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Interspecific den sharing: a study on European badger setts using camera traps

Emiliano Mori · Mattia Menchetti · Alessandro Balestrieri

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Abstract Many mammals, both potential competitors and preys, have been reported to use the complex burrow system of European badger *Meles meles* setts as shelter, mainly in northern Europe and during winter, when badgers are lethargic. Nonetheless, until recent times observations of den sharing have been largely restricted to anecdotal information, because of the mainly nocturnal activity of most sett occupants. Using camera-trapping, we investigated both the mammal fauna associated with 24 badger setts located in northern and central Italy, and seasonal variation in the composition of specific assemblages, without interfering with the occupants' activity. Trapping effort was 1,605 camera trap-days from December 2010 to December 2013. Badgers (two to six individuals per sett) shared their setts with a total of eight mammal species: crested porcupine *Hystrix cristata*, Eastern cottontail *Sylvilagus floridanus*, red fox *Vulpes vulpes*, pine marten *Martes martes*, stone marten *Martes foina*, wood mouse *Apodemus* sp., brown rat *Rattus norvegicus* and coypu *Myocastor coypus*. Den sharing was observed throughout the year, with a significant reduction of sharing during winter, when badgers were probably induced to move to alternative setts to avoid breeding porcupines. Eastern cottontails used badger burrows permanently and, at least in one occasion, reared their pups inside, although they can be easily preyed upon by badgers. Badger sett sharing may have favoured both the recent northward expansion of crested porcupines and settling of introduced cottontails in agricultural habitats.

Keywords Burrowing · Noninvasive monitoring · *Meles meles* · *Hystrix cristata* · *Sylvilagus floridanus* · Alien species

Introduction

Burrowing behaviour has been documented in about 58 % of living mammal genera (Kinlaw 1999). This habit provides two main advantages (Roper et al. 2001): protection from predators and buffering against harsh environmental conditions. However, behavioural aspects of burrow use are still poorly known.

The European badger *Meles meles* (Linnaeus, 1758) is a semifossorial large mustelid (Carnivora: Mustelidae), which occurs throughout Europe: the River Volga and the Caucasus broadly mark the Eastern boundaries of its range (Marmi et al. 2006). It is mainly nocturnal and spends most of daylight hours in communal burrows known as "setts" (Neal 1977). Main setts consist of multiple entrances and nest chambers and can be inhabited by up to 27 individuals (Kruuk 1989). The territory of these social groups may also contain a number of small setts ("outliers", "annexes" and "subsidiary setts"; Kruuk 1978; Thornton 1988), which may reduce the risk of infestation by ectoparasites and allow subordinate individuals to escape from harassment by dominants (Kruuk 1989; Neal and Roper 1991) and predators (Butler and Roper 1996). Badger setts are preferentially located in areas with dense vegetation cover (e.g. deciduous woodland and Mediterranean shrubs; Tinelli and Tinelli 1980; Remonti et al. 2006a), offering sloping and well-drained soils (Revilla et al. 2001).

Digging is energetically costly for mammals (Vleck 1979; Zelovà et al. 2010), and interspecific aggregations within the

E. Mori (✉)
Department of Agricultural, Forest and Food Science—Unit of Entomology and Zoology, University of Turin, via Leonardo da Vinci 44, 10095 Grugliasco, Turin, Italy
e-mail: moriemiliano@tiscali.it

M. Menchetti
Department of Biology, University of Florence, via Madonna del Piano 6, 50019 Sesto Fiorentino, Florence, Italy

A. Balestrieri
Department of Biosciences, University of Milan, via Celoria 26, 20133 Milan, Italy

same sett may occur. While ecological studies have often focused on competition and prey–predator relationships, negligible attention has been addressed to positive interspecific interactions (e.g. Selva et al. 2003; Kowalczyk et al. 2008). Many species of rodents, lagomorphs and carnivores have been reported to use badger setts as shelter (Roper 2010). Some species may occur in the sett simultaneously with badgers (e.g. crested porcupine *Hystrix cristata*: Tinelli and Tinelli 1980; Pigozzi 1986; Indian crested porcupine *Hystrix indica*: Salikhbaev 1981; red fox *Vulpes vulpes*: Kowalczyk et al. 2008; raccoon dog *Nyctereutes procyonoides*: Kowalczyk et al. 2008). Interspecific den sharing has been recorded mainly in northern Europe and during winter, when badgers are lethargic and use only a small part of the sett (Kowalczyk et al. 2004). Den sharing is particularly interesting when involving alien species, as badger setts have been suggested to facilitate their spread and invasion (Kowalczyk et al. 2008).

