Lynx, n. s. (Praha), **52**: 63–78 (2021). ISSN 0024-7774 (print), 1804-6460 (online)

Fauna and flight activity of bats in natural forests in the southern Brdy Mts. and the first information on the occurrence of *Hypsugo savii* in this area (Chiroptera: Vespertilionidae)

Luděk BUFKA[1] & Romana ZACHOVÁ[2]

[1] Administration of the Šumava National Park, Division of Research and Nature Protection, Sušická 399, CZ–341 92 Kašperské Hory, Czech Republic; ludek.bufka@npsumava.cz
[2] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Kamýcká 129, CZ–165 00 Praha-Suchdol, Czech Republic; zachova@fld.czu.cz

received on 8 November 2021

Abstract. The bat fauna was studied at six localities of protected natural forest fragments in the southern part of the Brdy Mts. (south-western Bohemia), in the years 2019–2020. Netting and acoustic detection on line transects were used in order to document the species composition and flight activity of bats at the localities under study. Altogether, 24 individuals of seven bat species were netted. In total, 643 minutes of the presence of flying bats were registered within 56.5 transect hours. With use of these methods, at least 16 bat species were recorded. Of them, *Myotis myotis*, *M. mystacinus* / *M. brandtii*, *M. nattereri*, *Eptesicus nilssonii*, *Pipistrellus pipistrellus*, *Plecotus auritus*, and *Barbastella barbastellus* represent the constant species group with respect to their occurrence at the localities. *Pipistrellus pipistrellus* was the most frequent species (54%), with the highest relative flight activity at all localities. The highest intensity of flight activity of the bat community was observed in habitats with rocks, boulder accumulation, and open stony debris (14.17 min+/h). The highest bat species diversity was registered in habitats with the prevalence of herb-rich mixed beech forest stands (15 species, diversity index H'=2.02; equitability E=0.75). A series of calls of *Hypsugo savii* was registered in the Na skalách Nature Reserve on 8 May 2020. It represents the first finding of this species in the region of the Brdy Mts.

Key words. Chiroptera, bat fauna, species diversity, flight activity, natural forests, *Hypsugo savii*.

INTRODUCTION

Although the research of the bat fauna of the Czech Republic has been traditionally of a high standard, there are territories on a finer spatial and habitat scale from which data are very scant or missing at all. This is the case of the natural forest remnants in the southern part of the Brdy Mts.

In 2019 and 2020, a survey of bat fauna was carried out in small-scale specially protected areas within the Třemšín (southern) part of the Brdy Mts. These reserves represent fragments of natural forest habitats within a more or less compact area of commercial forests with a prevalence of spruce plantations. The survey brings the first systematically collected information on bats in this territory. Although primarily a basic inventory, a large amount of data was eventually collected using standard methods. These data provide a fairly comprehensive overview of the

doi: 10.37520/lynx.2021.005

species composition, occurrence, and flight activity of bats, and allow for a partial comparison of the particular sites and habitats under study.

STUDY AREA

The survey was carried out at model forest localities in the territory belonging to the geomorphological unit "Brdská vrchovina" highlands, more specifically to its southern part, called "Třemšínská vrchovina"

Fig. 1. Schematic map of the study area (grey colour – forests, numbers represent particular localities, see Table 1).

highlands (Hrnčiarová et al. 2009). Several fragments of natural forests have remained preserved at these localities, most of which are currently defined as small-scale specially protected areas and/or Natura 2000 sites (SCI). The whole area under study is currently a part of the Brdy Protected Landscape Area. A total of six localities (small-scale protected areas), located at the altitudes of 592–778 m a. s. l., were subject to the study of bat fauna (Fig. 1). For each locality, the code of the mapping square of the KFME system (Slavík 1971) is given:

1 – Kokšín Nature Reserve (mapping square 6348) – situated on the northern and north-western slopes of the Kokšín hill, at the altitudes of 592–673 m a. s. l. It is located 1.2 km east of Mítov, in the Hořehledy cadastral unit. The nature reserve was established in 1955, its current area is 20.63 hectares. The remnants of natural forest ecosystems, in particular herb-rich beech forests and mixed beech-fir forest stands are among the main protected phenomena there.

2 – Fajmanovy skály and Klenky Nature Reserve (6448) – located on the slopes exposed southwest, around the Fajmanova skála rock, at the altitudes of 688–778 m a. s. l. The location is about 3 km SW of Nové Mitrovice, in the Chynín cadastral unit. The nature reserve was established in 1955, amended in 1991 and 1999; its current area is 30.04 hectares. The area is protected mainly because of the remains of relic pine forests on the lydite rocks and stony debris, and fir-beech-spruce forest stands. Much of the natural growth was strongly influenced or replaced by the Norway spruce and Scotch pine plantations in the past (Zahradnický & Mackovčin 2004).

3 – Chynínské buky Nature Reserve (6448) – lies about 4 km east of Nové Mitrovice, on the south-eastern edge of the Nad Marastkem plateau (ca. 800 m a. s. l.), at the altitude of 730–768 m a. s. l., in the Chynín and Roželov cadastral units. The nature reserve was established in 1933, the last amendment was in 1999 and the current area is 13.99 hectares. It is a well preserved fragment of a natural mixed beech forest. In some parts, the natural age and spatial structure of the forest has been preserved, with a number of old beech remains and dead fallen trunks at various stages of decay. Nevertheless, the absence or suppression of natural rejuvenation by game grazing is evident. The locality is dominated by herb-rich beech forest stands (Zahradnický & Mackovčin 2004).

4 – Míšovské buky Natural Monument (6448) – situated on a slightly bowed northern slope below the Nad Marastkem summit plateau (ca. 800 m a. s. l.) at the altitude of 715–740 m a. s. l. It is located in the Míšov cadastral unit, approx. 2.5 km of Míšov. The protected area was established in 1955, newly designated in 1999, currently with the area of 5.08 hectares. It is a small fragment of natural acidophilous beech forests with scattered fir trees. The forest retains its natural character in some parts, but the Norway spruce is predominant in most of the area. The age and spatial structure of the stands appears to be strongly influenced by the grazing pressure of the game.

