fox (*Vulpes vulpes*) are the two most common mesocarnivores in Hungary. The populations of both species are increasing. The badger has settled in various habitats in the last two decades, while the red fox can often be seen in urban habitats. Due to their wide tolerance of environmental conditions wildlife managers and conservation experts realized that both species have an important (predatory) role in many ecosystems. During the course of our research we examined the preferred locations of the den sites of the European badger and the red fox on the basis of set locations for both species in various areas across Hungary (badger: n = 142, fox: n = 113). Our aim was to find out whether there is a connection between these species' habitat selection on a small scale (locally) and on a large scale (at countrywide level). Field data were collected in four hilly areas and four lowland areas in Hungary. Badgers preferred deciduous and coniferous forests, and rarely used open areas, whereas foxes did not seem to use either coniferous forests or open areas. In the case of both species the preferred locations of the den sites were sharply demarcated in coniferous forests.

Key words: den site, burrow, habitat, vegetation, predators

Introduction

The European badger (*Meles meles*) and the red fox (*Vulpes vulpes*) are probably the two most common carnivores both in Europe and in Hungary (Kranz et al. 2008, Macdonald & Reynolds 2008, Heltai 2010), and therefore from a game management or nature conservation point of view they are very important mesopredators (Heltai 2010). The population of both species are increasing (Heltai et al. 2001, Heltai 2010). The badger has settled in various habitats in the last two decades (Heltai et al. 2001, Heltai 2010), similarly to the red fox, which can often be seen in urban habitats, too (Harris 1984, Heltai 2010). Because of their adaptation skills and opportunistic behaviour they can easily find various food sources and suitable habitats in many different environments (Harris 1981, 1984, Heltai 2010). The European badger used to be a protected species in Hungary until 2001. Nowadays it has an open season from the 1st of July to the last day of February. Badger population increased by 60 % between 1987 and 2000, and their area of occurrence has also expanded with occupying new habitats in the Hungarian Great Plain (southern Hungary) (Heltai et al. 2001). After 2003 population size declined then stabilized, and after that an increase was observed in badger numbers (Heltai et al. 2001, Heltai & Szemethy 2010). The mean population size is estimated to be ca. 40 thousand individuals (2011-2013, Csányi et al. 2011, 2012, 2013). Fox population also increased in Hungary from 1988 until 2002. After this period the population faced a slight decline until recent years, when foxes became more abundant again (Heltai 2010). According to the Hungarian National Game Management Database, the estimated mean population size was ca. 76 thousand individuals (2011-2013, Csányi et al. 2011, 2012, 2013). The red fox has a year-round open hunting season in Hungary due to its dense population and potential impact on small game species (Heltai 2010).

Both species are common at hills, mountains, lowlands and agricultural fields. Their burrows can

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often be found at forest edges or in gutters, ditches, mountain slopes and abandoned human environments (Heltai 2010). The fact that these species sometimes have an overlapping food preference (Lanszki et al. 1999, Lanszki 2012) and they also use similar habitats suggests that the fox and the badger might be competitors of each other (Fedriani et al. 1999, Kowalczyk et al. 2008). However, badgers and foxes do live together while using similar resources, and sometimes they even use each other's burrows (Kowalczyk et al. 2008, Heltai 2010). This confirms that these carnivores have a partial niche overlap, which results in a long-lasting coexistence. Soil type is one of the most important factors when it comes to burrow constructing (Smal 1995, Neal & Cheeseman 1996, Sidorovich et al. 2006), but prey density (Kruuk & Parish 1982, Da Silva et al. 1994, Revilla et al. 2000, Márton et al. 2014), disturbance (Neal & Cheeseman 1996) and vegetation in the surroundings of the burrows can also be important (Cresswell et al. 1990). The effect of other environmental factors on burrow site selection was examined by several studies. In the boreal climate zone badgers select the south-facing slopes of ravines where snow melts early in spring. On the contrary, in the Mediterranean zone the north-facing slopes are selected because they are cooler in summer (Neal & Cheeseman 1996, Virgós 2002). Several studies showed the importance of habitat fragmentation (Neal & Cheeseman 1996, Virgós 2001). In the areas where the fragmentation of forested habitats is high, badgers selected on the basis of the quality of fragments (distance to a larger forest, shrub cover, rock cover), but where fragmentation is low, the most important factor was the quality of habitats within the forests (Virgós 2001). In a hilly area the diversity of habitats was higher around the red fox burrows than in the case of badger setts (Márton et al. 2014).

