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Cimicids and bat hosts in the Czech and Slovak Republics: ecology and distribution

Ondřej Balvín[1] & Tomáš Bartonička[2]

[1] *Department of Ecology*, *Faculty of Environmental Sciences*, *Czech University of Life Sciences Prague*, *Kamýcká 129*, *CZ–165 21 Praha 6*, *Czech Republic*
[2] *Department of Botany and Zoology*, *Faculty of Science*, *Masaryk University*, *Kotlářská 2*, *CZ–611 37 Brno*, *Czech Republic*

Abstract. The species of the genus *Cimex* (Heteroptera: Cimicidae) belong to important ectoparasites of European bats. The two bat-related *Cimex* species (*C. pipistrelli*, *C. lectularius*) occurring in Central Europe share a very similar life style, but differ in their ecology and host interactions. The study reports on faunistic data obtained during a thorough investigation of roosts of diverse bat species on a west-east transect across the Czech and Slovak Republics. Most data reported in this study come from visits carried out during the systematic monitoring of two species of bats, i.e. *M. myotis* and *M. emarginatus*, but also from occasional surveys due to liquidation of bat shelters. We found a positive correlation between changes in abundance of bugs and bat numbers in colonies. Temporary decrease in bat numbers or entire absence of bats in the roost can be a good mechanism leading to a significant reduction in the abundance of bugs in the given roost. Finally, new information on recent cases of bats being an apparent source of cimicids invading homes and level of the risk of development of a bug population in humans is reported.

Ectoparasites, roost ecology, host specifity

Introduction

History of research in Central Europe

Although the species of the family Cimicidae are important parasites of bats, due to their hidden life in bat roosts they are seldom found and inconsistently studied. The European fauna of cimicids was first to have drawn attention and belongs among those best known. Still, crucial gaps even in taxonomy and host specifity remained until recently.

The earliest data available from the Czech and Slovak Republics are merely faunistic (Kraszny 1875, Duda 1885, Spitzner 1892). The first researcher important for Central Europe was Horváth (1910) wo described a new species (*Cimex dissimilis*) from Hungary and provided a determination key to the known Palaearctic species of cimicids. The key was translated into Czech and commented by Mužík (1911). Later, Horváth (1935) described another species, *C. stadleri,* from Czechoslovakia.

The validity of the two European *Cimex* species described by Horváth was discussed, with regard to the first described species of the complex (*C. pipistrelli* Jenyns, 1839), by later European researchers (e.g. Wendt 1941, Lansbury 1961, Usinger 1966). An important opinion on this problem was formulated by a Czech researcher Povolný (1957). Unlike others accepting two or three species or at least distinct forms, he did not accept more than a single morphologically recognizable species. Besides that, Povolný's work (1957) dealt with the origin of the common bed bug (*C. lectularius* Linneaus, 1958) and also brought data on ecology of the Central European

Cimex species. Nevertheless, neither his nor other studies on taxonomy and ecology of the Central European bat-related taxa are based on systematic investigations or representative sampling.

In recent years, ecology, host relationsand taxonomic and population genetic questions have been studied using a systematic approach and sampling. Povolný's (1957) taxonomic opinion has been confirmed (Balvín et al. 2013) and only a single species of the *C. pipistrelli* complex is nowadays recognized. However, the species limits in the complex still remain to be redefined. The bed bug *C. lectularius* was found to be common in Central European roosts of *Myotis myotis* and *M. emarginatus* and the collected material served in examining the relation with the human-associated lineage, which appears as a newly emerging species (Balvín et al. 2012a, Booth et al. submitt.). The ecological investigations by Tomáš Bartonička were focused mainly on host defense strategies (see below).

Ecology and host interactions of the Central European *Cimex* species

The two bat-related *Cimex* species occurring in the Czech and Slovak Republics (*C. pipistrelli*, *C. lectularius*) share a very similar ecology and life style. Although Povolný (1957) reported differences in host relations, *C. pipistrelli* being related mainly to crevice-dwelling species such as *Nyctalus noctula* and *C. lectularius* to attic-dwelling bats such as *Myotis myotis*, host records in total (see Usinger 1966 or Table 1) show that both *Cimex* species inhabit natural as well as synanthropic roosts of many bat species with different ecology. They spend most of their time in refugia located near the bat colonies. Typically, such refugia are hidden in crevices in wood, rocks or walling. Single individuals are often found on the surface of wood or walls of the roost.

In the refugia, the cimicids overwinter starving while the host bats move to winter roosts. *Cimex lectularius* was shown to be able to starve for 18 months (Johnson 1942, Povolný 1957, Overal & Wingate 1976, Marshall 1982), however, high temperatures limit the survival, and therefore starvation over two winters is unlikely and has never been reported. Bed bugs usually live around one year at a suitable temperature and optimal availability of the host (Usinger 1966).

Cimicids leave the refugia for feeding, locating the host based on CO_2 and thermal gradients, as well as host kairomones (Reinhardt & Siva-Jothy 2007). After feeding, the return to refugia is led by tracking contact pheromones (Levinson & Bar Ilan 1971). Alternatively, the bugs may remain attached to the host body in order to be transferred to new locations. The adults, especially mated females, which are able to start a new infestation, are more effective dispersal agents than larvae. Therefore, the records of exclusively adult, mostly female bugs on bats caught outside roosts strongly suggest that bugs remain attached to the bat leaving the roosts for the purpose of dispersal, rather than accidentally when feeding (Heise 1988, Balvín et al. 2012b). Moreover, among the records from mist-netted bats, the findings from *Nyctalus noctula* strikingly prevail. It is possible that the cimicids respond to the fission-fusion roosting model and the large extent of migratory behavior of such bat species by an increase in dispersal effort, in contrast with cimicids living on sedentary species such as *Myotis myotis*. However, the lack of genetic structure related to the host bat species in *C. pipistrelli* (Balvín et al. 2013) or in *C. lectularius* (Booth et al. submitt.) would suggest such variability to be due to adaptive plasticity and ability to recognize present host species rather than due to local adaptations.

When feeding, cimicids prefer hairless body parts: wings, forearms, uropatagium, feet and penis (Reinhardt & Siva-Jothy 2007). Wings, forearms and uropatagium are also the most likely places where cimicids can be found during transfers (Heise 1988). For the bats it is difficult to protect themselves by grooming. The cimicids produce large amounts of the defense substance and bats refuse to bite them (Usinger 1966). However, some bats are able to habituate and take a cimicid as a meal (Bartonička 2008, Bartonička et al. 2008).

