Vespertilio 15: 71–77, 2011
ISSN 1213-6123

Tree roosts and competitors of *Nyctalus noctula* in the Sihoť town park, Nitra, Slovakia

Ladislav Naďo[1], Martin Ceľuch[2], Martin Ševčík[3] & Peter Kaňuch[4]

[1] *Department of Ecology and Environmental Sciences*, *Constantine the Philosopher University*, *Tr. A. Hlinku 1*, *SK–949 74 Nitra*, *Slovakia*; *ladislavnao@gmail.com*
[2] *Slovak Bat Conservation Society*, *Andraščíkova 1*, *SK–085 01 Bardejov*, *Slovakia*
[3] *Department of Zoology and Anthropology*, *Constantine the Philosopher University*, *Nábrežie mládeže 91*, *SK–949 74 Nitra*, *Slovakia*
[4] *Institute of Forest Ecology*, *Slovak Academy of Sciences*, *Ľ. Štúra 2*, *SK–960 53 Zvolen*, *Slovakia*

Abstract. Old parks provide roosting opportunities for tree-dwelling species in an extensively urbanized landscape. We compared morphological characteristics of roosts inhabited by *Nyctalus noctula* bats with those of other species such as birds and socially living insects, to find preferences of various tree-dwelling guilds. Morphological characteristics of roosts used by *N. noctula* did not significantly differ from those of other tree-dwelling species, and the analysis revealed a large degree of overlap in their realised niches. Especially bats and birds used hollows with common attributes. Hence, a question arises about possible competition for tree hollows among different groups of dwellers.

Noctule bat, tree cavities, urban, breeding season, autumn

Introduction

For several species of temperate bats, tree cavities represent an important vegetation structure – providing space for roosting, breeding, mating and hibernation, or just a shelter against harsh outdoor conditions (e.g. Meschede & Heller 2000, Agosta 2002). Tree roosts also provide place for information transfer between members of colonies (Wilkinson 1992, Kerth & Reckardt 2003). Although tree cavities can last for several years, they are relatively temporary roosts. They are created through wood decay (Remm & Lõhmus 2011), excavation by primary users (Martin et al. 2004) or by random events (such as lightning strike), and they are lost by deterioration or by tree fall. The role of woodpeckers in cavity creation is undoubted, despite their declining diversity across Europe (Mikusiński & Angelstam 1998). However, it has been suggested that the cavity abundance is primarily influenced by a climatic factor, probably related to fungal decay, which is often limited by humidity (Remm et al. 2005). Due to forestry practices applied, most of the hollow trees are logged, with minority of them selected for retention, and the density of this micro-habitat remains reduced and insufficient. Recently a special attention has been given to this problem, with effort to gain information applicable in conservation management (Gibbons et al. 2002, Russo et al. 2004, Remm et al. 2005, Spada et al. 2008, Lučan et al. 2009, Ruczyński et al. 2010).

The mechanism of cavity selection depends on a wide complex of environmental and social factors and on many specific requirements resulting from different life strategies of the tree-dwelling species. The selection of cavities is very often explained by their morphological (internal and external) characteristics (Sedgeley & O'Donnell 1999, Gibbons et al. 2002, Russo et al. 2004, Kaňuch 2005, Willis & Brigham 2005, Spada et al. 2008, Ruczyński et al. 2010), by their distances to foraging habitats (Boonman 2000), parasite load (Richner et al. 1993), inter-specific

(Newton 1994, Perkins 1996) and intra-specific (Poonswad et al. 2005) competition with other tree dwellers, and predation risk (Martin 1993). The most leading factor driving the selection is microclimate, which seems to result from interaction of morphological characteristics and ability to intercept solar radiation of a roost (Sedgeley & O'Donnell 1999). Combination of temperature and humidity (Kerth et al. 2001, Sedgeley 2001, Willis & Brigham 2005) has a major impact on tree-hollow occupancy. Selecting roosts with specific microclimate conditions is important for maintaining positive energy budgets. Higher temperature helps tree dwellers to reproduce more efficiently (Racey 1973, Racey & Swift 1981, Webb 1987).

