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Emergence and flight routes of the lesser horseshoe bats *Rhinolophus hipposideros* (Bechstein, 1800) from a church at Ljubljansko barje, central Slovenia

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Abstract. The flight routes from roosts to feeding habitats are important for efficient conservation of bats, but in Slovenia they are poorly known. Emergence and flight routes of the lesser horseshoe bats *Rhinolophus hipposideros* from the Church of Sveti Duh at Vnanje Gorice, Ljubljansko barje, were monitored on ten different days in August and September 2009. In the beginning of August, 72 lesser horseshoe bats were counted in the attic; the number decreased to 29 in the beginning of September. Individuals of three other bat species were also found in the attic and belfry: the greater mouse eared bats *Myotis myotis*, serotine bats *Eptesicus serotinus* and a group of alpine long-eared bats *Plecotus macrobullaris*. The lesser horseshoe bats emerged only from a single opening in the attic. The first bat flew out on average 16 minutes after the sunset, while the first bat amongst those that did not return to the roost left on average 20 minutes after sunset. The lesser horseshoe bats flew few metres above the ground into the nearby forest Gulč on the northwestern side of the church. We observed flying bats at nine locations in this forest and at three locations on the forest edge, where they probably foraged. Bats flew along a lit road next to houses, close to a major road they had to cross, and next to a railway southwest from the church. The spatial and temporal distribution of observations indicated the flight towards the mixed forest Plešivica, where a lesser horseshoe bat was observed app. 1.7 km bee-line distance SW from the church at Vnanje Gorice. Considering that bats generally follow linear elements in the landscape, and on the basis of our observations at 21 locations and flight behaviour we envisaged the most likely course of their flight route. These data are important for efficient conservation of the lesser horseshoe bats roosting at Vnanje Gorice and maintenance of important landscape elements in the surrounding landscape.

Keywords: *Rhinolophus hipposideros*, emergence, flight routes, Vnanje Gorice, Ljubljansko barje, Slovenia

Izvleček. IZLETAVANJE IN LETALNE POTI MALIH PODKOVNJAKOV *RHINOLOPUS HIPPOSIDEROS* (BECHSTEIN, 1800) IZ CERKVE NA LJUBLJANSKEM BARJU, OSREDNJA SLOVENIJA – Letalne poti iz zatočišč do prehranjevalnih habitatov so pomembne za učinkovito varstvo netopirjev, a so v Sloveniji večinoma slabo poznane. V okviru naše študije smo deset dni v avgustu in septembru 2009 spremljali izletavanje in letalne poti malih podkovnjakov *Rhinolophus hipposideros* iz cerkve Svetega Duha v Vnanjih Goricah na Ljubljanskem barju. V začetku avgusta je porodniška skupina malih podkovnjakov na podstrešju štela 72 osebkov in se do začetka septembra zmanjšala na 29 osebkov. Na podstrehi in v zvoniku so bili najdeni še navadni netopirji *Myotis myotis*, pozni netopirji *Eptesicus serotinus* in skupina usnjebradih uhatih netopirjev *Plecotus macrobullaris*. Mali podkovnjaki so izletavali le iz ene okrogle line na podstrehi. Prvi netopir je v povprečju izletel 16 minut po sončnem zahodu, medtem ko je prvi izmed tistih, ki se niso vrnili v zatočišče, izletel iz line povprečno 20 minut po sončnem zahodu. Mali podkovnjaki so leteli nekaj metrov nad tlemi v gozd Gulč na severozahodni strani cerkve. Prelete malih podkovnjakov smo zabeležili na devetih lokacijah v gozdu Gulč in na treh lokacijah ob gozdnem robu, kjer so se verjetno prehranjevali. Opazovali smo jih med letom ob osvetljeni cesti blizu hiš, blizu večje ceste, ki so jo morali prečkati, in ob železnici jugozahodno od cerkve. Ob upoštevanju časovne in prostorske razporeditve opažanj kaže na let v smeri mešanega gozda Plešivice, kjer smo zaznali prelet malega podkovnjaka približno 1,7 km jugozahodno od cerkve v Vnanjih Goricah. Na osnovi opažanj na 21 lokacijah in smeri leta ter upoštevajoč ugotovitve, da netopirji v splošnem sledijo linearnim elementom v krajini, smo poskušali ugotoviti najverjetnejšo letalno pot malih podkovnjakov. Ti podatki so pomembni za učinkovito varstvo malih podkovnjakov v Vnanjih Goricah in za ohranitev ključnih elementov v okoliški krajini.

Ključne besede: *Rhinolophus hipposideros*, izletavanje, letalne poti, Vnanje Gorice, Ljubljansko barje, Slovenija

Introduction

The lesser horseshoe bat, *Rhinolophus hipposideros* (Bechstein, 1800), is the smallest species of horseshoe bats (Rhinolophidae) in Europe (Dietz *et al*. 2009). Its distribution range extends across the west Palaearctic to Kashmir, north-west Africa, Ethiopia and Sudan. In Europe, it occurs south of 52° latitude, and also in Ireland and SW England (Schofield 1999, Roer & Schober 2001). In Slovenia, it is the commonest horseshoe bat; records are missing only from parts of the River Mura basin in northeast and the high mountainous areas of the Alps in the northwest of the country (Petrinjak 2009).

During winter, the lesser horseshoe bat roosts mostly in caves and other underground shelters. In summer, only warmer caves in southern Europe harbour nursery colonies, whereas in central and northern regions they roost in attics of buildings (Dietz *et al*. 2009). Such are also the nursery roosts in Slovenia, with an exceptional observation of a colony under a bridge in the warmer south-western part of the country (Petrinjak 2009).

Flight routes are narrow flight corridors that bats regularly use to commute from the roost to foraging grounds. The long-term stability of flight routes (Schaub & Schnitzler 2007) makes them very important for conservation. As many other slow-flying bat species, the lesser horseshoe bats prefer to avoid open and exposed areas in the landscape (Ekman & De Jong 1996, Stone *et al*. 2009); their flight routes are therefore often parallel to linear landscape elements such as hedgerows (Schaub & Schnitzler 2007, Zahn *et al*. 2008). There is much evidence supporting the importance of linear landscape elements as guidelines for bat flight routes; they are suitable for echoacoustic orientation (Verboom *et al*. 1999), serve as foraging habitats and can provide protection against predators and wind (Verboom & Huitema 1997, Verboom & Spoelstra 1999). According to Reiter *et al*. (2008), the vicinity of linear landscape elements to the roost can result in safer emergence.