Table 1. Review of records of *Cimex* spp. in European bat species available in literature and documented by our material. The first reference for each bat species known to us is listed. For details on our records from bat roosts see Table 2; N – number of roosts in the Czech Republic and Slovakia, * roost shared with *M. myotis*

bat species	*Cimex lectularius* reference	N	*Cimex pipistrelli* reference	N
Eptesicus serotinus	Balvín et al. (2012a)	1/0	Southwood & Leston (1959)	
Myotis bechsteinii	Scheffler (2008)		Morkel (1999)	
Myotis blythii	*Tagil'cev (1971) – *Cimex* sp.		*Tagil'cev (1971) – *Cimex* sp.	
Myotis brandtii			Heise (1988)	1/0
Myotis dasycneme			van Rooij et al. (1982)	
Myotis daubentonii	Wagner (1967)		Heise (1988)	2/0
Myotis emarginatus	Usinger & Beaucournu (1967)	3/2	Usinger (1966)	0/1*
Myotis nattereri				1/0
Myotis myotis	Povolný (1957)	23/5	Lederer (1950)	37/12
Myotis mystacinus	Poppius (1912)		Kerzhner (1989)	
Myotis oxygnathus	Usinger (1966)			
Nyctalus lasiopterus			Balvín et al. (2012b)	
Nyctalus leisleri	Bobkova (2001)		Nelson & Smiddy (1997)	
Nyctalus noctula	Heise (1988)		Povolný (1957)	6/1
Pipistrellus nathusii			Heise (1988)	
Pipistrellus pipistrellus	Rybin et al. (1989)		Jenyns (1839)	
Pipistrellus pygmaeus			Bartonička (2007)	3/0
Pipistrellus sp.		2/1*		
Plecotus auritus	Balvín et al. (2012b)			
Vespertilio murinus	Dubinij (1947)		Horváth (1935)	

The usual defense strategy of bats consists in moving away from the cimicids. In non-dwelling bat species, the usually inhabited large attics allow for moving far enough from the cimicid refugia (Bartonička & Růžičková 2012). The dwelling bat species exhibit a distinct pattern of roost switching that has been shown to efficiently reduce the parasite load (Bartonička & Gaisler 2007, Bartonička & Růžičková 2013). The impact of cimicids on the fitness of bats has not been successfully interpreted. Bad condition of bats is often correlated with the parasite load (Christe et al. 2000, Walter 1966) but it has not been answered what is the cause and what the consequence (Lourenço & Palmeirim 2007). However, the cimicids have been shown to be vectors of diverse bat pathogens or to cause secondary infections (Williams et al. 1976, Bowers & Woo 1981, Adelman et al. 2013). Unfortunately, the high level of synanthropy of Czech and Slovak bat species causes the cimicids to be, under certain circumstances, a health problem for human inhabitants as well. Typically, such problem is caused by the affiliation of *Nyctalus noctula* to apartment buildings, especially to concrete blocks of flats. This bat species began to inhabit this type of buildings shortly after they started to be built in Czechoslovakia in the 1960s. Two cases of cimicids invading homes from roosts of *N. noctula* in such buildings were described as soon as in the early 1970s (Šmaha 1976). Such cases and spreading of information threaten the tolerance of synanthropic bat colonies by people and, therefore, represent a serious problem in bat conservation.

The present study brings a thorough review of records of *Cimex* species in bat roosts in the Czech and Slovak Republics, which were gathered during the sampling effort in recent population genetic, taxonomic and ecological studies. Also, we collected data on several recent cases of bat-related cimicids penetrating homes and tried to determine the reason for the cimicids leaving the bat roost and searching for an alternate host in order to find out if such situations can be prevented or anticipated.

Material and Methods

Most data reported in this study come from visits carried out during the systematic monitoring of three species of bats (*Rhinolophus hipposideros*, *Myotis myotis* and *M. emarginatus*) included in the Natura 2000 system. During the monitoring or on other occasions, roosts of other bat species were often visited as well. During the visit, the roost was examined for the presence of cimicids paying special attention to most likely shelters of their refugia: crevices in walls and wood below and around the colony or bottom side of objects lying below the colony. If unsuccessful, dead cimicids were searched for in the guano or spider webs.

As many cimicids as possible were collected during each visit. The material is kept in 96% alcohol and deposited in the collection of either of the authors. Species determination was made according to characters summarized e.g. by Usinger (1966). Only one species of the *Cimex pipistrelli* group is considered in this study.

During the visits of bat roosts, the abundance of cimicids was estimated and recorded. As the conditions for collecting are different each time and the proportion of cimicid shelters found vs. those not found is always unclear, an abundance scale was set based on the collector's point of view: 1 – only exuviae or dead bodies found; 2 – only one or two live cimicids collected with a significant effort; 3 – it was possible to collect 10 specimens within 30–60 minutes; 4 – it was not difficult to collect up to 100 cimicids; 5 – abundance so high that sweeping became a more effective way to collect than tweezers (see Table 2). During the visits, the number of bats in the colony was recorded as well; however, data on the number of bats in the particular roosts were mostly available from all years since 2001 (unpubl. data, Czech Bat Conservation Trust).

In localities where two or more surveys of cimicids were carried out between 2005 and 2014, we examined the relationship between the change in cimicid abundance and change in the number of bats. The changes in the number of bats and the abundance of bugs were calculated for two subsequent visits during 3 years. We analyzed the differences in bug abundance and bat numbers using the Pearson correlation coefficient. In total, we obtained 41 data sets in the colonies of *Myotis myotis*, 1 in *M. emarginatus*, 2 in *M. daubentonii*, 1 in *Pipistrellus pygmaeus* and 2 in *Nyctalus noctula*.

Results and Discussion

Host records

Until recently, the knowledge on *Cimex* species parasitizing bats in the Czech and Slovak Republics has been rather scattered and inconsistent. While studies based on material from the area of