Studies on the use of tree roosts have been carried out mostly in managed and unmanaged woodlands. Although old parklands may represent "islands" of favourable habitats, providing a wide variety of roosting opportunities for tree-dwelling species in an extensively urbanized landscape, studies aimed at bats inhabiting such habitats are rather rare (e.g. Červený & Bürger 1989, Glendell & Vaughan 2002, Kaňuch 2005). Populations of bats and birds in this environment may achieve very high densities (Červený & Bürger 1989, Kaňuch 2005), so the interactions among the cavity-dwelling fauna may be more intensive than in other habitats.

In this study we compared morphological characteristics of roosts inhabited by bats with other groups of tree-dwelling species (birds and socially living insects) in the same area during two major periods of the season (nesting of birds, formation of bat harems).

Material and methods

Study area

The study was conducted in the Sihoť town park (Nitra, western Slovakia, 48° 18' N, 18° 04' E; 140 m a. s. l.), with an area of 30 ha. The park has been formed from an alluvial forest in abandoned meanders of the Nitra river. Lime (*Tilia cordata*) and birch (*Betula pendula*) are dominant tree species, ash (*Fraxinus excelsior*) and aspen (*Populus nigra* variety *Italica*) are less abundant. The original tree species composition has been reduced and extended with various introduced ornamental species. After regulation of the river bed, the remains of river meanders have been transformed into a system of lakes which are (together with the nearby river) the most used foraging habitats of bats. A numerous bat fauna (10 species) has been recorded in this area (Ševčík & Ceľuch 2006). However, only one regular tree-dwelling species *Nyctalus noctula* (Schreber, 1774) has been actually found there (Ceľuch et al. 2007).

Data collection and analysis

Locations of most of the cavities were obtained from a former study (Ceľuch et al. 2007) conducted in this area. The roosts of *N. noctula*, with social calls audible at rather long distances (cf. Stratmann 1978), were found mostly acoustically. All hollows were checked visually by climbing techniques at approximately two-week intervals from April to December 2009 (in total 18 visits per hollow). To obtain information about the species presence in the roosts of complicated shape, a mirror and a flashlight were used for inspection. The following internal and external morphological characteristics of tree hollows were taken: entrance diameter, internal height above and below hollow entrance, internal hollow diameter, trunk diameter at the entrance, entrance height above the ground, trunk diameter at the breast height (DBH). In most cases, it was almost impossible to estimate the origin of the cavity. Therefore, this characteristic has been excluded from analysis.

To test the differences in morphology between occupied and unoccupied hollows, and to find differences in preferences among groups of tree-dwelling animals (i.e. to distinguish their realized niches), the Discriminant Function Analysis (DFA) was used. To maintain normal distribution, the data for this analysis were transformed by natural logarithm. Statistical calculations were performed using the Statistica 8 software (StatSoft, Inc.).

Results

Altogether 40 tree cavities were found on 29 trees, strongly varying in their morphological characteristics (Table 1). Noctule bats used tree hollows over the whole season, the highest total abundance was observed during autumn (95 ind.) when they used tree hollows for mating. The estimated maximum density of this species was approximately 0.32 ind×ha^{-1}. The number of

