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Fast recognition and usage of new passageways leading to a maternity roost of *Rhinolophus ferrumequinum* (Chiroptera: Rhinolophidae)

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Abstract. The last Austrian maternity roost of the greater horseshoe bat (*Rhinolophus ferrumequinum*) which is located in the loft of Eggenberg Palace in Graz, Styria, was accessible through two chimneys until 2019 when two ducts became available for the maternity colony as additional passageways. The recognition of the new passageways and the usage of all four passageways were studied in the years 2019–2023 by using infrared light barriers (ChiroTEC). The new passageways were recognised by the bats within 33 and 36 days, respectively after the spring arrival of the first bat in the maternity roost. Over the study period, the numbers of flight movements decreased at the chimneys and increased at duct 2. Nevertheless, over the study period, i.e. 5 years after installation of the ducts, chimney 1 remained the main passageway. In addition to the usual flights through the passageways, we observed high numbers of short and successively repeated in and out flights at the entrances of the passageways. These pendulum flights trigger the light barriers, and a large proportion of registrations can be attributed to them. It therefore should be concluded that the numbers of registrations obtained at roosts of the greater (and lesser) horseshoe bats must not be used for determining the numbers of individuals living in the roost.

Key words. Spatial orientation, recognition, new passageways, maternity roost, *Rhinolophus ferrumequinum*, *Rhinolophus hipposideros*, *Myotis myotis*.

INTRODUCTION

In the temperate zone, several bat species use lofts and other spaces within buildings as maternity roosts. Hence, for species, such as the greater mouse-eared bat, *Myotis myotis* (Borkhausen, 1797), lesser horseshoe bat, *Rhinolophus hipposideros* (André, 1797), and greater horseshoe bat, *R. ferrumequinum* (Schreber, 1774), the loss of roost sites caused by sealing of entrances to buildings is a main conservation concern. Even though retaining, relocation and installation of new entrances are widely recommended to conserve the accessibility of existing roosts (e.g. Stebbings 1988, Richarz & Limbrunner 1992, Schmidt 2014), little information has been published on the recognition and acceptance of new access ways (Berthinussen et al. 2014).

As the access to the last Austrian maternity roost of the greater horseshoe bat in Eggenberg Palace (Spitzenberger et al. 2010) was planned to be sealed because of fire regulations, two additional passageways were installed in 2019. Here, we document the fast recognition of the

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new entrances and the development of usage of the traditional and the new passageways over a period of five years after installation.

MATERIAL AND METHODS

Study site and study period

The last maternity roost of the greater horseshoe bat known to exist in Austria is located in the loft of Eggenberg Palace (Schloss Eggenberg) in the outskirts of Graz, Styria (47°04'29" N / 15°23'29" E, 353 m a. s. l.). The palace is listed as a UNESCO World Cultural Heritage Site as well as a Natura 2000 site under the European Union Habitats Directive. It is surrounded by a 17.9 ha park and lies at the foot of a mountain slope that is covered with suburban settlement, farmland and mixed deciduous forests.

Over the study period from 2019 to 2023, the maternity colony consisted of 45–56 adult females. We monitored the flight activity performed by the colony mates in the four passageways that lead the bats from the loft into the surroundings and back by using infrared light barriers of the company ChiroTEC (Lohra, Germany). For comparing the flight activity performed in different passageways we used t the light barrier registrations recorded from 1 May to 30 September of the years 2019 to 2023 (Figs. 4 and 5).

Passageways and light barriers

Regular visual evening counts performed before 2019 showed that the greater horseshoe bats leave the roost for hunting through two approximately 8 m high disused chimneys (chimneys 1 and 2; Fig. 1) and that chimney 1 was the preferred exit way.