5 – Getsemanka Nature Reserve (6348, 6448) – situated on the east to southeast facing slope of a ridge running from the Nad Marastkem plateau, through the Na Burku summit to the settlement of Teslíny, at the altitude of 680–748 m a. s. l. The location is spread over two cadastral units, Hutě pod Třemšínem and Věšín. The nature reserve was established in 1966, the last announcement is from 2013, the current area is 56.64 hectares. The fragments of natural beech and ravine forests are the main protected phenomena. The older (southern) part of the reserve (formerly referred to as Getsemanka I) has a primeval forest-like character, the forest stands in the northern part of the reserve head towards primeval character in terms of conservation objectives.

6 – Na skalách Nature Reserve (6348) – located on a rocky ridge and slopes with a mainly south-eastern exposure. The protected area itself is irregular in shape and extends around the Na skalách spot height. The site lies at the altitudes between 674–746 m a. s. l., ca. 3 km NW of Hutě pod Třemšínem, or ca. 2 km SE of Teslíny, in the Věšín cadastral unit. The nature reserve was established in 1966, revised in 1987, with the current area of 24.04 hectares. The remnants of the natural, in particular acidophilous beech forest ecosystems as well as mosaics of other forest habitats on the rocky ridge and slopes are the main protected phenomena. A part of the natural forest stands has been influenced by artificial support of conifers in the past. Currently, the spruce stands perish of droughts and bark beetles (AOPK 2013, DR ÚSOP 2020).

MATERIAL AND METHODS

The bat survey was conducted in the years 2019 and 2020. Bat occurrence was investigated by the following standard methods (e.g. BCT 2001):

(A) **Netting** (capture of bats in mist-nets). Netting was used as a complementary research method, to record also the species which are more difficult to detect by an ultrasound detector. It was carried out at the following sites on the following dates: at the Kokšín NR (1) on 18 August 2019; at the Fajmanovy skály and Klenky NR (2) on 2 August 2019; at the Chynínské buky NR (3) on 14 August 2019; at the Míšovské buky NM (4) on 30 August and 27 September 2019; at the Getsemanka NR (5) on 25 August and 8 September 2019; at the Na skalách NR (6) on 8 May, 14 and 20 August 2020. The captured individuals were released at the same site after the species and age determination, and recording of basic biometric data.

(B) **Acoustic detection**. Due to the patchy character and the relatively small area of the localities under study, the line transect method was chosen as the optimal method for the survey, in which the localities were walked representatively and all recorded bat calls were continually registered and recorded. The manual Pettersson D240 bat detector and the Zoom H2N digital recorder were used for the survey. The call recordings were subsequently analysed in the BatSound4 software. The time (number of minutes) during which a given species or pair of species was registered per hour transect (min+/h), was used as a measure of the flight activity of bats (McAney & Fairley 1988).
Each bat record or record series was assigned to a prevailing habitat type:

I – stands with a predominance of conifers, especially poor acidophilous beech forests and fir-beech forests with a high proportion of spruce at higher altitudes;

II – deciduous and mixed forest habitats with predominant stands of the character of herb-rich beech and ravine forests;

III – relic pine forests on rocks, rock ridges and open stony debris.

In addition to the number of species identified, species diversity in the particular habitats and localities was expressed using the Diversity Index (Shannon & Weaver 1963) and Equitability (Sheldon 1969). Timing of the study was chosen to capture the flight activity of bats during both the lactation and post-lactation periods at each locality and habitat type. The monitoring was carried out in standard weather conditions without precipitation, strong wind and extreme cold, from the dusk to the midnight (24:00 CET), on the following dates: at the Kokšín NR (1) on 18 May, 3 June, 18 August, and 1 September 2019; at the Fajmanovy skály and Klenky NR (2) on 5 and 7 June, 8 August, and 21 September 2019; at the Chynínské buky NR (3) on 5 June, 15 August 2019; at the Míšovské buky NM (4) on 30 June, 29 July, 30 August, and 27 September 2019; at the Getsemanka NR (5) on 14 June, 26 July, and 25 August 2019; at the Na skalách NR (6) on 8 May, 26 June, 20 August, and 10 October 2020. A general overview of the acoustic detection survey is provided in Table 1.

RESULTS AND DISCUSSION

Species diversity

Altogether, at least 16 species were identified by the methods used (Table 2): *Myotis bechsteinii* (Kuhl, 1817) – Mb, *Myotis myotis* (Borkhausen, 1797) – Mm, *Myotis nattereri* (Kuhl, 1817) – Mn, *Myotis mystacinus* (Kuhl, 1817) and/or *M. brandtii* (Eversmann, 1845) – Ms, *Myotis daubentonii* (Kuhl, 1817) – Md, *Eptesicus nilssonii* (von Keyserling et Blasius, 1839) – En, *Eptesicus serotinus* (Schreber, 1774) – Es, *Vespertilio murinus* Linnaeus, 1758 – Vm, *Hypsugo savii* (Bonaparte, 1837) – Hs, *Pipistrellus nathusii* (von Keyserling et Blasius, 1839) – Pn, *Pipistrellus pipistrellus* (Schreber, 1774) – Pp, *Pipistrellus pygmaues* (Leach, 1825) – Py, *Nyctalus noctula* (Schreber, 1774) – Nn, *Nyctalus leisleri* (Kuhl, 1817) – Nl, *Barbastella barbastellus*

Table 1. An overview of the acoustic detection survey carried out at individual localities and habitats

No.	site	coordinates	monitoring time (min)	positive minutes (min+)	dominance positive of minutes (%)
1	Kokšín	49.6044°N, 13.6757°E	630	103	16.0
2	Fajmanovy skály a Klenky	49.5790°N, 13.7235°E	570	143	22.2
3	Chynínské buky	49.5830°N, 13.7371°E	270	60	9.3
4	Míšovské buky	49.5972°N, 13.7384°E	660	57	8.9
5	Getsemanka	49.5951°N, 13.7537°E	540	133	20.7
6	Na skalách	49.6033°N, 13.7633°E	720	147	22.9
	habitat				
	I		840	70	10.9
	II		1 560	443	68.9
	III		990	130	20.2
	total		3 390	643	100.0

(Schreber, 1774) – Bb, and *Plecotus auritus* (Linnaeus, 1758) and/or *P. austriacus* (Fischer, 1829) – Pa.