Table 1. Morphology of all tree hollows (*n*=40) and cavities used by *Nyctalus noctula* for roosting (*n*=27)
Tab. 1. Rozmery všetkých stromových dutín (*n*=40) a dutín obsadzovaných *Nyctalus noctula* (*n*=27)

variable / parameter	all tree hollows		*Nyctalus noctula*	
	median	range	median	range
entrance diameter / priemer vstupného otvoru [cm]	5	3–8	5	3–6
internal hollow diameter / vnútorný priemer dutiny [cm]	21	9–36	23	13–34
height above the entrance / výška nad vchodom [cm]	12	0–125	10	0–67
height below the entrance / hĺbka dutiny [cm]	17	0–60	18	0–60
trunk diameter / priemer kmeňa [cm]	147	68–262	130	68–220
DBH / priemer kmeňa (vo výške pŕs) [cm]	223	111–465	250	119–346
entrance height / výška vstupného otvoru [cm]	543	132–800	530	260–800

hollows occupied by bats during one check ranged from 3 to 20, with an average of 11.7. Apart of regular presence of *N. noctula*, a solitary individual of *Myotis daubentonii* (Kuhl, 1817) was recorded once in the study period. The birds were present in hollows during the breeding season only. This local community comprised nests of *Dendrocopos major* (Linnaeus, 1758) in one hollow, *Sturnus vulgaris* (Linnaeus, 1758) in six hollows, and *Sitta europaea* Linnaeus, 1758 in one hollow.

The average overall rate of occupancy was 40.4%. The lowest occupancy of hollows was registered in December (6.8%), whereas the highest in September (59.1%) (Fig. 1). Thirteen cavities (32.5% of all roosts) were occupied exclusively by noctules. Seven cavities (17.5%) were used exclusively by insects and only one roost exclusively by birds (2.5%). Altogether 15 cavities (37.5%) were used by both bats and birds (separately in time). Socially living hymenopterans such as wasps and bees were recorded in tree-hollows over the whole observed season. Only four roosts exhibited negative occupancy. The classification according DFA for the breeding season (April – June) contained all three groups of dwellers (bats, birds and insects) and unoccupied cavities. This model was not significantly different from random (Wilks' λ=0.49; $F_{(12, 61)}$=1.58; p>0.05)

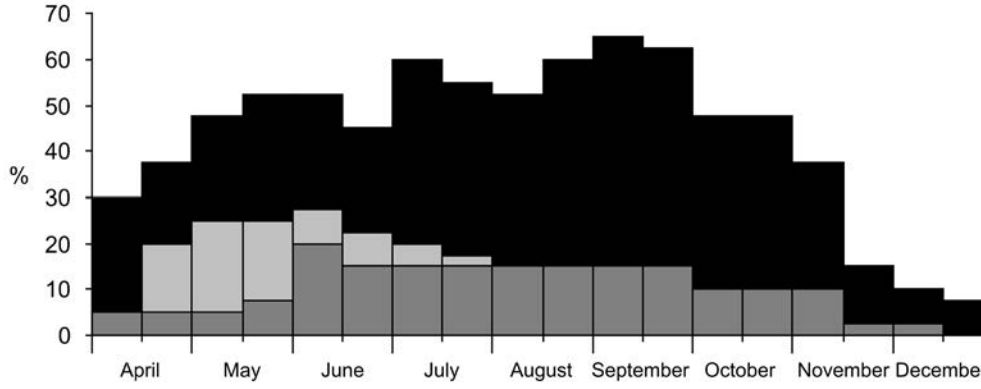

Fig. 1. Occupancy of tree hollows by *Nyctalus noctula* (black), birds (light grey) and bees or wasps (dark grey) during the season (*n*=40 roosts). Each column represents one check at two-week intervals.
Obr. 1. Obsadenie stromových dutín druhom *Nyctalus noctula* (čierna), vtákmi (svetlo sivá) a včelami alebo osami (tmavo sivá) počas sezóny (*n*=40). Stĺpce predstavujú kontroly, robené v dvojtýždňových intervaloch.