Foraging habitats and flight routes of the lesser horseshoe bat in Slovenia are poorly known also owing to the relatively difficult detection with bat detector (Petrinjak 2009). Studies from other countries, some of which included radiotelemetry, showed that forests near the roosts are the most important foraging habitats of this species (Schofield 1996, Motte & Libois 2002, Bontadina *et al*. 2002, Zahn *et al*. 2008). The distance between a roost and foraging habitat was mostly up to 2.5 km, and did not exceed 4-6.4 km (Schofield 1996, Holzhaider *et al*. 2002, Motte & Libois 2002, Bontadina *et al*. 2002, Bontadina *et al*. 2006, Zahn & Weiner 2004). Its diet consists mostly of crane flies, moths and neuropterans (McAney & Fairley 1989).

Lesser horseshoe bats are endangered in the greater part of their distribution range, with indications of stabilised or increased numbers only from some parts of Europe (Schofield 1999, Dietz *et al*. 2009). Disturbance at roosts (increasing cave tourism, improper renovation of buildings, i.e. during the nursery periods, by closing the flight openings), effects of pesticides and changes in natural landscape, such as forest fragmentation or the shifting of tree lines, are the major threats to this species (Bontadina *et al*. 2000, Motte & Libois 2002, Petrinjak 2009). The additional threat, light pollution, can negatively affect them at roosts (Decoursey & Decoursey 1964, Shirley *et al*. 2001, Downs *et al*. 2003, Boldogh *et al*. 2007),

and can also change the established flight routes near tree lines and forest roads (Stone *et al*. 2009).

The moor of Ljubljansko barje south of Ljubljana city in central Slovenia is one of the Natura 2000 sites under European Habitats Directive (92/34/EGS, Appendix 2), declared as such also with the aim to protect the lesser horseshoe bats (Official Gazette of the RS, No. 49/04, 110/04, 59/07 and 43/08). Nursery roosts of the species were found in nine churches in the area, several harbouring over 100 bats (Zagmajster 2008, Presetnik *et al*. 2009a, 2009b). In the Church of Sveti Duh at Vnanje Gorice, in the central part of Ljubljansko barje, a nursery of up to 70 lesser horseshoe bats was found (Presetnik *et al.* 2009b, Zagmajster 2008). The church is also inhabited by nurseries of mouse-eared bats *Myotis myotis* and serotine bats *Eptesicus serotinus* (Zagmajster 2008, Presetnik *et al*. 2009a, 2009b). In 2009, some individuals of the alpine long-eared bats *Plecotus macrobullaris* were observed (Presetnik *et al*. 2009b).

In this study, we investigated the emergence behaviour and flight behaviour of the lesser horseshoe bat colony at Vnanje Gorice, which had not been systematically studied before. We expected bats would fly into some of the forest patches in the surroundings of the church that present potential feeding grounds of the species. Our data presented the first information on the colony's flight routes and enabled predictions concerning parts of the flight routes.

Methods

Study area

Ljubljansko barje is a large wetland area (about 150 km^2) south of Ljubljana, with a highly mosaic structure of meadows, agricultural fields, draining ditches, hedgerows and some forest patches. The roost of the lesser horseshoe bats in the church at Vnanje Gorice is situated in the central part of Ljubljansko barje, separated from the potential large forested foraging area in the south (Krim forests) by wetland areas. The village of Vnanje Gorice lies in the central part of Ljubljansko barje, southeast from Ljubljana (Fig. 1). In the centre of the village, the hill Gulč covered with deciduous forests is standing, with the Church of Sveti Duh situated at its top (333 m elevation). The hill is surrounded with buildings, with their highest concentration on the hill's west side and in the area between Gulč and Veliki vrh, and another deciduous forest patch about 600 m east from the church (highest elevation about 373 m). Between the two hills stretches a belt of houses, with trees that form a tree line next to a street in some places. Most streets at Vnanje Gorice are lit with roadside lights during the entire night. The village's major and busiest road is situated west of the church, next to the single track railway, which runs in a straight line south towards Plešivica.

More than 900 m south of Vnanje Gorice the hill Grič (also called Dobčenica), covered with a mixed forest, stands at approx. 342 m a.s.l. About 1 km southwest of Vnanje Gorice stretch a large mixed forest patch Plešivica (390 m elevation) and the villages of Plešivica and Žabnica. The area between Vnanje Gorice, Plešivica and Grič (Fig. 1) is covered by moor meadows, mostly turned into agricultural fields and pastures. This area is crisscrossed by draining ditches, in places overgrown with hedgerows (hazel *Corylus sp.*, willow *Salix sp.*, alder *Alnus sp.*, and ash trees *Fraxinus sp.*).