Until recent times, observations of den sharing have been largely restricted to anecdotal information because of the mainly nocturnal activity of badgers (Neal and Cheeseman 1996). Pigozzi (1986) used infrared-light torches and cage traps to check six badger setts in the Maremma Natural Park (central Italy), although sett disturbance might prevent the persistence of different species within the same den (Jenkinson and Wheater 1998). Recently developed camera traps, located at the entrances of the setts, allow the simultaneous collection of a large sample of observations, with negligible disturbance to the animals (e.g. Anile et al. 2012; Rovero et al. 2013). We applied this noninvasive monitoring technique to a total of 24 badger setts, located in three study areas in northern and central Italy, with the aim of investigating (i) the mammal fauna associated to badger setts and (ii) seasonal variation in the composition of their specific assemblages.

Materials and methods

Study areas

The first study area (about 1.350 ha) was located in a rural hilly landscape (475–903 m a.s.l.) in southern Tuscany. The climate was submountainous, with mean yearly air temperature and rainfall of 12.8 °C and 1,000 mm, respectively. Main habitat types were mixed deciduous woods (*Quercus cerris*, *Ostrya carpinifolia* 52.1 %), fallows (19.5 %), chestnut woods (14.9 %), cultivated areas (mainly cereals and sunflower crops: 7.8 %), pinewood plantations (2.0 %), human settlements (2.0 %) and shrubwoods (*Juniperus* spp., *Rubus* spp., *Erica scoparia* 1.7 %). Badger sett density was 0.4 sett/km^2.

The second study area coincided with an isolated, 14.5 km^2 wide, hill (up to 147 m a.s.l.) in the middle River Po plain (Lombardy region, *ca.* 45° 11′ N, 9° 29′ E). Woodland consisted of oaks (*Quercus robur*, *Quercus petraea*) and alder (*Alnus glutinosa*). The southeastern part of the hill was extensively covered by vineyards. The climate was subcontinental temperate, with an average yearly temperature of 11.4 °C and an average yearly precipitation of 712 mm. Badger sett density was 0.6 sett/km^2.

The third area included a Natural Reserve (Garzaia di Valenza, *ca.* 45° N, 8° 30′ E) and its surroundings, covering about 10 km^2 of the left bank of the River Po. The climate was subcontinental temperate, with an average yearly temperature of 12.4 °C and an average yearly precipitation of 1,000 mm. About 80 % of the whole territory was flat, intensively cultivated, land (rice, maize and poplar plantations). Woodlands (20 % *ca.*) consisted of willows (*Salix cinerea*, *Salix alba*), oaks (*Q. robur*), poplars (*Populus alba* and various hybrids) and alder. Badger sett density was 0.21 sett/km^2 (Remonti et al. 2006a).

Methods

Setts were detected through the help of local hunters and lumberjacks, except for the third study area, which is the object of a long-term badger monitoring (e.g. Balestrieri et al. 2004, 2010; Remonti et al. 2006a, b). All the setts were located in deciduous woodlands.

We used digital scouting pocket cameras (Multipir 12 and Sg550) with Passive Infrared motion sensor (PIR), to record 30 s long videoclips (with a 60-s interval between two successive recordings). This is the most commonly used infrared system in camera traps, being less expensive and cumbersome than active (AIR) devices (Meek et al. 2012). Camera traps were tied to trees about 5 m from each active entrance of each surveyed sett. Apparently, unused holes were gently closed with branches as to prevent or detect their use during the trapping session. Trapping effort was expressed as camera-days (cd), while trapping success per species was expressed as percentage of the total number of videoclips (excluding false triggers, caused by wind moving vegetation in the cameras' detection zone).

