

THE EMERGENCE TIME AND FLIGHT ROUTES USED BY LESSER HORSESHOE BATS OF RADZIECHOWY COLONY (POLAND)

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The emergence time and flight routes used by lesser horseshoe bats of Radziechowy colony (Poland). — **M. Warchalowski, M. Pietraszko.** — Lesser horseshoes are bats quite strongly attached to their roost sites and are considered as sedentary species avoiding long-distance migration. In Poland, the range of occurrence of the lesser horseshoe bat is restricted to mountain areas, where they prefer overgrown mountain streams for their feeding grounds. Due to these features, even seemingly small habitat changes are likely to have serious implications for maintaining local subpopulations of this rare and endangered species. In Radziechowy village, where trees were cut in the Wieśnik stream (bat feeding area), a change in the use of feeding grounds by lesser horseshoe bats was observed. This publication additionally describes the time and the manner of departure of bats from their roost. The study was conducted before the logging (2012) and immediately after the logging (2013–2016), near a church, from the most beneficial point. The study was conducted by a team of 2–3 members, starting each time 15 minutes before sunset and finishing after the bats departure. Lesser horseshoe bats avoid light and open space and they leave their roost in a complicated way. It is established that there is a statistically significant correlation ($r = 0.992$, $p < 0.001$) between sunset and emergence time of bats from the roost site. In this paper, during the emergence time, the weather influence was observed. On a cloudy day, an earlier emergence time was observed — 9 minutes after the sunset, while the average emergence time for all observations was 23.3 minutes. The conducted detector watches proved that bats most likely use the closest environment of the colony within a radius of 150–200 meters. Lesser horseshoe bats were observed in ditches of roadside trees, dense hedges and backyard orchards overgrown with apples and pears, which is typical for this species.

Key words: mountain streams, emergence time, sunset, flight routes way, detector research.

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Introduction

The lesser horseshoe bat is under international legal obligations for protection through Bonn Convention (Eurobats) and Bern Convention, where those apply. The species is listed in Annex II (and IV) of EU Habitats and Species Directive and hence requires special measures for conservation including designation of Special Areas for Conservation. Some habitat protection is provided through Natura 2000.

The use of colony surroundings by horseshoe bats was investigated by both direct observation (McAney, Fairley, 1988; Schofield, 1996; Motte, Libois, 2002) and telemetry (Bontadina et al., 2002; Motte, Libois, 2002; Zahn et al., 2008, Knight, Gareth, 2009). Most authors emphasize the essence of linear elements of the landscape as factors important for the protection of the colonies. It should be remembered that lesser horseshoe bats avoid open spaces and use tree stacks, hedges, rocky overhangs, streams, fences or other linear landscape elements (McAney, Fairley, 1988; Motte, Libois, 2002; Ramovs et al., 2010). They also feed in deciduous and mixed forests (Holzhaider et al., 2002; Motte, Libois, 2002; Boughey et al., 2011), preferring organic forests (Wickramasinghe et al., 2003).

In the literature, there are also publications showing the impact of anthropogenic activities on the emergence time of bats from their bat roost, especially the effects of light illumination on the colony (Stone et al., 2009), and the impact of the immediate surroundings of the bat roost and the light itself while leaving the shelter (Schofield, 1996).

The emergence time and modes of departure used by lesser horseshoe bats were discussed in several studies (Harmata, 1960; Schofield, 1996; Weiner, Zahn, 2000; Reiter et al., 2008; Ramovs et al., 2010), but similar pieces of research were also carried out on other species such as *Rhinolophus ferrumequinum*, *Myotis bechsteinii*, *M. dasycneme*, *M. daubentonii*, *M. myotis*, *M. mystacinus*, *M. nattereri*, *Pipistrellus pipistrellus*, *Nyctalus leisleri*, *N. noctula*, *Vespertilio murinus*, *Eptesicus serotinus*, *E. nilssonii*, *Plecotus auritus* (Gareth, Rydell, 1994; Thomas, Jacobs, 2013).