A total of 24 individuals of seven bat species were captured using netting at all localities. A list of the captured individuals is provided in Table 3. The presence of 16 species or pairs of species was recorded by an analysis of acoustic detection (Table 4).

Table 2. List of bat species registered at the particular sites (for explanation of the site numbers see Table 1); D – acoustic detection, N – netting; K = constancy (%)

species \ site No.	1	2	3	4	5	6	K (%)
Myotis bechsteinii	D	–	D	–	D+N	N	66.6
Myotis myotis	D+N	D+N	D	D	D	D	100.0
Myotis nattereri	D	D	D+N	D+N	D+N	D	100.0
Myotis mystacinus / M. brandtii	D	D+N	D	D+N	D	D	100.0
Myotis daubentonii	–	–	–	–	D	N	33.3
Eptesicus nilssonii	D	D	D	D	D	D	100.0
Eptesicus serotinus	D	D	D	–	D	D	66.6
Vespertilio murinus	–	D	–	–	D	D	50.0
Hypsugo savii	–	–	–	–	–	D	16.6
Pipistrellus nathusii	D	D	–	–	D	D	66.6
Pipistrellus pipistrellus	D	D+N	D	D	D	D+N	100.0
Pipistrellus pygmaeus	D	–	–	–	–	D	33.3
Nyctalus noctula	D	D	D	–	D	D	66.6
Nyctalus leisleri	–	D	–	–	D	D	50.0
Barbastella barbastellus	D	D	–	D	D	D	83.3
Plecotus sp.	D+N	D+N	D+N	N	D+N	D+N	100.0
total of species	12	12	9	7	14	16	

Table 3. Bats documented by netting (site, date, number, sex)

species	catch
Myotis bechsteinii	Getsemanka (5) – 25 August 2019: 1 ♂; Na skalách (6) – 14 August 2020: 1 ♀
Myotis myotis	Kokšín (1) – 18 August 2019: 1 ♂; Fajmanovy skály a Klenky (2) – 2 August 2019: 1 ♂
Myotis nattereri	Chynínské buky (3) – 14 August 2019: 1 ♂; Míšovské buky (4) – 27 September 2019: 1 ♂; Getsemanka (5) – 8 September 2019: 1 ♂
Myotis mystacinus	Fajmanovy skály a Klenky (2) – 2 August 2019: 1 ♂; Míšovské buky (4) – 30 August 2019: 1 ♂
Myotis daubentonii	Na skalách (6) – 14 August 2020: 1 ♂
Pipistrellus pipistrellus	Fajmanovy skály a Klenky (2) – 2 August 2019: 1 ♂, 1 ♀; Na skalách (6) – 20 August 2020: 1 ♂, 1 ♀
Plecotus auritus	Kokšín (1) – 18 August 2019: 2 ♂♂; Fajmanovy skály a Klenky (2) – 2 August 2019: 1 ♂; Chynínské buky (3) – 14 August 2019: 1 ♂; Míšovské buky (4) – 30 August 2019: 2 ♂♂; Getsemanka (5) – 25 August 2019: 1 ♀, 8 September 2019: 1 ♂; Na skalách (6) – 20 August 2020: 1 ♂

In terms of constancy (sensu Tischler 1947 in Losos et al. 1984) and the prevalence found at the particular localities, seven euconstant bat species were present in all localities, namely *Myotis myotis*, *M. mystacinus* / *M. brandtii*, *M. nattereri*, *Eptesicus nilssonii*, *Pipistrellus pipistrellus*, *Barbastella barbastellus*, and *Plecotus auritus*. On the contrary, *Nyctalus leisleri* and *Vespertilio murinus* fall to the category of accessory species, and *Myotis daubentonii*, *Pipistrellus pygmaeus*, and *Hypsugo savii* as accidental species were present only at two or one of the localities (Table 2).

Forests generally represent an original natural habitat for bats, with numerous structured micro-habitats providing roosts and/or foraging grounds for a number of species (Patriquin & Barclay 2003, Řehák et al. 2007, Brigham 2007). Most of the central-European bat species use, in a species-specific way, the forest environments (see e.g. Meschede & Heller 2000), which is also true of the species found in the Czech Republic. The total number of species recorded at the localities under our study is relatively high for the complex of small-scale forest protected areas of the medium altitudes (590–780 m a. s. l.). In particular, the relatively large species diversity found at these localities may be a result of the high proportion of natural forest habitats and thus a diversified supply of roost and food microhabitats (Jung et al. 2012). The effect of the relatively large forest complex in the southern part of the Brdy Mts. together with the surrounding areas, which are relatively rich and not very fragmented in terms of suitable environment for forest bats, seems to be also important. Larger forest units (over 1000 hectares) are known to be of vital importance for bats in the Central European landscape, with a high species diversity and the presence of dendrophilous species (Řehák et al. 2008).

Hypsugo savii occurrence

The finding of *Hypsugo savii* represents the first evidence of this species from the southern Brdy Mts. and the adjacent areas of western and southern Bohemia. This record comes from the Na

skalách Nature Reserve (6), specifically from the summit ridge area with a number of smaller rock formations and stony debris (Fig. 2). The site has a relatively open character without a tree canopy, whose effect is currently amplified by the decay of stands with the dominating spruce trees in the close surroundings. A series of acoustic signals, corresponding to the flight and hunting of *Hypsugo savii* were registered four times between 21:59–22:40 CET on 8 May 2020. The new finding of *H. savii* in the area under study corresponds with the trend of expansion of this Mediterranean species northwards to Central Europe, documented since the 1990s (e.g. Spitzenberger 1997). This spreading was described in detail first in Austria (Spitzenberger 1997, Reiter et al. 2010b) and then documented in other countries, with newly established populations usually in the proximity of anthropic environments (Spitzenberger 2001, Gaisler & Vlašín 2003, Bartonička & Kaňuch 2006, Lehotská & Lehotský 2006, Danko 2007, Görföl et al. 2007, Reiter et al. 2010a). Within the territory of the Czech Republic, the species was first documented in southern Moravia (Reiter et al. 2010a), then gradually expanding through Moravia to central and northern Bohemia (Bartonička et al. 2017). The spreading is now documented throughout Central Europe (Uhrin et al. 2016, von Woiton et al. 2019). *Hypsugo savii* inhabits primarily natural rock habitats and uses rock crevices as roosts in the Mediterranean part of its distribution range (Horáček & Benda 2004, Kipson et al. 2018). The newly established populations in the northern areas use almost exclusively fissure-like roosts

