Roosting of the Eurasian Nuthatch (*Sitta europaea*) in various habitats of city environment

*Nocovanie brhlíka lesného (*Sitta europaea*) v rozličných habitaoch v mestskom prostredí*

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Abstract. *The Eurasian Nuthatch is a common bird species that uses artificial nest boxes for roosting in many areas across Europe. However, the knowledge about its roosting habits in urban habitats is lacking. In our study, conducted across three study sites in the city of Bratislava (forest, and two parklands), we observed this species roosting 151 times (1.7% of 9153 checked boxes). The mean nest-box occupancy by roosting Nuthatches, as well as their proportion among roosting birds, decreased from oakwood to parklands, varied significantly between checks, seasons, and was positively correlated with the number of roosting Great Tits. Mean relative air humidity and precipitation between 18:00 and 19:00 positively influenced nest box occupancy. The number of roosting Nuthatches also varied within a single winter (October to February), with the highest numbers recorded in November and December. A significant prevalence of recorded males was observed only in two parklands (accounting for 83.3% N = 18 and 79.2%, N = 22 of all records, respectively), while in woodland habitat, the sex ratio was nearly equal (males comprised 51.1%, N=94). Within a single winter season, 36.2% of roosting birds (N =58) were faithful to their roosting locality (i.e., recorded more than once in the season), with a mean fidelity rate of 0.1. Individuals recaptured over multiple winter seasons were observed only in the woodland area, accounting for 17.1% (N =35).*

Key words: *overnighting, urban ecology, cavity nesting birds, Slovakia*

Introduction

Roosting in cavities is one of the adaptations for winter survival in some non-migratory bird species of the boreal zone (Newton 1998, Krištín 2001, Veľký & Krištín 2008). By roosting in enclosed spaces, birds minimize heat loss, with energy savings increasing as outside temperatures decrease (Kendeigh 1961, Newton 1998, Cooper 1999). In addition to this advantage, roosting birds are sheltered from precipitation, wind, and attacks by aerial predators (Kluyver 1957, Drent 1984, Winkel & Hudde 1988, Cooper 1999, Veľký & Krištín 2008). However, roosting in cavities also carries risks, such as infection by parasites and pathogens, including fleas (Christe et al. 1994, Merilä & Aalander 1995) and zoo-pathogenic fungi that survive in old nest material (Hubálek & Balát 1974). There is also a potential risk of predation (Berndt & Winkel 1972, Winkel & Hudde 1988), though the data on predation of cavity-roosting birds are limited (Mainwaring 2011).

The Eurasian Nuthatch (*Sitta europaea*) is one of the species that roost in nest boxes during autumn and winter nights. In many studies, it has been the second most numerous roosting bird after the Great Tit (*Parus major*) (Czarnecki 1960, Juškaitis 1986, Winkel & Hudde 1988, Krištín et al. 2001, Zvářal 2007, Zang & Kunze 2009, Zvářal 2010, Tyller et al. 2012). They are more numerous in broad-leaved oak and beech forests, where constituting approx. 30% of all roosting individuals (Krištín et al. 2001, Zvářal 2010). In the urban habitat of Zvolen (Central Slovakia), the roosting Nuthatch was recorded only once, making up 3.2% of all recorded individuals (Veľký 2006). Otherwise, in some localities or habitats, this species is missing (Ilenko & Zagorodnyaya 1961, Prskavec 1989, 2012).

The number of roosting Nuthatches changes during the autumn and winter period. Some works found the linear decrease during the entire season (Creutz 1960, Krištín et al. 2001, Zang & Kunze 2009) in other localities no visible trend was observed (Busse & Olech 1968). Eurasian Nuthatches roost strictly individually; however, pair members defend winter territory together (Löhrl 1988). Therefore, sexes should roost almost equally (Winkel & Hudde 1988, Zang & Kunze 2009, Matejka et al. 2022). Also here, some exception occurred (Krištín et al. 2001). Some Nuthatch individuals show fidelity to their roosting sites within one or over more consecutive winters (Busse & Olech 1968, Krištín et al. 2001, Zvářal 2010).

In this paper we aimed to clarify the roosting events frequency, nest-box occupancy, and sex ratio by the roosting Nuthatches in the three different habitats in the urban environment. We also describe the temporal changes of nest box occupancy within and between different winters and the roosting site fidelity.

