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Original investigation

Foraging activity of central European *Myotis myotis* in a landscape dominated by spruce monocultures

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Abstract

In Bavarian forests dominated by spruce monocultures, radio-tracked *Myotis myotis* did not select stands of deciduous forests but used them according to their availability. The bats preferred tall single strata forests with little undergrowth. Twenty-six per cent of the foraging time was spent outside forests in meadows and fields. An explanation for the existing relationship in Bavaria between population density of the ground-gleaning *M. myotis* and the extent of deciduous forests appears to be the higher percentage of open floor suitable for foraging in old beech forests and beech-mixed forests compared to old stands of spruce. A major recommendation from our study is that in order to preserve the density of *M. myotis* in Bavaria, habitat management (use of beech in forestry, reintroduction of cattle grazing in forests) is necessary to compensate for an expected decrease in foraging area quality in spruce-dominated forests.

Key words: *Myotis myotis*, Foraging, Habitats, Spruce, Forest

Introduction

Myotis myotis is a gleaning bat which requires open spaces on the ground to hunt arthropods (Audet 1990, 1992; Arlettaz 1996; Güttinger 1997). In central Europe, the main foraging habitats of *M. myotis* are forests with sparse vegetation on the ground and on freshly mowed meadows or short-grazed pastures (Güttinger et al. 2001). Within forests, suitable conditions exist mainly in stands dominated by beech (*Fagus sylvatica*) and spruce (*Piceas abies*). In Bavaria, there is a positive correlation between population density of *M. myotis* and the extent of beech-dominated forests (Rudolph et al. 2004). Especially in areas where spruce monocultures dominate, population density is low despite the presence of large areas of forest. This observation suggests that spruce monocultures are less suitable as foraging areas for *M. myotis*, but Güttinger (1997) who determined the numbers of foraging areas in different forest types could not prove a selection against spruce forests in Switzerland. However, he did not test whether the bats spend more time in beech-dominated forests, which could explain their importance as foraging habitat for this species. To address this issue we conducted a radio-tracking study on *M. myotis* in western Bavaria.

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Material and methods

In 2002, we studied bats from two colonies in Wörleschwang (10°36′E, 48°26′N) and Biberbach (10°49′E, 48°31′N). Both sites are located close to the Nature Park "Augsburg Westliche Wälder". Spruce-dominated forest covered 43% of the area, fields, meadows, pastures and settlements the remainder. We glued 0.92 g radio transmitters (Titley Electronics, Ballina, NSW, Australia) between the shoulders of the bats using skin-bond cement. The lifespan of the battery was about 26 days. We tracked a total of 10 individuals (Table 1) which were captured and released at the two day roosts. We tracked bats from sunset to sunrise each night. Observers followed bats by car and located the position of each individual by taking cross bearings every 5 min. The bearings were synchronized using walkie-talkies. The cross bearings were mapped on topographic maps (1:25.000). "Homing in" on the animal was attempted, in order to come as close as possible to the bat when it was foraging. The data did not allow to discriminate between different foraging activities (gleaning, foraging on the wing). Locations where the bats were continuously foraging for at least 10 min after successful "homing in" were defined as foraging sites (according to Güttinger 1997). In addition, we defined an area as foraging site if more than 50 cross bearings were located from a small area (100 m radius).

At each centre of a foraging site we determined the land-use pattern (forest, meadows, fields, settlements) and, in case of forests, we described tree composition and the spatial structure in a radius of 30 m, taking the following parameters by visual estimation:

- Percent area of spruce (more than 90% spruce trees in upper and middle stratum), percentage area of deciduous forest (more than 90% beech or other deciduous trees) and percentage area of mixed forest (rest).
- Percent area covered by upper, middle and lower stratum.
- Percent area covered by trees of different heights (height classes: 0–10, 11–15, 16–20, > 20 m).
- Crown density (percent of closed canopy, classes: 40–70%, 71–80%, 81–90%, 91–100%).
- Percent area covered by different average tree densities (classes of average density: 1–2, 2–3, 3–4, 4–5, > 5 m).
- Percent of forest floor covered with herbs and shrubs, except moss (classes of ground cover: 0–25%, 26–50%, 51–75%, 76–100%).