Table 4. Relative intensity of flight activity of bats (min+/h) and species diversity at individual localities (1–6) and habitats (I–III)

species \ locality – habitat	1	2	3	4	5	6	I	II	III	total	total %
Myotis myotis	0.57	1.26	1.33	0.09	1.44	0.67	0.15	1.12	0.75	0.76	6.7
Myotis bechsteinii	0.10	–	0.44	–	0.22	–	–	0.23	–	0.11	1.0
Myotis nattereri	0.57	0.32	0.89	0.82	0.33	1.17	0.77	0.69	0.63	0.67	5.9
Myotis mystacinus / M. brandtii	0.20	0.42	1.11	0.27	0.44	0.42	0.08	0.54	0.31	0.35	3.1
Myotis daubentonii	–	–	–	–	0.22	–	–	0.15	0.13	0.11	1.0
Myotis sp.	–	0.30	–	–	0.33	0.16	0.08	0.12	0.25	0.14	1.2
Eptesicus serotinus	0.10	0.11	0.44	–	0.44	0.33	–	0.31	0.19	0.19	1.7
Eptesicus nilssonii	0.20	1.90	0.89	0.55	2.11	1.00	0.54	1.15	1.31	1.04	9.2
Hypsugo savii	–	–	–	–	–	0.42	–	–	0.25	0.09	0.7
Pipistrellus nathusii	0.40	0.32	–	–	1.22	0.25	–	0.69	0.13	0.37	3.3
Pipistrellus pipistrellus	5.80	6.11	13.33	2.55	5.89	6.42	2.69	6.46	8.90	6.11	54
Pipistrellus pygmaeus	0.10	–	–	–	–	0.08	–	0.04	0.06	0.04	0.4
Pipistrellus sp.	–	–	–	–	0.11	–	–	0.04	–	0.02	0.2
Nyctalus noctula	1.33	0.21	1.11	–	0.11	0.42	–	0.69	0.38	0.43	3.8
Nyctalus leisleri	–	0.11	–	–	0.78	0.25	–	0.35	0.13	0.19	1.7
Nyctalus sp.	–	0.32	0.22	–	–	–	–	0.04	0.19	0.07	0.6
Vespertilio murinus	–	0.42	–	–	0.11	0.08	–	0.04	0.31	0.11	1.0
Barbastella barbastellus	0.10	0.11	–	1.18	0.78	0.08	1.00	0.30	0.06	0.39	3.4
Plecotus sp.	0.20	0.21	0.44	–	0.22	0.08	0.15	0.15	0.19	0.12	1.1
total	9.67	12.12	20.2	5.46	14.75	11.83	5.46	13.11	14.17	11.31	100
number of species (pairs)	12	12	9	6	14	14	7	15	15	16	
diversity index H’	1.47	1.56	1.30	1.06	1.97	1.54	1.49	2.02	1.58	1.76	
equitability E	0.59	0.63	0.59	0.59	0.75	0.58	0.76	0.75	0.59	0.63	

Fig. 2. The locality Na Skalách – the site of finding of the Savi's bat (*Hypsugo savii*) on 8 May 2020. Photo by L. Bufka.

in the man-made structures. The connection with human settlements is mostly understood as a driver of the species expansion in the northern direction (Uhrin et al. 2016). Some authors, however, stress that climate warming primarily encourages the expansion of its distribution rather than synurbization (Ancillotto et al. 2018). Telemetry shows that the occurrence and spatial behaviour of *H. savii* in the newly occupied areas cannot be simply interpreted as syn-anthropically centered, as the bat uses roosts in the urban environments on one hand, but the hunting habitats are almost exclusively in the surrounding landscape and semi-natural habitats on the other hand (Ancillotto et al. 2018, von Woiton et al. 2019). Given the dynamics of the species expansion, the presence of *H. savii* can be expected also in other areas of the Czech Republic, probably not only in urban and suburban environments, as shown by our finding from a natural habitat in the middle of a larger forest unit.

Foraging activity

A total of 643 minutes of flight activity of bats was recorded during 56.5 hours of acoustic detection on line transects at six localities under study. The highest overall intensity of flight activity of bats was observed in the habitat type III with the presence of rocks and open stony debris (14.17 min+/h; Figs. 3, 4). Comparably high levels of the flight activity were also registered in the habitat type II, i.e. in the herb-rich mixed beech and ravine forests (13.11 min+/h). Conversely, the relatively least used habitat was the poor acidophilous beech forest with a high proportion of spruce (5.46 min+/h). In terms of specific localities, the highest level of flight activity of bats was recorded in the Chynínské buky NR (3; 20.2 min+/h) and the Getsemanka NR (5; 14.75 min+/h), while the lowest value was registered in the Míšovské buky NM (4; 5.46 min+/h).