Owing to these species' wide tolerance of environmental conditions and the rarity of large carnivores in Hungary both mesocarnivores have become apex predators in their habitats (Heltai 2010). Population increase might result in increased predation on small game and may also cause human-wildlife conflicts (e.g. crop damage, spreading diseases; Delahay et al. 2000, Heltai & Kozák 2004, Heltai 2010). Other impacts, such as predation on rare or economically important species (e.g. European pond turtle *Emys orbicularis* egg, European ground squirrel *Spermophilus citellus*), may occur as well (Lanszki 2004, 2005, Heltai 2010). High badger densities can also lead to an increase in crop damage (Biró et al. 2006). Furthermore, both species can act as a reservoir of parasites and a source of zoonosis (Sréter et al. 2003, Takács et al. 2012). Overabundant populations of highly opportunistic mesocarnivores may cause a significant impact on different trophic levels (Crooks & Soulé 1999). In order to minimalize this effect it is necessary to maintain a reliable and sustainable management (Adkins 2003, Kauhala 2004, Reynolds et al. 2010) through gathering information on both species' population size, reproductive capacity, feeding habits (Heltai 2010) and habitat preference (Heltai 2010, Márton et al. 2013b).

During the course of our research we collected and examined independent studies that investigated den site locations of the European badger (n = 8) and the red fox (n = 6). Our aim was to find out whether there is a significant difference between the species' den site selection on a small scale (locally) and on a large scale (at a countrywide level).

Study Area

Field data were collected in four hilly (H) areas of Hungary (1. Bakony, 2. Börzsöny, 3. Fonó, 4. Gödöllő Hills) and four lowland (L) areas (1. Erdőspuszta, 2. Hortobágy, 3. Kétújfalu, 4. Kiskunság) (Fig. 1).

The first study area in Bakony (H1) is a 3769 ha sized wild boar (*Sus scrofa*) hunting reserve (enclosure). Skeletal soils with low fertility are typical in Bakony. The bedrock consists of limestone and dolomite, which are sometimes covered with a thin layer of loess. This study area has the largest forest cover among sites studied (Table 1). Austrian oak (*Quercus cerris*) is the dominant tree species. Plough lands (≈400 ha) in the area are usually used for alfalfa (*Medicago sativa*) production.

The second study area is located near Márianosztra village at the southern part of Börzsöny Mountain (H2). It is 1257 ha sized. The high number of valleys, riverbeds and ravines results in a very indented topography. The lowest point of the area is 140 m a.s.l., the highest is 335 m a.s.l. The most common tree species are Austrian oak and sessile oak (*Quercus petrea*), but hornbeam (*Carpinus betulus*) and Scotch pine (*Pinus sylvestris*) are also typical. In open areas agricultural cultivation is dominant (73.9 %), while other parts consist mostly of high shrubby-grasslands (26.1 %). The agricultural fields are divided into meadows (≈50 %) and grain growing areas (≈50 %).

Erdőspuszta (L1), a 2922 ha sized forest steppe, is located near Debrecen. This study area has a fairly big forest cover (Table 1). Black locust (*Robinia pseudoacacia*), English oak (*Quercus robur*) and

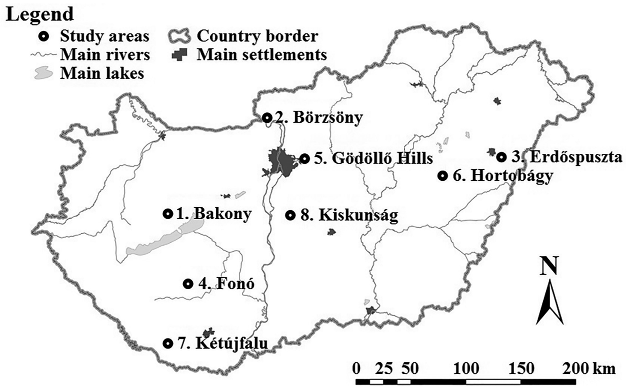

Fig. 1. The localization of sample areas.