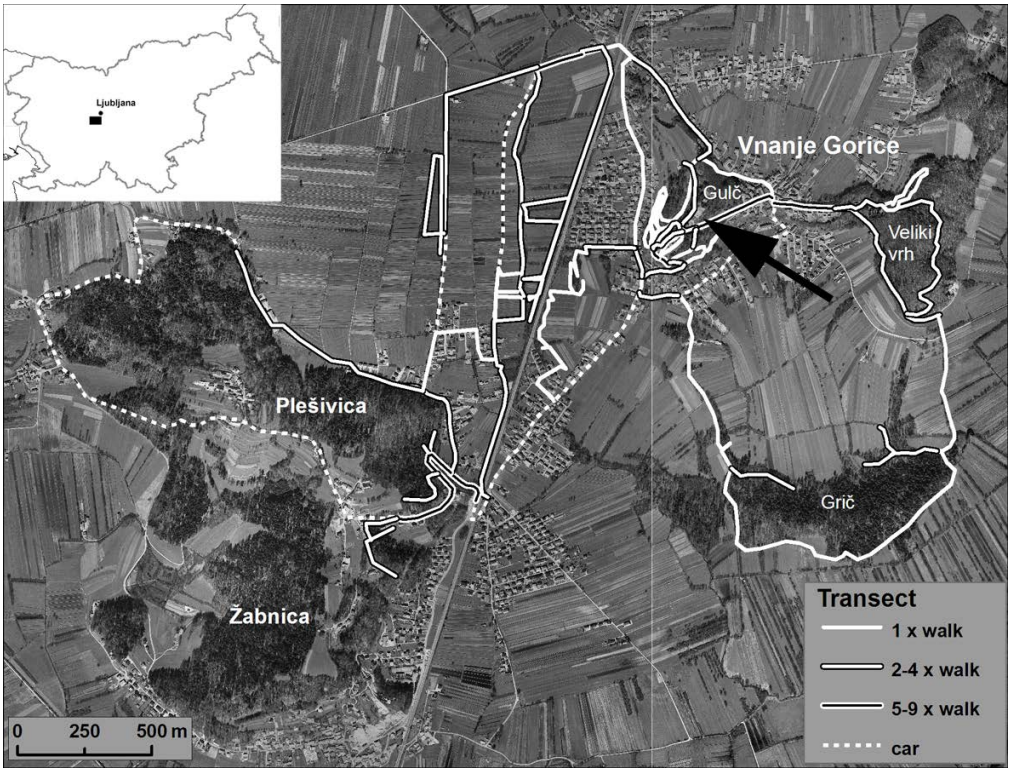

Figure 1. Study area at Ljubljansko barje with marked transects where lesser horseshoe bats were searched for with bat detectors during August and September 2009. Transects were walked on or slowly driven by car, with different numbers of repeats (see the legend). Arrow points to the Church of Sveti Duh at Vnanje Gorice with the lesser horseshoe bat nursery colony.

Slika 1. Preučevano območje na Ljubljanskem barju z označenimi transekti, na katerih smo ugotavljali navzočnost malih podkovnjakov z ultrazvočnim detektorjem avgusta in septembra 2009. Transekte smo prehodili ali prevozili s počasno vožnjo, z različnim številom ponovitev (glej legendo). Puščica označuje cerkev Svetega Duha v Vnanjih Goricah, kjer je nastala porodniška kolonija malih podkovnjakov.

Description of the church

The Church of Sveti Duh at Vnanje Gorice (Gauss Krueger coordinates X: 455126, Y: 95767) is a middle-sized Catholic church with its bell tower connected to the main part of the church. At night, the church is lit from three sides with four pale orange spotlights; with two from the south side (one was off during our study), with one spotlight from the north and one from the northeastern side (Figs. 2, 3). The spotlights were turned on around the time of the sunset (always before the bats started to emerge).

The church attic had openings leading out of it and to the belfry. The opening of 1.5 m x 0.80 m in size was located between the attic and the lower part of the belfry. There was no opening leading to the bells, as the 0.80 m x 0.80 m entrance was closed with a hatch. In the attic, at the southeastern part of the church, there are two round windows measuring 20 cm in diameter. One of the two windows was closed with a wire mesh, while the other was open. We found bat guano at the edge of the opening. There were several smaller openings between the attic's roof tiles (up to few cm in width), all too small for emergence of horseshoe bats. The entrance to the belfry is located at the church's choir and closed with a door. All windows and openings in the lower parts of the belfry are grilled. Some windows in the inner part of the church were open during our study.

Field work

Our study was conducted on ten different days in August and September 2009 (Tab. 1). We used different methods that are described in the following sections.

Table 1. Dates, weather conditions and research methods used during the study of emergence and flight routes of the lesser horseshoe bats of the Church of Sveti Duh at Vnanje Gorice in 2009. Days when emergence of the entire colony was monitored are marked with *. For the descriptions of methods see text.
Tabela 1. Dnevi, vremenske razmere in metode raziskovanja med preučevanjem izletavanja in letalnih poti malih podkovnjakov iz cerkve Svetega Duha v Vnanjih Goricah leta 2009. Dnevi, ko smo opazovali izletavanje cele kolonije, so označeni z *. Metode so podrobno opisane v besedilu.

Day of observation	Date	Weather	Roost survey	Emergence and flight observation	Tracking with ultrasound detector
1	6.8.2009	clear sky	✓		
2*	8.8.2009	clear sky		✓	✓
3*	9.8.2009	clear sky		✓	✓
4	12.8.2009	clear sky		✓	✓
5	13.8.2009	partly clouded with infrequent drizzling		✓	✓
6	28.8. 2009	clear sky	✓	✓	✓
7	30.8.2009	clear sky		✓	✓
8	31.8.2009	clear sky			✓
9*	1.9.2009	clear sky		✓	
10	2.9.2009	clear sky			✓

Roost survey

The attic of the church was examined on two occasions during daytime, when bats were in their roost (Tab. 1). The belfry above the bells was inspected only during our first visit. Bats were identified visually using halogen torches and with bat detector Pettersson D200 (Pettersson Elektronik AB), if they were active. The count of bats was performed with the minimum level of disturbance. We also looked for bat bone remains and droppings.

Emergence behaviour

The start of the evening emergence was monitored during seven evenings, starting 15 minutes before sunset (Tab. 1). On three occasions we observed the emergence of the entire lesser horseshoe bat colony, when we finished observations around 30 minutes after sunset, i.e. at least 15 minutes after the last bat flew out of the roost. On other occasions, the emergence was observed only until the first bat flew out of the roost to the nearby forest, after which we started to look for their flight routes (see next chapter). We recorded the time of the first bat flying out of the opening and the time of the first bat that had left the roost (without returning back). If possible, we determined the flight direction and the location of flight into the forest. We used halogen spotlights, which were not directed towards the flight opening but used only occasionally to track the flying bats. To detect flying bats, we used Pettersson D200 and D240 (Pettersson Elektronik AB) bat detectors in heterodyne mode (Russ 1999) and set on 110 kHz frequency. This is the specific frequency of the echolocation calls of the lesser horseshoe bats (Russo & Jones 2002). Their echolocation calls can be difficult to detect and often allow detection only about 5-6 m away (Motte & Libois 2002).