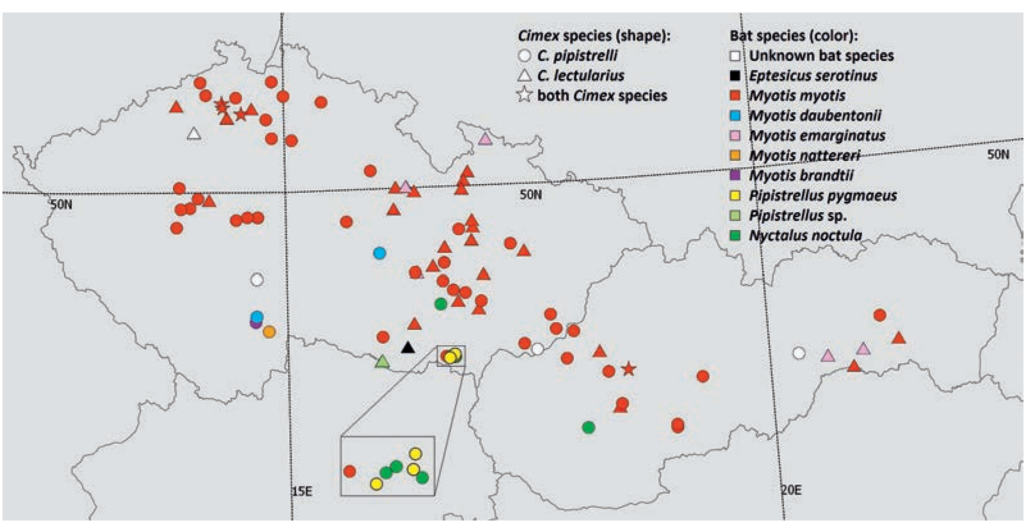

Fig. 1. Distribution of records of cimicids in bat roosts in the Czech Republic and Slovakia.

the Czech Republic have existed (Povolný 1957), presence of *C. lectularius* on bats in Slovakia was only briefly mentioned by Usinger (1966) and *C. pipistrelli* was reported from the country as late as by Krištofík & Kaňuch (2006).

Based on the recent records (Table 2, Fig. 1), both *C. lectularius* and *C. pipistrelli* can be regarded common in Czech and Slovak bat roosts. In total, *C. lectularius* was found in 24 roosts, *C. pipistrelli* in 45 roosts. Four other roosts (*Myotis myotis*) hosted both species. At Zemianske Kostoľany and Dubá (Table 2), both species were recorded at the same time. At Držovice and Úštěk, the two species were recorded on different occasions over several years. In many roosts the number of collected individuals was not representative enough to be able to responsibly exclude co-occurrence of the two *Cimex* species. However, the number of representative collections compared to the number of cases of co-occurrence suggest that such cases are rather rare and the population of cimicids in a particular roost mostly consists of one *Cimex* species. Based on such poor evidence, the mechanisms of competition or coexistence of *C. pipistrelli* and *C. lectularius* can be only speculated. However, the co-occurrence of the two *Cimex* species can be often due to co-occurrence of different bat species in the same roost. Attic-dwelling bat species such as *M. myotis*, frequently hosting *C. lectularius*, are often found to share the attic with crevice-dwelling bats such as *Pipistrellus* spp. (e.g. Hosťovce) or *Eptesicus* spp. (e.g. Oleksovice; see Table 2), regular hosts of *C. pipistrelli*.

When individual bat species are considered separately, the prevalence of cimicids in the roosts can be responsibly evaluated only in *Myotis myotis*. The maximum proportion of roosts found to be free of cimicids was 25%. However, in most of such negative records, the roost was either recently (re)colonized by the bat colony, or the colony consisted only of few individuals, or most often, the character of the roost did not allow examination of the most likely shelters of cimicids (roosts of other bat species than *M. myotis*). Therefore, stable roosts of *M. myotis* can be regarded as almost certain to host either of the *Cimex* species.

In *Myotis emarginatus*, the five positive records can be put in contrast to five negative ones, but obtained by responsible roost examinations. It is therefore likely that a stable roost of *M. emarginatus* is not always as suitable for cimicids as the roost of *M. myotis*. Furthermore, except the monastery at Jasov, Slovakia, housing colonies of many bat species, all roosts with exclusively *M. emarginatus*, only sometimes mixed with *Rhinolophus* spp., hosted *C. lectularius*.

For the other bat species, all from the dwelling ecological group, only few positive records exist. The negative records are not reliable due to the crevice character of the roosts. Still, when the positive records from these roosts (Table 2) are considered along with the records from mist-netted bats (Balvín et al. 2012b), at least *C. pipistrelli* can be regarded a regular parasite in the roosts of *Nyctalus noctula*, *Pipistrellus* spp. and *Myotis daubentonii*. Other records from the Czech or Slovak Republic come from *Eptesicus serotinus* (*C. lectularius*), *Myotis nattereri* (*C. pipistrelli*) and *M. brandtii* (*C. pipistrelli*) (Tables 1, 2).

Determinants of cimicid abundance

The estimate of cimicid abundance is expected to be rather vague in expressing the absolute number of cimicids in the bat roosts, however, considering the clear results of our analyses, it appears to be relevant when carried out repeatedly in one roost, showing a relative change. Based on 49 pairs of checks, obtained in a one, two or three year interval, we found a positive correlation between the changes in cimicid abundance and bat numbers in the colonies (Pearson correlation coefficient: $r=0.691$, $p<0.05$, $n=49$) (Fig. 2). An increase in bug abundance was detected in 20 pairs of checks, a decline in 20 pairs of checks and no change was recorded in nine cases. The increase in bug abundance followed an increase in bat numbers by 50.9±19.2% of the

Table 2. List of records of cimicids in bat roosts. HS – host species: more species listed mean mixed colonies (UBS – unknown bat species, *Eser* – *Eptesicus serotinus*, *Mbra* – *Myotis brandti*, *Mdau* – *M. daubentonii*, *Mema* – *M. emarginatus*, *Mmyo* – *M. myotis*, *Mbly* – *M. blythii*, *Moxy* – *M. oxygnathus*, *Mnat* – *M. naterreri*, *Nnoc* – *Nyctalus noctula*, *Pip* sp. – *Pipistrellus* sp. (*P. pipistrellus* or *P. pygmaeus*), *Ppyg* – *Pipistrellus pygmaeus*, *Reur* – *Rhinolophus euryale*, *Rfer* – *R. ferrumequinum*; NF – number of female bats in the collony; BS – cimicid species (*Clec* – *Cimex lectularius*, *Cpip* – *C. pipistrelli*); BA – bug abundance: scale based on the collector's point of view: 1 – only exuviae or dead bodies found; 2 – only one or two live cimicids collected with a significant effort; 3 – it was possible to collect 10 specimens within 30–60 minutes; 4 – it was not difficult to collect up to 100 cimicids; 5 – abundance so high that sweeping became a more effective way to collect than tweezers. * – data were used for correlation (Fig. 2)