Material and methods

Study sites

Our research was conducted at three localities within the city of Bratislava (W Slovakia). The study plots are located in the Zoological Garden (referred to as ZOO, 48.163611 N, 17.070556 E, 260 m a. s. l., 11 ha, 50 nest boxes), Botanical Garden of Comenius University (BG, 48.146111 N, 17.073333 E, 150 m a. s. l., 6.5 ha, 30 nest boxes), and the campus of the Faculty of Natural Sciences, Comenius University (FNS, 48.150556 N, 17.070833 E, 160 m a. s. l., 8.2 ha, 41 nest boxes) where are placed nest boxes of three different types (78 designated for the Great Tit, 39 for the Common Starling (ZOO = 18, BG = 21), four nest boxes for the Blue Tit (three in ZOO, one in BG)). In ZOO, most of the boxes are situated in a 70–85 years old oak-black locust-hornbeam forest with a well-developed undergrowth (mostly herb layer), while two are placed in an abandoned pear orchard adjacent to the forest (in entire manuscript we consider ZOO as the woodland area). In BG nest boxes have been installed in a parkland habitat dominated by non-native tree and shrub species. Similarly, FNS has a parkland character but, unlike BG, it features a high prevalence of native broad-leaved tree species (such as ashes, maples, and lindens) as well as Austrian Pine (*Pinus nigra*). All study sites are within 2 km of each other by aerial distance, with only 200 meters distant BG and FNS.

Methods

Night checks were conducted weekly from October to February (considered as winter period in entire manuscript), except for the 2017/18 when checks began in November, the winter of 2020/21 when COVID-19 restrictions forced us to end in December, and the winter of 2022/23 at the ZOO, where checks ended in January due to the bird flu epidemic closing the ZOO. Research was carried out over six winters at ZOO (2017/18–2022/23) and BG (2018/19–2023/24), and over two winters at FNS (2022/23 and 2023/24).

Checks always started 15 minutes after sunset. Sleeping birds were removed from the nest boxes, identified, ringed (all birds since 2018/19), and returned to nest boxes. All birds were also sexed according to Svensson (1992) and Winkler & Jenni (2009). Signs for ageing (Winkler & Jenni 2009), were not visible under

artificial light, so roosting Nuthatches were not aged.

Meteorological data were obtained from the meteorological station Bratislava – Mlynská dolina, located near the FNS study site. Mean monthly temperatures were calculated from daily means, and the average temperature during the winter season (October–February) was computed from monthly means. To analyse the influence of weather on nest-box occupancy, 24 characteristics of air temperature, relative humidity, and precipitation were tested. These characteristics include: daily mean temperature (computed from hourly means), daily temperature maximum and minimum (from hourly temperatures) on the day of the night check, average temperature during the day after the night check, temperature at 7:00, 14:00, 16:00, and 21:00 (all times are UTC+1) on the check day and at 7:00 on the following day, mean daily relative humidity on the day of the check (obtained from hourly means), relative humidity at 7:00, 14:00, 16:00, 21:00, and at 7:00 the following morning, the sum of precipitation in the afternoon of the check from 14:00 to 22:00, and precipitation in the hour preceding the check, measured from 15:00 to 22:00.

The height of the snow cover (Busse & Olech 1986, Báldi & Csorgő 1991, Bosch 2010) was not analysed due to the minimal number of checks with the snow cover during our study (up to 10 checks). The mean index of the North Atlantic Oscillation (NAOI) for the period from October to February was computed from monthly means obtained from the Climate Prediction Centre of the US National Weather Service (https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/norm.nao.monthly.b5001.current.ascii.table). NAOI was chosen because this phenomenon widely influences the weather across Europe (Trigo et al. 2002), although its effect on roosting birds has not been studied yet.

Statistical methods

All data, except for recaptures between winters (inter-seasonal fidelity), were analysed excluding the incomplete 2020/21 season. The results for inter-seasonal fidelity include data from this season because two individuals ringed in October 2020 were later recaptured during the subsequent winter, and one from the previous winter (2019/2020) was recaptured as roosting.

In this context, "recorded birds" refers to roosting Nuthatches without regard to their individuality; for example, one record of a Nuthatch in a nest box equals one bird. When mentioning "individuals," we refer only to ringed birds, except in cases of intra-seasonal fidelity and the number of individuals recorded for the first time in a season according to months (seasonal changes). In these cases, "individuals" includes ringed birds recorded in that season, even if they were ringed in the past (one bird recorded over two winters is counted as two). Nest box occupancy refers to the number of recorded Nuthatches (or Great Tits) divided by all available nest boxes at the study site. This ratio is presented as a percentage. The fidelity rate expresses the proportion of controls in one season where an individual roosts (it reaches values from 0 to 1.00, e.g. 1.00 = the individual was recorded during all night checks conducted during that season). Mean values are presented in the text as mean ± SE.

