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Occupancy of bat boxes in coniferous forests of western Bohemia (Czech Republic)

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Abstract. Occupancy of bat boxes and species composition of bats inhabiting bat boxes were studied in coniferous submontane forests in western Bohemia, Czech Republic, in 2011–2016. Altogether 147 boxes of three different types were installed; 32 big narrow wooden boxes, 30 small narrow wooden boxes and 85 cylindric woodcrete boxes. The occupancy rate of the boxes varied greatly depending on the box type, length of their exposure, and the season of a year. The boxes were occupied by bats most frequently in August and September. The largest differences in box occupancy were found in the period August–October (the boxes were monitored in this period at least twice in two different years): the occupancy was 71% in big wooden boxes, 53% in woodcrete and 12% in small wooden boxes. If bat droppings are also considered, the occupancy of woodcrete boxes was even 85% (the bat droppings fall out from the other two box types). Species composition of bats inhabiting the boxes varied greatly in accordance to the box type. *Pipistrellus pipistrellus*, *Myotis brandtii* and *M. mystacinus* prevailed in the wooden boxes, only *P. pipistrellus* dominated in the woodcrete boxes. Nine bat species were recorded in total: *Pipistrellus pipistrellus*, *Myotis brandtii*, *M. mystacinus*, *M. nattereri*, *M. daubentonii*, *Vespertilio murinus*, *Pipistrellus nathusii*, *Nyctalus leisleri*, and *Plecotus auritus*. No maternity colonies were found in the boxes. At least in *Pipistrellus pipistrellus*, the boxes were used frequently by mating harems formed by the same individuals in the consequent years (the individual identification was proven by banding).

Bat boxes, occupancy, coniferous forest, *Pipistrellus pipistrellus*, *Myotis brandtii*, *Myotis mystacinus*

Introduction

One of the key constraints affecting tree roosting bat populations is the quality and number of the roost sites (Zahn 1999, Kalcounis-Rüppel et al. 2005). The forest managed in a traditional way, using a clear-cutting system and the prevailing artificial regeneration, does not comprise trees with hollows, fissures or decortiating bark which provide potential roosts. To mitigate negative influence of the loss of natural roosts, artificial shelters have been installed increasingly in some regions and bat boxes have become a common management tool (Goldingay & Stevens 2009, Mering & Chambers 2012, Dodds & Bilston 2013, Rueegger 2016).

There is a great variety of bat boxes, which vary widely in dimensions, material, number of chambers or entrance location. The bat box design can affect efficiency of this management tool significantly (Tuttle et al. 2013, Dodds & Bilston 2013). Numerous studies aimed at the use of bat boxes have been undertaken in various habitats in diverse geographical areas occupied by different bat species with different ecological requirements. Despite that, the bat box design preference studies are relatively scarce with only nine studies from Europe (Rueegger 2016). Low number of studies is available from Central Europe – despite the fact that the installation of bat boxes

has a long history there and, e.g. in the Czech Republic, hundreds of bat boxes are put up anually (according to our communication with the major distributors and producers).

Our study reveals the level of bat box occupancy in a coniferous forest as recorded by a six year monitoring (2011–2016). The aim of the project was to increase roosting opportunities for bats in regions with deficiency of natural tree roosts. Although our project is at the beginning, these first results can provide some conclusions, mainly the comparison of efficiency of different bat box types.

Material and Methods

The bat boxes were installed in the Slavkovský Les Protected Landscape Area, its surroundings and in two nature reserves – Soos and Lužní potok – localised westwards of the PLA, all situated in western Bohemia (Figs. 1, 2).

In total, 147 bat boxes were installed: 32 big wooden boxes (WB-type), 30 wooden small boxes (WS-type) and 85 woodcrete boxes (C-type: 51 subtype 2F, 17 subtype 2FN and 17 subtype 3FN), see Table 1 and Figs. 3–10. The number

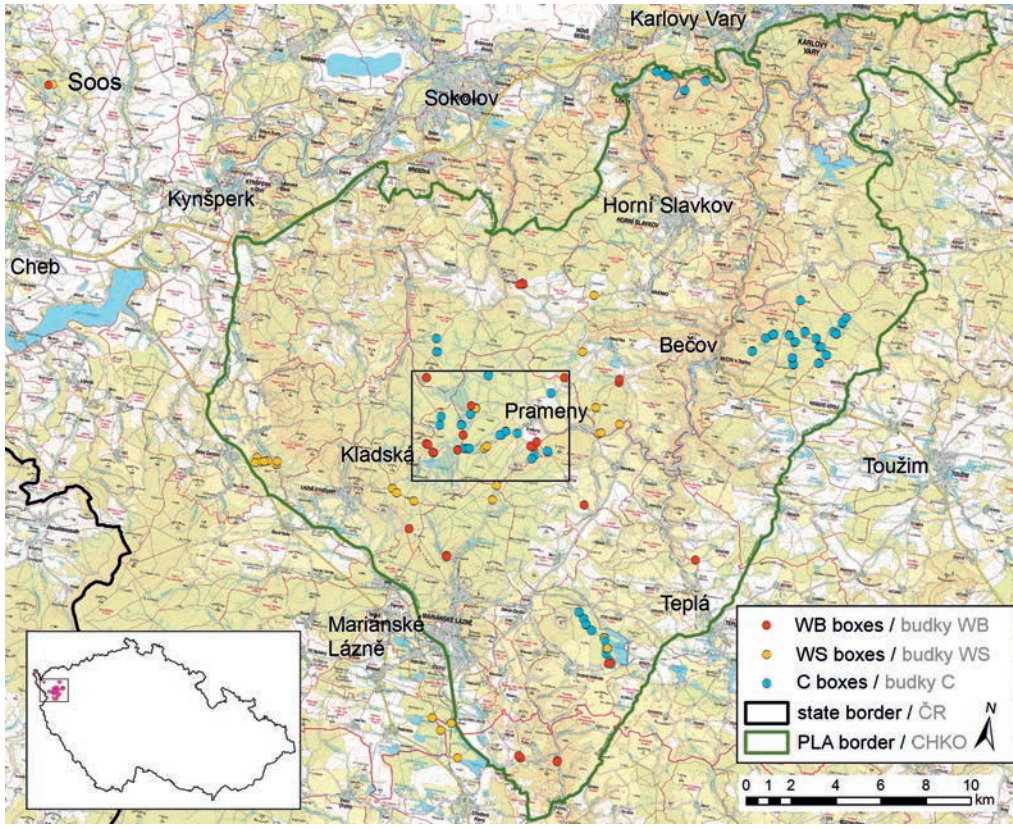

Fig. 1. The study area with localisation of the monitored bat boxes. The area defined by rectangle in the central part of the region is shown in a larger scale at Fig. 2.
Obr. 1. Studovaná oblast a umístění sledovaných budek. Střední část území zvýrazněná obdélníkem je zobrazena ve větším měřítku na obr. 2.

