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Bat diversity in traditional orchards in Saxony, Germany (Chiroptera: Rhinolophidae, Vespertilionidae)

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Abstract. Traditional orchards are considered to be valuable habitats for various species of mammals, among them many bats. We used acoustic survey and radio-tracking of three tree-dwelling bat species to investigate habitat use by bats in selected traditionally managed orchards in Saxony (Germany). Results include recordings of 15 species foraging, a high proportion of fruit trees in orchards used by nursery colonies of *Myotis nattereri* and *Plecotus auritus*, as well as considerable proportions of foraging areas of *Myotis nattereri*, *Myotis bechsteinii*, and *Plecotus auritus* within traditional orchards (35.4%, 26.1%, and 19.6%, respectively). Despite being strongly protected by nature conservation legislation, all orchards evaluated in this study are overaged and deteriorating due to abandonment or unfavourable usage and lack of maintenance. Therefore, as essential preservation measures we propose not only replacement plantings and reconnecting isolated tree groups but also the installation of bat boxes to sustain functioning roosts in the short term.

Key words. Traditional orchards, *Myotis bechsteinii*, *Myotis nattereri*, *Plecotus auritus*, radio tracking.

INTRODUCTION

The traditional orchards are part of the countryside in different regions of Saxony, where they cover small patches of land usually situated on the fringes of villages. Although small in size with 79% comprising less than 0.5 hectare, the total area of traditional orchards in Saxony amounts to more than 4,500 hectares (LfULG 2023).

Traditional orchards are characterised by scattered high trunk fruit trees growing on meadows or pasture land. They provide diverse habitats for a variety of organisms, including insects and tree dwelling bats (Schuboth & Krummhaar 2019) and are valued not only for their biological diversity but also landscape aesthetics (Herzog 1998). In Germany, traditional orchards are protected by law as habitats valuable for nature conservation.

As habitats for bats, orchards are mostly mentioned among other foraging sites or flight paths frequented by different bat species (Krull et al. 1991, Fuhrmann & Seitz 1992, Siemers et al. 1999, Ashrafi et al. 2013, Güttinger & Burkhard 2013, Dietz & Dietz 2015, Starik et al. 2021), but few studies look at traditional orchards as habitats for bats in particular (Bögelsack & Dietz 2013, Dietz et al. 2012, Hofmann 2019).

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Table 1. Radio-tracking data of each bat individual including location of the orchard, observation period, contact and flying time [hours:minutes), number of fixes obtained by triangulation and homing-in sites (coordinates where observer and bat are at the same position); T fixes = fixes by triangulation, H fixes = fixes by homing-in, time – h:min

species	location	observation period	contact time	flying time	T fixes	H fixes
Myotis nattereri	Naustadt	20–23 May 2020	20:05	15:15	91	7
	Pinkowitz	3–5 July 2020	09:28	09:28	109	4
	Zehren	13–17 July 2020	18:23	18:18	218	3
Myotis bechsteinii	Constappel	6–12 July 2020	16:22	14:36	132	20
	Constappel	9–12 July 2020	13:06	13:01	112	4
Plecotus auritus	Zehren	13–14 July 2020	07:26	07:16	45	3
	Laubach	20–23 July 2020	21:16	21:16	252	12

Our survey focuses on investigating the importance of old traditional orchards in Saxony for different tree-dwelling bat species and evaluating their current state in terms of long-term suitability for bat conservation.

STUDY AREA AND METHODS

The study area is situated in the district of Meißen along the valley of the river Elbe (Saxony, Germany) . The landscape is composed of villages surrounded by large areas of arable land (grain, vegetables, meadows, vineyards) and patches of old-growth forest which are distributed over the floodplain and the adjacent hillsides. Here, fruit trees are cultivated on steep, sun exposed slopes and around villages. We selected five traditional orchards with stands of fruit trees (*Prunus avium*, *Pyrus communis*, *Malus domestica*) of at least 80 years of age situated close to the villages of Naustadt, Pinkowitz, Zehren, Constappel, and Laubach, northwest and southeast of Meißen.

Acoustic surveys were conducted during 75 nights between June 2019 and August 2020 at 21 different sites within the selected traditional orchards. Bat calls were recorded automatically (batcorder, EcoObs) during at least 3–4 complete nights per location. Calls were analysed using bcAdmin and BatIdent software and species identification was manually verified with BatSound. Mist netting took place at 14 sites between May and July 2020. Bats extracted from nets were released immediately after determination of reproductive status and measurements of forearm length and weight.