Statistical tests were performed using the software Past 4.04 (Hammer et al. 2001) (for Fischer's exact test, χ^2 test) and R (R Core Team 2023) package stats (for correlation tests and generalized linear model). For data visualization, we used R packages ggplot2 (Wickham, 2016), ggpubr (Kassambara, 2023), and ggtext (Wilke & Wiernik 2022).

For comparison of proportions, contingency tables were used, and their significance was tested with Fisher's exact test. Significancy of the preference for nest box type was tested with the χ^2 test comparing sampled vs. expected values. Differences in the number of recorded Nuthatches of different sexes (e.g., significance of male prevalence) were assessed by comparing the sex ratio to a 1:1 ratio using the χ^2 test. Since the data distribution of seasonal nest box occupancy was not normal, for correlation analysis we used Kendall correlation.

Generalized linear model (GLM) was employed to investigate factors affecting nest

box occupancy. The explained variable was the arcsine-transformed nest box occupancy (to improve residual normality), explanatory variables were date of check, season, locality and the weather characteristics. A Gaussian family was chosen. The original model was later refined for maximum parsimony by values $p > 0.01$ (tested with ANOVA), while ensuring that non-significant differences between the original and final models were retained (tested with ANOVA). Checks with missing weather (four cases) values were removed.

For the relationship between the mean NAOI, mean seasonal and monthly temperatures, and the mean seasonal occupancy at ZOO and BG, seven linear regressions were performed due to data normality. Multiple linear regression was not feasible due to the number of seasons being smaller than the number of explanatory variables.

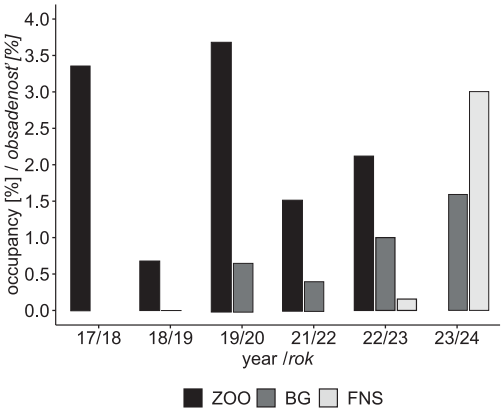

Fig. 1. Average nest box occupancy (in %) by the roosting Nuthatches in the different winters and study sites (ZOO: 2017/18 – 2022/23, BG: 2018/19 – 2023/24, FNS: 2022/23 – 2023/24).
Obr. 1. *Priemerná obsadenosť búdok (v %) nocujúcimi brhlíkmi počas rôznych zím na rozdielnych lokalitách (ZOO: 2017/18 – 2022/23, BG: 2018/19 – 2023/24, FNS: 2022/23 – 2023/24).*

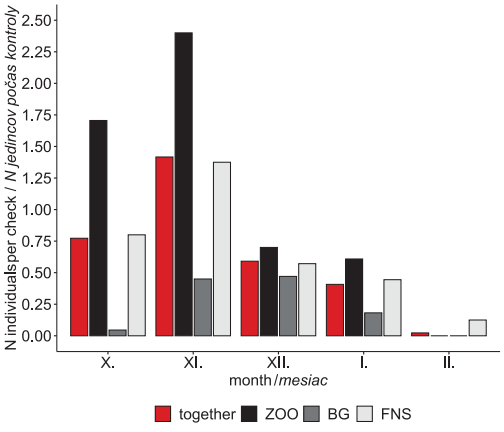

Fig. 2. Mean number of the Nuthatches per one night check in the different months in three study sites.
Obr. 2. *Priemerný počet brhlíkov na jednu nočnú kontrolu v jednotlivých mesiacoch na troch lokalitách.*

Results

Nest box occupancy and number of roosting Nuthatches

In all seasons pooled (excluding winter 2020/21), we conducted 233 night checks and examined a total of 9153 nest boxes (ZOO = 4712, BG = 2992, FNS = 1449). The Nuthatches were recorded in 1.7% of observations (151 from 9153) and 12.3% of occupied nest boxes (N = 1224). They mostly roosted individually; only once were two individuals found together in a single nest box (Matejka et al. 2023). For roosting were in ZOO and BG (localities where more nest box types were used) significantly ($p < 0.001$) preferred nest boxes with dimension for the Great Tit (95.3%, N = 127) than those for the Common Starling. Small nest boxes for the Blue Tit were not used at all.