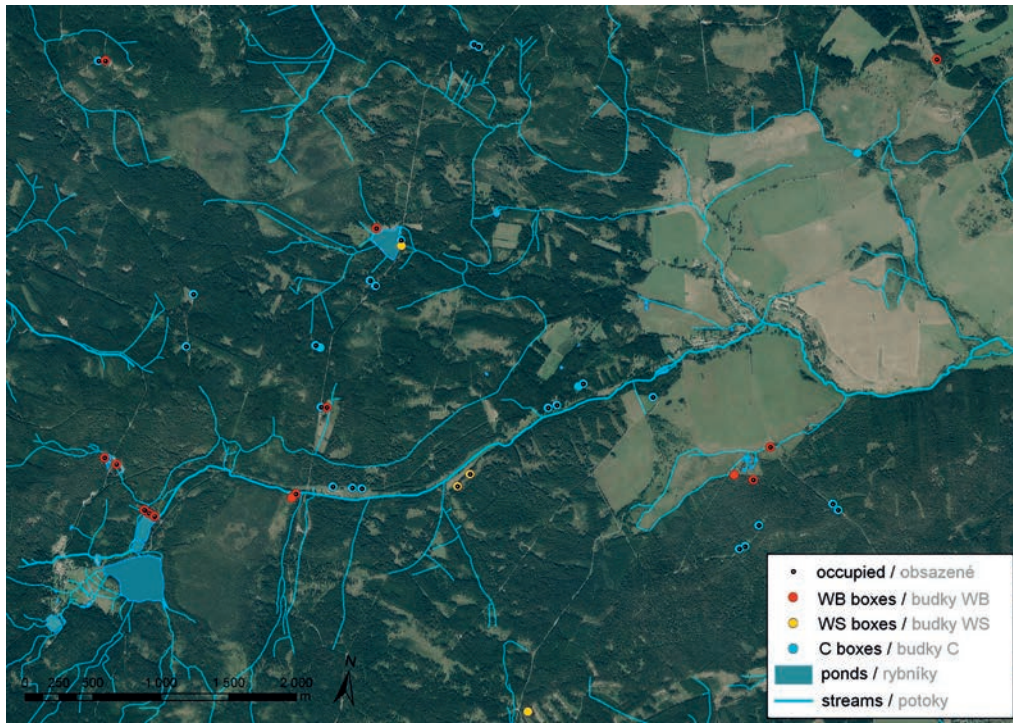

Fig. 2. The central part of the study area in the Slavkovský Les Protected Landscape Area – forests near Kladská and Prameny. The boxes were placed near water bodies (highlighted) and at forest edges.
Obr. 2. Střední část studované oblasti ve Slavkovském lese – lesy mezi v okolí Kladské a Pramenů. Budky byly umisťovány poblíž vodních ploch (zvýrazněna) a lesních okrajů.

and the diversity of used type (design) of the bat boxes increased during the study. In fact, the number of installed boxes was higher, but some of them were destroyed by logging or stolen in the first year. The boxes were put up in October or November. The altitude ranged between 382 and 875 m a. s. l., but 80% of the boxes were placed in 600–875 m a. s. l. (300–400 m: 5%, 400–500 m: 2%, 500–600 m: 11%, 600–700 m: 23%, 700–800 m: 36%, 800–900 m: 21%). The mean annual temperature for most of the study area is 5–7 °C, the mean January temperature is –3 to –5 °C, the mean July temperature is 15–17 °C, the annual precipitation is 600–800 mm (ČHMÚ 2016).

The bat boxes were installed following the rules recommended by previous studies (Tuttle 2005, White 2004, Dillingham et al. 2003): at the height of 4–6 m above the ground, at sunny places, especially at forest edges with southern, southeastern or southwestern expositions. Out of the total, 138 bat boxes were placed on tree trunks, seven on electricity posts and two on haylofts. The boxes were almost exclusively installed in areas with large and traditionally managed coniferous forests – on forest edges, at margins of forest clearings or at clearings along forest roads, and a close proximity of water bodies was highly preferred (Figs. 12–17). An important factor for the box site selection was also an easy access to enable frequent checks of the boxes. The woodcrete boxes were installed in five transects in four large forest complexes (Fig. 1). Two transects westwards and northwards of the Prameny village lead through traditionally managed forests and swampy spruce forests, the transect southwards of Prameny leads through a serpentinite pine forest, the transect westwards of Teplá leads along the bank of the Podhora water reservoir in a traditionally managed spruce forest and the transect eastwards of Bečov goes through a traditionally managed forest complex with pine and spruce. The boxes were usually placed in groups of two or three (10–20 m from each other). All types of boxes were checked in late August and in September and occasionally also in the period from March till November (Table 2). Most of the WB-type boxes were checked regularly for six years, WS-type for five years and C-type for one to three years.

Table 1. Studied types of bat boxes – specification, number and year of installation.
Tab. 1. Sledované typy budek – popis, počty a roky jejich vyvěšení v terénu.

box type typ budky	subtype podtyp	dimensions [cm / kg] rozměry [cm / kg]	description popis	since od roku	n počet
WB	–	width / šířka 60.5 height / výška 50.5 depth / hloubka 10 weight / váha 10	wooden box made from 3 cm thick boards, covered by tar paper (front and back side) and by galvanized sheet (sides and top); / dřevěná budka z 3 cm silných nehoblovaných prken, přední a zadní strana překrytá asfaltovou lepenkou, boky a horní strana pozinkovaným plechem; inner size / vnitřní rozměry 52×43×3.2–1.4 cm (narrower in the upper part / užší v horní části); entrance / vchod 52×3.2 cm. removed upper front part / odnímatelná přední horní část	2010 2011 2013	27 3 2
WS	–	width / šířka 25 height / výška 70 depth / hloubka 8.7	wooden box made from 1.7–2 cm thick boards; dřevěná budka z 1,7–2 cm tlustých prken. inner size / vnitřní rozměry 38×21×5.4 cm; entrance / vchod 21×3.2 cm; additional modifications: openable roof or front segment, lath above entrance inside the box / další úpravy: otevírací střecha nebo přední segment, lať zužující prostor těsně nad výletovým otvorem	2011 2013 2014	26 2 2
C	2F Schwegler	Ø 16 height / výška 36 weight / váha 4.3	woodcrete box with conical top and one front entrance / dřevobetonová budka s kuželovitou horní částí a jedním výletovým otvorem v přední části.	2013	51
C	2FN Schwegler	Ø 16 height / výška 36 weight / váha 4.3	woodcrete box with domed top and two entrances (front and bottom), partly selfcleaning; both entrances 18 mm wide; partly selfcleaning / dřevobetonová budka s polokulovitou horní částí a se dvěma výletovými otvory (přední a spodní); oba výletové otvory 18 mm široké; částečně samočistící	2015	17
C	3FN Schwegler	Ø 16 height / výška 36 weight / váha 4.9	woodcrete box with domed top and two entrances (front and bottom, wider than in 2FN), partly selfcleaning; front entrance 26 mm wide, bottom entrance 33 mm wide / přední výletový otvor 26 mm široký, spodní 33 mm; částečně samočistící	2015	17

