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SHORT COMMUNICATION

Roost selection and switching in two forest-dwelling bats: implications for forest management

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Abstract The structure of woodland bat communities is influenced by numerous environmental factors, and amongst these, the availability of suitable roosts is of prime importance. Temperate zone forest-dwelling bats use a great variety of roost types, ranging from natural tree cavities to human-made shelters. Given the frequent habit of forest bats to switch roosts, even within the reproductive season, bat-friendly forest management requires information about the number of cavities necessary to maintain populations. We identified the rate of roost switching, number of roosts used and site characteristics of two forest bat species at risk, the Bechstein's bat (*Myotis bechsteinii*) and the Barbastelle bat (*Barbastella barbastellus*) in suburban forests of SW Switzerland. Radio tracking of 9 *M. bechsteinii* females showed that a colony used at least 15 roost sites in an area of 3 km^2 throughout the reproductive season. *B. barbastellus* used at least 11 roost sites located in France in two areas 15 km from each other. This illustrates the borderless nature of bat conservation and calls for the maintenance of a trans-frontier cooperation programme. There were clear species-specific roost preferences: *M. bechsteinii* used tree cavities whereas *B. barbastellus* used exclusively human-made shelters. These results provide some preliminary guidance for bat-friendly forest management.

Keywords Bechstein's bat · Barbastelle bat · Roost preferences · Commuting · Radio tracking · Forest management

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Introduction

The composition of forest bat communities is influenced by complex environmental factors (Kanuch et al. 2008). Amongst them, roost availability affects bat species distribution and associations (Findley 1976), whilst roost structure and quality are essential features for thermoregulation (Kerth et al. 2001a), predator avoidance and social behaviour (Kerth et al. 2001b). Numerous forest-dwelling species use tree cavities for daytime resting, reproduction and hibernation. Roost site selection thus influences demographic parameters such as reproductive success and survival (Lewis 1995). Bats seek refuge in a wide variety of roost types in woodland, ranging from underground sites, human-made shelters to tree cavities (Hutson et al. 2001). Studies of roost site selection and roost switching behaviour are thus essential for designing appropriate guidelines for bat-friendly forest management (Russo et al. 2004, 2010). This is particularly important in human-dominated landscapes where natural forests have been extensively modified, fragmented or even cleared (Obrist et al. 2011).

Most bat species occurring in Western Europe have an unsatisfactory red list status and therefore require appropriate conservation and restoration measures. A majority uses forests in some way (Hutson et al. 2001), making this habitat crucial for the preservation of European bats. Our study area is located in the small Swiss canton of Geneva, which looks like an enclave surrounded by French territory. Its wildlife is threatened by the sprawl of Geneva agglomeration. Given this peculiar political configuration, we need better information about woodland bat roost requirements and use and this on both sides of the border so that to provide advice to both French and Swiss forestry managers. A bilateral forest management agreement is foreseen, which would pave the way for similar international action plans in other parts of Europe. To this aim, we investigated roost site selection and roost switching of two 'Near threatened' bat species, the Bechstein's bat (*Myotis bechsteinii*) and the barbastelle bat (*Barbastella barbastellus*). This provides recommendations for both bat conservationists and forest managers about the type of trees that should be preserved in priority to achieve sustainable, biodiversity-friendly forest management.

Methods

Study area

The study was carried out near Bernex (46°9′59″N, 6°2′39″E, 400-600 m altitude) (Fig. 1). The study area consists of mixed forest, mainly dominated by oaks, agricultural fields and fallow fields.