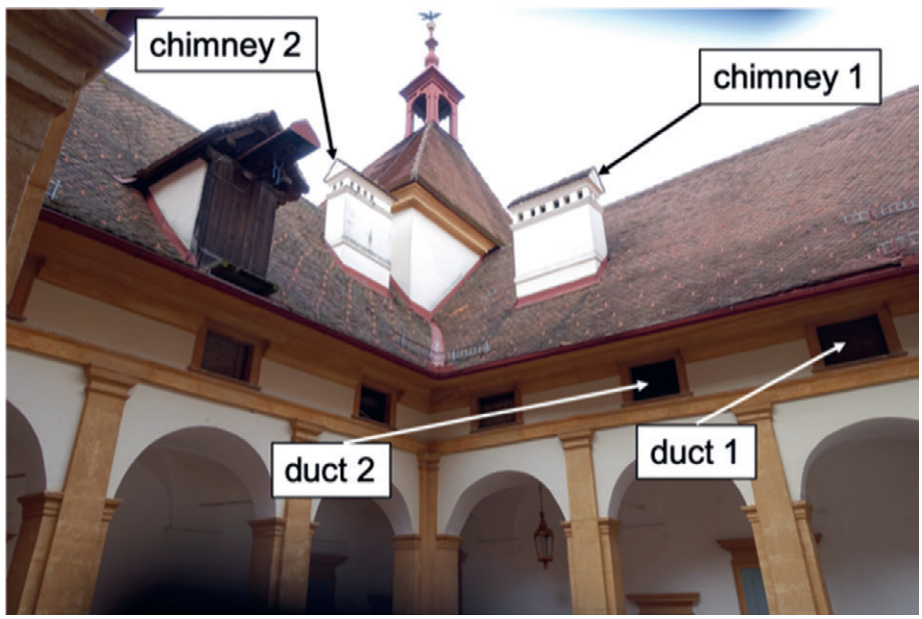

Fig. 1. Chimneys with openings on the upper edge, and location of the entrances to the ducts in a courtyard of Eggenberg Palace, Graz.

Table 1. Dates of the availability of the respective passageways, the installation of light barriers and the first registrations of bats in the passageways to the loft of Eggenberg Palace, Graz

passageway	available since	equipped with light barriers since	first registration of flight movement
chimney 1	many years	17 March 2019	18 March 2019
chimney2	many years	17 March 2019	24 March 2019
duct 1	8 April 2019	9 April 2019	19 April 2019
duct 2	8 April 2019	9 April 2019	22 April 2019

The chimneys are accessed through holes that are located about 40 cm above the loft floor (Fig. 2). The measurements of the holes are 40×60 cm (width×length), the cross section of the inner part of the chimneys is 50×50 cm. To record the flight movements from and to the roost, the holes were equipped with infrared light barriers on 17 March 2019 (Table 1). Obeying fire regulations that required sealing of the chimneys, two new approximately 1 m long passageways (duct 1 and duct 2) that lead the bats from the loft into a courtyard and back were installed on 8 April 2019. Protruding into the loft (Fig. 3), the entrances to the ducts are located in 3 m and 5 m distances from the entrances to the chimneys and end in openings to the courtyard (Fig. 1). On 9 April 2019, the openings of the entrances located in the loft were equipped with light barriers (Table 1). With the exception of the l light barriers in duct 1 that functioned only from 9 April 2019 to 20 July 2019 and in the years 2022 and 2023, all light barriers worked faultlessly. As a new solution regarding the fire regulations was found, it became possible to keep the original passageways open until today and thus allowed the surveillance of the usage of all four passageways by the bats.

For investigating acceptance and usage of the passageways and for measuring the level of bat activity, we calculated the totals of light barrier registrations of exit and access flights that were performed during the study period.

RESULTS

Recognition of the new passageways

The first registrations of a greater horseshoe bat arriving in the maternity roost after hibernation occurred on 18 March 2019 in chimney 1 and six days later in chimney 2. On 19 April 2019, the first greater horseshoe bat entering duct 1 came from the courtyard. Three days later the first registration in duct 2 was caused by a bat leaving the duct. Thus, the time lapse between arrival in the maternity roost after hibernation and the first registration of flight movements in the new ducts lasted 33 days (duct 1) and 36 days (duct 2), respectively.