Studying bat migration routes is an important issue for species protection, especially in species that use only linear elements of the landscape to migrate. These elements are often modified or removed from the environment due to investments. That could further result in increased fragmentation of the environment, affect the selection of far-fetched feeding grounds and result in colony deterioration due to the use of inferior feeding grounds (Bontadina et al., 2002; Reiter et al., 2008). There is also a risk of isolation and increased distance to a feeding ground, which could have a negative impact on the overall population (Bontadina et al., 2002, 2008; Tournant et al., 2013), which was confirmed by telemetry (Reiter et al., 2013) and genetic studies (Afonso et al., 2016).

In 2012, in the nearby Wieśnik stream, bed adjustments were carried out, along with intensive logging. An attempt to assess the impact of this investment on the local lesser horseshoe bat population was a direct reason for the observations. Changing the structure of the landscape caused by tree felling affects not only the reduction of the potential area of feeding grounds, which may adversely affect the size of the local population. It can also help to change the directions of flights and in extreme cases lead to the isolation of the subpopulation.

The aim of this study was to describe factors determining the emergence time and manner of departure from the shelter, changes in the size of colony and changes in the directions of bats flights caused by tree logging. It should be noted that research of this type has not yet been conducted in Poland.

Material and methods

The study was conducted before the logging (2012) and immediately after the logging (2013–2016), on the outside of a church from the most beneficial point by a team of 2–3 members, starting each time 15 minutes before sunset and finishing after the bats departure. In the immediate vicinity of the breeding colony, a detector study was conducted (Petersson D240X — 108 kHz). The observation point was established near the flow of vegetation, backyard gardens and streams, both by point method and pedestrian transect. Coordinates of the point of lesser horseshoe bat flight were determined using a GPS receiver (Garmin GPSmap 62s) and then mapped to QGIS version 2.6.1. Departure time correlated (Pearson correlation) with the time of sunset and dynamic population, the correlation was calculated with the help of the program Statistica 10.0.

The surface of logging was calculated based on the Geoportal orthophotomap PUWG system in 1992, using the triangulation method. Moreover, in 2013–2017, the monitoring of the number of bats was carried out in the church and the nearby chapel. Multiple counting of bats were conducted in May–September, at least twice a year ($N = 2–7$).

Radziechowy village is located in the Silesia district, in the Żywiecka Valley (Kondracki, 2011). There are mostly single-family houses built along the Wieśnik stream, which runs through the village. The western part of the village borders with a forest complex, dominated by spruce and beech. In the eastern and northern part, farmlands and pastures are the most common. From the south, the village borders with a mountain of 609 m a.s.l., with numerous pastures and wastes. Bat roost, located in the church of Saint Martin in Radziechowy, is the earliest discovered breeding colony in Żywiec area (Wołoszyn et al., 1994).

Currently, the colony consists of about 100 individuals. The church in Radziechowy (49°38'49.05" N, 19°7'40.99" E) is a monument; its oldest layer with stone part was built in 1590, the church was rebuilt several times. The church is located on the east-west axis and surrounded by numerous vegetation (thuja, spruce, oak, and ash). The facility is illuminated by three 250W POWERLUG lamps equipped with metalhalogen (HIT) bulbs.

There is another known breeding colony of this species nearby, in the "chapel at grandfather". The stream before regulation was a mountain stream typical for this area. Its width did not exceed 2 meters and the banks were covered by numerous tree species (willow, lime, ash) and shrubs. The substrate was dominated by fine stones, showing the presence of macrophytes. In the course of investment, the streambed was deepened, covered with concrete and the coastal vegetation was grubbed up.

Results

The way the bats left the roost turned out to be very repetitive. The bats before the emergence gather near the exit of the roost. After a few minutes, the first bats fly outside, however, after few meters, they immediately return to the bat roost. The next individuals after departure fly to the top, make several circles around the church tower and return to the colony. After a few minutes (from 5 to 15 minutes), individual bats decide to leave the shelter (red line on Fig. 1), and then the number of outgoing individuals increases until the departure stops.

Most of the observed individuals flew along the ridge of the roof and at the height of the first mark, turned left (north) and then flew down from the sloping roof. The groups of the bats decided to rest on the cornice of the roof just above the entrance to the sacristy. Then the bats divided into three variants:

Variant A — turned south and flew about 20—30 cm above the ground. They flew between thuja and then headed towards the orchard.

Variant B — turned north and flew towards an oak.

Variant C — very rare — single individuals flew directly from the tower in the south direction towards the ash. This is the shortest way.