Our fifth study area is located between Isaszeg and Pécel villages, in the Gödöllő Hills (H4). Its size is 1430 ha. The bedrock of the hillside is made of loess with a thin layer of diluvial sand sediment. Dominant (≈96 %) genetic soil type is brown forest soil. Due to the significant erosion in the area, the soil surface is usually dry. Typical tree species are the white locus (≈40 %) and pines (*Pinus sylvestris*, *P. nigra*) (≈30 %). Beside the forests fishing lakes and water reservoirs are common, but most areas are covered with agricultural fields (69.5 %). In the agricultural areas cereals, sunflower (*Helianthus annuus*) and rape (*Brassica napus*) are grown.

Table 1. Summarized data of areas studied (H = hilly, L = lowland, D = deciduous forests, C = coniferous forests, O = open areas, Ratio (%) = proportion of sample area to study area).

				Sample area				
Study area	Abbreviation	UTM code	Study area (ha)	Size (ha)	Ratio (%)	Landscape	Mean altitude (m a.s.l.)	Proportion of main habitat types (D-C-O) (%)
Bakony	H1	YN11	3769	1783	47.3	hilly	320	70-12-18
Börzsöny	H2	CU40	1257	503	40.0	hilly	238	51-3-46
Erdőspuszta	L1	ET55	2922	663	22.7	lowland	121	23-34-43
Fonó	H3	YM24	2350	740	31.5	hilly	143	5-0-95
Gödöllő Hills	H4	CT76	1430	413	28.9	hilly	237	19-11-70
Hortobágy	L2	ET05	9961	2440	24.5	lowland	85	6-0-94
Kétújfalu	L3	YL09	2050	515	25.1	lowland	113	29-0-71
Kiskunság	L4	CT61	3777	1594	42.2	lowland	99	8-1-91

Scotch pine are the typical tree species. The planted pine forests were predominantly located on hillocks. In agricultural areas corn (*Zea mays*), wheat (*Triticum aestivum*), horseradish (*Armoracia rusticana*) and triticale (x *Triticosecale*) are grown. Generally the area is composed of plains, with the exception of small sand hills. The soil consists mostly of sand, but small patches of heavy soils can also occur.

The fourth study area has a size of 2350 ha, and located in the Transdanubian hills in Somogy county. At Fonó (H3), agricultural production is more intensive than in other areas. West of Fonó's local fishpond old oak forests (*Quercus petraea-cerris*) are common. The vegetation in the northern lakeshore is a mix of willow (*Salix cinerea*), reeds and sedges (*Caricetum acutiformis-ripariae*, *Scirpo-Phragmitetum*). Large plough lands are situated at the eastern part of the lakeshore and wooded grazing lands (*Betula pendula*, *Robinia pseudo-acacia*) at the southern one. The altitude of the region varies from 125 to 160 m a.s.l. Genetic soil type of the area is loamy, calcareous chernozem.

The sixth study area is 9961 ha and located at Hortobágy (L2). It consists of two different parts. The first part is near Püspökladány. A survey was carried out in the protected areas of Hortobágy National Park, the alkali desert of Ágota-puszta, Farkasszigeti forest, and Hídláb forest. Micro-topography in open habitats is formed by alkaline deserts, short grasslands, plough lands and rushy areas. Genetic soil type is heavy alkaline soil. The other part of Hortobágy is located at Nádudvar. A survey was executed on grasslands with abandoned rice fields and fishing lakes. Heavy soils are common in this region.

Our seventh study area, Kétújfalu (L3), is close to the River Drava (103-123 m a.s.l.). It is 2050 ha sized and used to be a swamp-like region that had been drained with an extensive canal system. Most fields are utilized for agricultural purposes. Cultivated plants are mostly cereals, corn and soybean (*Glycine max*). Oak forests (*Quercus petrea*) and mixed forests (*Quercus* sp., *Ulmus* sp., *Fraxinus* sp.) are common at Kétújfalu. In the shrub stratum common spindle (*Euonymus europaeus*), rose (*Rosa canina*), pear (*Pyrus pyraster*), blackberry (*Rubus* spp.) and hawthorn (*Crategus* spp.) occur. Apart from the Korcsina canal, no notable water surface can be found at this location. Nevertheless spring and winter rains can remain for several months in small canals in the lowland areas. Dominant soil types are meadow soils and brown forest soils.