country	locality	coordinates	date	bat species	colony size	collector(s)	BS	BA
SK	Beckov, monastery attic	48°47'N, 17°53'E	17 August 2010	*Mmyo*	550	O. Balvín, M. Ševčík	*Cpip*	5
CZ	Bělá pod Bezdězem, castle attic	50°30'N, 14°48'E	11 June 2009	*Mmyo*	500	O. Balvín, D. Horáček	*Cpip*	3*
CZ	Bělá pod Bezdězem, castle attic	50°30'N, 14°48'E	6 June 2010	*Mmyo*	80	D. Horáček	*Cpip*	5*
CZ	Beroun, school attic	49°57'N, 14°04'E	16 May 2005	*Mmyo*	606	O. Balvín, D. Weinfurtová	*Cpip*	2*
CZ	Beroun, school attic	49°57'N, 14°04'E	21 June 2006	*Mmyo*	600	D. Weinfurtová	*Cpip*	2*
CZ	Bílá Lhota, church	49°42'N, 16°58'E	22 July 2008	*Mmyo*	320	O. Balvín, J. Šafář	*Clec*	2*
CZ	Bílá Lhota, church	49°42'N, 16°58'E	29 June 2011	*Mmyo*	516	O. Balvín, J. Šafář	*Clec*	3*
CZ	Blansko, church attic	49°21'N, 16°38'E	27 June 2006	*Mmyo*	226	O. Balvín, M. Pokorný	*Cpip*	4*
CZ	Blansko, church attic	49°31'N, 16°38'E	13 July 2011	*Mmyo*	209	H. Berková, T. Bartonička	*Cpip*	3*
CZ	Bohdalice-Pavlovice, house attic	49°13'N, 17°01'E	22 July 2010	*Mmyo*	41	H. Berková	*Cpip*	1*
CZ	Bohdalice-Pavlovice, house attic	50°36'N, 15°24'E	26 June 2012	*Mmyo*	35	T. Bartonička, H. Berková	*Cpip*	2*
CZ	Bohdalice-Pavlovice, house attic	49°12'N, 17°01'E	27 June 2006	*Mmyo*	169	O. Balvín, M. Pokorný	*Cpip*	4*
CZ	Bohuslavice, church	49°37'N, 16°57'E	28 June 2006	*Mmyo*	271	O. Balvín, M. Pokorný	*Clec*	1*
CZ	Bohuslavice, church	49°37'N, 16°57'E	30 July 2011	*Mmyo*	540	H. Berková, T. Bartonička	*Clec*	3*
CZ	Borotín, castle	49°34'N, 16°40'E	28 June 2006	*Mmyo*	62	O. Balvín, M. Pokorný	*Clec*	1*
CZ	Borotín, castle	49°34'N, 16°40'E	14 June 2005	*Mmyo*	472	M. Pokorný, T. Bartonička	*Clec*	4*
CZ	Boskovice, castle attic	49°29'N, 16°39'E	26 July 2011	*Mmyo*	0	H. Berková, T. Bartonička	*Cpip*	1*
CZ	Boskovice, castle attic	49°29'N, 16°39'E	24 July 2009	*Mmyo*	100	H. Berková	*Cpip*	3*
CZ	Brandýs nad Orlicí, house attic	50°00'N, 16°16'E	21 June 2006	*Mema*	42	O. Balvín, V. Lemberk	*Clec*	2
CZ	Brandýs nad Orlicí, church	50°00'N, 16°17'E	21 June 2006	*Mmyo*	50	O. Balvín, V. Lemberk	*Clec*	2
CZ	Brno, house window	49°12'N, 16°36'E	3 August 2005	*Nnoc*	?	T. Bartonička	*Cpip*	3
CZ	Bučovice, castle	49°08'N, 17°00'E	27 June 2006	*Mmyo*	453	O. Balvín, M. Pokorný	*Clec*	4*
CZ	Bučovice, castle attic	49°08'N, 17°00'E	14 July 2011	*Mmyo*	630	H. Berková, T. Bartonička	*Cpip*	2*
CZ	Býšť, church tower	50°07'N, 15°54'E	14 June 2007	*Mmyo*	450	O. Balvín, V. Lemberk	*Cpip*	5*
CZ	Býšť, church tower	50°07'N, 15°54'E	25 June 2014	*Mmyo*	450	O. Balvín, V. Lemberk	*Cpip*	5*
CZ	Černá Voda, house attic	50°18'N, 17°09'E	27 July 2011	*Mema*	42	J. Šafář, T. Bartonička	*Clec*	2*
CZ	Černá Voda, house attic	50°18'N, 17°09'E	20 July 2012	*Mema*	198	T. Bartonička, J. Šafář	*Clec*	1*
CZ	Český Dub, school attic	50°39'N, 14°59'E	21 June 2006	*Mmyo*	1044	D. Horáček	*Cpip*	4*
CZ	Český Dub, school attic	50°39'N, 14°59'E	11 June 2009	*Mmyo*	785	O. Balvín, D. Horáček	*Cpip*	1*
CZ	Chodouň, school attic	49°53'N, 13°59'E	16 May 2005	*Mmyo*	64	O. Balvín, D. Weinfurtová	*Cpip*	3*
CZ	Chodouň, school attic	49°53'N, 13°59'E	15 June 2006	*Mmyo*	186	D.Weinfurtová	*Cpip*	1*
CZ	Doksy, Kladno Dist., castle	50°33'N, 14°39'E	11 June 2009	*Mmyo*	0	O. Balvín, D. Horáček	*Clec*	1*
CZ	Doksy, Kladno Dist., castle	50°33'N, 14°39'E	15 July 2007	*Mmyo*	310	D. Horáček	*Clec*	4*
SK	Domaníky, church tower	48°15'N, 18°59'E	8 July 2011	*Mmyo*	105	O. Balvín, M. Ševčík	*Cpip*	2
CZ	Doubravník, paper mill	49°24'N, 16°22'E	25 July 2006	*Mema*	250	O. Balvín, J. Čejka	*Clec*	2