Acceptance and usage of the new and the original passageways

Over the study period we obtained 165,429 light barrier registrations (Table 2). At both chimneys, the numbers of registrations decreased continuously between 2019 and 2023. At chimney 1 and – at a much lower level – at chimney 2, the flight activity has almost halved. In contrast to the chimneys, in duct 2 the numbers of both the access and exit flights increased noticeably. While in duct 2 the numbers of access flights surpassed that of the exit flights, the proportion of access and exit flights remained constant at the chimneys (Fig. 4).

In duct 1, the numbers of access and exit flights were rather similar in 2022, but in 2023 the frequency of access flights overtopped the exit flights (Fig. 5). We observed the greater

Figs. 2, 3. 2 (top) – Entrance to the chimney in the loft. 3 (below) – Entrance to the ducts in the loft.

Table 2. Total numbers of registrations by the light barriers at chimneys 1 and 2 and duct 2 (2019–2023), and after repairing of the light barrier at duct 1 in 2022 and 2023

passageway	access registrations	exit registrations	total
chimney 1	53,584	60,067	113,651
chimney 2	11,085	12,230	11,085
duct 1	9,534	6,553	16,087
duct 2	15,365	9,241	24,606
total	89,568	75,861	165,429

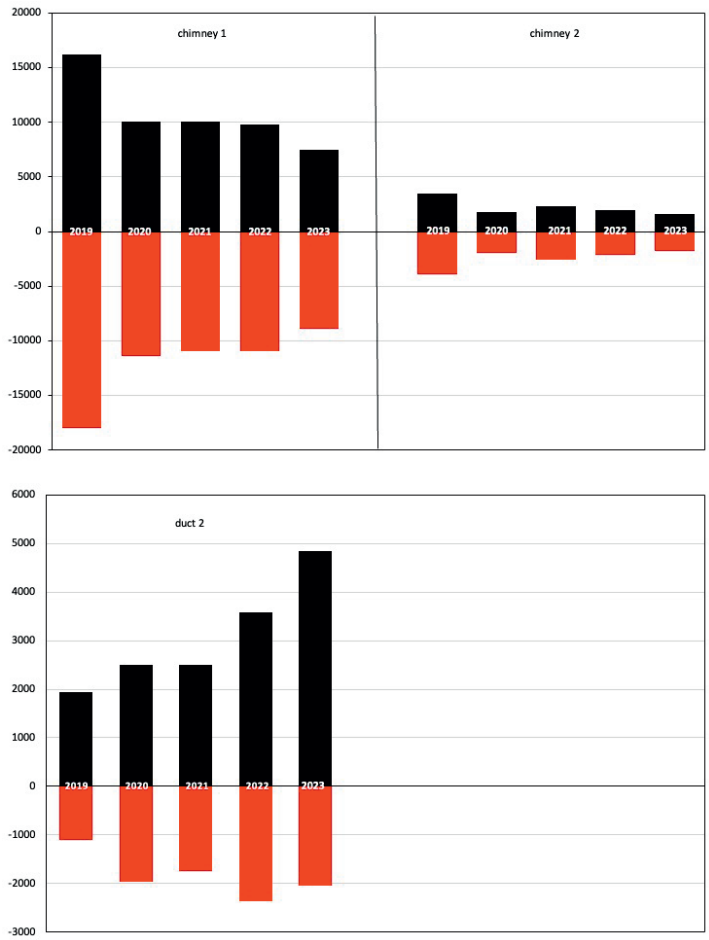

Fig. 4. Totals of incoming (black) and exit (red) registrations in chimneys 1 and 2 and in duct 2 in 2019–2023.