The eighth study area in Kiskunság (L4) is 3777 ha sized and located between Kunpeszér and Kunszentmiklós villages. Solontsak barrens, salt meadows and pastures are typical here. Groundwater level is high in spring, but in summer the area is dry due to the canal system, high temperature and evaporation. Water balance is poor at this site, soils are heavy and sand hills are common. The other part of the sample location is a typical mosaic agricultural landscape with small farms and forest patches.

Material and Methods

In order to detect badger and fox burrows we chose random north-south orientation stripe transects within the study areas (Table 1). Studies were carried out between 2004 and 2012. We differentiated between European badger and red fox burrows on the basis of indirect signs (footprints, latrine and odour). With the help of these signs we indentified abandoned and active burrows. Species specific tracks crossing trough burrow entrances and at least one other indirect sign indicated that the burrow is "active". Burrows that did not fulfill this criterion were recorded as "abandoned" (Márton et al. 2014). The fieldwork was carried out in the winter because it was easier to find all the burrows when the vegetation cover was lower. The width of each transect was recorded continuously during the survey. This was necessary because the changes in vegetation had affected the perception of the burrows. Further description of evaluation methodologies can be found in Heltai & Kozák (2004) and Heltai & Szemethy (2010).

On the basis of the geographical location of active burrows Jacobs-index (D, Jacobs 1974) was used to estimate preferred locations of the dens:

$D = (A – B)/(A + B – 2AB)$ where

A = is the proportion of the examined species' burrow in a given habitat type,

B = is the proportion of the given habitat type in the whole area,

D = is the preference ($0 < D > 1$) or avoidance ($–1 < D > 0$) calculated for different habitat types. "+1" means complete preference "–1" means complete avoidance for a given habitat type.

Habitat types were grouped into three main categories (deciduous forests, coniferous forests and open areas) or two main categories (deciduous forests and open areas) within each study area. Grouping was necessary because in some cases the proportion of a given habitat type (e.g. reed, orchard and scrub) was too low for reliable statistical analyses (Lechowicz 1982, Reiczigel et al. 2010). Two categories (deciduous forests and open areas) were only used when coniferous forests were not present in the study area (H3, L2, L3, Table 1). Fisher's exact test (Fisher 1922) was used to test the differences in burrow distribution among habitat types within each study area. Reliability of calculated preferences were verified by Bonferroni Z-test ($Z(2) = 2.28728$, $p < 0.05$, $Z(3) = 2.40749$, $p < 0.05$) (Byers et al. 1984). After categorizing the above mentioned habitat types, study areas were compared on the basis of the distribution of active burrows among habitat types (Fisher's exact test).

For evaluating the average habitat use of these mesocarnivores in Hungary, the above mentioned three habitat categories were summarized in all study areas. Active burrow numbers were merged also according to these habitat types. Chi-squared test was used for the nationwide comparison between the species' den site selection (Reiczigel et al. 2010).

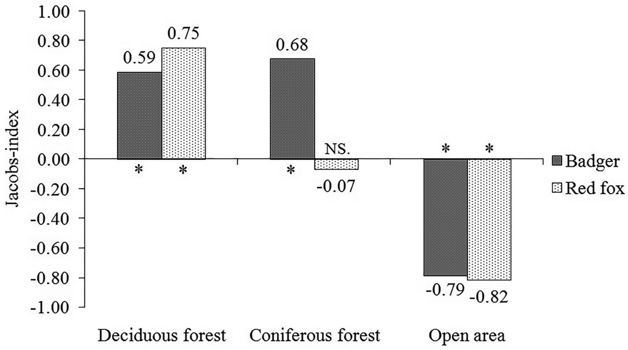

Fig. 2. The habitat preference of the badger (n = 142) and the red fox (n = 113) in Hungary („*": $p < 0.05$, „NS.": $p \geq 0.05$).