For each foraging site located in forests we randomly selected a "reference forest area" within a distance of 500 m. We assessed land use pattern, tree composition and spatial structure at reference areas using the same methods described for foraging sites. Variables obtained at foraging sites in forests and reference forest areas were compared by a paired sample test (Wilcoxon-signed rank test; Siegel and Castellan 1988). In addition, we determined tree composition (percent area of spruce forest, deciduous forest and mixed forest) in a radius of 1 km around the foraging sites using aerial photographs. These values were tested against the composition of the foraging sites.

Table 1. Foraging sites of *M. myotis* and time spent in different habitats. W: Wörleschwang, B: Biberbach, f+: female pregnant or lactating, f– : female not pregnant or lactating, m: adult male. Total foraging time: Contact time between foraging bat and tracker

Sex and status	Colony	Tracking period	Foraging sites in forests	Foraging sites in open landscape	Foraging time in deciduous forests [%]	Foraging time in spruce forests [%]	Foraging time in open habitats [%]	Total foraging time
f+	W	30.4–15.5	2	1	0.0	96.8	3.2	11′21″
f+	W	15.5–28.5	1	1	15.7	61.9	22.4	4′41″
f+	W	13.6–23.6	1	1	0.0	85.7	14.3	7′42″
f–	B	29.6–12.7	2	0	39.1	60.9	0.0	5′50″
f+	W	12.7–22.7	2	2	9.2	65.8	25.0	5′25″
f+	B	13.8–18.8	2	1	0.0	81.6	18.4	7′05″
m	B	22.8–29.8	1	1	0.0	73.6	26.4	8′23″
f+	B	3.9–07.9	5	4	11.7	65.0	23.3	6′34″
f–	W	12.9–18.9	0	1	0.0	0.0	100	2′33″

Results

We located 28 foraging sites of nine animals during the radio-tracking study (Table 1). Sixteen were located in forests and 12 in more open landscapes, such as meadows and fields. In addition, two bats foraged around their illuminated colony roost in the village. If these two cases are excluded, the average distance between colony site and foraging sites was 5.0 km (min 2.5, max 8.9 km). Foraging outside the forest was more common in late summer. Bats tracked between April 30 and July 12 spent 10% of their foraging time in open habitats, whereas individuals studied from July 12 to September 18 spent about 39% of their foraging time in open habitats. All foraging sites in open landscapes were sporadically available habitats: nine sites were freshly mowed or grazed meadows and three sites were fields without vegetation. With one exception, foraging sites in open landscapes were close to foraging areas in forests and the bats moved frequently between these sites. Two bats also foraged in the vicinity of their roost in the church in Biberbach. However, this only occurred on weekends when the church was illuminated until 1 o'clock in the morning. Unlike bats roosting in the church, the tracking signal from these two individuals was variable, indicating flight activity in the village. The lights around the church attracted many moths and several foraging bats of the genus *Myotis* were located with a bat detector nearby, indicating that not only the radio-tracked individuals hunted there.

The bats had slightly more foraging sites in deciduous forests than expected by availability of this forest type: four sites were mainly covered by deciduous forests, dominated by beech and including also other species such as *Fraxinus excelsior*, *Alnus glutinosa*, *Quercus* sp., *Betula pendula* and *Carpinus betulus*. A fifth site was composed of 20% deciduous forest and 80% spruce forest. All other 11 sites were mainly covered by spruce. Mixed forests were not present. On average, the percentage cover of deciduous forests was 25.0 (standard error 9.9) at the foraging sites and 16.6 (s.e. 7.4) in the reference areas. For spruce the values were 75.0% (s.e. 9.9) and 83.4% (s.e. 7.4).

The analyses of the forest in the 1 km-radius around the foraging sites revealed an average cover with deciduous forests of 21.5% (s.e. 3.1) and with spruce of 78.5% (s.e. 3.1). The difference between the foraging sites and the reference areas or the circuits was not significant.