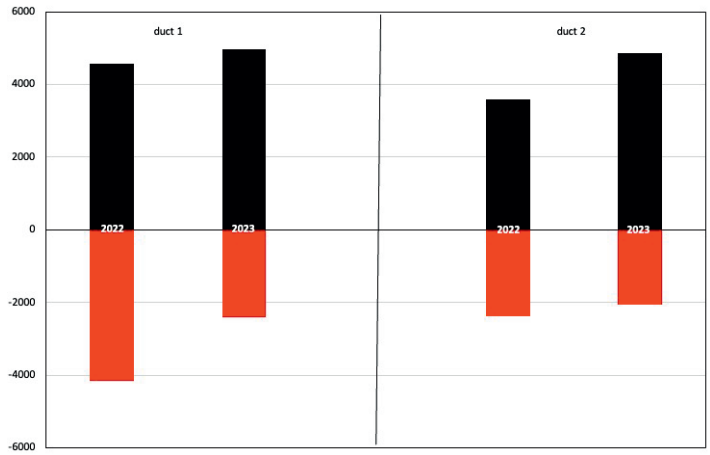

Fig. 5. Totals of incoming (black) and exit (red) registrations in ducts 1 and 2 in 2022 and 2023.

horseshoe bats performing numerous short and successively repeated back and forth flights at the entrances to passageways before accessing and leaving the roost.

DISCUSSION

Recognition

The recognition of two new passageways to the maternity roost after returning from hibernation within 33 and 36 days, respectively seems to be remarkable. It underlines the enormous competence of *Rhinolophus ferrumequinum* in spatial orientation. A high competence for fast learning and adapting to new situations in a loft used by a maternity colony of the lesser horseshoe bat has already been described by Zahn (2006).

The recognition capability of the greater horseshoe bat differs considerably from that of the greater mouse-eared bat (*Myotis myotis*), another loft-dwelling bat that used caves as year--round roosts before choosing warm lofts as maternity roosts in the temperate zone of Europe (Horáček 1984, Schober & Grimmberger 1987). The spatial orientation and spatial memory of *R. ferrumequinum* exceed by far that *of M. myotis*. Maternity colonies of *M. myotis* have difficulties to find displaced exit holes in their maternity roost when returning to the roost after hunting even when the spatial deviations are only slight (own observations).

The presumable causes for the differences in the quality of spatial orientation of the two species are:

(1) Different echolocation systems. The genera *Rhinolophus* and *Myotis* are only very distantly related. They belong to different suborders that were separated from each other more than 50 million years ago. They have developed different echolocation systems (Jones & Teeling 2006). In contrast to the rather simple echolocation system used by mouse-eared bats of the genus *Myotis*, that of the Old World horseshoe bats (Rhinolophidae) is the most sophisticated of all bat species (Jones 2005).

(2) Locomotion. Besides direct flights, bats of the genus *Myotis* use also crawling and climbing by entering and leaving a roost, whereas bats of the genus *Rhinolophus* are dependent on appropriate openings for flying in and out.

Numerous short in and out flights performed at the entrances to passageways by the greater horseshoe bats may serve for learning and habituation to a passageway that leads to a roost and may promote the recognition of novel entrances by conspecifics. However, the automatic registration of flight activity with light barriers does not allow to differentiate between different flight performances. The often repeated pendulum flights may be responsible for a large proportion of the flight movements registered by the light barriers. Therefore, we conclude that light barrier registrations of flight movements obtained at roost entrances of the greater horseshoe bat are unusable for determining the numbers of the roost inhabitants. A similar behaviour was observed in the lesser horseshoe bat, *Rhinolophus hipposideros* (own data).

Changes in the use of the passageways over the study period

The addition of two new passageways to the maternity roost changed the performance of the roost mates at accessing and leaving the roost considerably. Soon after recognition, the new passageways (in particular duct 2) became increasingly used. The 8 m high chimney 1 remained the most used passageway although the number of flight movements has here almost halved. The proportion of access and exit flights did not change in the chimneys, but both ducts became used mainly for entering. Our results support the assumption that the fast recognition and knowledge of alternative passageways are an important cognitive ability of the greater horseshoe bat and other *Rhinolophus* species that originally lived in caves.

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