Flight routes

After recording the location of the flight into the forest, we followed the lesser horseshoe bats using bat detectors (Tab. 1). In six cases, we followed the bats to the forest near the church, until losing track of the echolocation calls. In the following evening one member of our research team began his tracking activities at the place of the last bat observation during the preceding night (as in Motte & Libois 2002). In four nights, we started observations at the places where bats had been heard last during the previous night, but away from the church itself (from 28 Aug onward, see Tab. 1). On days when we started observations at the church (6 days, Tab. 1), we checked the potential presence of lesser horseshoe bats near the church also around midnight of the same night to see whether some bats would be present in its vicinity for potential feeding near the church or returning back into the roost.

Every time we lost track of the flying lesser horseshoe bats, we continued the search for the species in the neighbouring forest patches, at hedgerows. We were looking for bats while walking; only in four cases did we occasionally use the car and make observations through the open window at a speed of 20 km/h. We had set the bat detector to the frequency of 110 kHz, and when the bat was heard, the location was marked with GPS (Garmin). All locations were mapped and analysed using ArcGIS, ver. 9.2 (ESRI).

Results

Bats in the church

On 6 Aug 2009, there were 72 lesser horseshoe bats roosting in the attic. We observed some females with juveniles and thereby confirmed previous reports of a nursery colony in the church (Presetnik et al. 2009b). We also recorded guano and three mummified remains of the lesser horseshoe bats. Some lesser horseshoe bats and one female with juvenile were observed in the belfry, on the ceiling of the room right under the compartment with bells.

The number of lesser horseshoe bats in the attic decreased to 30 on 28 Aug 2009. The count of the bats during their emergence four days after this inspection revealed almost the same number of bats (29 individuals).

During the first visit, we observed three other bat species. One serotine bat was climbing on the wooden trunk under the roof of the attic, and according to the fresh guano it is highly likely that more individuals of the species were present there, but could not be seen. Seven greater mouse-eared bats were in the belfry, in the compartment above the bells only. Social calls suggested that the group, hidden in the cranny, consisted of more bats than we were able to see. Therefore, as far as the greater mouse-eared and serotine bats are concerned, the observed numbers should be considered minimal. In the attic, a group of 12 alpine long-eared bats was observed in a cluster on the wooden trunk close to the roof. During our second visit, when only the attic was checked, a single alpine long-eared bat was recorded, besides lesser horseshoe bats.

Figure 2. Position of the flight opening that lesser horseshoe bats use to emerge from the attic of the Church of Sveti Duh at Vnanje Gorice. Black arrow indicates the round opening, white arrow points to the window in the lower part of the church that remained open during our study. a) View of the southern part of the church, b) Close-up of the flight opening and open window, c) View of the flight opening from the attic. Photo: S. Zidar.

Slika 2. Položaj odprtine, ki so jo mali podkovnjaki uporabljali za izletavanje s podstrehe cerkve Svetega Duha v Vnanjih Goricah. S črno puščico je označena okrogla odprtina, z belo puščico pa okno v cerkev, ki je bilo v času naše raziskave odprto. a) Pogled na južno pročelje cerkve, b) Bližnji pogled na izletalno odprtino in odprto okno c) Pogled na izletalno odprtino s podstrehe. Foto: S. Zidar.

Emergence of lesser horseshoe bats from the roost

Lesser horseshoe bats were using one round opening, situated on the southeastern side of the church, to emerge from the attic (Figs. 2, 3). The opening was located in the shadow, hidden from the light emitted by the spotlights that lit up the church from its eastern side.

The emerging bats did not fly directly from the roost to the nearby forest, but made a few circles in front of the opening and returned to the roost. On seven days, we observed some bats flying to the window at the southeastern part of the church, many of them making a turn under the vault of the window (Fig. 3). This window was in the shadow as well, shaded by the side wall from the spotlights.

Lesser horseshoe bats passed the corner of the church flying low, some of them even less than a metre above the ground (Fig. 3). They flew higher when circling (several times) under the vault of the belfry, just under the ceiling. One bat was seen making even seven turns (on 9 Aug 2009). On their flight away from the belfry, bats flew close to the ground again. They entered the forest northwest from the church, flying over the wall of the cemetery that surrounds the church (Fig. 3).

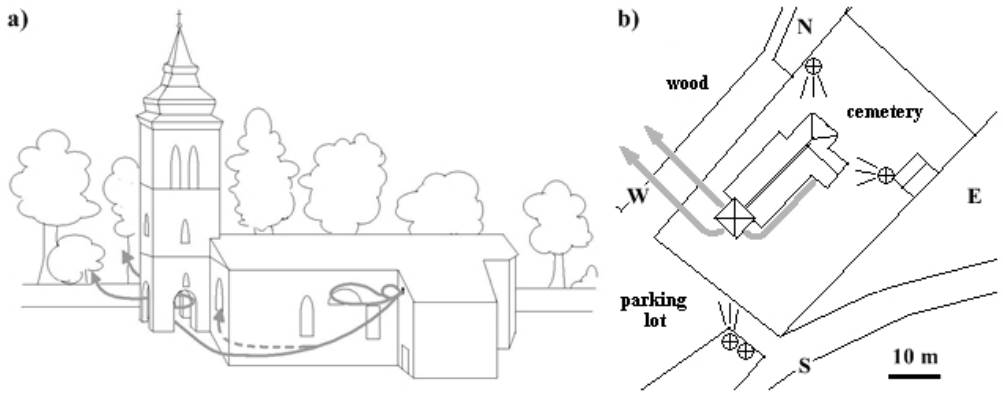

Figure 3. Observed flight routes of the lesser horseshoe bats after emerging from the attic of the Church of Sveti Duh at Vnanje Gorice. Some bats were flying in and out of the church through the open window (hatched line). a) Scheme of the southeastern side of the church with flight routes; b) Top view of the church with marked position of spotlights and direction of lights (bottom southeastern spotlight was not lit during our study).

Slika 3. Opažene letalne poti malih podkovnjakov po izletu iz podstrehe cerkve Svetega Duha v Vnanjih Goricah. S črtkano linijo je označen let nekaj netopirjev, ki so leteli v in iz cerkve skozi odprto okno. a) Shematski prikaz cerkve z jugovzhodne strani z letalnimi potmi; b) Tloris cerkve z označenimi reflektorji in smerjo svetenja (skrajni jugovzhodni reflektor v času raziskave ni bil prižgan).