Considering the spatial structure of the forest, the bats preferred tall single strata forests with little undergrowth. The foraging habitats were significantly ($P<0.05$) more dominated by a single strata [mean cover of foraging sites 91% (s.e. 3.2) and of reference areas 75% (s.e. 6.5.)]. The bats avoided young, dense stands. At their foraging sites we found significantly ($P<0.05$) less stands of the size classes below 15 m [means: 0–10 m: 1.6% (s.e. 0.6), 11–15 m: 9.7% (s.e. 2.4) of the areas] than in the reference areas [means: 0–10 m: 7.5% (s.e. 2.1), 11–15 m: 22.1% (s.e. 4.9) of the areas]. On average, only 32.1% of the foraging sites were covered by stands with tree-distances below 3 m, whereas in the reference areas the value was 61.1% [means at foraging sites: 1–2 m: 8.2% (s.e. 1.4), 2–3 m: 23.7% (s.e. 3.0), means of references areas: 1–2 m: 30.0% (s.e. 5.9), 2–3 m: 31.1% (s.e. 3.4)]. Despite the preference for older stands, the bats avoided sites where the canopy was not closed. Dense crown cover (class 91–100%) covered on average 95.1% (s.e. 1.0) of the foraging sites but only 86.8% (s.e. 3.2) of the reference areas ($P<0.01$). The cover of the ground was significantly lower ($P<0.05$) at the foraging sites than in the reference areas. Areas of low-density cover of herbs (open ground 51–75% of the forest floor) covered on average 51.3% (s.e. 11.3) of the foraging sites but only 1.9% (s.e 1.4) of the reference areas, and bare ground (vegetation cover below 25%, Fig. 1) existed only at the foraging sites (30.6%, s.e. 10.7).

Myotis myotis does not strongly select deciduous forests for foraging in the study area. This was supported by the times spent in the different forest types (Table 1). On average, the bats spent 8.4% (s.e. 4.3) of their time "on the wing" in the deciduous forests, 65.7% (s.e. 9.1) in spruce forests and 25.9% (s.e. 9.8) in open habitats outside the forests. If only the foraging time in forests is considered, and if the forest composition in

Fig. 1. Typical foraging habitat in a spruce forest.

the 1 km circuits around the foraging sites is taken as representative for the availability of deciduous and spruce forests, the time spent foraging in different stands (25.0 versus 75.0%) reflects their availability fairly accurately (Fig. 2).

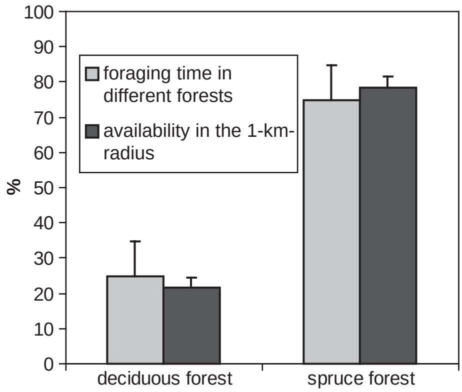

Fig. 2. Comparison of the availability of different forest types and the foraging time spent there. Data are means and standard error for nine radio-tracked bats.

Discussion

Our conclusion is that *M. myotis* does not select foraging habitat in forests on the basis of forest composition, but is rather influenced by the spatial structure of the forest. This result is supported by the findings of Güttinger (1997) in Switzerland where the bats also preferred tall single strata forests with little undergrowth. Güttinger (1997) also observed the increasing use of habitats outside forests during summer. In fact, the prey composition of this bat species in different parts of its distributional range reflects the availability of different habitat types (Güttinger et al. 2001). In southern Europe, the species does not depend on forests at all (Pereira et al. 2002). Therefore, the relationship between population density of *M. myotis* and deciduous forests in Bavaria (Rudolph et al. 2004) cannot result from a simple preference for this habitat type.