For radio-tracking, seven breeding females of three species (*Myotis nattereri*, *Myotis bechsteinii*, *Plecotus auritus*) were radio-tagged (tags <0.35 g, Telemetrieservice, Dessau; medical glue Sauer GmbH Germany) and followed for at least three consecutive nights (receivers VR-500 YAESU, HB9CV antennae, Wagener). Foraging bats were located by two persons taking bearings synchronously every five minutes or by homing-in on the animal, with the observer aiming to reach the position of the animal followed (Kenward 1987). Radio-tracking data for each bat including location of the orchard, observation period, contact and flying time as well as the number of fixes are given in Table 1. Fixes obtained by triangulation using Animove (Faunalia, Florence University, Italy) for QuantumGis were used to calculate the size of home ranges (Minimum Convex Polygon, MCP), foraging areas (95% kernel) and core foraging areas (50% kernel) by means of adehabitatHR (Calenge 2015). To establish colony sizes, bats were counted emerging at dusk by 2–3 observers and with the help of video footage (Sony Camcorder HDR-PJ780VE, Canon XA40) and infrared light.

RESULTS

A total of 9,179 sequences of bat calls were recorded, of which 11 species and two species pairs (*Plecotus auritus / P. austriacus* and *Myotis brandtii / M. mystacinus*) were identified (Fig. 1). Mist netting confirmed the presence of 12 species including both species of each of the acoustically indistinguishable pairs *Plecotus auritus / P. austriacus* and *Myotis brandtii / M. mystacinus.* In 10 species, reproducing females and/or juveniles were encountered (*Eptesicus serotinus*, *Pipistrellus pipistrellus*, *Plecotus auritus*, *P. austriacus*, *Barbastella barbastellus*, *Myotis myotis*, *M. bechsteinii*, *M. nattereri*, *M. brandtii*, *M. mystacinus*).

All seven females (*Myotis nattereri*, *Myotis bechsteinii*, *Plecotus auritus*) followed by radio-tracking spent time foraging in traditional orchards, and five of the nursery colonies found used at least one fruit tree for roosting (Table 2).

Colonies of *Myotis nattereri* comprised 40 adults and 29 adults and juveniles, respectively. In Zehren, roost switching took place nearly every night. Home ranges of *Myotis nattereri* were very small and distances between nursery roosts and foraging sites rarely exceeded 1,000 m (Table 3, Figs. 2–4). Four out of five roosting trees and 35% of fixes in foraging areas were located in traditional orchards. Other foraging habitats were patches of old-growth deciduous and riparian forests.

Both females of *Myotis bechsteinii* were captured at the same site and belonged to the same nursery colony of 58 adults. Likewise, they changed roosts between two oaks and a willow and

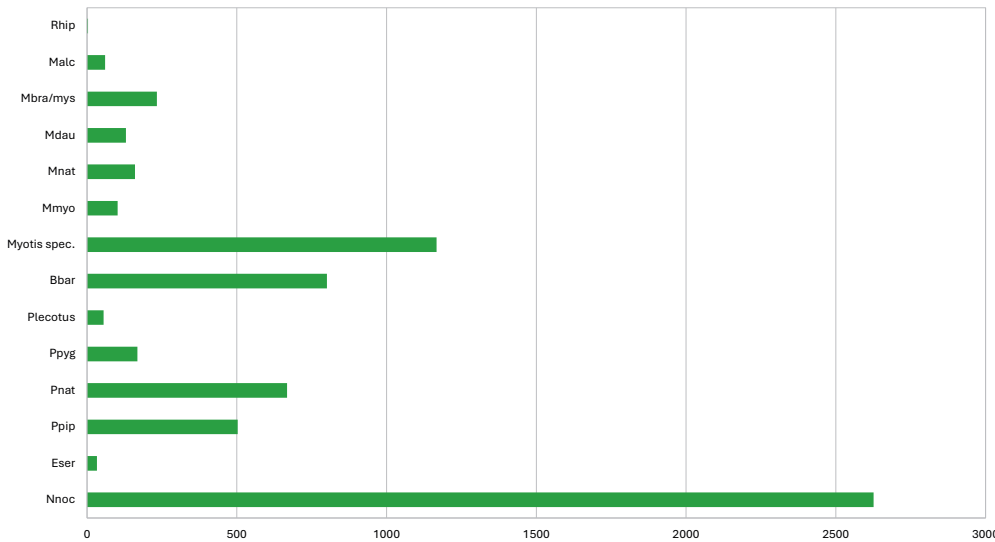

Fig. 1. Number of bat calls, total of 21 sites within five orchards, Rhip – *Rhinolophus hipposideros*, Malc – *Myotis alcathoe*, Mbra/mys – *Myotis brandtii* or *M. mystacinus*, Mdau – *Myotis daubentonii*, Mnat – *Myotis nattereri*, Mmyo – *Myotis myotis*, Bbar – *Barbastella barbastellus*, Plecotus – *Plecotus auritus* or *P. austriacus*, Ppyg – *Pipistrellus pygmaeus*, Pnat – *Pipistrellus nathusii*, Ppip – *Pipistrellus pipistrellus*, Eser – *Eptesicus serotinus*, Nnoc – *Nyctalus noctula*.