country	locality	coordinates	date	bat species	colony size	collector(s)	BS	BA
CZ	Doubravník, church tower	49°25'N, 16°21'E	25 July 2006	*Mmyo*	600	O. Balvín, J. Čejka	*Cpip*	5*
CZ	Doubravník, church tower	49°25'N, 16°21'E	13 July 2007	*Mmyo*	610	T. Bartonička	*Cpip*	5*
CZ	Držovice, house attic	50°36'N, 14°19'E	16 July 2008	*Mmyo*	1020	B. Franěk	*Cpip*	2*
CZ	Držovice, house attic	50°36'N, 14°19'E	10 September 2005	*Mmyo*	320	B. Franěk	*Clec*	4*
CZ	Držovice, house attic	50°36'N, 14°19'E	10 July 2014	*Mmyo*	0	B. Franěk, D. Sadílek	*Clec*	1*
CZ	Dubá, house attic	50°32'N, 14°32'E	13 May 2013	*Mmyo*	1200	O. Balvín, B. Borel	*Clec**	4*
CZ	Dubá, house attic	50°32'N, 14°32'E	20 May 2014	*Mmyo*	1200	O. Balvín, D. Sadílek	*Clec**	4*
CZ	Dubá, house attic	50°32'N, 14°32'E	11 June 2009	*Mmyo*	1200	O. Balvín, D. Horáček	*Clec*	3
CZ	Hanušovice, church	50°05'N, 16°56'E	2 December 2007	*Mmyo*	858	T. Bartonička	*Clec*	4*
CZ	Hanušovice, church	50°05'N, 16°56'E	17 April 2012	*Mmyo*	312	T. Bartonička	*Clec*	5*
CZ	Hanušovice, church	50°05'N, 16°56'E	12 August 2012	*Mmyo*	867	T. Bartonička	*Clec*	5*
CZ	Hanušovice, church	50°05'N, 16°56'E	15 April 2013	*Mmyo*	380	T. Bartonička	*Clec*	5*
CZ	Hanušovice, church	50°05'N, 16°56'E	6 August 2014	*Mmyo*	400	T. Bartonička	*Clec*	5*
CZ	Hnanice, gamekeeper's house	48°48'N, 15°58'E	4 May 2003	*Pip*. sp.		J. Vilímová	*Clec*	4
CZ	Hnanice, hunting hide	48°48'N, 15°58'E	1 June 1998	*Pip*. sp.		J. Vilímová, A. Reiter	*Clec*	4
SK	Hontianske Nemce, church attic	48°17'N, 18°59'E	8 July 2011	*Mmyo*	1000	O. Balvín, M. Ševčík	*Cpip*	4
SK	Horná Súča, church attic	48°58'N, 17°58'E	17 August 2010	*Mmyo*	400	O. Balvín, M. Ševčík	*Cpip*	2
SK	Hostie, church attic	48°27'N, 18°26'E	8 July 2011	*Mmyo*	0	O. Balvín, M. Ševčík	*Cpip*	2
SK	Hosťovce, church	48°34'N, 20°51'E	13 July 2011	*Mmyo*, *Pip*. sp.	280	O. Balvín, M. Ševčík	*Clec*	4
SK	Jasov, monastery	48°40'N, 20°58'E	11 July 2011	mainly *Mema*		O. Balvín, M. Ševčík	*Clec*	4
CZ	Jeřišno-Heřmaň, church tower	49°47'N, 15°38'E	18 September 2007	*Mmyo*	260	O. Balvín	*Cpip*	4*
CZ	Jeřišno-Heřmaň, church tower	49°47'N, 15°38'E	24 July 2005	*Mmyo*	650	T. Bartonička	*Cpip*	3*
CZ	Jeřišno-Heřmaň, church tower	49°47'N, 15°38'E	27 July 2001	*Mmyo*	260	J. Hotový	*Cpip*	4*
CZ	Jevišovice, castle attic	48°59'N, 15°59'E	17 July 2002	*Mmyo*	450	A. Reiter	*Cpip*	3*
CZ	Jevišovice, castle attic	48°59'N, 15°59'E	27 June 2005	*Mmyo*	620	A. Reiter, T. Bartonička	*Cpip*	5*
CZ	Jílové u Děčína, school attic	50°45'N, 14°06'E	19 July 2006	*Mmyo*	330	O. Balvín, P. Benda	*Cpip*	5*
CZ	Jílové u Děčína, school attic	50°45'N, 14°06'E	13 July 2007	*Mmyo*	550	P. Benda	*Cpip*	5*
CZ	Karlštejn, castle	49°56'N, 14°11'E	26 Jule 2006	*Mmyo*	9	D. Weinfurtová	*Clec*	3*
CZ	Karlštejn, castle	49°56'N, 14°11'E	30 June 2005	*Mmyo*	35	O. Balvín	*Clec*	1*
CZ	Kerhartice, school attic	49°58'N, 16°22'E	14 June 2007	*Mmyo*	45	O. Balvín, V. Lemberk	*Clec*	1
CZ	Klentnice, church attic	48°50'N, 16°38'E	17 July 2007	*Mmyo*	100	T. Bartonička	*Cpip*	4*
CZ	Klentnice, church attic	48°50'N, 16°38'E	25 June 2006	*Mmyo*	40	T. Bartonička	*Cpip*	1*
CZ	Klentnice, church attic	48°50'N, 16°38'E	3 June 2005	*Mmyo*	230	J. Chytil	*Cpip*	4*
CZ	Komňa, church attic	48°59'N, 17°47'E	29 July 2006	*Mmyo*	600	O. Balvín, P. Wolf	*Cpip*	5
SK	Košické Oľšany, church	48°43'N, 21°20'E	11 July 2011	*Mmyo*	180	O. Balvín, M. Ševčík	*Clec*	2
SK	Krásnohorské Podhradie, church	48°39'N, 20°35'E	9 July 2011	*Mema*	150	O. Balvín, M. Ševčík	*Clec*	4
CZ	Krnsko, church attic	50°22'N, 14°51'E	11 June 2009	*Mmyo*	43	O. Balvín, D. Horáček	*Cpip*	2
CZ	Křivoklát, castle tower	50°02'N, 13°52'E	4 July 2007	*Mmyo*	144	O. Balvín, D. Weinfurtová	*Cpip*	3
CZ	Křtiny, church attic	49°17'N, 16°44'E	10 June 2007	*Mmyo*	553	M. Pokorný, T. Bartonička	*Cpip*	5*
CZ	Křtiny, church attic	49°17'N, 16°44'E	27 June 2006	*Mmyo*	254	O. Balvín, M. Pokorný	*Cpip*	4*
CZ	Kvítkov, house attic	50°39'N, 14°29'E	11 June 2009	*Mmyo*	327	O. Balvín, D. Horáček	*Cpip*	3
CZ	Ledce, gamekeeper's house attic	50°21'N, 15°04'E	10 June 2007	*Mmyo*	2600	T. Bartonička, V. Hanzal	*Cpip*	4*