Table 2. Standardized coefficients of canonical variables which entered the model
Tab. 2. Štandardizované koeficienty kanonických premenných, ktoré boli použité v testovanom modeli

variable / parameter	root 1	root 2	root 3
internal hollow diameter / vnútorný priemer dutiny [cm]	-0.679	0.457	0.633
entrance diameter / priemer vstupného otvoru [cm]	0.478	-0.665	0.466
trunk diameter at hollow entrance / priemer kmeňa [cm]	0.801	0.329	0.649
internal height above hollow entrance / výška nad vchodom [cm]	-0.694	-0.593	-0.017
eigenvalues	0.636	0.229	0.015
cumulative proportion / kumulatívny podiel	0.721	0.981	1.000

and no discriminant root was significant (Fig. 2A). The model constructed for the autumn season (July–December) contained only two groups of dwellers, bats and insects as well as unoccupied hollows. The overall classification for this season was significantly different from random (Wilks' λ=0.51; $F_{(8, 48)}$=2. 40; p=0.029). But only the first discriminant root was statistically significant (χ^2=17.16; df=8; p=0.029). The variables entering the model (*F*-remove=3.27) were: trunk diameter, height above entrance, entrance diameter and internal hollow diameter. The first discriminant function (Root 1) was weighted positively by trunk diameter and negatively by height above the entrance and internal hollow diameter (Fig. 2B). This root explained 72.1% of the data variation (Table 2); however, the correct classification rate was only 69.4%.

Discussion

Although roosting opportunities for bats are rare in an urbanized landscape, in our study we did not find as high population density as could be expected (see Červený & Bürger 1989 or Kaňuch

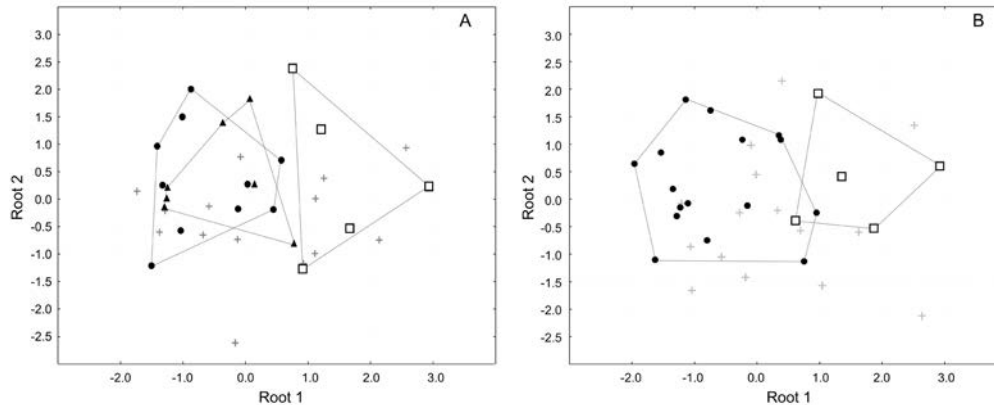

Fig. 2. Discrimination among different tree-dwelling guilds (*Nyctalus noctula* – circles, birds – triangles, bees or wasps – squares, unoccupied – crosses) in the breeding (A) and autumn (B) seasons in canonical analysis scatterplots (variables entering the models are shown in Table 2).
Obr. 2. Rozlíšenie rôznych gíld využívajúcich stromové dutiny (*Nyctalus noctula* – kruhy, vtáky – trojuholníky, včely alebo osy – štvorce, nevyužívané dutiny – krížiky) v hniezdnej sezóne (A) a na jeseň (B), ako výsledok kanonickej analýzy (premenné použité v modeli sú uvedené v tab. 2).

2005). This can be explained by low density of natural hollows in the managed parkland. Since noctule bats respond to the decreasing amount of suitable roost trees by selecting habitats offering them the highest potential number of roosts (Ruczyński et al. 2010), such low density in the town park of Nitra could be a result of the recent urbanisation process of this species (e.g. Ceľuch et al. 2006). Abundant artificial roosts (prefab houses) are available outside the tree vegetation. Generally, the species composition recorded in the cavities was similar as in other surveys from this area (Krištín 1974, Ceľuch et al. 2007).