The proportion of Nuthatches among roosting birds varied significantly between sites ($p < 0.001$), though in all localities, this species ranked second after the more numerous Great Tit. The highest proportion was in the oakwood at ZOO (16.4%), less in the parkland localities (BG = 10.5%, FNS = 6.4%).

On average, Nuthatches occupied 1.5 ± 0.2% of all available nest boxes, with occupancy varying from 0% to 16.7% during different night checks. Mean occupancy by roosting Nuthatches decreased from ZOO (2.2 ± 0.3%) to FNS (1.6 ± 0.4%) and BG (0.7 ± 0.2%). Final model ($R^2 = 0.51$, Table 1) provided a significant support for influence of the date, study site, season, nest box occupancy by

Table 1. Factors influencing the nest box occupancy by the roosting Nuthatches with test criterium (F) and significance values (p). Significant values are in bold.
Tab. 1. *Faktory ovplyvňujúce obsadenosť búdok nocujúcimi brhlíkmi a ich hodnoty testového kritéria (F) a významnosti (p). Štatisticky významné hodnoty sú hrubo vyznačené.*

factor	F	p
date of check	**4.97**	**0.027**
locality	**13.62**	**p < 0.001**
season	**9.11**	**p < 0.001**
occupancy by the Great Tit	**34.79**	**p < 0.001**
daily mean temperature	2.85	0.093
daily mean humidity	**5.88**	**0.016**
precipitation 18–19 UTC	**3.97**	**0.048**
interaction date and locality	2.32	0.1
interaction date and season	**11.65**	**p < 0.001**
interaction locality and season	**3.04**	**0.019**
interaction date, locality, season	**3.47**	**0.0091**

the Great Tit, mean relative humidity in the evening of the check and precipitation between the 18:00 and 19:00. With the occupancy by the Great Tits and the weather characteristics was the relationship positive.

When investigating sources of inter-seasonal variation in nest box occupancy (Fig. 1) at sites with sufficient seasonal data (ZOO and BG), we found significant relationships only in two cases: a linear dependence of mean nest box occupancy on mean winter temperature at BG and on mean temperature in December at ZOO. Both relationships were positive (Table 2), indicating that higher temperatures were associated with increased numbers during winter seasons.

Seasonal aspects

The number of recorded roosting Nuthatches also varied within a single winter (see influence of date in Table 1) showing the same pattern across study sites (Fig. 2) with the highest numbers during October and November an almost missing during February (one case of roosting in FNS). Similarly, most individuals (N = 58) were for the first time recorded in October (N = 27) and November (N = 21). The checks with the highest numbers of recorded birds also occurred in November. Except this, at ZOO we observed a linear decline in nest box occupancy by roosting Nuthatches during four out of five winter seasons (Fig. 3).

Table 2. Coefficient of determination (R^2) and the significance (p) of the linear regression between the mean seasonal nest box occupancy by the roosting Nuthatches and the various climate characteristics in the ZOO and BG. Significant values are in bold.
Tab. 2. *Koeficient determinácie (R^2) a štatistická významnosť (p) lineárnej regresie medzi priemernou sezónnou obsadenosťou búdok nocujúcimi brhlíkmi a rôznymi charakteristikami klímy v ZOO a BG. Štatisticky významné hodnoty sú hrubo vyznačené.*

climate characteristics/ *charakteristiky klímy*	ZOO		BZUK	
	R^2	p	R^2	p
mean NAOI from October to February	0.35	0.29	0.12	0.57
mean temperature from October to February	0.03	0.78	**0.8**	**0.039**
mean temperature in October	0.021	0.81	0.25	0.39
mean temperature in November	0.16	0.51	0.13	0.85
mean temperature in December	**0.82**	**0.035**	0.28	0.36
mean temperature in January	0.04	0.75	0.22	0.43
mean temperature in February	0.35	0.29	0.12	0.57