On the front (southwestern) side of the church, a window was opened every day during our observations, leaving about 40 cm wide opening (Figs. 2b and 3). One lesser horseshoe bat was observed flying out of that window on 9 Aug 2009 after the bats started their emergence from the attic roost. On 1 Sep 2009, a lesser horseshoe bat was seen flying in and out of the same window. Since there is no open connection between the attic and the interior of the church, the bat had to enter the church through this window also on 9 Aug 2009.

On 9 Aug 2009, three lesser horseshoe bats were observed flying towards southeast after emerging. By following one of them, we discovered that it circled above the parking lot next to the church and then continued its flight towards the same forest as other bats.

On 13 Aug 2009, when the weather was cloudy with infrequent drizzles, bats did not exhibit circular flights in front of the church. After emerging, they flew directly under the belfry into the forest.

On average, the first lesser horseshoe bat was observed exiting the roost 16 minutes after the sunset (Fig. 4), with the first bat flying into the forest 20 minutes after the sunset. On 13 Aug 2009, when the weather was cloudy, bats emerged from the roost later than on other days, 26 minutes after the sunset.

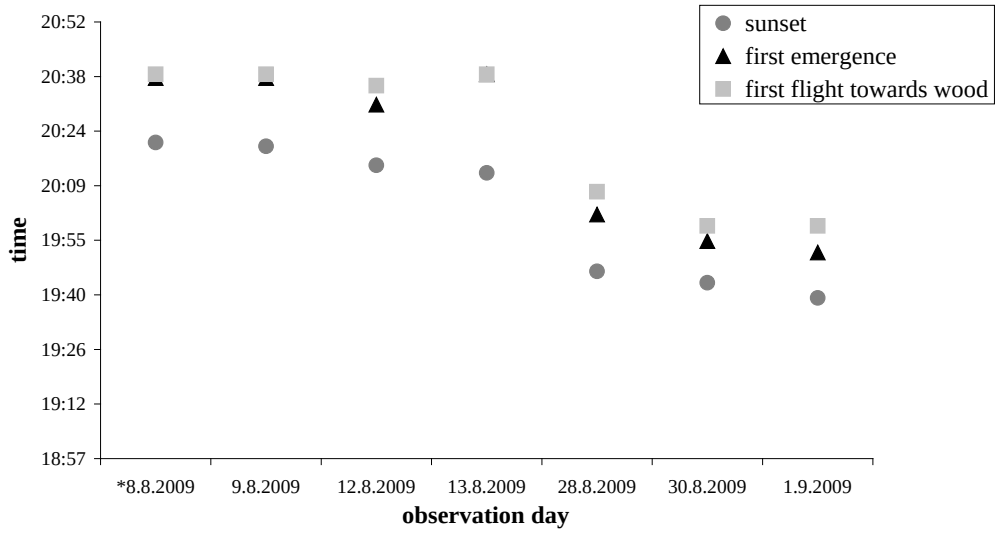

Figure 4. Time of sunset, time of the first lesser horseshoe bat's emergence from the roost (with return shortly afterwards), and time of the first bat leaving the roost and flying into the forest next to the Church of Sveti Duh at Vnanje Gorice, as recorded during the seven days of August and September 2009.

Slika 4. Čas sončnega zahoda (označen s krogom), čas prvega izleta malega podkovnjaka iz zatočišča (trikotnik) in čas prvega izleta malega podkovnjaka proti gozdu ob cerkvi Svetega Duha v Vnanjih Goricah (kvadrat), kot so bili zabeleženi v sedmih dneh avgusta in septembra 2009.

Flight routes of lesser horseshoe bats

After leaving the roost, the bats flew towards the Gulč forest, northwest from the church (points 1-6, 7, 11, 12, Fig. 5, Tab. 2). In six cases, they were recorded at the western and southern edges of the forest. Bats flew out of the forest near the points 8-10 (Fig. 5, Tab. 2), where a small clearing lies in the forest. One evening (13 Aug 2009), the lesser horseshoe bats were also recorded flying along the outer western edge of the forest (points 13-15, Fig. 5, Tab. 2). We had not observed this kind of behaviour during any other night visits of the forest. The longest period from the time that bats first entered the forest to the time we detected them for the last time in the forest was 40 minutes.

We observed lesser horseshoe bats in Plešivica forest on three occasions:

- on 13 Aug 2009 (point 19, Fig. 5, Tab. 2) a bat was detected between the forest and the orchard, near the house at the unlit part of the forest road leading to Plešivica;
- on 30 Aug 2009 (point 20, Fig. 5, Tab. 2) a bat was seen passing the unlit part of the same road 100 m southwest from point 19;
- on 2 Sep 2009 (point 21, Fig. 5, Tab. 2) one bat flew along the unlit edge of the forest next to the road, near the orchard.

To check for the flight routes between Vnanje Gorice and Plešivica, we checked the area between Plešivica and Gulč on four occasions (Fig. 1). The lesser horseshoe bats were observed at three locations:

- on 30 Aug 2009 a bat was flying along the unlit street (point 16, Fig. 5, Tab. 2);
- on 30 Aug 2009 one bat was observed in the meadow near the rail, close to the draining ditch and line of trees t (point 17, Fig. 5, Tab. 2);
- on 31 Aug 2009 a bat was observed above the railway, near a humid meadow and a line of trees (point 18, Fig. 5, Tab. 2).

We did not detect any lesser horseshoe bats in the forest patches of Veliki vrh and Grič during the three evenings they were inspected (on 8 Aug, 9 Aug, and 12 Aug 2009, Figs. 1, 5). We did detect presence of other bat species we are not reporting on in this article.