Characteristics of roosts used by *N. noctula* did not significantly differ from those of the other tree-dwelling species. The observed degree of overlap in cavity morphology either indicates that (1) the number of hollows was in surplus compared to requirements of the studied groups, or (2) other variables not measured in this study affected occupancy and selection of the hollows.

The results of the presented study do not give evidence of the importance of structural characteristics for different tree-dwelling species (cf. Gibbons et al. 2002). The coexistence of different groups of animals in a common environment is enabled by differences in their realized niches. In an ideal case, the realized niches of the tree-dwelling species will not overlap, and each group will occupy hollows with different morphological characteristics. However, in our study area especially bats and birds shared hollows with common attributes and a considerable overlap between them. Although observations of direct interactions between these species are only anecdotal (Mason et al. 1972, Sparks et al. 2003); questions arise about possible competition for tree-hollows among different groups of dwellers. Such situation may occur not only in two separate guilds but also within the group itself. Here, the structural characteristics of tree cavities were found determining for several bat species (e.g. Sedgeley & O'Donnell 1999, Boonman 2000, Gibbons et al. 2002, Russo et al. 2004, Kaňuch 2005). Due to similarities in some characteristics, a potential for niche overlap was suggested (Timpone et al. 2009). However, we suggest that the structural characteristics, determining also the microclimate (Kerth et al. 2001, Sedgeley 2001), play only one of the roles in the roost-site selection of tree-dwelling species.

Súhrn

Stromové dutiny a konkurenti *Nyctalus noctula* v mestskom parku Sihoť, Nitra. Staré parky poskytujú v intenzívne urbanizovanej krajine úkrytové možnosti pre živočíchy využívajúce stromové dutiny. Rozdiely v preferenciách medzi jednotlivými skupinami živočíchov sme porovnávali na základe morfologických charakteristík úkrytov využívaných netopiermi *N. noctula* a ostatnými živočíchmi (vtáky a sociálny hmyz). Morfologické charakteristiky úkrytov využívanými *N. noctula* sa nelíšili od charakteristík dutín ostatných druhov a analýzy naznačujú vysoký stupeň prekrytia ník. Najmä netopiere a vtáky využívali dutiny rovnakých rozmerov. Tento fakt otvára otázky možnej konkurencie medzi rôznymi skupinami druhov využívajúcimi stromové dutiny.

Acknowledgements

We would like to acknowledge the staff of the Ponitrie Protected Landscape Area Administration (Nitra) for their help with the equipment. For help with data collection we thank (in alphabetical order) Tatiana Aghová, Katarína Bahnová, Lucia Domaracká, Renáta Džubáková, Jozef Gallik, Laura Hodálová, Denisa Löbbová, Marta Miklášová, Jozef Sluka, Dominik Smažák, Tomáš Veselovský. Preparation of this paper was partly supported by the grant VEGA 2/0110/09.

References

Agosta S. J., 2002: Habitat use, diet and roost selection by the big brown bat (*Eptesicus fuscus*) in North America: a case for conserving an abundant species. *Mammal Review*, **32**: 179–198.

Boonman M., 2000: Roost selection by noctules (*Nyctalus noctula*) and Daubenton's bats (*Myotis daubentonii*). *Journal of Zoology, London*, **251**: 385–389.

Ceľuch M., Danko Š. & Kaňuch P., 2006: On urbanisation of *Nyctalus noctula* and *Pipistrellus pygmaeus* in Slovakia. *Vespertilio*, **9–10**: 219–221.

Ceľuch M., Ševčík M. & Nemček M., 2007: Stromové dutiny ako konkurenčné prostredie živočíchov [Foraging assemblages and roosts of bats in the City park Sihoť in Nitra]. P.: 8. In: Stloukal E. (ed.): *Zborník abstraktov z konferencie 13. Feriancove dni* [*Proceedings of Abstracts from the 13th Ferianc Days Conference*]. Faunima, Bratislava, 56 pp (in Slovak).