Table 2. (continued)

country	locality	coordinates	date	bat species	colony size	collector(s)	BS	BA
CZ	Ledce, gamekeeper's house attic	50°21'N, 15°04'E	9 June 2005	*Mmyo*	3000	H. Jahelková, O. Balvín	*Cpip*	2*
CZ	Libochovice, house attic	50°24'N, 14°01'E	10 June 2005	*Mmyo*, *Nnoc*	78	Mr. Krupička	*Clec*	3
CZ	Lipov, church tower	48°54'N, 17°27'E	29 July 2006	*Mmyo*	500	O. Balvín, P. Wolf	*Cpip*	3
CZ	Loukov u Semil, church tower	49°12'N, 17°02'E	10 June 2011	*Mmyo*	845	D. Horáček	*Cpip*	3*
CZ	Loukov u Semil, church tower	49°12'N, 17°02'E	3 June 2012	*Mmyo*	780	D. Horáček	*Cpip*	1*
SK	Ľubovec, church tower	48°54'N, 21°10'E	11 July 2011	*Mmyo*	230	O. Balvín, M. Ševčík	*Cpip*	3
CZ	Luhačovice, castle attic	49°05'N, 17°44'E	29 July 2006	*Mmyo*	700	O. Balvín, P. Wolf	*Cpip*	5*
CZ	Luhačovice, castle attic	49°05'N, 17°44'E	29 April 2009	*Mmyo*	420	L. Růžičková	*Cpip*	2*
SK	Lupoč	48°21'N, 19°32'E	17 June 2010	*Mmyo*		M. Ceľuch	*Cpip*	5
CZ	Lužnice, chimney	49°04'N, 14°45'E	28 May 2005	*Mnat*		O. Balvín, R. Lučan	*Cpip*	2
CZ	Lysice, church	49°27'N, 16°32'E	28 June 2006	*Mmyo*	254	O. Balvín, M. Pokorný	*Clec*	2
CZ	Milovice, batbox	48°49'N, 16°43'E	21 May 2005	*Nnoc*	1-10	T. Bartonička	*Cpip*	3*
CZ	Milovice, batbox	48°50'N, 16°41'E	26 May 2004	*Nnoc*		T. Bartonička	*Cpip*	3*
CZ	Moravičany, church	49°45'N, 16°58'E	8 July 2014	*Mmyo*	598	T. Bartonička, J. Šafář	*Clec*	4*
CZ	Moravičany, church	49°45'N, 16°58'E	26 July 2013	*Mmyo*	428	T. Bartonička, J. Šafář	*Clec*	4*
CZ	Moravičany, church	49°45'N, 16°58'E	29 June 2011	*Mmyo*	391	O. Balvín, J. Šafář	*Clec*	3*
CZ	Moravský Krumlov, church	49°3'N, 16°19'E	16 July 1998	*Mmyo*	35		*Clec*	1
CZ	Mrač, pitman's house attic	49°49'N, 14°42'E	4 July 2008	*Mmyo*	677	P. Nová - Schnitzerová	*Cpip*	3*
CZ	Mrač, pitman's house attic	49°49'N, 14°42'E	8 July 2009	*Mmyo*	376	P. Nová - Schnitzerová	*Cpip*	2*
SK	Nitra, park, batbox	48°18'N, 18°04'E	2007	*Nnoc*		M. Ševčík	*Cpip*	2
CZ	Nová Lhota, cottage attic	48°51'N, 17°35'E	summer 2009	UBS		P. Haša	*Cpip*	3
CZ	Nové Hrady, castle	49°51'N, 16°8'E	21 June 2006	*Mmyo*	170	O. Balvín, V. Lemberk	*Clec*	2*
CZ	Nové Hrady, castle	49°51'N, 16°8'E	19 June 2007	*Mmyo*	200	O. Balvín, V. Lemberk	*Clec*	2*
CZ	Nové Mlýny, batbox	48°50'N, 16°43'E	1 October 2004	*Ppyg*	5	T. Bartonička	*Cpip*	2*
CZ	Nové Mlýny, batbox	48°50'N, 16°43'E	20 May 2005	*Ppyg*	20	T. Bartonička	*Cpip*	3*
CZ	Nové Mlýny, batbox	48°51'N, 16°43'E	20 October 2004	*Ppyg*		T. Bartonička	*Cpip*	3
CZ	Nové Mlýny, batbox	48°51'N, 16°43'E	5 May 2006	*Ppyg*	30	T. Bartonička	*Cpip*	2
CZ	Nové Mlýny, batbox	48°50'N, 16°43'E	5 May 2006	*Ppyg*	6	T. Bartonička	*Cpip*	2
CZ	Nové Mlýny, hunting hide	48°51'N, 16°43'E	25 June 2005	*Ppyg*	30	T. Bartonička	*Cpip*	2
CZ	Nové Mlýny, hunting hide	48°51'N, 16°43'E	5 May 2006	*Ppyg*	6	T. Bartonička	*Cpip*	2
CZ	Nové Mlýny, hunting hide	48°51'N, 16°43'E	31 July 2010	*Ppyg*	20	T. Bartonička	*Cpip*	2
CZ	Nové Mlýny, crib	48°48'N, 16°42'E	5 May 2006	*Ppyg*	11	T. Bartonička	*Cpip*	3
CZ	Nové Mlýny, hunting hide	48°48'N, 16°42'E	5 May 2006	*Nnoc*	26	T. Bartonička	*Cpip*	3*
CZ	Nové Mlýny, hunting hide	48°48'N, 16°42'E	30 April 2008	*Nnoc*	17	T. Bartonička	*Cpip*	3*
SK	Očová, church tower	48°35'N, 19°17'E	5 August 2006	*Mmyo*	30	M. Ševčík	*Cpip*	3
CZ	Ohníč, house attic	50°35'N, 13°50'E	14 July 2008	*Mmyo*	430	B. Franěk	*Clec*	2
CZ	Oleksovice, church	48°54'N, 16°14'E	2 July 2001	*Eser*		J. Vilímová, A. Reiter	*Clec*	1
CZ	Olomouc, house	49°35'N, 17°15'E	July 2014	*Nnoc*		J. Šafář	*Cpip*	5
CZ	Otaslavice, church	49°23'N, 17°04'E	24 July 2008	*Mmyo*	368	H. Berková	*Clec*	4*
CZ	Otaslavice, church	49°23'N, 17°04'E	28 June 2006	*Mmyo*	232	O. Balvín, M. Pokorný	*Clec*	2*
CZ	Povrly, house attic	50°40'N, 14°09'E	6 June 2005	*Mmyo*	270	B. Franěk	*Cpip*	2