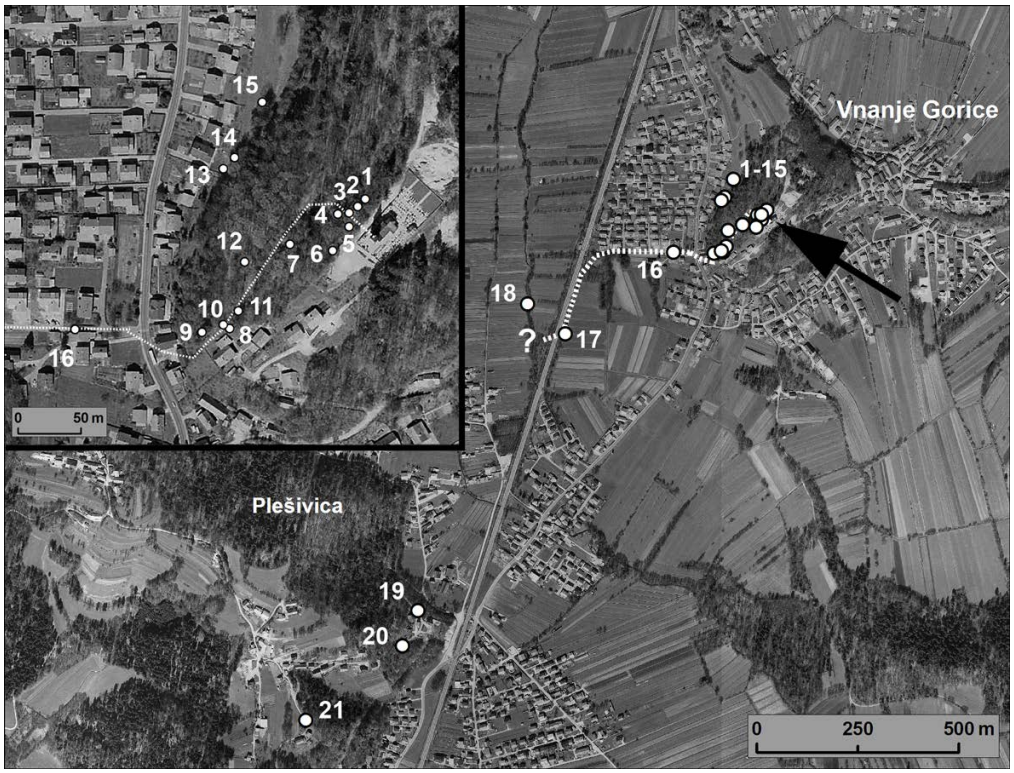

Figure 5. Locations around the Church of Sveti Duh at Vnanje Gorice (arrow), where lesser horseshoe bats were observed with bat detectors during August and September 2009. The dotted line presents part of the most likely flight route of the lesser horseshoe bats from the church (for detailed explanations see the text). In the rectangle in top left part of the figure is a close-up of the area around the church. See also Tab. 2.

Slika 5. Lokacije v okolici cerkve Svetega Duha v Vnanjih Goricah (puščica), kjer smo avgusta in septembra 2009 z ultrazvočnim detektorjem opazovali male podkovnjake. Črtkana črta ponazarja del najverjetnejše letalne poti malih podkovnjakov iz cerkve (za podrobnejšo razlago glej besedilo. V pravokotniku v zgornjem levem delu slike je prikazano povečano območje v bližnji okolici cerkve. Glej tudi Tab. 2.

Table 2. Locations where lesser horseshoe bats were observed with bat detectors in wider surroundings of the Church of Sveti Duh at Vnanje Gorice in August and September 2009. The Gauss-Krueger coordinates, bee-line distance from the church, the time when a bat was observed and time of sunset are given. See also Fig. 5.
Tabela 2. Točke v širši okolici cerkve Svetega Duha v Vnanjih Goricah, kjer smo avgusta in septembra 2009 z ultrazvočnimi detektorji slišali male podkovnjake. Podane so Gauss-Kruegerjeve koordinate, najkrajša oddaljenost od cerkve, čas, ko je bil netopir opažen, in čas sončnega zahoda. Glej tudi sl. 5.

Point No.	Date	Sunset	Time	Coordinates		Distance from the church [m]
				X	Y	
1	9.8.2009	20:20	20:52	455112	95805	28
2	8.8.2009	20:21	20:57	455106	95799	27
3	9.8.2009	20:20	21:06	455099	95794	29
4	9.8.2009	20:20	20:55	455090	95793	37
5	9.8.2009	20:20	21:04	455099	95783	25
6	9.8.2009	20:20	21:22	455086	95764	41
7	12.8.2009	20:15	21:17	455052	95769	73
8	13.8.2009	20:13	20:42	455004	95702	143
9	13.8.2009	20:13	20:39	454982	95699	163
10	13.8.2009	20:13	20:57	454999	95705	145
11	13.8.2009	20:13	20:43	455011	95716	129
12	12.8.2009	20:15	20:53	455016	95755	111
13	13.8.2009	20:13	20:51	454999	95829	134
14	13.8.2009	20:13	20:48	455008	95838	130
15	13.8.2009	20:13	20:49	455030	95882	139
16	30.8.2009	19:44	20:16	454881	95712	255
17	30.8.2009	19:44	20:40	454613	95499	583
18	31.8.2009	19:42	20:26	454519	95573	639
19	13.8.2009	20:13	22:22	454247	94813	1305
20	30.8.2009	19:44	22:17	454192	94743	1396
21	2.9.2009	19:39	22:05	453969	94540	1694

Based on distribution of 21 localities, where lesser horseshoe bats were detected (Fig. 5, Tab. 2), observations of their flight directions and considering that bats generally follow linear elements in the landscape (Verboom & Huitema 1997, Zahn *et al.* 2008), we envisaged one part of the hypothetical flight route of the lesser horseshoe bats from their roost (Fig. 5). According to our observations, bats needed to cross the well lit and heavily trafficked road west of Vnanje Gorice. Our observation of a lesser horseshoe bat at point 16 (Fig. 5, Tab. 2), flying along the unlit street, supports the prediction that crossing the main road is part of their flight route. Since the calls of the species were detected on both sides of the railway (points 17 and 18, Fig. 5, Tab. 2), we can confirm that the lesser horseshoe bats cross it (Fig. 5).

Discussion

We found four bat species in the Church of Sveti Duh at Vnanje Gorice, whose presence was expected according to the previous studies (Presetnik et al. 2007, 2009a, 2009b, Zagmajster 2008). We found a group of alpine long-eared bats in the church, where a year earlier only single individuals had been found (Presetnik et al. 2009b). We were unable to capture and measure the individuals, but according to the season they were highly likely females with juveniles, which should be taken into account for the conservation purposes of this roost. The closest nursery roost of the alpine long-eared bats was found in the Notranje Gorice church, 2.4 km bee-line distance away (Zagmajster 2008).