For the WB- and WS-types, the presence or absence of bats was determined by shining by a strong torch lamp into the box crevice from below (from the ground). The C-type boxes were checked by opening the front segment of the boxes (from a ladder). During each check of the C-type box, the presence of bat droppings was recorded as an indication of

Figs. 3–10. Fig. 3. A scheme of the big wooden bat box (WB-type). Figs. 4–10. The used types of bat boxes: 4 – WB; 5 – WB; 6 – WS; 7 – WS; 8 – C (2F); 9 – C (2FN); 10 – C (2FN).
Obr. 3–10. Obr. 3. Plánek velké dřevěné budky (typ WB). Figs. 4–10. Použité typy budek: 4 – WB; 5 – WB; 6 – WS; 7 – WS; 8 – C (2F); 9 – C (2FN); 10 – C (2FN).

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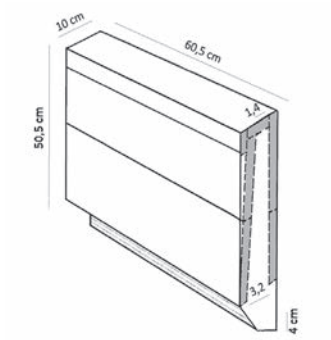

Table 2. The percentage of positive checks and ocuppied boxes comparing the different box types in different seasons. Calculated only for boxes monitored at least twice in August–October in two different years
Tab. 2. Procenta kontrol, během nichž byly v budkách zaznamenáni netopýři a procenta obsazených budek v různých typech budek v různých ročních dobách. Počítáno pouze pro budky sledované alespoň dvakrát ve dvou různých letech během srpna–října

	positive checks pozitivní kontroly			occupied boxes obsazené budky
box type typ budky	March–May březen–květen	June–July červen–červenec	August–October srpen–říjen	August–October srpen–říjen
WB	17 (7 / 41)	16 (5 / 32)	26 (49 / 192)	71 (22 / 31)
WS	0 (0 / 10)	4 (1 / 26)	5 (3 / 59)	19 (3 / 16)
C	0 (0 / 7)	0 (0 / 2)	21 (42 / 199)	53 (26 / 49)

a permanent or temporal occupancy. After each inspection, the boxes were cleaned (all bat droppings, old bird, wasp and hornet nests were removed) to enable recording of new occupancies during the next check. The occupied C-type boxes were taken down from the trees or posts and the number, species, sex and biometrics of bats were recorded. After that, bats were put back to the box and the respective box was hanged again carefully; the bats often flew away from the box though. For this reason we checked the boxes late of the day to minimise a possibility of predation.

When possible, the bat droppings were recorded also in the WB- and WS-type boxes, although their disposition and the method of check usually did not allow reliable detection of the droppings. Usually only a more substantial amount of droppings was detected, typically in spider nets in or beneath the box.

In three transects, bats were marked by rings in 2014–2016, sexed, weighed to the nearest 0.5 g and forearm lengths was recorded to the nearest 0.1 mm.

Results

Occupancy

In total, 578 checks of 147 bat boxes were carried out between September 2011 and October 2016. The presence of bat individuals was recorded in 108 cases (19%). Percentage of occupied boxes varied widely depending on the box type, length of their exposure and the season of a year (Fig. 11, Table 2). The most frequently occuppied boxes were the big wooden ones (WB-type) and the woodcrete ones (C-type). During the initial three years of the survey, bats were recorded at least once at 63% of the checks of the WB-type boxes and at 56% of the C-type boxes. The percentage of the boxes used by bats is much higher when also the signs of bat presence (droppings) are considered. For the C-type boxes, where the droppings can be detected reliably, the recorded occupancy was at 85% (for details see Tables 6–8).

The bats occupied the boxes most frequently between August and October (Table 2). Alhough the C-type boxes were monitored almost exclusively in late summer and autumn, the amount of recorded bat droppings indicated that bats only rarely occupied the boxes in previous months. No maternity colonies were found in the boxes.

Due to the relatively small data set from other seasons, the occupancy of boxes was compared statistically only for the period August–October. Concerning the occupancy, the box types differred significantly (χ^2=11.55, df=2, p=0.003), the WS-type box showed the lowest occupancy in comparison with the other types.

Species composition

Nine bat species were recorded in the bat boxes in total (Table 3), the species preferences and numbers of individuals differed in accordance to the bat box type (Tables 3–5). The C-type boxes

Table 3. Numbers of records of individual bat species.
Tab. 3. Počty záznamů jednotlivých netopýřích druhů.
Abbraviations / zkratky: Ppip = *Pipistrellus pipistrellus*, Mbra = *Myotis brandtii*, Mmys = *Myotis mystacinus*, *Mm/Mb* = *Myotis mystacinus* or *Myotis brandtii*, Vmur = *Vespertilio murinus*, Mnat = *Myotis nattereri*, Mdau = *Myotis daubentonii*, Pnat = *Pipistrellus nathusii*, Nlei = *Nyctalus leisleri*, Paur = *Plecotus auritus*, indet = species indetermined / druh neurčen, Σ S = total species / úhrnem druhů, Σ B = total bats / úhrnem netopýrů

box-type typ budky	Ppip	Mbra	Mmys	Mm/Mb	Vmur	Mnat	Mdau	Pnat	Nlei	Paur	indet	Σ S
WB	25	11	5	11	1			1			1	5
WS			2	1						1		3
C	39				1	1	1		1			5
Σ B	64	11	7	12	2	1	1	1	1	1		9

were occupied almost exclusively by *Pipistrellus pipistrellus*. In the WB-type boxes, *P. pipistrellus* prevailed too, but similar abundances were shown also by *Myotis brandtii* and *M. mystacinus*. The WS-type boxes were occupied mainly by *Myotis mystacinus* (or by unspecified bats of the *M. mystacinus* group). Two species together in one box were found only once – three individuals of *Pipistrellus pipistrellus* with a male of *Myotis mystacinus* in a WB box on 1 September 2011. Concerning the regional fauna, important findings included nine *Nyctalus leisleri* in a C-type box and *Pipistrellus nathusii*.

Re-captures

In 2014 and 2015, 27 individuals of *Pipistrellus pipistrellus* from the boxes were banded; seven of them were recorded in the same box again and three other banded individuals were recorded without reading a band number. Approximately one third of the bats ringed in a bat box were found in a bat box later; four individuals were recorded in the same bat box; two were found in another box within the same group (about 10 m apart); and one bat in a bat box 0.5 km away. Apparently, at least a part of the bat boxes are occupied by identical individuals for several years.