country	locality	coordinates	date	bat species	colony size	collector(s)	BS	BA
CZ	Pozořice, church	49°12'N, 16°47'E	18 July 2009	*Mmyo*	7	H. Berková	*Clec*	2*
CZ	Pozořice, church	49°12'N, 16°47'E	27 June 2006	*Mmyo*	35	O. Balvín, M. Pokorný	*Clec*	5*
CZ	Prostějov, house	49°28'N, 17°05'E	August 2014	*Nnoc*		J. Šafář	*Cpip*	5
CZ	Račice-Pístovice, castle attic	49°16'N, 16°52'E	15 July 2007	*Mmyo*	190	T. Bartonička	*Cpip*	1*
CZ	Račice-Pístovice, castle attic	49°16'N, 16°52'E	27 June 2006	*Mmyo*	240	O. Balvín, M. Pokorný	*Cpip*	4*
CZ	Raškov, church	50°02'N, 16°54'E	17 August 2013	*Mmyo*	518	Z. Buřič, T. Bartonička	*Clec*	4*
CZ	Raškov, church	50°02'N, 16°54'E	25 August 2012	*Mmyo*	82	T. Bartonička	*Clec*	2*
SK	Rochovce, church tower	48°42'N, 20°17'E	10 June 2008	*Rfer*, *Mmyo*, *Mema*	250	O. Balvín, F. Svoboda	*Cpip*	4
CZ	Ruda nad Moravou, castle	49°58'N, 16°52'E	17 August 2013	*Mmyo*	3	Z. Buřič, T. Bartonička	*Clec*	1*
CZ	Ruda nad Moravou, castle	49°58'N, 16°52'E	27 July 2012	*Mmyo*	1126	T. Bartonička	*Clec*	3*
CZ	Snědovice, house attic	50°30'N, 14°23'E	8 August 2008	*Mmyo*	240	B. Franěk	*Clec*	2*
CZ	Snědovice, house attic	50°30'N, 14°23'E	12 July 2005	*Mmyo*	102	B. Franěk	*Clec*	2*
CZ	Sruby, church	50°0'N, 16°10'E	19 June 2007	*Mmyo*	500	O. Balvín, V. Lemberk	*Clec*	4
SK	Timoradza, church	48°48'N, 18°14'E	17 August 2010	*Mmyo*		O. Balvín, M. Ševčík	*Clec*	2
CZ	Točník, castle stairs	49°53'N, 13°53'E	16 July 2005	*Mmyo*	450	O. Balvín, D. Weinfurtová	*Cpip*	5*
CZ	Točník, castle stairs	49°53'N, 13°53'E	17 June 2006	*Mmyo*	350	O. Balvín	*Cpip*	5*
SK	Topolčianky, church	48°25'N, 18°24'E	8 July 2011	*Mmyo*	51	O. Balvín, M. Ševčík	*Clec*	3
CZ	Týnec nad Sázavou, castle tower	49°49'N, 14°35'E	21 July 2010	*Mmyo*	264	P. Schnitzerová	*Cpip*	3
CZ	Úštěk, church attic	50°35'N, 14°20'E	6 June 2005	*Mmyo*	320	B. Franěk	*Cpip*	1*
CZ	Úštěk, church attic	50°35'N, 14°20'E	10 July 2014	*Mmyo*	320	B. Franěk, D. Sadílek	*Clec*	3*
CZ	Velká Bystřice, church tower	49°35'N, 17°21'E	27 July 2012	*Mmyo*	40	T. Bartonička	*Cpip*	2
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	25 May 2004	*Mdau*	55	O. Balvín	*Cpip*	3*
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	28 May 2005	*Mdau*	55	O. Balvín	*Cpip*	3*
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	15 October 2006	*Mdau*	55	O. Balvín	*Cpip*	3
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	30 May 2006	*Mdau*	55	O. Balvín	*Cpip*	3
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	2 December 2007	*Mdau*		O. Balvín	*Cpip*	3
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	29 May 2001	*Mdau*		J. Vilímová	*Cpip*	3
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	1 September 2001	*Mdau*	55	J. Vilímová	*Cpip*	3
CZ	Veselí nad Lužnicí, old limekiln	49°09'N, 14°41'E	28 May 2004	*Mdau*		J. Vilímová	*Cpip*	3
CZ	Veselí nad Lužnicí, mill attic	49°07'N, 14°41'E	26 August 2006	*Mbra*	30	A. Zieglerová	*Cpip*	3
CZ	Veselíčko, castle	49°31'N, 17°30'E	year 2011	*Mmyo*	200	O. Balvín, J. Šafář	*Clec*	3
CZ	Vranová Lhota, church tower	49°42'N, 16°49'E	19 July 2007	*Mmyo*	1000	O. Balvín, V. Lemberk	*Cpip*	4*
CZ	Vranová Lhota, church tower	49°43'N, 16°49'E	28 June 2012	*Mmyo*	1180	T. Bartonička	*Cpip*	3*
SK	Vysočany, church attic	48°40'N, 18°19'E	17 August 2010	*Mmyo*	1300	O. Balvín, M. Ševčík	*Cpip*	5
CZ	Vysoký Újezd, church attic, kostel	49°48'N, 14°28'E	4 July 2008	*Mmyo*	155	P. Schnitzerová	*Cpip*	3
CZ	Zaječov, monastery attic	49°45'N, 13°50'E	30 June 2005	*Mmyo*	130	O. Balvín, D. Weinfurtová	*Cpip*	3
CZ	Zdislava, church attic	50°45'N, 14°52'E	10 June 2010	*Mmyo*	0	T. Bartonička	*Cpip*	1*
CZ	Zdislava, church attic	50°45'N, 14°52'E	11 June 2009	*Mmyo*	25	O. Balvín, D. Horáček	*Cpip*	1*
SK	Zemianske Kostoľany, church	48°41'N, 18°31'E	17 August 2010	*Mmyo*	50	O. Balvín, M. Ševčík	*Clec*+*Cpip*	2
CZ	Žďár nad Sázavou, bridge	49°33'N, 15°58'E	20 July 2005	*Mdau*	20	O. Balvín, V. Helešic	*Cpip*	3*
CZ	Žďár nad Sázavou, bridge	49°33'N, 15°58'E	11 July 2007	*Mdau*	30	O. Balvín, V. Helešic	*Cpip*	3*

colony size recorded during the previous check in the 20 cases; the decrease in bug abundance followed a decline in bat numbers by 74.7±22.5% in the other 20 cases. When the numbers of bats in colonies changed by more than 50% compared to the previous colony size, in all cases this led to the change in abundance of bugs.

The cimicid abundance showed to vary according to changes in bat numbers. This suggests that long term survival of cimicid infestations depends on the stability of the bat colony. Temporal changes in bat numbers can reduce the parasite load and possibly serve as a antiparasitic strategy in attic-dwelling bats, similarly as suggested for crevice-dwelling bat species (Bartonička & Růžičková 2013).