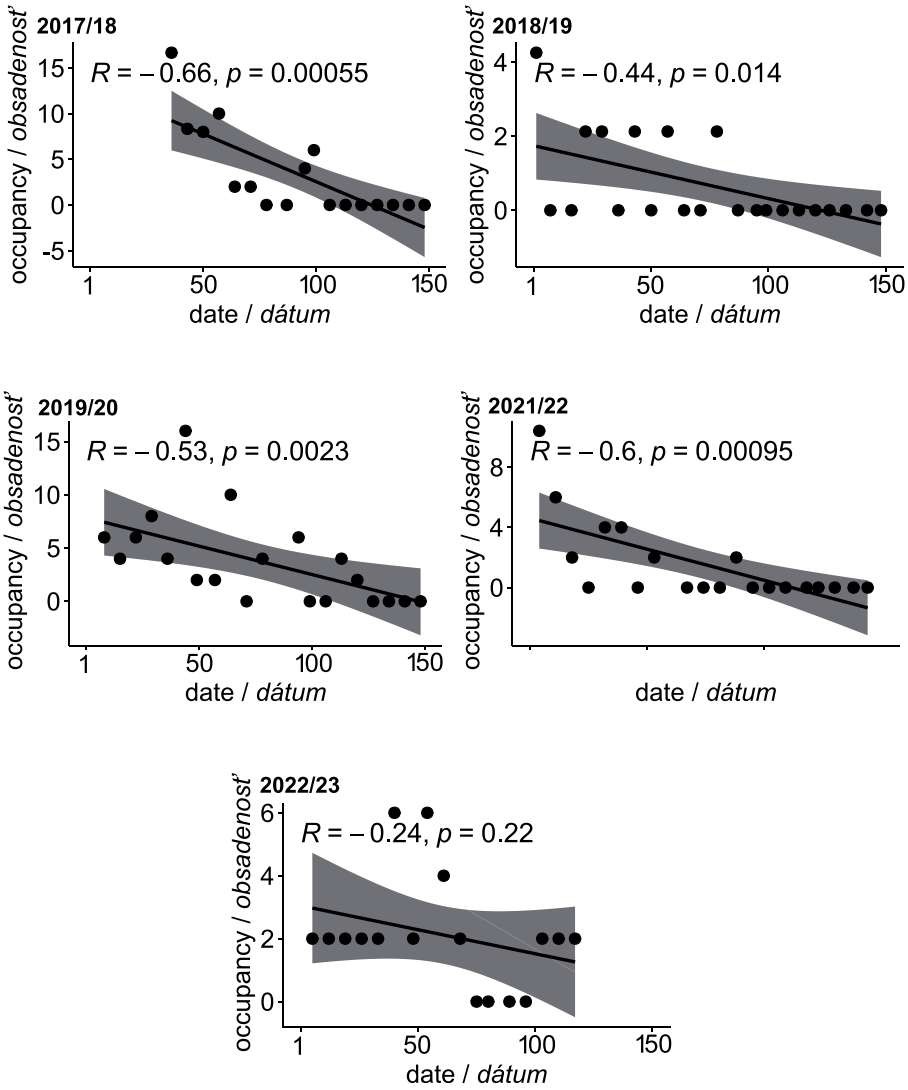

Fig. 3. Corelation (Kendall´s) between the nest box occupancy by the roosting Nuthatches (in %) and the date of night check (1= 1-st of October) in the different season in the ZOO.
Obr. 3. *Korelácia (Kendallova) medzi obsadenosťou búdok nocujúcimi brhlíkmi (v %) a dátumom nočnej kontroly (1 = 1. október) počas jednotlivých sezón v ZOO.*

Sex structure

Of the 49 sexed individuals (from 50 ringed), there were 31 males (63.3%) and 18 females (36.7%) (p = 0.063). Males predominated over females at all study sites (ZOO = 18 males/14 females; BG = 9/2; FNS = 4/2), but this prevalence was significant only at BG (p = 0.035).

The sex ratio of recorded birds (Fig. 4) differed significantly between sites (p = 0.016). Males outnumbered females significantly only at BG (p = 0.0047, N = 18) and FNS (p = 0.0043, N = 22). Number of recorded individuals per check varied during winter similarly for both sexes (Fig. 5).

Roosting site fidelity

Within one winter season, we recaptured 36.2% of all roosting Nuthatches (N = 58) with no signi-

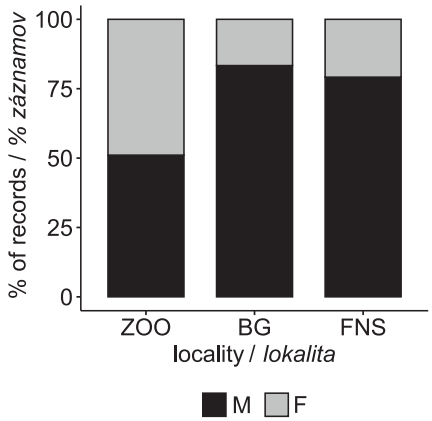

Fig. 4. Sex ratio of the roosting Nuthatches (M = males, F = females) in three study sites.
Obr. 4. *Pomer pohlaví nocujúcich brhlíkov (M = samce, F = samice) na troch* študovaných lokalitách.