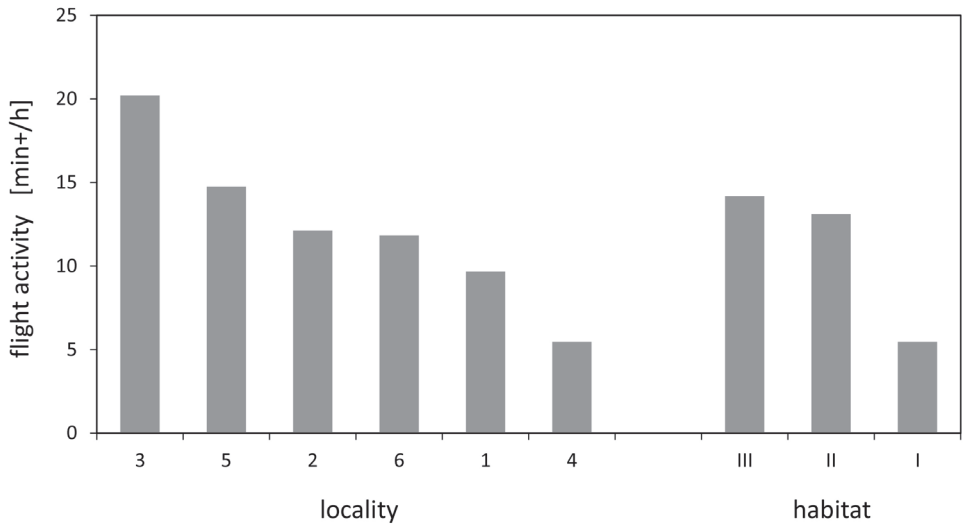

Fig. 3. Total relative intensity of flight activity of bats at the localities and habitats under study.

Fig. 4. Relic pine forests on rocks, rock ridges and open stony debris represent an important habitat type within the study area, with the relatively highest flight activity of bats. Photo by L. Bufka.

Analysing the whole data set, the highest flight activity was observed in *Pipistrellus pipistrellus* (mean 6.11 min+/h). The registered activity for this species was significantly higher than for all other species, in almost all localities and in all habitat types under study (Fig. 5). Other species with a relatively high flight activity were *Eptesicus nilssonii* (1.04 min+/h), *Myotis myotis* (0.76 min+/h), *M. nattereri* (0.67 min+/h), *Nyctalus noctula* (0.43 min+/h), *Barbastella barbastellus* (0.39 min+/h), *Pipistrellus nathusii* (0.37 min+/h), *Myotis mystacinus / M. brandtii* (0.35 min+/h). On the other hand, *Eptesicus serotinus* was registered uncommonly (0.19 min+/h), as well as *Nyctalus leisleri* (0.19 min+/h*), Plecotus* sp. (0.12 min+/h), *Myotis daubentonii* (0.11 min+/h), *M. bechsteinii* (0.11 min+/h), and *Vespertilio murinus* (0.11 min+/h). *Pipistrellus pygmaeus* (0.04 min+/h) and *Hypsugo savii* (0.09 min+/h) were detected only rarely.

The habitat type of the predominant herb-rich beech and ravine forests represented the species richest type of environment in terms of flight activity of bats. In total, 15 species or pairs of species were identified there (diversity index H'=2.02; equitability E=0.75; Table 4, Fig. 7). There was a relatively high proportion of *Myotis myotis*, *M. mystacinus / M. brandtii*, *M. bechsteinii*, *Nyctalus noctula*, *N. leisleri*, and *Pipistrellus nathusii* in this habitat compared to the overall distribution of the intensity of flight activity of individual species (Fig. 6). This finding corresponds with the known fact that the preserved natural mixed beech forests (as a potential natural vegetation type in most of the Czech Republic) generally represent an important habitat type for bats, and are inhabited by a large number of bat species (Řehák et al. 2007). The stands of herb-rich mixed beech forest within the localities under study are highly diverse in terms of age and spatial structure, including spontaneous dynamics in space and time (in general, the presence and activity of bats increases with increasing heterogeneity of structural parameters of the forest; see e.g. Jung et al. 2012). This increases the attractiveness of this habitat type for bats by offering the roosting and foraging microhabitats.

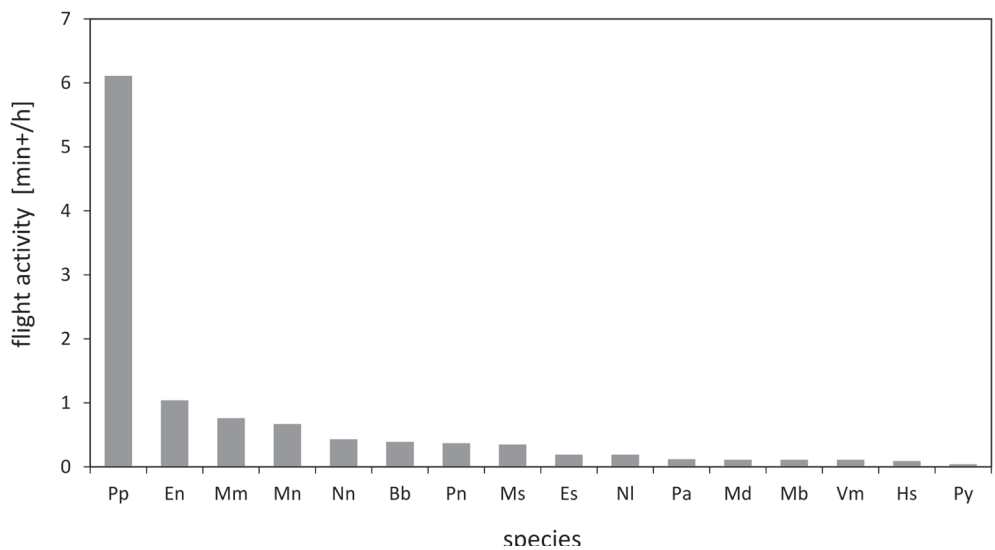

Fig. 5. The relative intensity of flight activity of individual bat species in the study area (all localities pooled, for species abbreviations see the text).