Table 2. Badger and red fox den site selection among habitat types in the study areas („-": no data, „n": number of dens).

Study area	badger Fisher's test	n	red fox Fisher's test	n
H1	$p \geq 0.05$	20	$p \geq 0.05$	58
H2	$p < 0.025$	13	$p < 0.01$	18
H3	$p < 0.005$	11	$p < 0.001$	12
H4	$p < 0.001$	27	$p < 0.005$	7
L1	$p < 0.005$	20	$p \geq 0.05$	12
L2	$p \geq 0.05$	27	-	-
L3	$p \geq 0.05$	4	$p \geq 0.05$	6
L4	$p < 0.001$	20	-	-

Table 3. Preference indices (Jacob-index) for the den sites of badgers and red foxes in the study areas („*": $p < 0.05$, „NS.": $p \geq 0.05$, „-": no data, „n": number of dens).

			Habitat type					
			Deciduous forest		Coniferous forest		Open area	
Species	Study area	n	Jacobs-index	Z-test	Jacobs-index	Z-test	Jacobs-index	Z-test
badger	H2	13	1.00	*	–1.00	*	–1.00	*
	H3	11	0.98	*	-	-	–0.98	*
	H4	27	0.69	*	0.72	*	–1.00	*
	L1	20	0.06	NS.	0.71	*	–1.00	*
	L4	20	0.90	*	0.92	NS.	–0.95	*
red fox	H2	18	0.88	*	–1.00	*	–0.87	*
	H3	12	0.99	*	-	-	–0.99	*
	H4	7	1.00	*	–1.00	*	–1.00	*

Table 4. Comparison of burrow-distribution of badger and red fox based on habitat types in the study areas.

Species	Study areas	Fisher's test	n
badger	H2/H4	$p < 0.005$	40
	H2/L1	$p < 0.001$	33
	H2/L4	$p \geq 0.05$	33
	H4/L4	$p < 0.025$	47
	L1/H4	$p < 0.05$	47
	L1/L4	$p < 0.001$	40
red fox	H2/H4	$p \geq 0.05$	25

Results

The badger showed significant selection for certain habitat types in five study areas out of eight. In the case of the red fox there were three study areas (from six) where significant selection occurred (Table 2).

Where the badger's habitat type selection was significant (respectively: H3, H2, H4, L4, L1) deciduous forests were preferred, but in study area L1 preference was not significant (Table 3). Coniferous forests were significantly preferred in two study areas (H4, L1), whereas badgers completely avoided coniferous forests for den sites in area H2. However, badgers did not prefer open areas in any of the five cases.

The selection of habitat types by the red fox was significant in three cases (respectively: H3, H2, H4) and preference was shown toward deciduous forests in all cases. In H2 and H4 foxes did not seem to use coniferous forests for den selection, and statistically significant aversion could be detected in the case of open areas too. In H3 coniferous forests were absent (Table 3). Badger burrow-distribution in different habitat types showed significant difference in all study areas except H2/L4 (Table 4).

Comparing the burrow-distribution between the badger and the fox

In study areas where both species were investigated and selection was also detectable (H2, H3 and H4), we could compare the burrow-distribution between the badger and the fox. Statistically significant difference was only shown in H4 (Fisher's exact test, $p < 0.05$, n = 34), but not in the two other sites (H2: $p > 0.999$, n = 31; H3: $p = 0.590$, n = 23). In H4 study area badgers preferred coniferous forest, but red foxes did not.

After investigating preferred locations of the den sites and burrow-distribution at study area level, we also calculated countrywide values. Selection of both species was significant based on Chi square-test (badger: $\chi^2 = 68.092$, df = 2, $p < 0.001$, n = 142; fox: $\chi^2 = 52.462$, df = 2, $p < 0.001$, n = 113). According to Jacobs-index badgers preferred deciduous forests and coniferous forests, but they rarely used open areas (Fig. 2). The red fox preferred deciduous forests, but rarely used coniferous forests and open areas (Fig. 2). Although in this case the avoidance of coniferous forests for den sites was not significant according to Bonferroni Z-test.