We observed typical bat behaviour shown by the first individuals that emerged from the roost, called light sampling (Fure 2006). Bats did not fly directly out of the roost, but rather circled in front of the emergence opening and then returned to the roost, which was repeated several times. Such behaviour was also observed in the lesser horseshoe bats emerging from the winter roosts in north-western Slovenia in spring 2002 (Petrinjak & Jokhadar 2003). During light sampling, bats check the intensity of light, and emerge from the roost at low light intensities to avoid predators (like birds), but not too late to miss the peak of evening insect activity (Rydell et al. 1996, Duverge et al. 2000, Fure 2006). We observed a lesser horseshoe bat flying in and out of the interior of the inner part of the church through the open window. This might be just random behaviour, but it could also be interpreted as searching for new openings leading from the church.

Lesser horseshoe bats were flying less than 5 m above the ground, which is quite characteristic of the species (Russ 1999). They flew through the Gulč forest near the church relatively fast, but it is possible that they also foraged there. On 13 Aug 2009, we detected several bats flying along the outer edge of the Gulč forest on its western side. It may be that on that day bats were foraging so early due to the worse weather compared to our other observation evenings. We were at the same forest edge on four other evenings, but did not observe any lesser horseshoe bats there.

It is very probable that the lesser horseshoe bats observed in the Plešivica area are the ones emerging from the Church of Sveti Duh at Vnanje Gorice. Directions of bats flying from Vnanje Gorice and the timing of our observations support this possibility. On 13 Aug 2009, the last lesser horseshoe bat at Gulč was detected at 20:57 hrs. The species was observed at Plešivica about 1.5 h later. The greatest bee-line distance between the Vnanje Gorice church and the locations where species was detected at Plešivica was 1.7 km from the church. This is within the range of the average lesser horseshoe bat foraging area (Bontadina et al. 2002, Bontadina et al. 2006). It would be possible that individual lesser horseshoe bats roosted in any of the buildings in the Plešivica area, but no such roost has been discovered so far. The next nearest colony is situated in the Church of Sveti Vid at Preserje (Presetnik et al. 2009a), which is 4.6 km bee-line distance away from Plešivica. Presence of the lesser horseshoe bats in the Plešivica area indicates that this could be their feeding habitat, or one of them at the least.

It is possible that lesser horseshoe bats also foraged near linear landscape elements during commuting (Zahn et al. 2008), but no such behaviour was observed. Such foraging behaviour is more often observed for other bat species (Racey & Swift 1985, Verboom & Spoelstra 1999).

Illuminating the roost entries negatively affects emergence of different bat species from their roost (Decoursey & Decoursey 1964, Shirley *et al.* 2001, Downs *et al.* 2003, Boldogh *et al.* 2007, Kozjek *et al.* 2008). According to the recent study by Stone *et al.* (2009), lesser horseshoe bats were affected by street lighting when introduced along their regular flight routes. In our study we have observed that while flying near the church, lesser horseshoe bats always remained in the unlit area, shaded by the side nave. However, bats from Vnanje Gorice have to cross the lit and trafficked road as part of their flight route. This indicates lesser horseshoe bats could perhaps be able to adjust to certain light conditions. Part of their flight route is also the open meadow area between Gulč and the road. However, we assume that they use lines of trees and bushes near the drainage ditches as primary element of their flying routes between the railway and Plešivica, considering the fact that they prefer to fly along linear landscape elements (Schaub & Schnitzler 2007, Zahn *et al.* 2008).

Our observations agree with the finding that recording of lesser horseshoe bats with detectors is hard due to high atmospheric attenuation of their directed high frequency calls, which do not allow detection on long distances (Russ 1999, Russo & Jones 2002). The time of detection of one bat was also limited, since the bat quickly passed the area where it could be detected. Obviously, we did not detect all lesser horseshoe bats present in the monitored areas; however, by detecting some individuals we were able to reconstruct the most probable course of their major flight route. Further research using methods of labelling and tracking specific individuals should provide more information to determine habitat use and flight routes of this colony.

During our research, no lesser horseshoe bats were found in the forests of Veliki vrh and Grič. Neither were the bats of this species observed on car transects with bat detectors conducted near both forest patches on 5 Aug 2009 (Zagmajster 2009). That is surprising, given that both forests are the nearest wooded areas and could be easily accessible without crossing illuminated areas, roads or railways. Motte and Libois suggested (2002) that structure is crucial for forest suitability as a foraging habitat. Maybe the structure of both forest patches is less suitable for the lesser horseshoe bats; however, there seems not to be a great difference in composition of all three forests. Possible reason for preference of the Plešivica forest could also be its size – Plešivica forest is much larger than Veliki vrh and Grič. Another explanation takes into consideration the period when our study was conducted. In the late summer, bats start to migrate from their summer to winter roosts (Dietz *et al.* 2009). It is possible that lesser horseshoe bats fed in closer forest patches in other parts of the season, but were on their migration routes leading toward southern forests at the time of our study. Indeed, bats were gradually leaving the roost during our study, as halving of the number of lesser horseshoe bats in the roost was observed during the 25 days. Whether habitat use differs during the summer and whether lesser horseshoe bats sometimes use the nearby forest areas should be determined by further studies.

Lesser horseshoe bats were flying low above the ground and had to cross a busy road and railway. Thus, bats from Vnanje Gorice could be occasional traffic casualties. Lesser horseshoe bats already have been found victims of the car traffic close to a church with nursery colony at Tomišelj south of Vnanje Gorice (Denac 2003).

For effective conservation of bats in the church, other threats to the bats must also be identified. As already shown, bats use unlit areas of the church during emergence; it is important to leave these parts of the church not illuminated. Furthermore, lesser horseshoe bats used a single exit opening, which is actually a window that used to be closed with the net. This window must remain open to enable bats to enter and exit the roost.

Our observations present the first information on flight routes of the lesser horseshoe bats roosting at Vnanje Gorice. It would be necessary to continue the studies, extending them to the whole season and using additional methods, for example radio-tracking individual bats. Gained data will be important for planning the efficient conservation that includes preservation of the nearby suitable habitats besides roost protection.