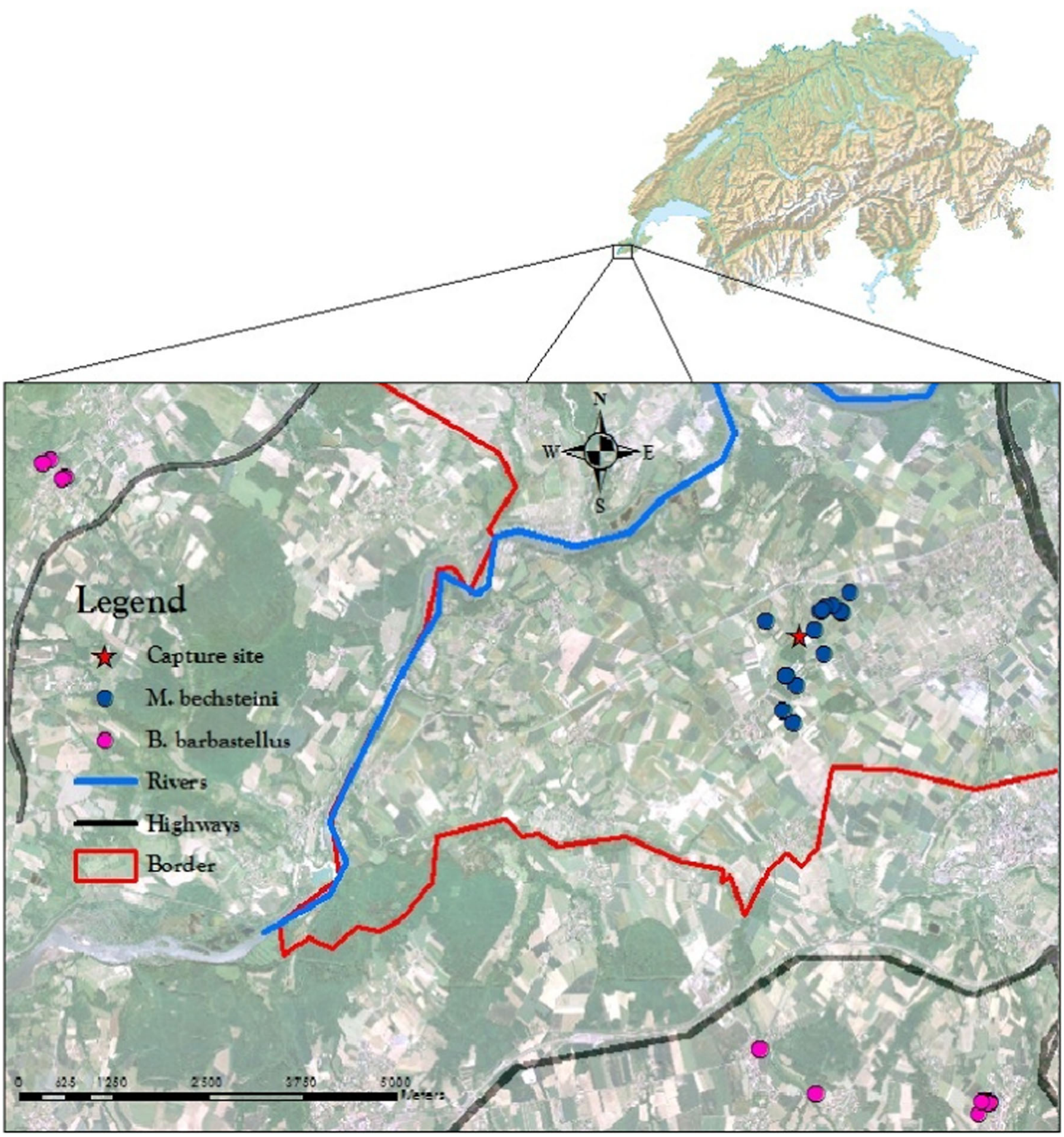

Fig. 1 Map of the study area and location of roosts

Bat capture and tagging

From the 8th of June to the 19th of August 2010, we performed 16 nights of capture at one site. Captures were conducted with authorization provided by 'La Direction Générale de la Nature et du Paysage' of the canton of Geneva. Adult females were fitted with 0.46 or 0.5-g radio transmitters (Holohil Systems Ltd.). The transmitters were glued with Skin Bond from Smith+Nephew.

Location and characteristics of roost sites

Radio tracking was conducted by foot and by car using a roof antenna (range 0.5–2 km) (Australis 26k radio receiver, Lawnton, Australia). Once retrieved, the location of roosts was recorded with GPS (Garmin eTrex vista HCX) as well as the height of the roost and the species of a tree. Using the software ArcGIS, we measured four variables important for bats (Braunish et al. 2014) around each natural roost and around 14 randomly chosen control trees with no known roost: roosting tree circumference, distance to edge, distance to first road and distance to water. At artificial roosts or human-made shelters, only height was recorded.

Group size

Light amplifiers (Vectronix BIG25, Heerbrug, Switzerland, Victory NV ZEISS, Oberkochen, Deutschland) were used to count the number of individuals inhabiting a specific roost. We assumed that all adults had left the roost when 15 min had elapsed since the last bat emergence.

Data analysis

Wilcoxon test were used to test if roosting tree circumference, distance to edge, distance to first road and distance to water differed between trees harbouring one roost with the ones measured at control sites. Statistical analyses were done in JMP v 7.0.0. Values are presented as mean ± s.d..

Results and discussion

Location and characteristics of roost sites

Bats were followed until transmitters fell of for a period ranging from 5 to 22 days. We discovered the location of 26 different roost sites by radio tracking 9 *M. bechsteinii* and 5 *B. barbastellus* (Table 1). *M. bechsteinii* roosted exclusively in oak trees (*Quercus robur*) as shown in other studies (Napal et al. 2009), except on one occasion where an individual was located in a nest box. The *M. bechsteinii* colony used at least 15 roosts distributed over an area over 2.95 km^2 which corresponds to an occupied tree every 19.7 h. The limited distances (mean = 492 m) between consecutive roosts are well below the species' foraging range (1–5 km) (Kerth et al. 2001b).