Table 2. Roosts found by radio-tracking, listed for each radio-tracked bat individual: species and number of roosting trees, for bats using more than one roost the distance between these roosts is given, colony sizes were established for five bats and contain numbers of adults (ad) or adults and juveniles combined (ad+juv); RT distance = distance of roosting trees

species	location	roosting trees	number of roosts	RT distance [m]	colony size
Myotis nattereri	Naustadt	*Fraxinus excelsior*	1	–	–
	Pinkowitz	*Prunus avium*	1	–	40 ad
	Zehren	*Prunus avium* 3×	3	130–500	29 ad+juv
Myotis bechsteinii	Constappel	*Quercus robur* 2×, *Salix* sp.	3	350–1150	58 ad
Plecotus auritus	Zehren	*Prunus avium*, *Robinia pseudoacacia*	2	200	16 ad+juv
	Laubach	*Prunus avium*, *Pyrus communis* 2×, *Aesculus hippocastanum*	4	50–200	22 ad+juv

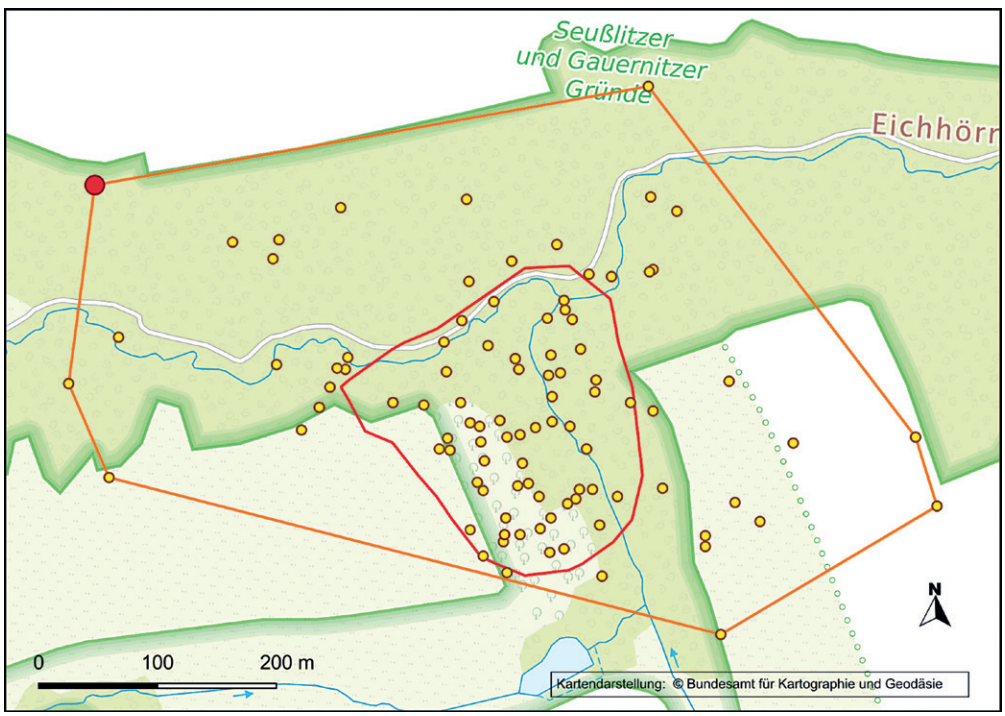

Fig. 2. *Myotis nattereri* (Naustadt), foraging areas in a traditional orchard and adjacent forest, roost (red dot), fixes (yellow dots), MCP 100% and kernel 50%.