In the first study area, between December 2010 and December 2012, seven setts were surveyed for 12–14 days once a season (838 cd); the number of monitored active entrances ranged between 3 and 7 (mean±SD=4.5±1.4). In the other two areas, the setts were surveyed only once, for 6–7 days in March (seven main setts and one subsidiary sett, 276 cd) and for 14–17 days in November 2013 (three main setts and six outliers, 491 cd). The number of active entrances per main sett was 5–9 (mean±SD=6.4±1.3) and 7–9, respectively.

Sett sharing was defined as the simultaneous (i.e. during a survey period) use of a sett (i.e. part of the underground burrow system) by both badgers and one or more other species. Each species was considered to use a sett if at least one individual was recorded to go into and out of at least one of its entrances.

To assess if occupation by badgers affected the use of setts by the other species, the relation between the number of videoclips of badgers and other occupants was tested by Spearman's correlation test, respectively. As the community of potential occupants differed between northern and central Italy, two tests were run separately. Seasonal (spring: III–V, summer: VI–VIII, autumn: IX–XI, winter: XII–II) variation in the number of shared entrances was tested by the chi-squared test (χ^2).

We recorded the number of both badger individuals and species sharing the same sett/entrances. Although badgers were not individually recognizable, the synchronization of the date and time of all cameras, together with the triggering interval set, helped to prevent double-counts. Moreover, the appearance of the tail was useful to solve some uncertainties (Dixon 2003).

Results

In the first study area, badgers were recorded 386 times (one videoclip per 2.2 cd); the number of badgers per main sett ranged from two to six individuals, with the highest numbers occurring during the warm seasons. Other species detected within badger setts were crested porcupine, red fox, pine marten *Martes martes*, stone marten *Martes foina* and wood mouse *Apodemus* sp. Up to three species were recorded to use a same sett simultaneously (Table 1).

Den sharing was observed throughout the year and in all the surveyed setts, with a reduction in the total number of shared entrances in winter (χ^2=4.88, df=3, p=0.18). The number of badger videoclips was inversely related to that of porcupines (rho=−0.326, p=0.014, N=56).

The crested porcupine was the most common co-occupant of badger setts, having been detected in 38.3 % of videoclips (Table 2). Porcupines shared burrow entrances with badgers during the weaning of newborn badger cubs (sett 1 in the spring of 2012), while badgers were never observed in the sett used by breeding pairs of crested porcupines (setts 5, 6 and 7; Table 1), which were recorded mainly in winter (Table 1). Also, breeding red foxes were recorded in both used (sett 5, summer of 2011) and temporarily disused (sett 3, spring of 2012) badger setts.

In 73.2 % of recorded cases, all the species shared the same entrance. Only the stone marten always used an entrance different from those used by the other species (26.8 %).

In the second study area, badgers were recorded 122 times (30.6 %; one videoclip per 2.3 cd); groups consisted of 2–4 individuals (mean±SD=2.8±0.99).

Table 1 Patterns of den sharing in the first study area (central Italy)

Sett	2011				2012			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
1	EB (2), AP (2)	EB[a] (6), PM (1)	CP (3), EB (4), PM (2)	CP (3), EB (4), PM (1)	EB (4), AP (2), PM (2)	EB[a] (4), CP (2)	EB (4), CP (2)	EB (2), CP (2)
2	CP (6)	CP (6), EB (1), SM (1)	CP (9)	CP (8), EB (1)	CP (6), AP (2), SM (2)	CP (6), EB (2)	EB (2)	EB (2)
3	CP (1)	CP (1), EB[a] (3)	EB (3), RF (1)	EB (4), RF (2)	RF (2)	RF[a] (2)	CP (1), EB (2)	CP (1)
4	CP (1), AP (1)	–	EB (6)	CP (1), EB (5)	EB (2)	EB[a] (3), CP (2)	EB (2)	EB (2)
5	CP[a] (4)	CP (3), EB (1)	EB (2), RF[a] (3)	EB (2), RF (1)	RF (2)	RF (1)	RF (1)	EB (2), RF (1)
6	CP[a] (2)	EB (1), CP (4)	CP (4)	CP[a] (6)	CP[a] (8)	CP (4)	CP[a] (6)	CP (4)
7	EB (4), AP (2)	EB[a] (5)	EB (5), CP (2)	EB (3), CP(2)	CP[a] (4)	EB (1), CP (3)	EB (4), CP (2)	CP[a] (4)