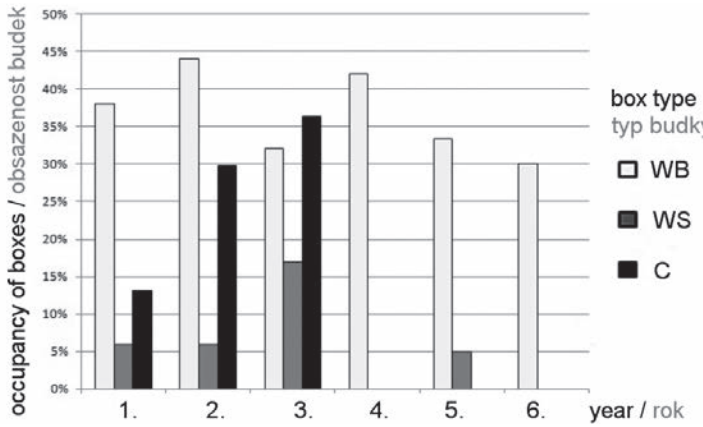

Fig. 11. The relative occupancy of the boxes by bats depending on box type and length of exposure.
Obr. 11. Obsazenost budek netopýry v závislosti na době její přítomnosti v terénu a typu budky.

Table 4. Numbers and sex of bats recorded in the boxes.
Tab. 4. Počty a pohlaví netopýrů nalezených v budkách.
Explanations / vysvětlivky: BT = box type / typ budky, *Mmys/Mbra* = *Myotis mystacinus* or / nebo *M. brandtii*, max = maximum number of individuals / maximum zjištěných jedinců, med = median. ♂ = male / samec, ♀ = female / samice, s.i. = sex indermined / pohlaví neurčeno

BT	*Pipistrellus pipistrellus*					*Myotis brandtii*					*Myotis mystacinus*					*Mmys/Mbra*		
	max	med	♂	♀	s.i.	max	med	♂	♀	s.i.	max	med	♂	♀	s.i.	max	med	Σ
WB	3	1	2	4	28	5	1	3	4	15	3	1	2	0	4	4	1	18
WS											1	1	1	1	0	1	1	1
C	5	2	30	38	14													

Less frequent species are not included in the table / méně početné druhy nejsou v tabulce uvedeny: *Vespertilio murinus* 1×♂, 1×♀; *Myotis daubentonii* 1×♂; M. *nattereri* 1×♂; *Pipistrellus nathusii* 1×♂; *Nyctalus leisleri* 1×2♀♀, 7 individuals of unknown sex / jedinců nezjištěného pohlaví.

The findings of banded bats in the bat boxes also indicate certain information about the landscape use by bats. Besides the findings of *Pipistrellus pipistrellus* individuals banded and recorded in bat boxes, we recorded two bats, banded at a swarming place and then found in a bat box.

A male *Pipistrellus pipistrellus* found in the WB-type box on 13 October 2014 was marked during a netting session when swarming in Mariánské Lázně (7.2 km west) on 17 August 2012. A male *Myotis dabentonii* was found in the C-type box in the Ohře river valley on 11 October 2015 that was banded during a netting session when swarming at the Wildbahner mine entrance near Hřebečná (23 km north) on 24 August 2013.

Bat boxes types

Big wooden boxes (*WB-type*)
In 2010, 32 WB-type boxes were installed, representing 22% of all monitored boxes and the number of their checks is 46% of all checks. The occupancy of WB boxes by bats was stable and high since the first year of monitoring (Table 6, Fig. 11). No wasp, hornet or bird nests were recorded in these types of boxes. In the period 2011–2016, 22 WB-type boxes (69%) were used at least once by bats and 27 boxes (84%) when also records of bat droppings are included. When once occupied, the boxes were usually used by bats repeatedly: 20 boxes (63%) were occupied at least twice in two different years, while only five boxes (16%) were occupied only once. In 31 cases, the bats were found in the same box also in the following year, while in 20 cases no bats were found. The particular boxes occupied by bats repeatedly were often used by a different species at a different time: *Pipistrellus pipistrellus* followed by (→) *Myotis brandtii* (three boxes), *Pipistrellus pipistrellus* → *Myotis mystacinus* (2), *Pipistrellus pipistrellus* → *Myotis mystacinus* or *M. brandtii* (2), *Pipistrellus pipistrellus* → *Myotis mystacinus* → *Pipistrellus nathusii* (1), *Pipistrellus pipistrellus*

Table 5. Numbers of boxes occupied by the particular bat species; for abbreviations see Tables 3, 4
Tab. 5. Počty budek obsazených jednotlivými druhy netopýrů; zkratky viz tab. 3, 4

BT	Ppip	Mm/Mb	Mbra	Mmys	Vmur	Mnat	Mdau	Pnat	Nlei	Paur	indet.
P	12	8	7	5	1			1			1
WS		1		2						1	
C	29				1	1	1		1		
Σ B	41	9	7	7	2	1	1	1	1	1	1

Table 6. Percentage of occupied WB-type boxes in particular years (numbers of occupied boxes in brackets)
Tab. 6. Procenta obsazených budek typu WB v jednotlivých letech (počty obsazených budek v závorkách)

year / rok	1	2	3	4	5	6	Σ 1–3	Σ 1–6
number of boxes / počet budek	27	18	23	19	27	27	32	32
bats / netopýři	38 (10)	44 (12)	32 (8)	42 (8)	33 (9)	30 (8)	63 (20)	69 (22)
bats or bat droppings / netopýři nebo jejich trus	–	–	–	–	–	–	66 (21)	84 (27)

→ *M. mystacinus* → *Vespertilio murinus* (1). Two boxes were repeatedly used only by *Pipistrellus pipistrellus*, one by *Myotis brandtii* and six by *M. mystacinus* or *Myotis brandtii*.

Small wooden boxes (*WS-type*)
Of the WS-type, 30 bat boxes were installed, representing 20% of all monitored boxes and the number of their checks is 16% of all checks. The relative occupancy of the WS boxes was the lowest of all three monitored box types. In the period 2012–2016, only four WS-type boxes (13%) were used by bats and eight of these boxes (27%) when also records of bat droppings are included. Bats were not recorded repeatedly in any of these boxes.

Woodcrete boxes (*C-type*)
Of the C-type, 85 bat boxes were installed. They represent 58% of all monitored boxes, but they were installed later than the other types and thus, the number of their checks represent only 36% of all checks. The relative occupancy of these boxes rapidly increased in the subsequent years (Fig. 11, Table 8). For comparison of the relative occupancy with other box types we used only 44 C-type boxes (2F subtype) exposed for three years: 26 boxes (65%) were used at least once (with bats found) and 34 (85%), when also records of bat droppings are included. When only the boxes localised in continuous coniferous forests are counted, 91% (35/38) of these bat boxes were occupied by bats. Particular boxes were subsequently used by the same bat species only.