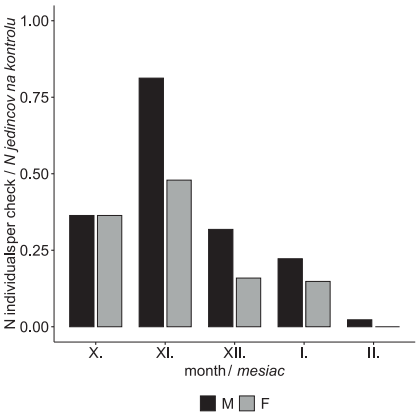

Fig. 5. Sex ratio of the Nuthatch (M = males, F = females) during various months.
Obr. 5. *Pomer pohlaví brhlíka (M = samce, F = samice) v jednotlivých mesiacoch.*

ficant difference between sites (p = 0.24). The proportion of intra-seasonally faithful individuals was nearly identical between sexes: 36.4% for males (N = 33) and 37.5% for females (N = 24).

The mean fidelity rate for all recorded individuals was 0.1 ± 0.014, and 0.2 ± 0.03 for the group of faithful birds. Most of the recaptured roosting birds were recorded during less than 25% of the night checks, typically during two or three checks. Among sexes was the fidelity rate the same (0.1).

Six individuals (11.3%, N = 53) were found roosting during more than one winter. Including the incomplete winter season 2020/21. Inter-seasonally faithful individuals were present only at ZOO, where they constituted 17.1% (6 out of 35). Three individuals were recorded during three consecutive winters (the winter of ringing plus two subsequent winters). Although the proportion of faithful birds among females at ZOO (25% = 4 out of 16) was considerably higher than among males (10.5% = 2 out of 19), the difference was not significant (p = 0.38).

Discussion

Nest box occupancy and number of roosting Nuthatches

Our results show that the Nuthatch was the second most common bird roosting in nest boxes after the Great Tit in all our plots corroborating findings from other studies (Table 3). However, the number of roosting birds varied significantly between study sites. The highest proportion of roosting Nuthatches was observed in the oak woodland in ZOO, while their numbers were much lower in parkland areas (BG, FNS) probably due to their lower suitability (Nilsson 1976, Löhrl 1988, Matthysen 1990). This species defends their territories year-round (Nilsson 1976, Löhrl 1988), and parkland areas with abundant conifers and numerous non-native tree species may not offer the same quality as oak woodlands, which are preferred in European conditions (Nilsson 1976, Löhrl 1988). In BG and FNS, Nuthatches roosted and bred only in nest boxes surrounded by broad-leaved trees (Matejka, unpubl.). Moreover, in BG and FNS, they may prefer roosting in buildings for better safety and insulation, as observed e. g. in Great Tits (Veľký & Krištín 2008, Zonov 2017, personal observations). Another potential factor for lower occupancy in BG and FNS could be increased traffic noise and light pollution (Halfwerk et al. 2016 but see Raap et al. 2018).

The availability of various nest box types could also affect their occupancy (Lambrechts et al. 2010, Paclík 2019). Nevertheless, we do not consider the different number of nest boxes with various dimensions as the main factor affecting nest box occupancy in different study

Table 3. Proportion (%) of the Eurasian Nuthatch in the population of the roosting birds in different sites and habitats.
Tab. 3. *Zastúpenie (%) brhlíka lesného v populácii nocujúcich vtákov v rôznych lokalitách a habitatoch.*

locality *lokalita*	habitat *habitat*	study years *roky výskumu*	author *autor*	proportion of Eurasian Nuthatch [%] *zastúpenie brhlíka [%]*	N
Northern Moravia (CZ)	mixed broad leaved - coniferous forest (dominant oak)	2005 – 2007	Adamík (2008)	58.8	34
Central Moravia (CZ)	mixed forest (dominant oak, 250 – 350 m a. s. l.)	2004 – 2010	Zvářal (2010)	30.7	883
Central Slovakia	oak-hornbeam forest (335 – 338 m a. s. l.)	1998 – 2001	Krištín et al. (2001)	28	157
North-east Germany (Harz)	broad leaved forests and pinewoods (200 – 900 m a. s. l.)	1982 – 2006	Zang & Kunze (2009)	26.7	1702
ZOO	**oak-hornbeam-black locust forest in city**	**2017 – 2023**	**this study**	**16.5**	**637**
South-western Lithuania	spruce-birch forest	1979 – 1982	Juškaitis (1986)	15	433
Central Germany	mixed and deciduous forests	1969 – 1975	Winkel & Hudde (1988)	13.3	17286
Northern Germany	birch wood	1937 – 1952	Creutz (1960)	10.6	56
BG	**parkland**	**2018 – 2024**	**this study**	**10.5**	**209**
Central Poland	oak-birch-pine forest edge	1957 – 1961	Busse & Olech (1968)	10	289
Northern Germany	forest nursery with old conifers	1937 – 1952	Creutz (1960)	6.8	
FNS	**parkland**	**2022 – 2024**	**this study**	**6.4**	**377**
Northern Moravia (CZ)	managed floodplain forest (204 m a. s. l.)	2007 – 2010	Tyller et al. (2012)	5	1319
Northern Germany	parkland	1953 – 1959	Creutz (1960)	3.8	57
Northern Germany	parkland	1937 – 1952	Creutz (1960)	3.6	168
Central Slovakia	urban green (292 m a. s. l.)	2003 – 2005	Veľký (2006)	3.2	45
Northern Germany	pinewood	1953 – 1959	Creutz (1960)	2.5	135
Northern Germany	orchard	1937 – 1952	Creutz (1960)	0.7	494