Interestingly, both before the logging (2012) and immediately after it (2013–2016) no changes were noticed in the way of departing the colony. Changes only occurred in the further migration of bats (see next). Observation worth noting was made on 21.07.2014. During departure, a marten (*Martes foina*) was observed on the ledge of the church foundation. The animal headed towards the place where the bats flew quite low over the ground in the direction of nearby vegetation strings. After a short while, the marten realized that it was being observed and immediately run away. After this incident, no more martens were observed.

In these studies, statistically significant correlation ($r = 0.992$, $p < 0.001$) was found between sunset and emergence time (Fig. 2). The relation between the emergence time and sunset is evident.

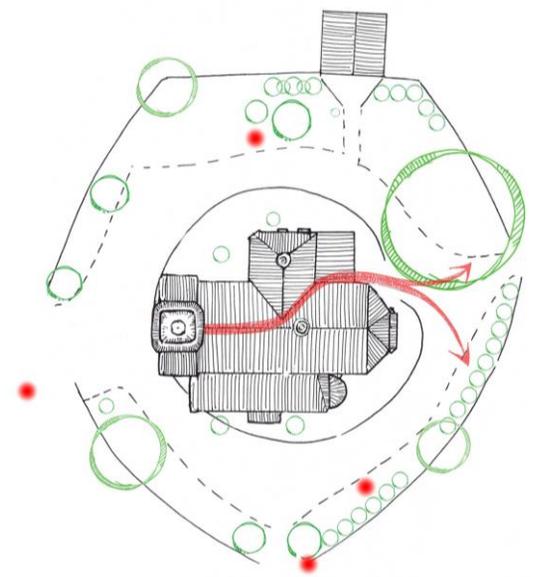


Fig. 1. Church plan; red arrows mark the leaving routes from the shelter. Red dots mark the location of light illuminators.

Рис. 1. План церкви; червоні стрілки позначають маршрути вильоту зі схованки. Червоні точки позначають ліхтарі.

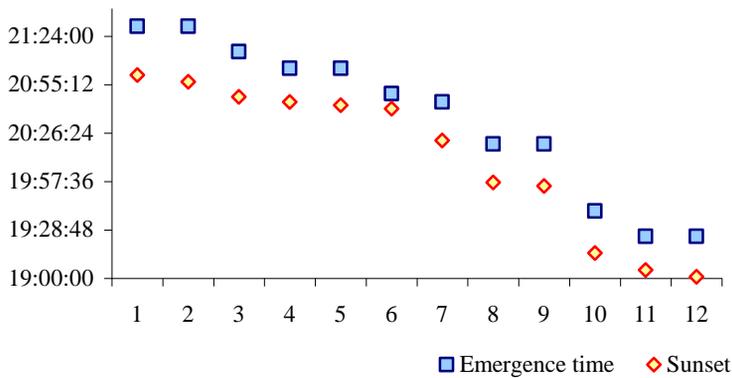


Fig 2. Sunset time and emergence time.

Рис. 2. Часи заходу сонця та появи кажанів.

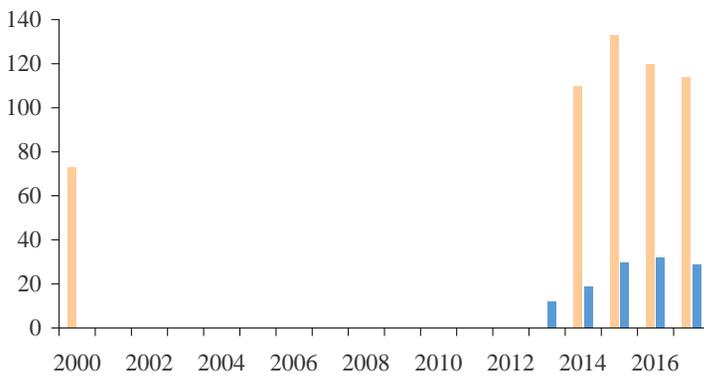


Fig. 3. Dynamics of the number of bats in the church and chapel in Radziechowy (blue boxes — chapel; red boxes — church).

Рис. 3. Динаміка числа кажанів у церкві та каплиці у Радзеховах (сині стовпи — каплиця, червоні — церква).