This percentage is very high, particulary when a significant number of these boxes were unsuitable for bats due to the presence of hornet nests (on average 8% per year), wasp nests (12%) and bird nests (7%). No bats were found in boxes with bird nests, but bat droppings were found there in five cases. Boxes with wasp nests (but always without living wasps) were occupied by bats in three cases and droppings were found in three cases. The identified wasps belonged mostly to the rather small-sized species *Dolichovespula saxonica* and *D. adulterina*. On the other hand, nests of the hornet (*Vespa crabro*) usually filled the whole space of the boxes and often covered also the outside surface of the boxes (Figs. 20 and 21). Bats were never found in boxes

Table 7. Percentage of occupied WS-type boxes in particular years (numbers of occupied boxes in brackets)
Tab. 7. Procenta obsazených budek typu WS v jednotlivých letech (počty obsazených budek v závorkách)

year / rok	1	2	3	4	5	Σ 1–3	Σ 1–5
number of boxes / počet budek	18	16	6	8	19	30	30
bats / netopýři	6 (1)	6 (1)	17 (1)	0	5 (1)	12 (3)	13 (4)
bats or bat droppings / netopýři nebo jejich trus	–	–	–	–	–	–	27 (8)
wasp nests / vosí hnízda	–	–	–	–	–	–	7 (2)
bird nests / ptačí hnízda	–	–	–	–	–	–	7 (2)

Table 8. Percentage of occupied C-type boxes (numbers of occupied boxes in brackets)
Tab. 8. Procenta obsazených budek typu C v jednotlivých letech (počty obsazených budek v závorkách)

year / rok	1	2	3	Σ 1–3
number of boxes / počet budek	85	47	44	48
bats / netopýři	13 (11)	30 (14)	36 (16)	56 (27)
bats or bat droppings / netopýři nebo jejich trus	31 (26)	72 (34)	82 (36)	85 (41)
wasp nests / vosí hnízda	4 (3)	13 (6)	7 (3)	17 (8)
hornet nests / sršní hnízda	9 (9)	17 (8)	7 (3)	46 (22)
bird nest / ptačí hnízda	9 (8)	4 (2)	7 (3)	27 (13)

with hornets and only twice droppings were present in boxes with smaller hornet nests (always without living hornets).

Similarly to the WB-type boxes, when bats once used the box, they then often used it repeatedly: 23 boxes (56%) were occupied at least twice in two different years. Only five (12%) of once occupied boxes were not occupied in the following years. In 31 cases, bats or bat droppings were found in the same box also in the following year, while only in five cases they were not found.

Fig. 12. Typical positions of bat boxes (WS and C types) at the edge of an older spruce forest and a forest clearing. Transect along the bank of the Podhora water reservoir.
Obr. 12. Typické umístění sledovaných budek na rozhraní starší smrčiny a paseky, typ WS a C. Transekt podél vodní nádrže Podhora.

Fig. 13. A WB-type box at the edge of a clearing along the power line near Prameny.
Obr. 13. Budka (typ WB) ve stěně smrkového lesa na okraji průseku elektrického vedení u obce Prameny.

The occupancy of the particular C-box subtypes was not analysed since the 2FN and 3FN subtypes were surveyed only for one year. By far the most frequent species in the C-type boxes was *Pipistrellus pipistrellus* (39 cases). In 28 cases (72%), two or more individuals of *P. pipistrellus* were present. Sex of all individuals in the respective boxes was determined in 33 cases: 5×1 ♂, 5×1 ♀, 15×1 ♂+1 ♀, 5×1 ♂+2 ♀, 2×1 ♂+3 ♀ and 1×1 ♂+4 ♀. Four more species were recorded in the C-type box, but all of them only once (Table 3).

Pipistrellus pipistrellus was the most frequent species in all three monitored subtypes. In the 2F type, *Vespertilo murinus*, *Myotis daubentonii* and *M. nattereri* were also recorded, in 2FN subtype also *Nyctalus leisleri* (2F monitored for 3 years, 2FN and 3FN for one year).

Discussion

Despite the lack of systematic approach to the initial stage of the placements and checks of the bat boxes (which has limited the amount of relevant data for evaluation), some statistically significant results were obtained and interpretation of several patterns in the data is possible. A comparison of the relative occupancy or the species composition with other studies seems to be rather difficult. No studies from similar habitats – coniferous submontane forests – are available from Central Europe. However, studies from the other parts of Europe or other woodland habitats exist and allow at least a rough comparison of our results. On the other hand, the design of these studies was different (frequency of checks, forest microhabitats of box localisations, box types, etc.). The relative occupancy is usually reported as the percentage of roosts used at least once during the surveys, but the duration of surveys largely differs in the particular studies. To enable comparison with our study, we expressed the relative occupancy related to the duration time, where possible.

Occupancy

The relative occupancy recorded in our bat boxes is comparable to other studies from Europe. Most of these studies were carried out in the regions or habitats with probably much higher population densities of bats (Alcalde et al. 2013, Dodds & Bilston 2013, Chytil 2014, McAney & Hanniffy 2015). Thus, the rather high relative occupancies recorded in our study might be surprising. However, as it was demostrated in other studies, the bat boxes localised in the secondary coniferous forests showed a higher relative occupancy than the boxes in forests with a higher ratio of indigenous forest species (Ciechanowski 2005) or in the farm forest plantations versus intact forests (Smith & Agnew 2002) – probably due to the lack of available natural roosts in traditionally managed coniferous forests.

When only the WS-type boxes are compared, the relative occupancy in our study area is relatively low. In other studies from Europe, the most frequent species in these boxes were *Pipistrellus pygmaeus* and *P. nathusii*. However, these two species are very rare in the Slavkovský Les PLA. *Pipistrellus pipistrellus*, a relative of the former two species, which is abundant in the Slavkovský Les PLA, may have different roosting requirements. Another species also frequently reported from the WS-type boxes installed in Europe is *Plecotus auritus*; however, a reason of its absence in our boxes remains uncertain.

In our study, the highest relative occupancy was recorded in WB-type boxes. It seems possible that several design modifications (Fig. 3) of the commonnly used WS (Stratmann) box type have a positive impact on the box occupancy. The relative occupancy of the WB-type boxes was even slightly higher than for the C-type boxes.

Unlike the studies showing a relatively high occupancy of the WS-type boxes (Lesiński 2009, Baranauskas 2010, Chytil 2014), our results demonstrated, that in the coniferous submontane forests, the occupancy can be very low. Thus we recommend that the design of this widely produced

Fig. 14. A box (C-type, 2F) at the edge of a spruce forest and a non-forest enclave along the road and power line clearing near Kladská.
Obr. 14. Budka (typ C, 2F) na okraji smrčiny a nelesní enklávy podél silnice a průseku elektrického vedení u Kladské.