sites, since between FNS and BG it was similar, although these plots differ strong in types of used nest-boxes (see Study sites).

Inter-seasonal variability in nest box occupancy (Fig. 1) has been reported in other studies (Zvářal 2007, Zang & Kunze 2009), and several factors could affect this variability. Our results support a positive influence of higher winter (or December) temperatures on the mean winter nest box occupancy (Table 2), consistent with the findings of Nilsson (1987) and Zvářal (2007, 2010). Nest boxes are probably used due to their safety, energy-saving and microclimatic advantages over open spaces (Kendeigh 1961, Cooper 1999, Paclík & Weidinger 2007) even during milder winters.

Significant seasonal differences (Table 1) in the nest box occupancy could be also linked to population changes associated with bird density, age structure, survival or local immatures' invasions (Nilsson 1987, Löhrl 1988, Matthysen 1989, Glutz & Bauer 1993). Higher survival rates

of yearlings during autumn in years with a good beech crop could be reflected in December numbers (Matthysen 1989). However, Nilsson (1987) and Zang & Kunze (2009) found any such relationship for this species.

The competition with other roosting species (especially Great Tit) could negatively affect the number, occupied nest boxes as was found by the Blue Tit (*Cyanistes caeruleus*) (Kempenaers & Dhondt 1991, Zang & Kunze 2009, Typiak & Typiak 2018, personal observations). However, similarly to findings of Zang & Kunze (2009), we found a positive (in our case significant) relationship between the nest box occupancy of these two species. This relationship could indicate similar population dynamics in these two species and exclude a negative impact from Great Tits.

Changes in nest box occupancy may be influenced by weather conditions. Among 24 weather variables, only relative mean humidity on the night of the check and precipitation between 18:00 and 19:00 (UTC+1) showed significant positive relationships (Table 1). Unlike the Great Tit and Tree Sparrow (*Passer montanus*), whose roosting numbers increase with decreasing temperatures, temperature does not seem to affect the Nuthatches in the same way (Busse & Olech 1968). Furthermore, our results (Tab. 2) show the positive effect of higher temperature on mean seasonal occupancy.

Seasonal aspects

The number and nest box occupancy of roosting Nuthatches show notable variation during the winter season, with the highest numbers at its beginning (Fig. 2). It was also reported in other studies (Creutz 1960, Juškaitis 1986, Winkel & Hudde 1988, Krištín et al. 2001) except Central Poland, where the number of occupied nest boxes remained stable (Busse & Olech 1968). Intra-seasonal changes in nest box occupancy may be affected by population dynamics (the autumn influx and dispersal of young birds – Löhrl 1988, Glutz & Bauer 1993, higher mortality during the winter – Nilsson 1987, Matthysen 1989), shifts in roosting preferences possibly due to the superior insulation properties of natural cavities (Grüebler et al. 2014). Disturbances caused by research activities (Schmidt & Drengwitz-Nees 1984, Tyller et al. 2012), could also play a role. Nevertheless, we do not believe that the research method (capture and handling of sleeping birds) fully accounts for seasonal changes, as significant differences have been observed even with limited check frequencies (Juškaitis 1986, Wikel & Hudde 1988, Krištín et al. 2001, Zang & Kunze 2009).