Červený J. & Bürger P., 1989: Density and structure of bat community occupying an old park at Žihobce (Czechoslovakia). Pp.: 475–488. In Hanák V., Horáček I. & Gaisler J. (eds.): *European Bat Research 1987*. Charles University Press, Prague, 718 pp.

Gibbons P., Lindenmayer D. B., Barry S. C. & Tanton M. T., 2002: Hollow selection by vertebrate fauna in forests of southeastern Australia and implications for forest management. *Biological Conservation*, **103**: 1–12.

Glendell M. & Vaughan N., 2002: Foraging activity of bats in historic landscape parks in relation to habitat composition and park management. *Animal Conservation*, **5**: 309–316.

Kaňuch P., 2005: Roosting and population ecology of three syntopic tree-dwelling bat species (*Myotis nattereri*, *M. daubentonii* and *Nyctalus noctula*). *Biologia, Bratislava*, **60**: 579–587.

Kerth G. & Reckardt K., 2003: Information transfer about roosts in female Bechstein's bats: an experimental field study. *Proceedings of the Royal Society of London, Series B: Biological Sciences*, **270**: 511–515.

Kerth G., Weissmann K. & Konig B., 2001: Day roost selection in female Bechstein's bats (*Myotis bechsteinii*): a field experiment to determine the influence of roost temperature. *Oecologia*, **126**: 1–9.

Krištín A., 1974: *Výskyt a ochrana chránených druhov živočíchov* (*stavovcov*) *v Nitre a jej blízkom okolí* [*Occurrence and Conservation of Protected Animal Species* (*Vertebrates*) *in Nitra and its Neighbourhood*]. Unpubl. Thesis. Gymnasium, Nitra, 91 pp.

Lučan R. K., Hanák V. & Horáček I., 2009: Long-term re-use of tree roosts by European forest bats. *Forest Ecology and Management*, **258**: 1301–1306.

Martin K., Aitken K. E. H. & Wiebe K. L., 2004: Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: nest characteristics and niche partitioning. *The Condor*, **106**: 5–19.

Martin T. E., 1993: Nest predation and nest sites: new perspectives on old patterns. *BioScience*, **43**: 523–532.

Mason C. F., Stebbings R. F. & Winn G. P., 1972: Noctules (*Nyctalus noctula*) and starlings (*Sturnus vulgaris*) competing for roosting holes. *Journal of Zoology, London*, **166**: 467.

Meschede A. & Heller K. G., 2000: *Ökologie und Schutz von Fledermäusen in Wäldern. Schriftenreihe für Landschaftspflege und Naturschutz 66*. Bundesamt für Naturschutz, Bonn-Bad Godesberg, 325 pp.

Mikusiński G. & Angelstam P., 1998: Economic geography, forest distribution, and woodpecker diversity in Central Europe. *Conservation Biology*, **12**: 200–208.

Newton I., 1994: The role of nest sites in limiting the numbers of hole-nesting birds: A review. *Biological Conservation*, **70**: 265–276.

Perkins J. M., 1996: Does competition for roosts influence bat distribution in managed forest? Pp.: 164–174. In: Barclay R. M. R. & Brigham M. R. (eds.): *Bats and Forests Symposium. October 19–21, 1995. Victoria, British Columbia, Canada*. British Columbia Ministry of Forests, Victoria, 292 pp.

Poonswad P., Sukkasem C., Phataramata S., Hayeemuida S., Plongmai K., Chuailua P., Thiensonggrusame P. & Jirawtkavi N., 2005: Comparison of cavity modification and community involvement as strategies for hornbill conservation in Thailand. *Biological Conservation*, **122**: 385–393

Racey P. A., 1973: Environmental factors affecting the length of gestation in heterothermic bats. *Journals of Reproduction and Fertility Supplement*, **19**: 175–189.