Minimum number of individuals in brackets

EB European badger, *CP* crested porcupine, *RF* red fox, *SM* stone marten, *PM* pine marten, *AP Apodemus* sp

[a] Breeding species

Four main setts and the subsidiary sett were shared with the Eastern cottontail *Sylvilagus floridanus*, with wood mice also dwelling in two of them. Cottontails were camera-trapped 215 times (53.9 %), of which 145 were in the subsidiary sett, where five cubs found refuge and were probably reared. In three main setts, cottontails and badgers shared 1–2 entrances per sett. Wood mice were recorded 11 times (2.8 %) and used only one entrance per sett, of which one was also used by the main occupant.

In the Natural Reserve, badgers were recorded in one main sett, while the others were only sporadically visited. As a consequence, badgers were recorded 54 times (5 %; one videoclip per 9.1 cd); groups consisted of 2–3 individuals (mean±SD=2.25±0.5). Other sett occupants were the Eastern cottontail (56.3 %), the brown rat *Rattus norvegicus* (10.4 %), the wood mouse (7.4 %), the red fox (3.4 %) and the coypu *Myocastor coypus* (0.2 %; Table 2).

In the only sett continuously occupied by badgers, the main occupant shared two entrances with the cottontail, while badgers and either rats or foxes were recorded to sporadically use the same entrance of another main sett and a subsidiary one, respectively. Coypus used two entrances of a disused subsidiary sett dug into an about 10 m high embankment built on the left bank of the River Po.

For both study areas in northern Italy, setts were used by *c.* 2–3 adult cottontails and 4–5 brown rats, while single individuals were presumably recorded for the other occupant species. No relationship (r=0.19) was found between the number of videoclips of badgers and the other occupants.

Discussion

Large setts have been suggested to increase badger breeding success, either by improving cub survival or allowing subordinate females to rear their cubs without being harassed by dominant ones (Roper 1993). Alternatively, in large setts, the use of several sleeping nests may prevent ectoparasite accumulation in the bedding materials (Roper et al. 2001). Whatever the reason for their importance to badgers, if any (see Revilla et al. 2001), well-established setts can be occupied by successive badger generations for centuries (Neal 1977) and it is often hard to exclude badgers from their burrows (Roper et al. 1991). Such evidence, together with the preference for specific habitat conditions at sett sites—mainly slope, drained soils and cover (Neal and Roper 1991; Doncaster and Woodroffe 1993)—suggests that setts are a limiting resource (Roper 1993). Accordingly, hinterland latrines have been reported to serve to protect either main setts or mating resources from conspecifics belonging to neighbouring social groups (Roper 1993). At low population density, scent marking focuses on setts and their surroundings as an ultimate deterrence strategy (Revilla and Palomares 2002; Balestrieri et al. 2011). In contrast, sett sharing by several other medium-sized mammals suggests that badgers consider such tenants as neither threats nor potential competitors (Roper 2010).

According to available knowledge on the selection for resting sites by both stone (Santos-Reis et al. 2005) and pine martens (Zalewski 1997), these mustelids were occasional occupants of badger setts, and the latter showed mainly diurnal habits, not overlapping with those of badgers (Zalewski 2000). As previously reported (Macdonald et al. 2004), red foxes used badger setts as breeding sites, without any aggressive interaction being recorded.

In central Italy, the crested porcupine was the main occupant of badger setts throughout the year, the number of videoclips suggesting that the two species tended to avoid each other, particularly in winter. In agreement with Greaves and Aziz Khan (1978) about Himalayan crested porcupines *Hystrix brachyura*, badgers were never recorded in the same den with porcupines when cubs of the latter were present. Although the crested porcupine does not present a marked seasonal reproductive period, births peaked during the cold season (see also Sonnino 1998). Thus, in winter, badgers might be induced to move toward alternative setts, which were widely available in the rich in cavernous limestone study area, to avoid breeding porcupines.