Povzetek

Mali podkovnjak *Rhinolophus hipposideros* (Bechstein, 1800) je razširjen po skoraj vsej Sloveniji, kjer prezimuje v podzemnih jamah, porodniške kolonije pa ima večinoma na podstrešjih stavb (Petrinjak 2009). Je ogrožena vrsta, po podatkih iz zadnjih nekaj desetletij pa naj bi se njena številčnost po strmem upadanju stabilizirala ali v nekaterih delih Evrope celo začela povečevati (Schofield 1999, Dietz *et al*. 2009). Poleg svetlobnega onesnaževanja, neustreznih prenov stavb, uporabe pesticidov in jamskega turizma malega podkovnjaka ogroža tudi spreminjanje gozdne krajine (Bontadina *et al*. 2000, Motte & Libois 2002, Petrinjak 2009). V Sloveniji so prehranjevalni habitati malih podkovnjakov slabo poznani, tudi zaradi razmeroma težkega zaznavanja te vrste z ultrazvočnimi detektorji (Petrinjak 2009). Kot druge počasi leteče vrste netopirjev se tudi mali podkovnjaki na svojih letalnih poteh izogibajo odprtim predelom (Ekman & De Jong 1996, Stone *et al*. 2009). Letalne poti so redno uporabljeni letalni koridorji od zatočišč do prehranjevalnih habitatov, ki zaradi mnogih ugodnosti za netopirje pogosto potekajo ob linearnih elementih krajine, kot so žive meje in linije dreves (Verboom & Huitema 1997, Verboom & Spoelstra 1999, Verboom *et al*. 1999). Zaradi stalnosti letalnih poti (Schaub & Scnitzler 2007) pa so te tudi pomemben del učinkovitega varstva netopirjev.

V naši raziskavi smo spremljali kolonijo malih podkovnjakov iz cerkve Svetega Duha v Vnanjih Goricah na Ljubljanskem barju deset dni v avgustu in septembru 2009. S pregledom podstrehe in zvonika smo popisali netopirje v začetku avgusta in ponovno v začetku septembra (ko dela nad zvonovi nismo pregledali). Male podkovnjake smo opazovali med izletavanjem, spremljali smer letenja ter jim sledili z ultrazvočnimi detektorji, dokler nismo izgubili signala. Iz lokacij, kjer smo jih zaznali, smo sklepali na potek letalne poti iz zatočišča in potencialne prehranjevalne habitate.

Mali podkovnjaki imajo porodniško skupino na podstrehi cerkve Svetega Duha, ki je v času pregleda podstrehe 6.8.2009 štela 72 osebkov. V cerkvi v Vnanjih Goricah so bile opažene še tri druge vrste netopirjev, ki so bile na podlagi preteklih raziskav pričakovane: navadni netopir *Myotis myotis*, pozni netopir *Eptesicus serotinus* in usnjebradi uhati netopir *Plecotus macrobullaris* (Presetnik *et al.* 2009a, 2009b). Prvič smo našli večjo skupino usnjebradih uhatih netopirjev. Pri pregledu podstrešja konec avgusta smo našli le 30 malih podkovnjakov in enega usnjebradega uhatega netopirja.

Edina nezamrežena in primerna odprtina za izlet malih podkovnjakov iz podstrešja je okroglo okno premera približno 20 cm na jugozahodni strani cerkve. Prvi netopir je iz te line izletel približno 16 minut po sončnem zahodu. Zatem smo opazili značilno vedenje s kroženjem pred lino in vračanjem v zatočišče za domnevno preverjanje jakosti svetlobe. Prvi netopir je v povprečju izletel iz zatočišča (tako da se ni več vrnil vanj) 20 minut po sončnem zahodu. Netopirji so tik ob cerkvi leteli nizko, do 4 metre visoko, namenjeni naravnost v gozd Gulč na severozahodni strani cerkve. Čeprav se verjetno mali podkovnjaki pri letu skozi ta gozd tudi prehranjujejo, pa so ga vsakič zapustili v razmeroma kratkem času. Male podkovnjake smo zaznali na 9 lokacijah v gozdu in na 6 lokacijah ob robu gozda. Pri iskanju letalnih poti smo jih zaznali tudi ob prometni in osvetljeni cesti ter železniški progi, ki vodi proti Plešivici jugozahodno od cerkve. Na osnovi zabeleženih lokacij in upoštevajoč ugotovitve, da netopirji v splošnem sledijo linearnim elementom v krajini, smo ugotavljali najverjetnejšo letalno pot malih podkovnjakov. Ti se namreč na letalnih poteh izogibajo odprti krajini in osvetljenim predelom (Stone *et al.* 2009), primerni elementi za njihove letalne poti so linije dreves in grmovja, ki rastejo ob osuševalnih jarkih na območju do Plešivice (Schaub & Schnitzler 2007, Zahn *et al.* 2008). Pri tem morajo prečkati nekaj bolj odprtih predelov kot tudi osvetljeno in prometno cesto ter železniško progo. Ker smo male podkovnjake nekajkrat slišali v gozdu na področju Plešivice, najbolj oddaljena lokacija je bila 1,7 km stran od cerkve v Vnanjih Goricah, predvidevamo, da gre najverjetneje za netopirje iz tega kotišča, ta gozd pa bi lahko bil tudi primeren prehranjevalni habitat. V drugih raziskavah je bilo ugotovljeno, da so najpomembnejši prehranjevalni habitati malih podkovnjakov bližnji gozdovi, oddaljeni maksimalno 2,5 do 6,4 km od zatočišča (Schofield 1996, Holzhaider *et al.* 2002, Motte & Libois 2002, Bontadina *et al.* 2002, Zahn & Weiner 2004, Bontadina *et al.* 2006).

Naša raziskava je prispevek k poznavanju ekologije malih podkovnjakov cerkve Svetega Duha v Vnanjih Goricah, čeprav je trajala relativno kratek čas. Za izboljšanje poznavanja kolonije bi bilo treba spremljati kolonijo v drugih delih sezone kot tudi uporabiti dodatne metode (npr. telemetrijo). Za uspešno varstvo malih podkovnjakov je poleg varovanja zatočišča pomembno tudi poznavanje letalnih poti in rabe habitatov v njegovi okolici.

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