Fig. 15. Boxes (WB-type) at the edge of an old waterlogged spruce forest near the Dlouhá Stoka stream and the Bahňák pond near Kladská.
Obr. 15. Budky (typ WB) na okraji staré podmáčené smrčiny u potoka Dlouhá stoka a rybníka Bahňák u Kladské.

box type was modificated according to our WB type, especially considering that coniferous forests represent the dominant habitat where WS boxes are installed (particularly, when the WS-type box is one of the most commonly installed box types in Europe).

Species composition

Similarly to our results, most of the previous studies reported 1–2 (3) dominant species in the bat boxes (Ciechanowski 2005, Lesiński 2009, Baranauskas 2010, Dodds & Bilston 2013, Chytil 2014, Mering & Chambers 2014, McAney & Hanniffy 2015); however, contrary to our findings, usually without a distinct species preference of any box type.

The following bat species were found to roost frequently in bat boxes across Europe: *Plecotus auritus*, *Myotis daubentonii*, *Pipistrellus pipistrellus*, *P. nathusii*, *P. pygmaeus*, *Myotis nattereri*, and *Nyctalus leisleri*. The C-type boxes (2F or 2FN) are in Europe used mostly by *Pipistrellus pipistrellus, P. pygmaeus, Nyctalus leisleri*, *Myotis nattereri*, and *Plecotus auritus* (Ciechanowski 2005, Flaquer et al. 2006, Poulton 2006, Dondini & Vergari 2009, Baranauskas 2010, Alcalde et al. 2013, Dodds & Bilston 2013, Chytil 2014, Mering & Chambers 2014, McAney & Hanniffy 2015).

Although *P. auritus*, *M. daubentonii* and *M. natterreri* are the most common species in the Slavkovský Les PLA and surrounding areas, they were recorded only exceptionally in our boxes (each of them only once). Hence, bat boxes seem to be not attractive for these species in the submontane coniferous forests. On the other hand, almost no studies report on the presence of *Myotis mystacinus* and/or *M. brandtii* in bat boxes, although some studies were conducted in areas where both species are common. Since we found them commonly in the WB-type boxes

(and even in the WS-type that is the most used box type in Europe), these species are probably more abundant in western Bohemia than in other regions or habitats in Europe, where the bat fauna of bat boxes was studied.

Nevertheless, the following ten bat species were missing in our bat boxes, although they are present in the westernmost Bohemia (own observations): *Myotis bechsteinii*, *M. myotis*, *Eptesicus nilssonii*, *E. serotinus*, *Pipistrellus pygmaeus*, *Nyctalus noctula*, *Barbastella barbastellus*, and *Plecotus austriacus*, very rarely also *M. emarginatus* and *M. dasycneme*.

Our results suggest that bat roost requirements vary markedly between seasons and that none of the commonly used box types is likely to meet all roost requirements. Contrary to the previous studies, very uniform species composition and also only the late summer or autumn presence of bats was recorded in the C-type boxes. Therefore, the results of the previous studies dealing with the C-type boxes may suggest that even after three years we can still expect an important increase of the species number and also changes in the seasonal occupancy preferences (maternity colonies are formed in the boxes rather long after their installation; Poulton 2006).

Obviously, our boxes are well suitable only for some species and only in some parts of a year. First of all, there is an exceptional use of these boxes for male displays in *Pipistrellus pipistrellus*, which attract females there in the autumn. The sex ratio in *Pipistrellus pipistrellus* from our C-boxes recorded in the period from August till October corresponds with the ratio of the harem mating groups, as described by Gerell & Lundberg (1985). The WB boxes are probably used in a similar way, although the sex ratio in *P. pipistrellus* was rather difficult to record, considering their construction and the way of monitoring.

Fig. 16. Box (WB-type) nearby the Kyselé Jezero Pond.
Obr. 16. Budka (typ WB) u rybníka Kyselé jezero u Kladské.

Fig. 17. The WB-type and C-type boxes at the south facing side of a hayloft, non-forest enclave near Kladská.
Obr. 17. Budky (typ WB a C) na jižní stěně seníku, nelesní enkláva u Kladské.

The group of *Nyctalus leisleri* found in our C-type (2FN) box was also probably a harem mating group (to minimize the disturbance of bats, the sex was checked only in two females; Fig. 22). Anyway, this species is only scarcely recorded in western Bohemia, and in the westermost part of the Czech Republic, it was recorded only by bat detector and only in the region along the Ohře river with well-preserved beech forests (an area about 20 km northeast; own observation).

Ciechanowski (2005) and Lesiński (2009) mentioned a high relative occupancy of boxes in July–August also for *Pipistrellus nathusii*. This species was several times recorded in the study area, but we still do not have even an approximate outline of its occurrence in the region (similarly to *P. pipistrellus*, it only rarely hibernates in traditionally monitored underground hibernacula). *P. nathusii* is a rare species in the region and the record in the bat box represents the first finding of an individual in the summer period in the region (except detectoring; own observation).

As shown in several previous studies (Bartonička & Řehák 2007, Kerth et al. 2001), the temperature above 40 °C may have an important negative effect on the presence of maternity colonies in the roosts. Since we attempted to maximize the insulation of the installed boxes, we suppose that high temperature inside the boxes is not a key factor causing the low recorded occupancy during the breeding season (some of the boxes were partly shaded).

Bat box types

WB-type
This big narrow wood bat box type is not used commonly. A high relative occupancy of this type was recorded in neighbouring Bavaria, but exact data are not available (Oberpfälzische Waldverein, Ortsgruppe Georgenberg, pers. comm.). The high occupancy is very probably caused by its massive construction and bigger size (especially width) than of other box types mostly used in

Europe. A significant positive correlation between the occupancy and box size (quantified as linear roost space) was also referred by Tuttle et al. (2005) from North America. Mering & Chambers (2012) monitored similarly sized box types (>40 cm wide) in pine mountain forests of Arizona (altitude between 2100–2300 m a. s. l.) made of 1 cm wide plywood or resin. During the first year after installation, bats occupied 11% of plywood and 25% of resin boxes, in the second year 48% and 46%, respectively. It is very difficult to compare these relative occupancy values with our results, because of completely different conditions (habitat, bat diversity, check frequency). The higher relative number of positive checks by Mering & Chambers (2012) is also influenced by monitoring of bat guano that was caught by wire mesh installed below the box. This simple complement might reasonably expand our knowledge of the box occupancy and we plan to use it in the next years too (it will also allow to compare succes rate of the WB and C-type boxes).

The WB-type boxes showed several benefits: wasps, hornets and birds do not use them; there is no need of cleaning them from bat droppings; only torch and camera with telephoto lens allowing bat determination is sufficient for checks (a ladder is not needed). A disadvantage of this box type is the uneasy capturing of the roosting bats (when needed; Figs. 18, 19). In addition, maternity colonies appear to be present more frequently in domed woodcrete boxes than in the WB-type boxes (Rueegger 2016).