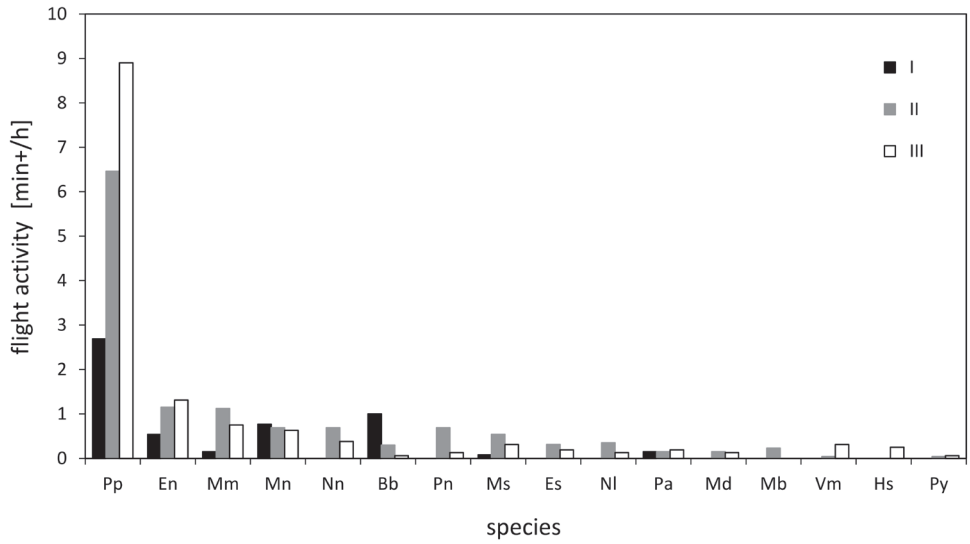

Fig. 6. The relative flight activity of individual bat species in three habitat types under study.

Fig. 7. The highest species diversity of bats was found in the predominant herb-rich mixed beech and ravine forests (Kokšín Nature Reserve). Photo by L. Bufka.

The high species diversity was also found in the habitat type III – relic pine forests on rocks, rock ridges and open stone debris. In total, 15 species were found there as well, but with a lower equitability of their quantitative representation (H'=1.58, E=0.59). *Pipistrellus pipistrellus* and *Eptesicus nilssonii* significantly dominated and the occurrence of *Hypsugo saviii* was found only in this habitat type. These habitats usually offer a structured environment with a large number of crevice roosts and, in some circumstances, can probably provide a rich food supply. It is worth to note the direct observation of an intense foraging of several individuals of *Pipistrellus pipistrellus* around the highly heated rock formations at the Fajmanovy skály and Klenky NR (2) on 2 August 2019 (Fig. 8).

A relatively balanced composition of the bat community, but with a significantly low species diversity comprising only seven species, was recorded in the habitat type I – poor acidophilous beech forests and fir-beech forests with a high proportion of spruce at higher altitudes (H'=1.49; E=0.76). There was a relatively low dominance of *Pipistrellus pipistrellus* and, conversely, a high representation of *Barbastella barbastellus* compared to other habitats. This pattern corresponds with the results of previous studies. For example, within the study comparing bat communities in different (semi)natural forests at different altitudes in the Czech Republic, a relatively low species diversity as well as total foraging activity was found in the forests at altitudes above 700 m a. s. l. with a high proportion of spruce. The lack of food supply in these climatically

Fig. 8. Rocks and open stony debris offer a structured environment with a large number of roost opportunities, warm rocks can attract a rich food supply (Fajmanovy skály a Klenky Nature Reserve; 23 October 2021). Photo by L. Bufka.

unfavourable conditions, as well as the low supply of roosting opportunities in spruce forest stands are stated as the main reason by various authors (see Řehák et al. 2007, Bartonička et al. 2015).

Assessing the species diversity at the particular localities, the highest value was found in the Getsemanka NR (5; 14 species, H'=1.97; E=0.75) and in the Na Skalách NR (6; 14 species, H'=1.54; E=0.58). A relatively high species diversity was also observed in the Kokšín NR (1; 12 species, H'=1.47; E=0.59) and the Fajmanovy Skály and Klenky NR (2; H'=1.56; E=0.63). In contrast, a smaller species number and lower diversity were found in the Chynínské buky NR (3; 9 species, H'=1.3; E=0.59) and the lowest values were recorded in the Míšovské buky NM (4; 6 species, H'=1.06; E=0.59; Table 4). The intensity of foraging activity and species diversity at each locality undoubtedly corresponds to the representation of the habitat type (see above). Furthermore, the species diversity at the particular localities is probably also positively influenced by the size of the particular protected area, or also by the proximity or connection with another area – in our particular case, proximity of the Getsemanka NR (5) and the Na Skalách NR (6).

CONCLUSIONS

Relatively species-rich communities of bats were found during our survey in natural forest fragments of the southern part of the Brdy Mts. At least 16 bat species were identified at the six localities, which are listed as small-scale specially protected areas. This result has confirmed the great importance of these sites, which represent a natural forest environment for bats, with an abundant and structured micro-habitats, wide range of roosting and foraging opportunities. Herb-rich mixed beech and ravine forests were the species richest type of environment in terms of foraging activity of bats, while the lowest species diversity was found in acidophilous beech and fir-beech forests with a high proportion of spruce. This broadly corresponds to the findings of species diversity and foraging activity of bats in various natural and semi-natural forest habitats in different altitudes in the Czech Republic. Rocks and stony debris may be very important structures and habitats for bats in the study area. The relatively high species diversity and the highest intensity of flight activity were detected in this habitat type. It offers a rich-structured space with a large number of potential crevice roosts. The warm rock formations can be probably attractive for some insects and other invertebrates and so, they can provide a good food supply for bats. An important aspect in terms of bat foraging is not only the representation of individual habitat types, but also, presumably, the size of particular reserves and their proximity to each other within large and compact forest units. Also, on the larger landscape scale, the existence of relatively varied, wooded, and rather extensively human-used adjacent areas can contribute to the local rich composition of bat fauna. The confirmed occurrence of *Hypsugo savii* represents the first finding of this species in the study area and adjacent regions. It is also interesting as the record was made in a relatively large and compact forest.