Racey P. A. & Swift S. M., 1981: Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus pipistrellus*) from year to year. *Journals of Reproduction and Fertility*, **61**: 123–129.

Remm J., Lõhmus A. & Remm K., 2005: Tree cavities in riverine forests: What determines their occurrence and use by hole-nesting passerines? *Forest Ecology and Management*, **221**: 267–277.

Remm J. & Lõhmus A., 2011: Tree cavities in forests – the broad distribution pattern of a keystone structure for biodiversity. *Forest Ecology and Management*, **262**: 579–585.

Richner H., Oppliger A. & Christe P., 1993: Effect of an ectoparasite on reproduction in great tits. *Journal of Animal Ecology*, **62**: 703–710.

Ruczyński I., Nicholls B., MacLeod C. D. & Racey P. A., 2010: Selection of roosting habitats by *Nyctalus noctula* and *Nyctalus leisleri* in Białowieża Forest – Adaptive response to forest management? *Forest Ecology and Management*, **259**: 1633–1641.

Russo D., Cistrone L., Jones G. & Mazzoleni S., 2004: Roost selection by barbastelle bats (*Barbastella barbastellus*, Chiroptera: Vespertilionidae) in beech woodlands of central Italy: consequences for conservation. *Biological Conservation*, **117**: 73–81.

Sedgeley J. A., 2001: Quality of cavity microclimate as a factor influencing selection of maternity roosts by a tree-dwelling bat, *Chalinolobus tuberculatus*, in New Zealand. *Journal of Applied Ecology*, **38**: 425–438.

Sedgeley J. A. & O'Donnell C. F. J., 1999: Factors influencing the selection of roost cavities by a temperate rainforest bat (Vespertilionidae: *Chalinolobus tuberculatus*) in New Zealand. *Journal of Zoology, London*, **249**: 437–446.

Ševčík M. & Ceľuch M., 2006: Lovné zoskupenia a úkryty netopierov Nitrianskeho mestského parku Sihoť [Foraging assemblages and roosts of bats in the City park Sihoť in Nitra]. P.: 243. In: Uhrin M. & Ceľuch M. (eds.): *Chiropterologický seminár 2006* [*Chiropterological Seminar 2006*]. *Vespertilio*, **9–10**: 237–244 (in Slovak).

Spada M., Szentkuti S., Zambelli N., Mattei-Roesli M., Moretti M., Bontadina F., Arlettaz R., Tosi G. & Martinoli A., 2008: Roost selection by non-breeding Leisler's bats (*Nyctalus leisleri*) in montane woodlands: implications for habitat management. *Acta Chiropterologica*, **10**: 81–88.

Sparks D. W., Simmons M. T., Gummer C. L. & Duchamp J. E., 2003: Disturbance of roosting bats by woodpeckers and rackoons. *Northeastern Naturalist*, **10**: 105–108.

Stratmann B., 1978: Faunistich-ökologische Beobachtungen an einer Population von *Nyctalus noctula* im Revier Ecktannen des StFB Waren (Müritz). *Nyctalus* (*N. F.*), **1**(1): 2–22.

Timpone J. C., Boyles J. G., Murray K. L., Aubrey D. P. & Robbins L. W., 2009: Overlap in roosting habits of Indiana bats (*Myotis sodalis*) and northern bats (*Myotis septentrionalis*). *The American Midland Naturalist*, **163**: 115–123.

Webb D. R., 1987: Thermal tolerance of avian embryos: a review. *The Condor*, **89**: 874–898.

Wilkinson G. S., 1992: Information transfer at evening bat colonies. *Animal Behaviour*, **44**: 501–518.

Willis C. K. R. & Brigham M. R., 2005: Physiological and ecological aspects of roost selection by reproductive female hoary bats (*Lasiurus cinereus*). *Journal of Mammalogy*, **86**: 85–94.

došlo 13. 12. 2011