WS-type (*Stratmann*)

This small and narrow wooden bat box is one of the most common types used with small design differences for a long time across Europe, see the review below.

Ciechanowski (2005) monitored a similar type of wooden boxes but of a slightly smaller size (102 boxes, inner dimensions 40×13×4 cm, entrance 15.5×1.5 cm, walls 2 cm thick) in pine, beech and oak-beech forests of northern Poland. The boxes were checked from 1998 till 2001, in some years every two weeks from April to September. The author observed only *Pipistrellus nathusii*

Fig. 18. A look into the entrance of the big wooden box (WB).
Obr. 18. Pohled do výletové štěrbiny velké dřevěné budky (WB).

Fig. 19. *Myotis brandtii* in the big wooden box, photographed from the ground using a telephoto lens and a flash.
Obr. 19. *Myotis brandtii* ve velké dřevěné budce, foceno ze země teleobjektivem s použitím blesku.

and *Plecotus auritus* in these boxes. The relative occupancy of the boxes was much higher in the 50–70 year-old coniferous forest (average 36 bats per 100 boxes) than in the 150 year-old beech forest (average 3.4 bats per 100 boxes) and 80 year-old oak-beech forest (average 1.8 bats per 100 boxes). Wasps and hornets were present in 14% of the boxes.

Lesiński (2009) surveyed a similar type of wooden boxes (70 boxes, inner dimensions 25×25×7 cm) in central Poland in 2005–2007. The boxes were installed along a forest road (2 km transect) in 50–80 year-old pine forests with a small admixture of birch and oak, and with a 7 ha water reservoir nearby. The box occupancy increased in the subsequent years, to nearly 50% in 2007. The boxes were inhabited by *Myotis myotis*, *Nyctalus noctula*, *Pipistrellus nathusii*, and *Plecotus auritus*. The boxes were occupied as early as in March and April by small numbers of *Plecotus auritus*. The number of bats subsequently increased to reach the maximum (n=128) in August (2007). Lesiński (2009) also referred to an older study from Germany, where the relative occupancy of this box type was reported at ca. 50%.

Baranauskas (2010) checked a similar type but also smaller wooden boxes (168 boxes, inner dimensions 35×15×4 cm, entrance 15×2 cm, walls 2.5 cm thick) in pine and mixed forests of Lithuania. The boxes were checked once per month between May and October 2009. Contrary to other (multichambered) boxes used in the study, no breeding colonies were found in these small wooden boxes. The relative occupancy of the boxes is not mentioned in the study and the boxes were occupied mostly by *Pipistrellus nathusii* and *P. pygmaeus*, in lesser volume also by *Plecotus auritus*, *Eptesicus nilssonii*, *Nyctalus noctula*, and *Myotis daubentonii*.

Dodds & Bilston (2013) monitored woodcrete boxes with a wooden back panel (13 boxes, external dimensions 43×27×14 cm, entrance 21×2.4 cm; type Schwegler 1FF) in a semi-mature

lowland deciduous woodland with oak and ash and with a hazel understorey in central England. The relative occupancy was compared with four types of domed woodcrete boxes spaced together with Schwegler 1FF type at a 300 m transect. The boxes were installed on trees in a closed canopy, inside a closed woodland, 25–35 m from the forest edge. The boxes were checked once per month between May and October in 2011 and 2012. The relative occupancy of 1FF compared to other box types (including 2F and 2FN monitored in our study) was rather low (11%). The only recorded species were *Myotis nattereri* and *Plecotus auritus*.

Chytil (2014) monitored identical WS-type boxes (even dark painted too, 33 boxes) in southern Moravia, Czech Republic, in 1998–2007; 30% of these boxes were at least once occupied by bats during the initial five years of the monitoring. This is a much higher relative occupancy than in our study (13%), probably due to a different habitat with a much higher abundance of prey and thus, higher population densities of bats (lowland thermophilous oak or hornbeam forest and floodplain forest). A different species composition is related to the different habitat too – the only species recorded in the initial five years of the survey was *Pipistrellus pygmaeus*, later on, also *P. nathusii*, *Nyctalus noctula*, *Barbastella barbastellus*, and *Myotis* sp. were recorded. Maternity colonies prevailed in the records (78%), mainly of *Pipistrellus pygmaeus* (rarely also *Barbastella barbastellus* and *Nyctalus noctula*).

Figs. 20, 21. Hornet nest often fill the whole space of the wood-cement boxes and sometimes cover even the external side (C-type, 2F).
Obr. 20, 21. Hnízda sršní často vyplňovala nejen celý objem dřevobetonových budek, ale často budky obalovala i zvenčí (typ C, 2F).

Fig. 22. *Nyctalus leisleri* in the woodcrete box near Bečov (typ C, 2FN).
Obr. 22. *Nyctalus leisleri* v dřevocementové budce u Bečova (typ C, 2FN).

C-type (*domed woodcrete*)
Dodds & Bilston (2013; for details see above) found a lower relative occupancy of the C-type boxes than was demonstrated in our study. For the period between July and October, they reported the occupancy of the 2F and 2FN boxes to reach around 30% in the first year and that of the 2F boxes to be around 40% in the second year (in our study 31% for the 2F, 2FN and 3FN boxes in the first year and 72% for the 2F boxes in the second year). In both studies, bat droppings were recorded as an indication of a temporary presence of bats. Similarly to our results, Dodds & Bilston (2013) found the 2FN boxes to be frequently occupied by nesting birds; this represents an important competition for bats.

Alcalde et al. (2013) surveyed in total 405 woodcrete bat boxes of five different models (1FD, 1FF, 1FW, 2FN, 2F, Schwegler) and other two original types in eleven areas of northern Spain with quite variable habitats. The boxes were placed in 2009–2011 and checked during September–November 2012 (no visits were made during the initial three years). The total relative occupancy was 60% (0–90% in various sites): bats were present in 26% of boxes, other 33% of boxes contained bat droppings. Ten bat species were recorded, the most frequent and abundant were *Pipistrellus pygmaeus* and *Nyctalus leisleri*. These two dominant species were found in different areas and bat preference was observed for certain models of boxes; the 1FF and 2F models with a double front panel (Schwegler) were the most occupied types. Significant differences were found between the occupancy and the forest structure: the more open forest structure, the greater relative occupancy. Bird nests were present in 9% of boxes, wasp nests in 5% of boxes.