Sex structure

Across all our study sites together, males consistently prevailed, which is consistent with studies in Germany (Winkel & Hudde 1988, Zang & Kunze 2009) founding only a slight male prevalence. A more pronounced male prevalence was noted in Central Slovakia (Krištín et al. 2001). Notably, there were differences in sex ratios across our study sites. In parklands (BG, FNS), males predominated, whereas in woodlands (ZOO), the sex ratio was nearly balanced (Fig. 4). This suggests a potential link between sex structure and habitat quality. Less suitable habitats may be occupied by young, unpaired males, which serve as a population reserve (Matthysen 1990). In contrast, better-quality habitats, with winter territories defended by both sexes, would have a more balanced sex ratio (Löhrl 1988, Matthysen 1990). Additionally, differences in migration strategies among young birds might also explain the higher male prevalence in parklands, however no significant differences between sexes have been found (Matthysen & Schmidt 1987). Females may also be displaced from territories by unpaired males during the non-breeding period (Glutz & Bauer 1993), though paired individuals do not typically attack non-paired females (Löhrl 1988, Matthysen 1990, Glutz & Bauer 1993). Both sexes showed the same pattern in nest box occupancy with peak numbers in November (Fig. 5), followed by a decline, consistently with other studies (Winkel & Hudde 1988, Zang & Kunze 2009).

Roosting site fidelity

The proportion of faithful individuals (those recaptured within one season) in our study was 36.2%, without differences between study plots. It is notably lower compared to the 71.3%

recorded in the oak-hornbeam forest (Krištín et al. 2001). It suggests the effect of urban habitat on the wider scales, probably due to higher bird mortality in cities (Loss et al. 2015). The lack of significant differences in fidelity between sexes (as found in both our study and Krištín et al. 2001) is likely related to their paired winter territory defence (Löhrl 1988, Matthysen 1990).

The proportion of inter-annually recaptured Nuthatches in our study (11.3%) is similar as 13.6% found in Central Slovakia (Krištín et al. 2001) and significantly lower than the 52.4% reported in Central Poland (Busse & Olech 1968). The presence of inter-annually faithful individuals exclusively in the ZOO site may indicate lower habitat quality and/or lower survival in parkland sites (especially in BG, where the research duration was comparable to ZOO). We retrapped three individuals during the three consecutive winters (3 out of 35 recorded individuals in 6 seasons). In a forest near Warsaw, one individual was recorded over five winters (Busse & Olech 1968) and near Zlín (Czech Republic), one roosting Nuthatch (0.4%) was found to be over seven years old (Zvářal 2010).

Conclusion

Our research provides new insights into nest box occupancy, population structure, and fidelity by the roosting Eurasian Nuthatches in different habitats of city environment. Habitat (oakwood in city vs. parkland) strongly influences nest box occupancy. In parkland sites, were numbers lower and males were more prevalent compared to the oak forest fragment. The individuals using nest boxes across multiple winters were observed also only in the woodland plot. These findings highlight potential habitat differences and underscore the need for further research to assess long-term trends on large scales.

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Súhrn

Brhlík lesný patrí k bežným druhom vtákov využívajúcim na nocovanie vtáčie búdky. Bližšie údaje o obsadenosti búdok, pohlavnej štruktúre či vernosti nocovisku z mestského prostredia však chýbajú. V priebehu šiestich sezón sme na troch lokalitách v meste Bratislava: ZOO, Botanická záhrada (BG) a okolie Prírodovedeckej fakulty (FNS) uskutočnili spolu 233 nočných kontrol v zimnom období a skontrolovali spolu 9153 búdok. Brhlík bol nájdený v 151 prípadoch. V búdkach nocovali vtáky po jednom, len raz sme zaznamenali spoločné nocovanie dvoch. V zastúpení brhlíkov spomedzi nocujúcich vtákov i v obsadenosti búdok týmto druhom sa lokality medzi sebou líšili štatisticky významne. Výrazne početnejšie boli brhlíky v biotope s charakterom dubového lesa v ZOO oproti parkovým biotopom (BG a FNS). Obsadenosť búdok týmto druhom sa líšila aj medzi sezónami a pozitívne korelovala s obsadenosťou búdok sýkorkou veľkou. Počas dní s vyššou priemernou dennou vlhkosťou a daždivejších večerov (úhrn zrážok medzi 18:00 a 19:00) obsadenosť rástla štatisticky významne. Najvyšší počet zaznamenaných jedincov bol v mesiacoch november (ZOO, FNS) a december (BG). Samce prevažovali nad samicami signifikantne na lokalitách s charakterom parku (BG a FNS), v dubovom lese v ZOO bol pomer pohlaví vyrovnaný. V rámci jednej zimnej sezóny bolo 36,2 % nocujúcich jedincov (N = 58) odchytených v búdkach viac než jedenkrát, bez rozdielov medzi pohlaviami. Medziročne verné jedince sa nám podarilo u tohoto druhu zachytiť iba v ZOO, kde tvorili 17,1 %

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