In spite of the lack of valuable feeding grounds, over the years of 2013–2014 the abundance of the local population did not decline. Interestingly, during the long-term monitoring studies carried out in the area, there was no noticeable decrease in the number of bats listed in the colony in the church and chapel (Fig. 3). The size of the colony residing in the church is still growing in abundance, with a maximum of 130 bats in 2016 (data for adults; 73 — 15.07.2000 (Piksa, 2010), 110 — 30.07.2014; 133 — 10.07.2015, 120 — 4.07.2016; 114 — 4.07.2017; $r = 0.91$ ($p < 0.05$)), with the number of bats in the chapel increasing very clearly (data for adults; 9.07.2013 — 12, 17.07.2014 — 19, 10.07.2015 — 30, 4.07.2016 — 32, 27.06.2017 — 29; $r = 0.86$, NS).

The field study proved that lesser horseshoe bats mostly used strings of vegetation in the immediate vicinity of their shelter and that the species avoids light places, near street lamps and illuminators. In 2012, the reconstruction of the riverbed with logging (surface 9889 sq. m) and brickwork edge was carried out in the Wieśnik stream. The research in 2012 showed that lesser horseshoe bats were often observed in Wieśnik, as a confirmed hypothesis, that it was a migration direction (orange arrow on Fig. 4) and good feeding area. However, in 2013 and 2014 the bats did not fly south, where the stream is located.

Bats, after logging, most likely headed west and east. They definitely traveled less often to the north. On the map (Fig. 4), red numbers indicate the places where lesser horseshoe bats (detector observations) were recorded. Such directions of migration are probably due to the specific shape of the vegetation strips and places with favorable feeding grounds.

Discussion

The emergence time may be influenced by many factors. In this paper, during the emergence time, the weather influence was observed. On a cloudy day (23 July 2014), an earlier emergence time was observed — 9 minutes after the sunset, while the average emergence time for all observa-

tions was 23.3 minutes. Similar results were shown by Reiter et al. (2008) on the influence of mostly rainy and cloudy weather on the emergence time of the lesser horseshoe bat. Opposite results were presented by Ramovs et al. (2010), where the first bat was observed near the bat roost entrance on an average of 16 min after sunset, and first bat roost entry was observed about 20 min after the sunset. In rainy days, a later emergence time was observed, about 26 min after the sunset. A significant correlation was found between emergence time and sunset ($r = 0.98$, $n = 47$, $p < 0.001$ — Reiter et al. 2008; $r = 0.992$ $p < 0.001$ — this study) and sunset can be considered as an undeniably decisive factor. Schofield (1996) showed a similar result. The author presented the significant correlation between light intensity of 10 lux and bats activity ($r^2 = 0.909$, $p < 0.001$, $n = 11$). That is why weather can affect the emergence time. In these studies, it is shown that the lesser horseshoe bat avoids light places, near street lamps and illuminators. This behavior is a method of avoiding predators, mostly birds (Duverge et al., 2000). A similar observation was made by other authors (Arlettaz et al., 2000; Stone et al., 2009), where bats avoided light from sodium and modern LED bulbs (Stone et al., 2012). Some authors also point out the long-term negative impact of illumination on bat roost that can possibly lead to the loss of colonies (Boldogh et al., 2007; Rydell et al., 2017). Therefore, according to the authors, there is a need to change the way light illuminates the breeding colony in Radziechowy, so that the lamp does not light bats' air routes.

The next factor that influenced the emergence time was breeding status. Seasonal differences were causing a worse flight of pregnant bats (later emergence time). On the other hand, bats lactating time was the biggest energy demand that led to earlier emergence time, which resulted in bigger predator attack risk. The earliest emergence time was observed in the post lactating period. Similar seasonal behavioral differences were observed in the feeding time of lesser horseshoe bats (McAney, Fairley, 1988; Reiter et al., 2008) by research detectors near the bat roost. In late summer and early autumn, the lesser horseshoe bat forages more intensively than in the rest of seasons. This hypothesis was confirmed by Knight and Gareth (2009) in telemetry research, where seasonal changes in the feeding area were also observed. Similar results were reported for other species: *Pipistrellus pipistrellus* and *Myotis daubentonii* (Kapfer, Serge, 2007), and *Nyctalus leisleri* (Shiel, Fairley, 1999). It is worth noting, that seasonal differences were not described in this work. As some authors think, diet can affect emergence time. Earlier feeding allows bats to hunt dipterous insects during higher than average activity at dusk (Gareth, Rydell, 1994), while bats that hunt on moths fly out later.