McAney & Hanniffy (2015) presented the most long-lasting bat box project in Europe; they monitored 162 woodcrete Schwegler boxes, mainly of the 1FF, 2F and 2FN types, in four separated semi-natural broadleaf or mixed forests of Ireland in 1999–2015. During the initial four years, the boxes were inspected once a month from April to September and occasionally also in other parts of a year. The total relative occupancy was 19% (10–39% in various sites); the highest relative occupancy was found in the forest with a higher proportion of conifers: around 45% of the 1FF boxes (August–October), around 25% of the 2FN boxes (June–July and August–October). *Pipistrellus pipistrellus* and/or *P. pygmaeus*, *Plecotus auritus*, *Nyctalus leisleri*, rarely also *Myotis nattereri*, *M. daubentonii* and *M. mystacinus* and/or *M. brandtii* were found in the boxes. The pipistrelles showed a clear preference of the 1FF boxes and *P. auritus* of the 2FN boxes. Geographical aspect of the box position appeared to be an important factor influencing the box occupancy; while *N. leisleri* used the north and east facing boxes, pipistrelles used the west and east facing boxes and *P. auritus* most selected the south facing boxes. More bats were present in the boxes in spring than in summer and autumn, although pipistrelles were more often recorded in the 2FN boxes in summer than in other seasons. Relative occupancy and presence of maternal colonies in boxes increased with the length of the box presence on the place. A considerable occupancy of the 2FN boxes by bird nests is also reported in the study.

Conclusions

The box type, length of exposure and time of the year are the main determinants of bat box occupancy rate. In our study, the most occupied type of bat boxes were the big narrow wooden boxes (WB-type, 71% after six years) and woodcrete dome boxes (C-type, 53% after three years, 85% bat droppings incl.). The recorded relative occupancy ranked among the highest reported from central Europe (Mering & Chambers 2014). Low occupancy of small narrow wooden boxes (WS-type) indicates that these boxes are less suitable for bats, at least in the submontane coniferous forests in Central Europe. Thus, we recommend to modify the design of the widely used WS-type boxes to be similar to the WB-type box.

Despite the high relative occupancy, the importance of bat boxes for bat populations in the study region remains questionable. The boxes were used mainly in August and September and no maternity colonies, representing the most sensitive part of the bat life-cycle, were proved. Although we expect a presence of the maternity colonies in the woodcrete boxes in the following years, the bat boxes obviously cannot fully substitute the natural roosts. An effective protection of bats in coniferous traditionally managed forests should thus be based on the protection of natural roosts. Monitoring of bat boxes might be an important supplement to improve the knowledge of the local fauna. Two rare species in the westernmost Bohemia were recorded in the bat boxes – *Nyctalus leisleri* and *Pipistrellus nathusii*.

Souhrn

Úspěšnost netopýřích budek v jehličnatých lesích západních Čech. V průběhu let 2011–2016 jsme sledovali přítomnost a druhové složení netopýrů ve 147 netopýřích budkách. Sledované budky byly rozděleny do tří základních typů: široké dřevěné štěrbinové (šířka 60 cm), úzké dřevěné štěrbinové (šířka 25 cm) a uzavřené válcovité dřevobetonové (typ 2F, 2FN a 3FN). Budky byly umístěny převážně v podhorských jehličnatých lesích chráněné krajinné oblasti Slavkovský les, obvykle na stromy, ve výšce 4–6 m nad zemí. Instalovány byly na osluněná a jižně orientovaná stanoviště v lesích nebo při jejich okrajích, často na rozhraní lesních porostů a pasek, nejlépe nedaleko rybníků nebo vodních toků.

Obsazenost budek se významně lišila v závislosti na typu budky, doby (počtu let) jejího vyvěšení a roční době. Nejčastěji byly budky obsazovány během srpna až října a nejčastěji obsazovaným typem budek byly široké dřevěné budky. Jednotlivé typy budek nebyly sledovány po stejně dlouhé období a stejně často. Nejlepší srovnání úspěšnosti budek nám umožňuje porovnání obsazenosti budek kontrolovaných alespoň dvakrát ve dvou různých letech pro období od srpna do října – obsazenost širokých dřevěných budek byla 71 %, dřevobe-

tonových 53 % a malých dřevěných 12 %. Vezmeme-li za doklad obsazenosti budek i přítomnost netopýřího trusu, pak byla obsazenost dřevobetonových budek 85 % (ze štěrbinových budek trus vypadává).

V jednotlivých typech budek se lišilo i druhové složení netopýrů. V dřevěných budkách se nejčastěji vyskytovali *Pipistrellus pipistrellus*, *Myotis brandtii* a *M. mystacinus*, v dřevocementových dominoval *P. pipistrellus*. Celkem bylo v budkách zjištěno devět druhů netopýrů (pořadí dle počtu záznamů): *Pipistrellus pipistrellus*, *Myotis brandtii*, *M. mystacinus*, *Vespertilio murinus*, *Myotis nattereri*, *M. daubentonii*, *Pipistrellus nathusii*, *Nyctalus leisleri* a *Plecotus auritus*. *Pipistrellus pipistrellus* vytvářel v budkách koncem léta a na podzim harémová uspořádání tvořená v následujících letech často stejnými jedinci, jak bylo zjištěno na základě odečtu kroužků u okroužkovaných jedinců. Z regionálně faunistického hlediska je významný nález *Nyctalus leisleri* (devět jedinců v jedné dřevocementové budce), který byl doposud z území nejzápadnějších Čech znám pouze z oblasti zachovalých listnatých lesů v údolí řeky Ohře na úpatí Doupovských hor.

Úzké dřevěné budky, které jsou pravděpodobně jedním z nejčastěji používaných typů netopýřích budek v Čechách, byly netopýry obsazovány nejméně. Doporučujeme proto výrobcům upravit jejich rozměry tak, aby se více blížily námi použitým větším budkám.

Obsazenost dřevocementových budek se v jednotlivých letech postupně významně zvyšovala. Na základě studia odborné literatury pokládáme za pravděpodobné, že se v dalších letech úspěšnost dřevobetonových budek ještě zvýší a budou se zde vyskytovat i mateřské kolonie netopýrů. Přesto považujeme námi použitý a poměrně netradiční typ širokých dřevěných budek za velmi úspěšný – častěji jej využívá více druhů netopýrů, neobsazují jej vosy, sršni ani ptáci, kteří brání obsazování budek netopýry, a nemusejí se čistit.

Ačkoliv námi prokázané hodnoty obsazovanosti budek patří k nejvyšším v Evropě (Mering & Chambers 2014), jejich význam pro netopýry pravděpodobně není příliš výsoký. Během průzkumu se totiž v budkách nepodařilo prokázat výskyt žádné mateřské kolonie, tedy jedné z nejzranitelnějších fází v netopýřím vývoji silně spjatou s úkryty, které mají budky nahrazovat. Účinná ochrana netopýrů by tedy měla spočívat především v ochraně přirozených úkrytů, tedy doupných, odumírajících a starých stromů se štěrbinami a odlupující se kůrou a také ve zvyšování prostorové rozmanitosti lesů (zachovávání přirozeně vznikajících světlin apod.).

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