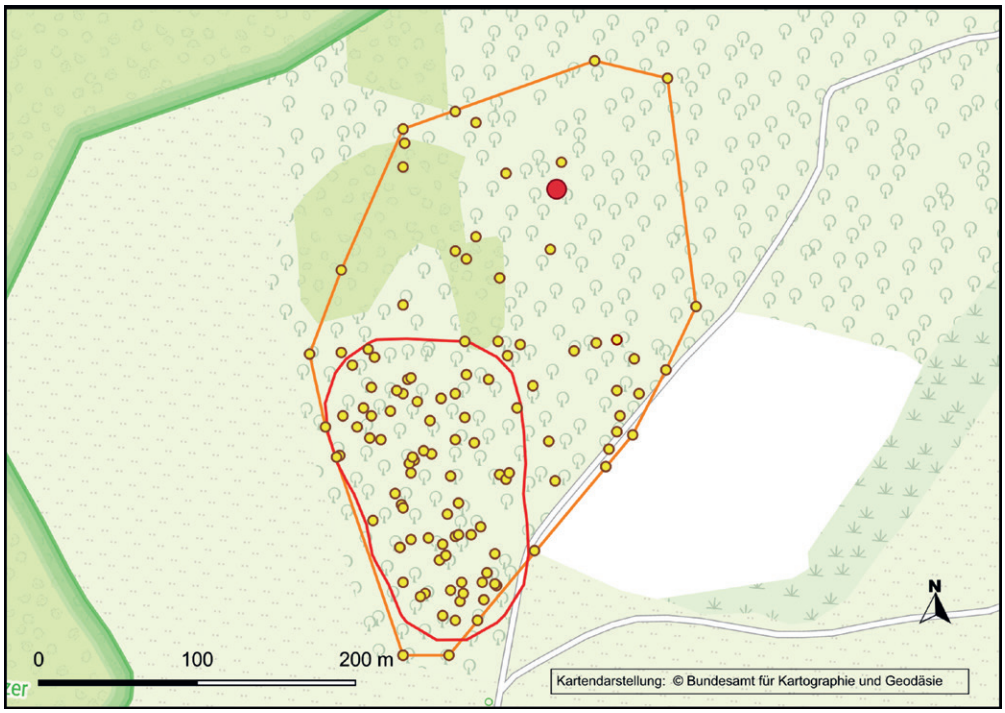

Fig. 3. *Myotis nattereri* (Pinkowitz) roosting and foraging in a traditional orchard, roost (red dot), fixes (yellow dots), MCP 100% and kernel 50%.

had similar home ranges, which were the largest in size of all three species (Table 3). Concerning foraging areas, 26% of fixes were obtained in traditional orchards. Foraging also took place in old-growth deciduous forests and along tree lines adjacent to arable land.

Table 3. Home range areas for each radio-tracked bat individual as MCP (100% minimum-convex-polygons), 95% Kernel (foraging area), 50% Kernel (core foraging area), maximum distance between nursery roost and most distant fixes in foraging sites (maximum distance)

species	location	MCP [ha]	kernel 95% [ha]	kernel 50% [ha]	maximum distance [m]
Myotis nattereri	Naustadt	22.5	24.1	4.3	750
	Pinkowitz	6.0	8.4	1.9	300
	Zehren	21.2	13.4	2.7	1150
Myotis bechsteinii	Constappel	194.4	196.3	40.7	1900
	Constappel	185.0	292.8	53.7	1600
Plecotus auritus	Zehren	46.1	97.7	27.1	800
	Laubach	119.9	124.1	22.5	1400

Table 4. Proportion of traditional orchards used by particular bat species, percentage of roosts in fruit trees situated in traditional orchards, percentage of fixes in orchards, percentage of fixes in other habitats

species	roosts in orchards	fixes in orchards	percentage of fixes in other habitats
Myotis nattereri	80.0%	35.4%	deciduous and riparian forests, 62.3% forest edge and tree line adjacent to arable land, 2.3%
Myotis bechsteinii	–	26.1%	deciduous forests, 45.5% arable land, 12.7% tree line adjacent to arable land, 4.9% village, 2.6%
Plecotus auritus	66.7%	19.6%	deciduous forests, 26.9% arable land, 30.5% single tree / village, 15.0% forest edge and tree line adjacent to arable land, 8.0%

Colonies of *Plecotus auritus* consisted of 16 and 22 adults and juveniles, respectively, and they switched roosts almost every night using mostly fruit trees within a distance of at most 200 m.

In Laubach all of the roosting trees were situated in gardens at the edge of the village whereas the nearest, and one of the most extensively frequented, foraging site consisted of a single large lime tree inside the village. *Plecotus auritus* also foraged in deciduous forests, over arable land (e.g. cabbage fields), and in traditional orchards (19.6% of fixes).