SOUHRN

Fauna a letová aktivita netopýrů v přirozených lesích jižních Brd a první informace o výskytu netopýra Sáviova (*Hypsugo savii*) v tomto území (Chiroptera: Vespertilionidae). Průzkumem bylo zjištěno poměrně druhově bohaté společenstvo netopýrů využívajících fragmenty přirozených lesů jižních Brd. Celkem na šesti lokalitách, které jsou vedeny jako maloplošná zvláště chráněná území, bylo zjištěno minimálně16 druhů netopýrů. Potvrdil se tak velký význam těchto lokalit, které představují přirozené

lesní prostředí pro netopýry, s množstvím strukturovaných mikrostanovišť a škálou úkrytových možností a dobrých potravních podmínek. Druhově nejbohatším typem prostředí z hlediska letové aktivity netopýrů byla stanoviště typu převažujících květnatých bučin a suťových lesů, naopak druhově chudé byly kyselé bučiny a jedlové bučiny s vysokým podílem smrku. To rámcově odpovídá zjištěním o druhovém zastoupení a letové aktivitě netopýrů v různých přirozených a polopřirozených lesních stanovištích a v různých nadmořských výškách v České republice. Velmi důležitými strukturami a stanovišti ve studovaném území jsou skály a kamenná moře, kde byla zjištěna také poměrně vysoká druhová diverzita a vůbec nejvyšší intenzita letové aktivity. Tato stanoviště obvykle nabízejí bohatě strukturovaný prostor s velkým množstvím štěrbinových úkrytů a za určitých okolností patrně vysokou potravní nabídku. Důležitým aspektem z hlediska využívání netopýry je nejen zastoupení jednotlivých typů stanovišť, ale patrně také velikost jednotlivých rezervací a jejich vzájemná poloha uvnitř větších kompaktních lesních celků. Také návaznost na poměrně pestrou, lesnatou, a lidmi spíše extenzivně využívanou krajinu v širším okolí může přispívat k bohatšímu lokálnímu složení netopýří fauny. V rámci průzkumu byl akustickou detekcí zjištěn výskyt netopýra Saviova (*Hypsugo savii*), což je první nález pro vlastní Brdy a také prozatím pro celou navazující oblast západních a jižních Čech.

Acknowledgements

The research was supported within the project "Monitoring and mapping of selected species of plants and animals and inventory of small-scale specially protected areas in nationally important areas in the Czech Republic" (# EIS: CZ.05.4.27/0.0/0.0/17_078/0005239). The authors are grateful to Tomáš Bartonička (Masaryk University Brno), Radek Lučan (Charles University Prague), and Martin Brejška (Prague) for consultations on the call identification of *Hypsugo savii*.

REFERENCES

AOPK ČR [Agentura ochrany přírody a krajiny ČR], 2013: *Rozbory Chráněné krajinné oblasti Brdy* [*Analyses of the Brdy Protected Lanscape Area*]. Unpubl. manuscript. AOPK ČR, Praha, 170 pp (in Czech).

Ancillotto L., Budinski I., Nardone V., Di Salvo I., Della Corte M., Bosso L., Conti P. & Russo D., 2018: What is driving range expansion in a common bat? Hints from thermoregulation and habitat selection. *Behavioural Processes*, **157**: 540–546.

BCT [Bat Conservation Trust], 2001: *The UK's National Bat Monitoring Programme. Final Report 2001*. DEFRA, Norwich, 156 pp.

Bartonička T. & Kaňuch P., 2006: Savi's pipistrelle (*Hypsugo savii*): bat species breeding in the Czech Republic (Chiroptera: Vespertilionidae). *Lynx*, *n. s.*, **31**: 19–21.

Bartonička T., Řehák Z., Flousek J. & Furmankiewicz J., 2015: *Netopýři českých a polských Krkonoš / Nietopierze czeskich i polskich Karkonoszy* [*Bats of the Czech and Polish Krkonoše Mts*.]. Správa KRNAP & Dyrekcja KPN, Vrchlabí & Jelenia Góra, 184 pp (in Czech and Polish, with a summary in English).

Bartonička T., Benda P. & Juda J., 2017: První nálezy a fenologie netopýra Saviova (*Hypsugo savii*) na Děčínsku (Chiroptera, Vespertilionidae) [First findings and phenology of *Hypsugo savii* in the Děčín District, Czech Republic (Chiroptera, Vespertilionidae]. *Lynx*, *n. s.*, **48**: 5–14 (in Czech, with an abstract in English).

Brigham R. M., 2007: Bats in forests: what we know and what we need to learn. Pp.: 1–15. In: Lacki M. J., Hayes J. P. & Kurta A. (eds.): *Bats in Forests*: *Conservation and Management*. The John Hopkins University Press, Baltimore, 318 pp.

Danko Š., 2007: Reprodukcia *Hypsugo savii* a *Pipistrellus kuhlii* na východnom Slovensku: ďalšie dôkazy o ich šírení na sever [Reproduction of *Hypsugo savii* and *Pipistrellus kuhlii* in eastern Slovakia: further evidence of their spreading northwards]. *Vespertilio*, **11**: 13–24 (in Slovak, with an abstract in English).

DR ÚSOP [Digitální registr ústředního seznamu ochrany přírody], 2020: *Digitální registr ústředního seznamu ochrany přírody* [*A Digital Database of the Central List of the Nature Protection*]. URL: https://drusop. nature.cz (in Czech).

Gaisler J. & Vlašín M., 2003: Second record of the Savi's pipistrelle *Hypsugo savii* in the Czech Republic. *Vespertilio*, **7**: 181–182.

Görföl T., Dombi I. & Zsebők S., 2007: Az alpesi denevér (*Hypsugo savii* Bonaparte, 1837) Magyarországon – a faj hazai adatainak áttekintése, új eredmények [Savi's pipistrelle (*Hypsugo savii* Bonaparte, 1837) in Hungary – review of Hungarian data and new results]. Pp.: 85–97. In: Molnár V. (ed.): *Az V. Magyar Denevérvédelmi Konferencia* (*Pécs*, *2005. december 3–4*.) *és a VI. Magyar Denevérvédelmi Konferencia* (*Mártély*, *2007. október 12–14*.) *kiadványa* [*Proceedings of the 5th Conference on the Bat Conservation in Hungary* (*Pécs*, *3–4 December 2005*) *and the 6th Conference on the Bat Conservation in Hungary* (*Mártély*, *12–14 October 2007*)]. CSEMETE Egyesület, Szeged (in Hungarian).