However, forests must play a key role as foraging areas at least during some periods of the year, otherwise they would not be a limiting factor for the population. It is plausible that the bats depend on them in spring, when they are gaining weight after hibernation. At this time the warmer climate in forest favours insect activity, making foraging outside forests less profitable. In addition, large carabids, which are the main prey of *M. myotis* in central Europe, are supposed to be most abundant in forests during spring and early summer (Güttinger 1997).

That especially the area of deciduous forest correlates with population density of *M. myotis* can be easily explained in some areas of northern Bavaria: The forests there are often dominated by pine (*Pinus sylvestris*) instead of spruce and pine forests are not suitable for *M. myotis* because of its dense undergrowth which impedes ground foraging and therefore the bats select areas of beech forest which offering better conditions (Rudolph and Liegl 1990). In areas where spruce is dominant, such as our study area, the role of deciduous forests is less obvious. These forests may offer a better food supply (Zahn 1995; Güttinger 1997). However, this advantage cannot be great otherwise the bats would react more obviously and spend more time in deciduous stands. The switch to foraging outside forests when profitable food such as cockchafers *Melolontha* sp. or tipulids *Tipula* sp. (Arlettaz 1996; Güttinger 1997) are available and at least the foraging activity around the illuminated church on weekends demonstrate the flexible response of this species to prey availability.

One explanation for the importance of deciduous forests for foraging is the density of the undergrowth in this habitat compared to spruce forest (Güttinger 1997). Specifically, as spruce forests age, a gradual decline in crown density favours herb and shrub growth, making old stands with low tree densities unsuitable for foraging. In contrast, in beech forests even old stands have a dense canopy that prevents development of a dense undergrowth. Given forests of the same size and age composition, in beech (and mixed) forests a higher percentage of the area is suitable as foraging habitat for *M. myotis* than in spruce forests.

The lower suitability of spruce forest as habitat for *M. myotis* may become a conservation concern in the future given current trends in forest management in Bavaria. To favour development of a more natural forest structure, the density of game species will be reduced in parts of Bavaria (Sperber 2002). Without the browsing activity of game species such as roe deer, the growth of shrubs and tree seedlings in forests will greatly increase. The result will be positive for overall forest health but potentially negative for *M. myotis* conservation. A major recommendation from our study is that in order to preserve the high density of *M. myotis* in Bavaria (Rudolph 2000), the use of beech in forestry should be increased especially around colony sites, to compensate for a decreasing foraging area of *M. myotis* in spruce-dominated forests. In addition, the reintroduction of low-intensity cattle grazing in woodlands most probably would maintain or create optimally structured hunting habitats for *M. myotis* (Güttinger 1997).

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Zusammenfassung

Die Jagdaktivität mitteleuropäischer Mausohren (*Myotis myotis*) in einer von Fichtenmonokulturen geprägten Landschaft

Telemetrierte Mausohren bevorzugten in einem von Fichtenmonokulturen dominierten Waldgebiet im Westen Bayerns nicht die Laubwaldinseln, sondern nutzten sie ihrer Verfügbarkeit entsprechend. Die Tiere jagten hauptsächlich in einschichtigen, unterwuchsarmen Hochwäldern. 26% ihrer Jagdzeit verbrachten sie außerhalb der Wälder auf Wiesen und Feldern. Eine mögliche Erklärung für die in Bayern bestehenden, höheren Mausohrbestandsdichten in laubwaldreichen Landschaften wäre der im Vergleich zu älteren Fichtenwäldern höhere Anteil unterwuchsarmer Bodenfläche in älteren Buchen- und Buchenmischwäldern, da das Mausohr vorwiegend Insekten vom Boden aufnimmt und deshalb auf unterwuchsarme Wälder angewiesen ist. Aus der Studie läßt sich folgern, daß für die langfristige Sicherung der Bestände des Mausohrs in Bayern ein aktives Habitatmanagement (z.B. die Erhöhung des Buchenwaldanteils auf Kosten der Fichtenbestände oder lokal auch die Beweidung von Wäldern mit Rindern) sinnvoll erscheint, da die Eignung von Fichtenwäldern für Mausohren in Zukunft abnehmen dürfte.

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