DISCUSSION

Traditional orchards in the study area provide roosting trees and foraging habitats as well as flight paths within an increasingly fragmented landscape. This is reflected in a high number of species recorded during hunting and commuting, foraging duration and regularity as well as a high amount of roosts in fruit trees. Studies in Hesse, Baden-Württemberg and Luxembourg (Dietz et al. 2012, Bögelsack & Dietz 2013) as well as in Saxony-Anhalt (Hofmann 2019) produced similar results emphasizing the particular importance of roosting trees in orchards for *Myotis nattereri*, *M. bechsteinii*, and *Plecotus auritus* (Siemers et al. 1999, Dietz et al. 2012). In our study area, fruit trees were occupied by nursery colonies of all three species during lactation (including *Myotis bechsteinii*; Schmidt et al. 2013). Trees in traditional orchards are grown at greater distances from each other and are more exposed to sunlight than tree roosts inside forests, therefore they might be selected especially by lactating females preferring warmer roosts with optimal conditions during juvenile development (Kerth et al. 2001, 2002, Hörig & Dietz 2013).

Females of all three species observed had small home ranges, hunting less than 2,000 m away from roosts, and foraged in traditional orchards in close proximity to their roosts. Nevertheless, they rarely foraged in traditional orchards exclusively but usually in connection with adjacent woodland.

Home range sizes of *Myotis nattereri*, which showed the largest portion of roosts and foraging time in orchards, were smaller or at the lower end within the values of area calculations for this species radio-tracked in other regions (Siemers et al. 1999, Smith & Racey 2008, Zeale

et al. 2016). This suggestst that old-growth orchards can provide sufficient prey abundance for individuals of a bat species that exhibits a high degree of foraging site fidelity (Mordue 2023). In contrast, home range sizes of *Myotis bechsteinii* were considerably larger in the study area than in previous studies from other regions (Schofield & Morris 2000, Kerth et al. 2002, Albrecht et al. 2002, Brinkmann et al. 2007, Dietz & Pir 2009, Napal et al. 2010, Dietz et al. 2013, Krannich & Dietz 2013, Bögelsack & Dietz 2013) which might be due to the highly fragmented landscape in the Elbe valley. Also, as Bechstein´s bats are known to be faithful to their feeding sites (Kerth 1998), the individuals may visit remnants of collapsed traditional orchards that offered roosts in the vicinity of foraging habitats only a few years ago. This is indicated by the deteriorating condition of orchards identified as foraging sites in the study area.

In *Plecotus auritus*, home range sizes and commuting distances found in this study lay within the wide range of findings in other study areas where *P. auritus* foraged primarily in forests (Murphy et al. 2012, Krannich & Dietz 2013, Starik et al. 2021), with individual trees and traditional orchards being of importance as well (Entwistle et al. 1996, Ashrafi et al. 2013).

All three species benefit from old traditional orchards providing combinations of roosting possibilities, well spaced broad-crowned trees and unimproved grassland or pasture. Such

Fig. 4. *Myotis nattereri* (Pinkowitz), roosting tree *Prunus avium* in an overaged traditional orchard (photo by C. Schmidt).

places attract bat species with different habitat preferences and hunting strategies and can be used as feeding sites depending on the size and availability of other suitable landscape elements as well as seasonality (Dietz et al. 2012, 2013). Due to their historical placement between villages and the surrounding landscape, they also connect roosts in buildings with a variety of other foraging sites.

However, periodic maintenance measures are required to preserve the orchards and to ensure stability of roosting opportunities over time. These include pruning, replacement planting and managing unimproved grassland. As Obrist et al. (2011) were able to show for chestnut orchards, the number of bat species as well as foraging activity was considerably higher in managed orchards compared to the unmanaged ones.

All of the orchards within the study area were planted around the same time during the first half of the 20th century. They are now distinctly overaged, and cattle grazing is almost the only use currently applied. This will lead to decreasing tree vitality and eventually to the collapse of many old orchards due to two main factors. First, the lack of fruit harvesting and processing poses no incentive for maintenance and replanting of trees. Second, cattle tend to destroy bark and low hanging branches, contributing even further to the ongoing degradation of trees. Thus, our recommendations in terms of saving traditional orchards as habitats for bats involve to prefer grazing by sheep instead of cattle, continuous replacement plantings to ensure future development of different age classes of trees resulting in constantly available cavities for roosting bats, and reconnecting isolated tree groups to enhance connectivity within fragmented landscapes. Providing bat boxes as a transitional solution to mitigate roost loss should also be considered. However, the key to preserving of the orchards is to continue their originally intended purpose as fruit producing crops used by local communities (Bögelsack & Dietz 2013).

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