Moreover, interactions between badgers and other sett tenants are not always bloodless: Himalayan crestless porcupines, which escaped from a wildlife collection in Devon, were able to displace badgers from their setts (Greaves and Aziz Khan 1978); in central Italy, lethal aggression by crested

Table 2 Camera-trapping success expressed as percentage of videoclips per species

Study area	Percentage of videoclips										Total number of videoclips	False triggers
	Meles meles	*Hystrix cristata*	*Sylvilagus floridanus*	*Martes martes*	*Martes foina*	*Vulpes vulpes*	*Myocastor coypus*	*Rattus norvegicus*	*Apodemus* sp.	Other species		
1	48.2	38.3		0.5	1.0	6.6			4.0	0.4	801	76
2	30.6		53.9		1.3	0.3			2.8	11.3	399	194
3	5.0		56.3			3.4	0.2	10.4	7.4	17.4	1,089	949
Total	24.6	13.5	36.3	0.2	0.6	4.0	0.1	5.0	5.4	10.4	2,282	1,219

porcupines on young badgers have been recorded in proximity to the breeding den of the rodent (Mori et al. 2014).

On the other hand, predation by badgers has been recorded on cubs of raccoon dogs and red foxes, both inside (Kowalczyk et al. 2008) and in the surrounding of shared setts (Macdonald et al. 2004).

Badger diet only partially overlaps that of crested porcupines (cf. Bruno and Riccardi 1995) martens and foxes (Ciampalini and Lovari 1985; Remonti et al. 2012), suggesting that competition for food should be low.

The co-occupancy of badger setts by potential prey species is harder to explain. Mice and rats may either dig small size tunnels inside badger burrows (Neal and Cheeseman 1996), thus reducing the possibility of running into the main occupant, or, as in our third study area, dwell into burrows disused by badgers.

Eastern cottontails were introduced in northwestern Italy in 1966 (Spagnesi 2002). They do not dig burrows and, in their native range, they have been reported to use those of groundhogs *Marmota monax* and prairie dogs *Cynomys* spp., mainly in winter or to escape predators (Nowak 1999). In our study areas, cottontails used badger burrows permanently and, at least in one occasion, reared their pups inside. The overwhelming percent frequency of videoclips showing cottontails roaming on the spoil heaps in the two northern study areas suggests that burrows may play a major role as a refuge than previously reported for North America. It would be worth investigating to what extent this behaviour is the result of rapid adaptation (Prentis et al. 2008) to the lowered availability of permanent dense cover in intensively cultivated habitats (Vidus Rosin et al. 2010). Both adult and young cottontails can be easily preyed upon by badgers, although in northern Italy they represent a negligible fraction of the overall diet of this mustelid (Balestrieri et al. 2004). Similarly, wild rabbits *Oryctolagus cuniculus* are common commensals of the badger throughout Europe, despite being under heavy predation from them in some areas (e.g. SW Spain; Martin-Franquelo and Delibes 1985).

Coypus, which were introduced in northern Italy in the late 1950s, were also recorded as sharing badger setts, provided they were not far from water bodies, in other areas of the River Po plain; both badgers and coypus were trapped by snares at the same entrances of two setts (unpublished data; see Balestrieri et al. 2006).

Positive interactions can increase species diversity and may promote the spread of both native and alien species (Hacker and Gaines 1997; Richardson et al. 2000). Furthermore, they may play a pivotal role in reducing biotic/physical stresses and in exploiting limiting resources, i.e. dens (Bruno et al. 2003; Kowalczyk et al. 2008). The shelter from harsh environmental condition provided by badger sett has been reported to favour the invasion of raccoon dog *Nyctereutes procyonoides* in Bialowieza Primeval Forest (Kowalczyk et al. 2008). Further studies are needed to point out the role played by badger setts sharing in both the recent range expansion of crested porcupines, which origin (native or nonnative) is to be clarified yet, in the northern and eastern Italian peninsula (Mori et al. 2013) and settling of introduced cottontails in the agricultural landscape of northern Italy.

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