Horáček I. & Benda P., 2004: *Hypsugo savii* (Bonaparte, 1837) – Alpenfledermaus. Pp.: 911–941. In: Krapp F. (ed): *Handbuch der Säugetiere Europas*. *Band 4*: *Fledertiere*. *Teil II*: *Chiroptera II*. *Vespertilionidae 2*, *Molossidae*, *Nycteridae*. Aula-Verlag, Wiebelheim, 605–1186 pp.

Hrnčiarová T., Mackovčin P. & Zvara I. (eds.), 2009: *Atlas krajiny České republiky* [*Landscape Atlas of the Czech Republic*]. Ministerstvo životního prostředí ČR & Výzkumný ústav Silva Taroucy pro krajinu a okrasné zahradnictví, Praha & Průhonice, 332 pp (in Czech).

Jung K., Kaiser S., Böhm S., Nieschulze J. & Kalko E. K. V., 2012: Moving in three dimensions: effects of structural complexity on occurrence and activity of insectivorous bats in managed forest stands. *Journal of Applied Ecology*, **49**: 523–531.

Kipson M., Šálek M., Lučan R., Uhrin M., Maxinová E., Bartonička T., Andreas M., Kipson K., Pušić A., Rnjak D., Naďo L. & Horáček I., 2014: Foraging habitat, home-range size and diet of a Mediterranean bat species, Savi' pipistrelle. *Acta Chiropterologica*, **20**: 351–360.

Lehotská B. & Lehotský R., 2006: First record of *Hypsugo savii* (Chiroptera) in Slovakia. *Biológia*, *Bratislava*, **61**: 192.

Losos B. (ed.), 1984: *Ekologie živočichů* [*Animal Ecology*]. Státní pedagogické nakladatelství, Praha, 316 pp (in Czech).

McAnney M. C. & Fairley J. S., 1988: Habitat preference and overnight and seasonal variation in the foraging activity of the lesser horseshoe bats. *Acta Theriologica*, **33**: 393–402.

Meschede A. & Heller K. G., 2000: *Ökologie und Schutz von Fledermäusen in Waldern*. *Schriftenreihe für Landschaftspflege und Naturschutz 66*. Bundesamt für Naturschutz, Münster, 374 pp.

Patriquin K. J. & Barclay R. M. R., 2003: Foraging by bats in cleared, thinned and unharvested boreal forest. *Journal of Applied Ecology*, **40**: 646–657.

Reiter A., Bartonička T., Lučan R. K. & Řehák Z., 2010a: New records of *Hypsugo savii* in the Czech Republic. *Vespertilio*, **13–14**: 121–125.

Reiter G., Wegleitner S., Hüttmeir U. & Pollheimer M., 2010b: Die Alpenfledermaus, *Hypsugo savii* (Bonaparte 1837), in Mitteleuropa. *Nyctalus* (*N. F.*), **15**: 158–170.

Řehák Z., Bartonička T., Zukal J., Simprová P. & Džingozovová Ž., 2007: Flight activity of bats in a forest. P.: 198. In: Bryja J., Zukal J. & Řehák Z. (eds.): *Zoologické dny Brno 2007. Sborník abstraktů z konference 8.–9. února 2007* [*Zoological Days Brno 2007*. *Proceedings of Abstracts of the Conference held on 8–9 February 2007*]. Ústav biologie obratlovců AV ČR, Brno, 224 pp.

Řehák Z., Bartonička T., Džingozovová-Horáčková Ž. & Zukal J., 2008: *Sledování vlivu fragmentace lesních porostů na společenstva netopýrů* [*The Influence of Forest Fragmentation on the Bat Communities*]. Unpubl. Final Report. Czech Bat Conservation Trust, Praha, 33 pp (in Czech).

Shannon C. E. & Weaver W., 1963: *The Mathematical Theory of Communication*. University Illinois Press, Urbana, 144 pp.

Sheldon A. L., 1969: Equitability indicies: Dependence on the species count. *Ecology*, **50**: 466–467.

Slavík B., 1971: Metodika síťového mapování k připravovanému fytogeografickému atlasu ČSR [Methods of grid mapping to proposed phytogeographical atlas of the Czech Republic]. *Zprávy České Botanické Společnosti*, **6**: 55–62 (in Czech, with a summary in German).

Spitzenberger F., 1997: Distribution and range expansion of Savi's bat (*Hypsugo savii*) in Austria. *Zeitschrift für Säugetierkunde*, **62**: 179–181.

Spitzenberger F., 2001: *Die Säugetierfauna Österreichs*. Bundesministrerium für Land- und Forstwirtschaft Umwelt und Wasserwirtschaft, Graz, 896 pp.

Uhrin M., Hüttmeir U., Kipson M., Estók P., Sachanowicz K., Bücs S., Karapandža B., Paunović M., Presetnik P., Bashta A. T., Maxinová E., Lehotská B., Lehotský R., Barti L., Csösz I., Szadoray-Paradi F., Dombi I., Görföl T., Boldogh S. A., Jére C., Pocora I. & Benda P., 2016: Status of Savi's pipistrelle *Hypsugo savii* (Chiroptera) and range expansion in Central and south-eastern Europe: a review. *Mammal Review*, **46**: 1–16.

von Woiton A., Kühn N., Helbig-Bonitz M., Held M., Henrichmann C., Kerth C., Kunth J., Ludwig M. & Ohlendorf B., 2019: Erstnachweis der Alpenfledermaus (*Hypsugo savii* Bonaparte, 1837) mit Reproduktionsstatus in Leipzig. *Nyctalus* (*N. F.*), **19**: 230–245.

Zahradnický J. & Mackovčin P. (eds.), 2004: Plzeňsko a Karlovarsko [The Plzeň and Karlovy Vary Regions]. In: Mackovčin P. & Sedláček M. (eds.): *Chráněná území ČR. Svazek XI* [*Protected Areas of the Czech Republic. Volume XI*]. Agentura ochrany přírody a krajinyČR a EkoCentrum Brno, Praha, 588 pp (in Czech).