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ORIGINAL INVESTIGATION

Foraging activity of *Rhinolophus hipposideros* on the Island of Herrenchiemsee, Upper Bavaria

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Abstract

We studied the foraging behaviour of *Rhinolophus hipposideros* on the island "Herrenchiemsee" in Lake Chiemsee (Upper Bavaria) during summer 2001. The island offers extensively managed woodlands, highly structured open landscapes and a broad reed belt around the shore. On average the flight activity of the 6 radio tracked females outside the roost lasted 229 min per night. The home range size varied between 6.8 and 62.7 ha (mean 25.2 ha). The size of the activity centres varied between 2.8 and 8.2 ha (mean 5.3) and all except one were located almost exclusively in woodland. Within woodlands the bats did not select for specific spatial structures (different age classes of the stands or canopy densities). Only two bats regularly foraged in additional habitats outside woodlands. One of these bats used orchards and tree rows; the other foraged over artificial ponds and gardens adjoining to its woodland foraging area. We never found the bats foraging over the lake or the reed belt. Longer linear landscape elements as tree lines were used during commuting flights but there was no indication of a continuous foraging activity along these elements. Two females left the island to forage on the mainland in August after the fledging of juveniles. To reach the mainland shore, the bats had to fly at least 1.2 km across the lake.

Assuming that most foraging flights on the island occur in woodlands, a bat density in this habitat type of 0.7 bats/ha can be calculated.

Keywords: *Rhinolophus hipposideros*; Foraging; Activity; Habitats; Bavaria

Introduction

Only three colonies of *Rhinolophus hipposideros*, once a common bat species in the mid of 20th century, are left in Bavaria (Zahn and Weiner 2004). An adequate management of the foraging sites plays a key role in the conservation of the small population. In England, Lesser Horseshoe-bats forage along linear landscape elements like hedgerows and in a highly structured landscapes (Jones and Rayner 1989). Such habitats seem to be important for other populations too (Lutz and Mühletaler 1997). Recent studies conducted in Belgium (Motte and Libois 2002) and England (Bontadina et al., 2002) indicate that woodlands are important feeding grounds for *Rhinolophus hipposideros.* In Austria, Reiter (2002, 2004) showed that the colonies were surrounded by areas with higher percentages of woodland areas than sites with no horseshoe bats. First results from Bavaria also support the importance of woodland as foraging areas (Holzhaider et al. 2002). However, it is not clear whether the reason for the preference of woodlands in

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these studies is that bats avoid low quality open landscape habitats, caused by intensive agriculture or actively seek out high quality woodland areas.

To answer this question we studied bats from a colony on the island "Herrenchiemsee" in Lake Chiemsee during summer 2001. The island offers extensively managed woodlands, highly structured open landscapes (meadows and pastures) and a broad reed belt around the shore. The reed habitat, connected with groups of trees and woodland edges, offers an insect-rich alternative foraging habitat. We therefore assumed that radio tracked individuals would have excellent alternatives to choose foraging sites outside woodlands. Since most bats left the island in winter, we also expected to get information on whether the bats regularly cross the lake in summer for foraging on the mainland.

Material and methods

The studied colony roosts in the attic of King Ludwig's II castle situated on a 230 ha island (Herreninsel, 12°24′ east, 47°52′ north) in Lake Chiemsee (Upper Bavaria). The study was conducted between July 19th and August 28th 2001. The colony size was at that time about 60 adult bats. The island is mainly covered by woodlands, meadows and pastures. The shore is surrounded by a wide reed belt, partly mixed with loose stands of alder (*Alnus glutinosa*). The open areas are structured by tree-lines, hedges, solitary tress and small orchards. The dominating tree species in the deciduous woodland of the island are *Fagus sylvatica*, *Fraxinus excelsior*, *Acer* spec. and *Alnus glutinosa*. The coniferous woodland consists mainly of *Picea abies* and *Pinus* spec. Agriculture on the island was limited to pastures for horses, meadows and orchards. Apart from the castle, a former monastery and two houses, only a few other buildings (some stables and huts) exist on the island.

We tracked 6 adult lactating females (weight 7.25–8.25 g). Each animal was tracked for 3–6 nights in a row. We used 0.4 g transmitters (Titley-Electronics, Australia) which were glued between the shoulders of the bats using skin bond cement. The lifespan of the battery was about 10 days. The radio-tracking equipment included two 5-element Yagi antennae and two Yupiteru MVT-7100 radio-receivers. To test the accuracy of our measurements we conducted tests in the study area, using an activated transmitter carried by a person. We took bearings for different distances and in different habitats. We estimated our bearings to be exact to about $+/5°$. Tracked animals could be detected in woodland up to a distance of 300–500 m and in open areas up to 2 km (Holzhaider et al. 2002).

Bats were handled under permits by the Government of Upper Bavaria.They were caught in the morning at the roost entrance, an open window, when they returned to the colony roost after foraging. Bats were followed by bicycle; observations lasted from dusk to dawn. The animal's position was located by simultaneous cross bearings every 5–10 min. Bearing were synchronized by using walkie-talkies. A fluctuation in intensity and a change of direction of the received signal indicated a flying bat. The bat was assumed to be stationary when the signal was stable. All positions of bats on the wing were regarded as "locations" of bats in potential foraging habitats. To compare the habitat composition of foraging habitats with the available habitats on the island we analysed the landscape on the island using aerial photographs (aerial view 1:5000 summer and winter period). We distinguished between broadleaf woodland (>90% deciduous trees), mixed woodland (between 10% and 90% deciduous trees), conifer woodland (<10% deciduous trees), woody-elements outside woodland (tree-lines, park areas, hedges, solitary trees, and orchards), open area (meadows, pastures, roads) ponds and riparian vegetation.

Additionally, we used the aerial photographs to distinguish between woodland stands of different age (mature old forest stand, old forest stand, tree forest stand, pole wood, thicket, afforestation and stands with several storeys) and canopy density (cover of <10%, cover of 10–40%, cover of 41–60%, cover of 61–90%, cover of >90%). These habitats, including woodland stands of different spatial structure, and all locations of foraging bats were mapped into a geographical information system (GIS; Arc view). We then analysed this information with a "point in polygon" query to connect the area information of the habitat data with the point information from the foraging bats locations. Conducting area statistic queries we analysed the number of foraging bat locations in different habitats and the total area of the different habitat types on the island. As a commonly applied method to estimate home range size we used a minimum convex polygon (Anderson 1982; Harris et al. 1990) A minimum convex polygone (MCP) describes the area containing all observed locations of a given animal. To account for extreme outliers, we used MCP 90, containing 90% of all locations for an animal. However, this method does not account for heterogenity of the habitat and does not consider different intensities of use in certain parts of the foraging area. A method that accounts for one or more centres of activity is the harmonic mean method (Dixon and Chapman 1980). A 90% harmonic mean (HM90, including 90% of all locations for a given animal) was used to estimate home range size and a 50% harmonic mean (HM50) was used to estimate the size of the centres of activity. For each animal we additionally determined the mean percentage of locations in different habitats and woodland stands of different spatial structure and calculated the means. These values, representing the habitat use of the bats, were compared to the distribution of available habitats.

Results

The bats foraged on a total of 230 ha around the island. The longest foraging distance recorded on the island was 1.3 km from the roost. Two females left the island to forage on the mainland in August after the fledging of juveniles. Both animals started to cross the lake from the same point on the islands shore (Fig. 1). To reach the mainland shore, the bats had to fly at least 1.2 km across the lake. Considering the direction of the signal when the bats left the island, the distance was