Discussion

Based on our habitat selection results, badgers preferred deciduous forests in four of the eight study areas. This result is consistent with other studies (UK: Neal & Cheeseman 1996, Czech Republic: Bičík et al. 2000, Hungary: Márton et al. 2013a, Spain: Virgós & Casanovas 1999, Virgós 2002). Badgers rarely used coniferous forests for burrow sites in Börzsöny, although this habitat type was preferred in Gödöllő Hills and Erdőspuszta, and the preference was not significant in Kiskunság (Table 3). In Erdőspuszta, forested habitats are on sandy soils. The preference of coniferous forests may be explained by various terrain features on a small scale level. Here, the pine forests are usually planted on hillocks, where the hydrological conditions are probably better (Hayashi & Rosenberry 2002). This might be the reason of badgers' den site preference (Neal & Cheeseman 1996, Kozák & Heltai 2006).

In Gödöllő Hills open areas were dominant (70 %). The forested habitats on brown forest soil type are fragmented. The preference of deciduous forests and coniferous forests is about the same and the open areas were rarely used (Table 3). This indicates that vegetation that covers badger burrows is important for the species (Neal & Cheeseman 1996, Virgós 2001). This result seems to differ from other studies conducted in England. Studies showed that badgers will only occupy coniferous forests if there is no better vegetation nearby, but they will not prefer this vegetation (Neal & Cheeseman 1996). In Börzsöny, forested habitats are on Ramann brown forest soil and the pines are surrounded by deciduous forests. However, in this study area deciduous forests are adjacent to open areas where badgers can forage (Bičík et al. 2000).

At a countrywide level, badgers rarely used open areas (–0.79), thus we infer that the tolerance of open areas by badgers can be the reason of the increase in their occurrence area size in Hungary during the last two decades (Heltai et al. 2001, Kozák & Heltai 2006, Heltai 2010). The avoidance of open areas was shown by other studies as well (Skinner et al. 1991, Santos & Beier 2008), although several investigations proved the preference of this habitat type, too (Revilla et al. 2001, Rosalino et al. 2008).

The red fox preferred deciduous forests in three out of six sample sites (Börzsöny, Fonó, Gödöllő Hills), while coniferous forests and open areas were rarely used (Table 3).

In the case of several study areas neither species showed selection in different habitat types (Table 2). Comparison of burrow-distribution showed difference only in one sample area (Gödöllő Hills). By summarising the sample areas both carnivores seem to prefer deciduous forests and they rarely used open areas (Fig. 2). Preference for coniferous forests could only be detected in the case of badgers. It seems that the two carnivore species' habitat selection differ mostly in their attitude towards coniferous forests, although significant aversion to this habitat type could not be observed in the case of the red fox (Fig. 2). This could be attributed to other factors, for example food sources. We think that rodents, which are the primary food sources for the fox (Jędrzejewski & Jędrzejewska 1992, Lanszki et al. 1999, 2006, 2007), are more abundant in deciduous forests than in coniferous forests (Fuller et al. 2004).

After summarizing the sample areas we also observed that the values showed a strong selection, and statistically significant difference was found between the two carnivores' burrow-distribution. Based on this, we infer that the applicability and reliability of our method could be increased by extending the sample/study area (Hernandez et al. 2006). The reason for this is that a larger area results in a higher number of samples (burrow numbers) and more home ranges (Weber & Meia 1996, Tuyttens et al. 2000, Kowalczyk et al. 2003), which would result in a lower bias (Hernandez et al. 2006).

In conclusion, badgers select habitat types for making burrows that provide better coverage. This can be explained by the fact that badgers use their burrows all year round (Neal & Cheeseman 1996, Kowalczyk et al. 2008). In contrast, red foxes use their burrows mostly in the cub rearing period (Kowalczyk et al. 2008). Also, vixens often raise their cubs alone (Heltai 2010), thus food sources in the vicinity of burrows will be more important than coverage, as vixens can decrease time spent on predation with preys found nearer (Fuller et al. 2004, Suchomel et al. 2012). Our data show that apart from habitat type other factors may also be determinant in burrow site selection. Therefore future studies dealing with preferred locations of the den sites should also focus on different soil types, hydrology, habitat fragmentation, food sources and micro scale terrain features.

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