The use of the environment by a lesser horseshoe colony was discussed in many publications. Some were based on direct and detector observation (McAney, Fairley, 1988; Schofield, 1996; Motte, Libois, 2002), others on telemetry methods (Bontadina et al., 2002; Motte, Libois, 2002; Zahn et al., 2008; Knight, Gareth, 2009).

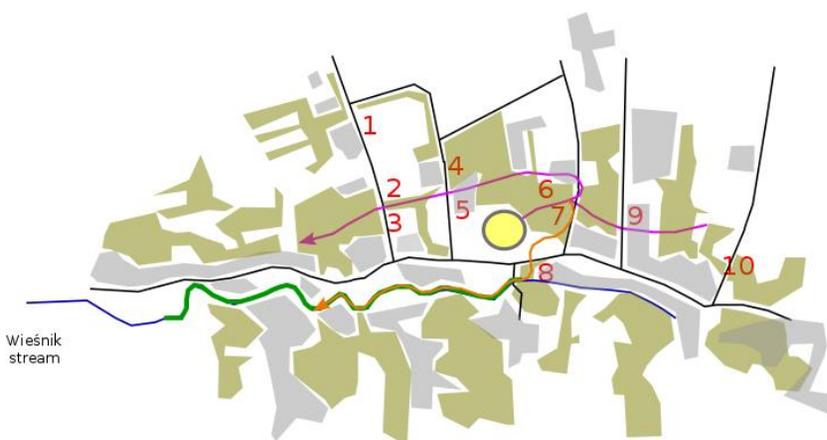


Fig. 4. Flying directions of bats before (orange) and after (purple) the logging; yellow point — church, red numbers — bat recording places, green line — places of tree logging, blue line — Wieśnik stream.

Рис. 4. Напрямки польоту кажанів до (оранжеве) та після (фіолетове) вирубки; жовта пляма — церква, червоні цифри — місця реєстрації кажанів, зелена лінія — місце вирубки дерев, синя лінія — потік В'єшнік.

All these works emphasize the importance of feeding grounds, which are located in the immediate vicinity of the colony, within a radius of 2–3 km. In addition, as the results of the research carried out by Bontadina team indicate that the most important seems to be the surrounding within a radius of 600 m from the shelter. It is also confirmed by other observations (Ramovs et al., 2010), where the majority of their detector observations were performed within 600 m from the breeding colony (18 of 21). The work carried out by Kokurewicz team indicates the need to protect the environment within a radius of 800 meters (Kokurewicz et al., 2008). The observations also found that the setup of this work indicates the immediate colony environment within 150/200 m, as a space used by most bats, and that is why it should be a subject of a special protection. During these observations, bats were reported almost exclusively in linear elements of the landscape (rows of roadside trees and shrubs).

Feeding areas along streams seem to be valuable, rich feeding grounds. Catches and detector research indicate that streams are readily used by bats, and not just by the lesser horseshoe bat (Rusoo, Gareth, 2003; Zukal, Řehák, 2006; Kurek et al., 2007 a, b). Accordingly, these sites appear to be crucial for the species' protection. Perhaps the overall creek grubbing up caused the bats to become reluctant to head south, toward other feeding area fragments, which forced them to forage in poorer and more vulnerable orchards sprayed with household insecticides. These areas seem to be less stable feeding grounds because their stretch is performed without any control. According to the authors, there is a need to restore or compensate for the loss of feeding grounds in Radziechowy.

Conclusion

Since a significant part of roosts of the lesser horseshoe bat is located in churches, in towns and villages, there are often significant changes in their immediate environment. These changes are the result of ongoing renovations or construction investments and can have a significant impact on the local populations of bats. However, as our observations indicate, these changes can be very difficult to notice.

- There was an increase in the number of the bats in the reported roosts.
- It was observed that bats after the destruction of their dominant feeding grounds have chosen the nearby stream as their other common feeding ground.
- Linear landscape elements were very important for maintaining the colony.
- Emergence time was positively and significantly correlated with sunset.
- Weather influences emergence time.

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