Table 1 Roost characteristics for each *M. bechsteinii* (Bech) and *B. barbastellus* (Barba) individual adult females followed by radio tracking

Roost ID	Used by individual	No of days occupied	Height m	Cavity type	Tree	Distance to capture site m
MB_1	Bech_1, 9	3	7–8	Woodpecker hole	Oak	624
MB_2	Bech_1, 9	7	7–8	Woodpecker hole	Oak	1096
MB_3	Bech_2	2	9–10	Woodpecker hole	Oak	623
MB_4	Bech_2	6	9–10	Woodpecker hole	Oak	874
MB_5	Bech_3, 4, 5	4	17	Woodpecker hole	Oak	529
MB_6	Bech_3, 4, 5	6	25–26	Woodpecker hole	Oak	531
MB_7	Bech_5	2	7	Woodpecker hole	Oak	495
MB_8	Bech_6	4	6–7	Woodpecker hole	Oak	629
MB_9	Bech_7, 8	6	4.5–5	Bird nest box	Birch	602
MB_10	Bech_7	1	9	Woodpecker hole	Oak	378
MB_11	Bech_7	3	–	Not identified	Oak	200
MB_12	Bech_8	3	7	Woodpecker hole	Oak	514
MB_13	Bech_8	2	10	Woodpecker hole	Oak	425
MB_14	Bech_9	5	8–9	Woodpecker hole	Oak	953
MB_15	Bech_8	2	–	Not identified	Oak	457
BA_1	Barba_1	1	6–7	Behind shutter	–	6382
BA_2	Barba_1	3	5–6	Behind shutter	–	6403
BA_3	Barba_1	1	2.5	Behind sidings	–	5798
BA_4	Barba_1, 2	36	7	Behind shutter	–	6494
BA_5	Barba_3	13	6–7	Behind shutter	–	5258
BA_6	Barba_4	8	4	Behind sidings	–	10,153
BA_7	Barba_4	2	5–6	Behind shutter	–	10,234
BA_8	Barba_5	4	5–6	Behind shutter	–	6430
BA_9	Barba_4	5	2	Behind shutter	–	9902
BA_10	Barba_5	11	6	Behind shutter	–	6378
BA_11	Barba_4	2	2	Behind shutter	–	9938

In contrast, all *B. barbastellus* were found roosting exclusively in human-made shelters, namely behind shutters. The space behind shutters of a house mimics the exfoliating bark found in beech forests that is seldom found in oaks (Russo et al. 2004). Shutters may thus offer interesting alternatives that effectively replace natural suitable roosts for *B. barbastellus*. All *B. barbastellus* roosts were found at least 5.2 km (7579 m ± 1998, Table 1) from the capture site and were all located in France (Fig. 1). This illustrates the borderless nature of bat conservation and calls for the maintenance of a trans-frontier cooperation programme. Moreover, the distance between roosting and foraging sites demonstrated that any habitat management plan for *B. barbastellus* must take into consideration both the forest in which they forage and the landscape surrounding that forest (Hillen et al. 2009; 2010; Zeale et al. 2012; Ancillotto et al. 2015).

For *M. bechsteinii*, the mean diameter of the roost trees was 58.7 cm ($N=14$; range 32–91) and was not different that of the control trees (mean 41.3 cm, range 6–92, $z=-1.61$, $p=0.16$). Neither the distance to water ($z=0.505$, $p=0.613$) nor that to forest edge ($z=0.94$, $p=0.349$) differed between roost and control trees. However, roost trees were further away from a road than control trees (311 m ± 156 versus 194 ± 148: $z=-1.999$, $p=0.045$).

Group size and roost switching

The number of bats inhabiting a roost was counted on 59 occasions. Mean colony size was 34 individuals (range 7–63) for *M. bechsteinii* and 18 (range 9–37) for *B. barbastellus*, respectively. *M. bechsteinii* switched roosts on average every 3 days (range 1–6; $N=63$) and used a mean of 2.7 roost sites (range 2–5), whereas roost switching occurred on average every 7.4 days (range 1–41; $N=86$) with a mean number of roost sites of 2.4 (range 1–4) for *B. barbastellus*. Such roost switching has already been observed in these two species (Reckardt and Kerth 2007; Russo et al. 2005). Moreover, we observed a decrease of roost switching during the lactation period probably to avoid carrying non-volant young (Russo et al. 2007). Whatever the reasons for roost switching, their consequences for bat conservation are numerous because switching means that a large number of cavities have to be available in the environment where a colony lives. Indeed, the main question that remains to be answered for a bat-friendly forest management is related to the number and the location of favourable trees within the forest.

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