As discussed above, cimicids should not be able to survive a season (including two winters) without the presence of a bat colony. However, in *M. myotis* colonies, the cimicids do not have to be completely eradicated even if the whole colony switches the roost for the breeding season. The colonies of *M. myotis* are known to temporarily abandon their roosts from time to time. In the Czech Republic, 2.9% (8) of regularly inspected roosts of *M. myotis* have been found free of bats in the last three years (unpubl. datasets, Czech Bat Conservation Trust). In all cases, bats arrived back after they roosted elsewhere for one or two years.

First, nursery colonies of *M. myotis* generally exchange their members among each other, when females use other roosts in the vicinity of their own roost (Zahn 1998). The colony is therefore likely to be reinfested soon after the bats come back. Second, an occasional presence of several bats, e.g. non-reproducing bats or males, is likely to maintain the infestation. These bats are

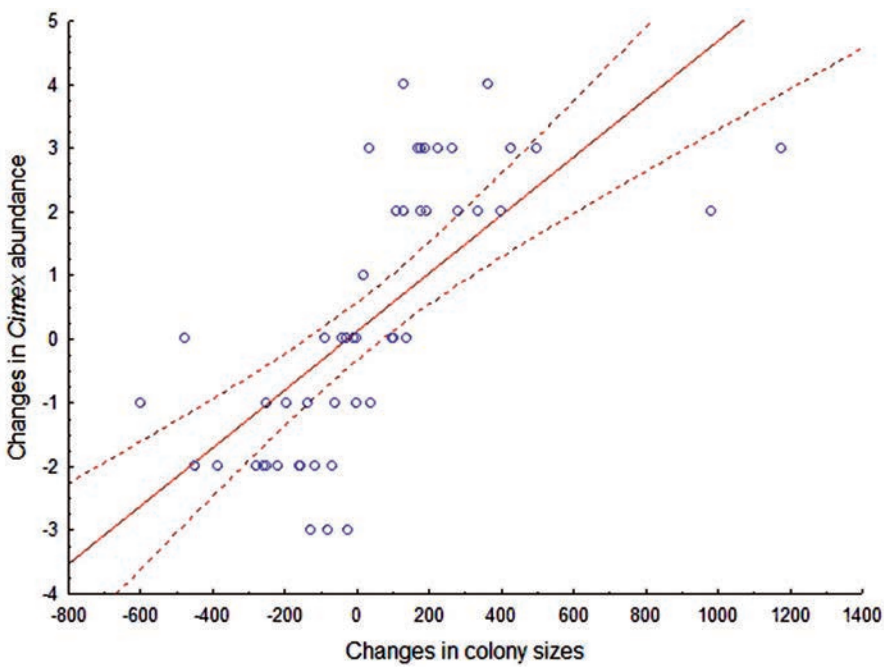

Fig. 2. Correlation between the abundance of bugs and number of bats in a colony. Dashed lines show the 95% confidence.

likely to appear in the roosts outside the lactation and early postlactation period, when standard monitoring activities are carried out, and thus do not have to be recorded. Bats usually occupy a specific site in the roost marked by smell, and the surviving cimicids can easily locate the few occasional visitors. Such situation was probably observed at Boskovice, where surviving cimicids were found two years after the colony left.

Bat-related cimicids as a health problem for people

We collected information on 12 recent cases of bats being an apparent source of cimicids invading homes. In six cases, the cimicids were determined as *Cimex pipistrelli* and, as such, certainly originated from a bat colony. Two cases were identified as *C. lectularius*, however, according to the mtDNA analysis, both infestations belonged to the bat-associated lineage (Balvín et al. 2012a). The association of the remaining four cases to bats was found very likely from the context.

Nyctalus noctula was identified as the source of cimicids in six cases. On three other occasions, *N. noctula* was likely to constitute the colony according to its typical habitat. On one occasion, *Pipistrellus* sp. was identified. Two cases came from summer houses, in contrast to the rest coming from apartment buildings. In one of these cases, the distinct phenotype of *C. lectularius* collected in the house strongly suggested a colony of *Pipistrellus* sp. appearing in the attic. The bat species in the other summer house was not identified.

At least five of these bat colonies were monitored for multiple years. At least in eight cases the cimicids appeared in the apartments repeatedly and without any obvious change in the bat colony. Only in one case it was clear that the cimicids attacked humans because the colony was eradicated and the cimicids set off to search for blood meal. Although such immediate gap in food source can make the cimicids search for an alternative, it is very likely that cimicids often leave the bat roost when the bats are still present.

In contrast to *N. noctula* and *Pipistrellus* spp., we are not aware of any cases of cimicids from the roosts of *Myotis myotis* penetrating homes. It is true that only a small part of these roosts is located in attics of residential buildings. Here, thousands or tens of thousands of cimicids are often found only one ceiling from people’s bedrooms. The bats leave their roost for the whole winter; despite that not a single case of cimicids searching for blood meal has been reported from any time of the year. Most of such roosts are situated in church or castle attics. Given that more than 250 such roosts are known only in the Czech Republic (Bartonička & Gaisler 2010), if the bugs tended to disperse, they would be often found inside the church and their occurrence would be reported.

We believe that the difference in the problem with cimicids leaving roosts of *M. myotis* and roosts of *N. noctula* or *Pipistrellus* spp. is caused by the same reason as the discrepancy of records of cimicids in mist-netted bats (Balvín et al. 2012b). While the cimicids are regularly found in mist-netted *N. noctula* and the records from *Pipistrellus* spp. are not rare either, almost no cimicids have been found in *M. myotis*. This led to the conclusion that the dispersal behavior of cimicids can vary according to bat species, being more intense in cimicids hosted by *N. noctula*, likely as a response to the migratory behavior of this bat species.

In conclusion, in case of *N. noctula* and possibly other crevice-dwelling bat species, it is necessary to admit that the situations with cimicids penetrating homes will eventually repeat. It also seems that such cases become more frequent; five of the cases reported here come from 2014. On one hand, *N. noctula* hosts almost only *C. pipistrelli*, which is not able to survive permanently on people (Southwood 1959, L. Mazánek in litt.). On the other hand, permanent colonies will constitute a permanent source of such temporary infestations. The problem can only be prevented by eradication of the bat colony, which is not desirable and can be penalized. However, if the bat colony disappears, the cimicids will disperse due to starvation and the infestation of homes can get temporarily more severe.

Such cases should be approached individually with care and diplomacy. The affected inhabitants should be encouraged to withstand the situation, informed about the low risk in *C. pipistrelli*, carefully warned against the increase in infestation due to removal of the bat colony and advised concerning means of reducing the problem, i.e. suitable insecticides. If the path of cimicids from the colony to the home is found, e.g. through the window (at least in two of the cases reported here, see also Lýsek 1966), targeted treatment of such area can efficiently reduce or even eliminate the penetration.

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