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Utilization of artificial shelters by bats (Chiroptera) in three different types of forest

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A b s t r a c t . The use of wooden (modified Stratmann) boxes by bats was studied in three different tree stands (80-year old beech forest, 150-year old oak-beech forest with admixture of pine, 50–70-year old pine forest) of a managed woodland (Darżlubska Forest) in northern Poland. Two species (*Pipistrellus nathusii* and *Plecotus auritus*) inhabited these boxes after 2–13 months. The occupation of shelters in pine monoculture was several tens of times higher than in both deciduous forests. The main factors responsible for such differences are: 1) almost complete lack of natural roosts (tree holes) in young pine forest, 2) unfavourable (colder and more humid) microclimate in broadleaf (especially beech) forests, 3) much higher abundance of some invertebrates (mainly gastropods), that make boxes in beech forest unattractive for bats.

Key words: bat boxes, *Pipistrellus nathusii, Plecotus auritus,* northern Poland

Introduction

One of the main threats to bats in managed forests is a deficit of natural daytime roosts, mainly due to the removal of old, hollow trees. Various artificial roosts (bat boxes), being a substitute for tree holes, are used by foresters and conservationists (M a y l e 1990). However, several aspects of their efficiency as a conservation tool are still not recognised. Most papers related to this subject analysed differences in occupation of various types of boxes (e.g. G e r e l l 1985, T a a k e & H i l d e n h a g e n 1989). Such studies up to the present have not taken into account habitat differences between types of forests, such as plant community and age of tree stand, where boxes were installed. This problem has been partially studied only in relation to the use of bird nestboxes by some bat species (J a r z e m b o w s k i et al. 1998). The occupancy of artificial roosts in a forest is considered to be negatively correlated with the abundance of natural shelters. However, the only paper demonstrating this effect was based on two study plots located in two different forest complexes, where several other habitat factors (e.g. abundance of water) affected the density of bats (K a s p r z y k & R u c z y ń s k i 2001). Occupation of nestboxes by animals other than bats and birds has been poorly studied (H a r m a t a 1997, J u š k a i t i s 1999), except for dormice (Rodentia: Gliridae) and their potential competitors (J u š k a i t i s 1995, J u š k a i t i s 1997, N o w a k o w s k i & B o r a t y ń s k i 1997, M a r s h & M o r r i s 2000). It has not been taken into account as a factor influencing the use of boxes by bats, except for some anecdotal information (M a y l e 1990).

The aim of this investigation was to determine differences in occupation of bat boxes located in three types of forest (differing in plant community and age) in managed woodland of northern Poland.

Study Area, Material and Methods

The Darżlubska Forest (18 000 ha) is the northernmost forest complex in Poland (54° N, 18° E). The mean annual rainfall is about 600 mm, mean temperature in January is –1.8 °C, while mean temperature in July is 16.8 °C (weather-station in Lębork, 1951–1970). The dominating forest communities are: suboceanic pine forest (*Leucobryo-Pinetum*), acidophilus lowland beech forest (*Luzulo pilosae-Fagetum*) and oak-beech forest (*Fago-Quercetum*) (D ą b r o w s k i 1978). Most tree stands are affected by forest management at various levels of intensity. Ten species of bats were recorded there: *Myotis daubentonii* (Kuhl, 1817), *Myotis nattereri* (Kuhl, 1817), *Vespertilio murinus* Linnaeus, 1758, *Eptesicus serotinus* (Schreber, 1774), *Pipistrellus pipistrellus* (Schreber, 1774) *Pipistrellus pygmaeus* (Leach, 1825), *Pipistrellus nathusii* (Keyserling et Blasius, 1839), *Nyctalus noctula* (Schreber, 1774), *Nyctalus leisleri* (Kuhl, 1817) and *Plecotus auritus* (Linnaeus, 1758) (C i e c h a n o w s k i 2003). Three of them – *M. nattereri*, *P. nathusii* and *P. auritus* – appeared to be the commonest bat inhabitants of nestboxes in Polish forests (K o w a l s k i & L e s i ń s k i 1994).

In the present study, Stratmann wooden bat boxes (G e r e l l 1985, T a a k e & H i l d e n h a g e n 1989) modified by P. H. C. L i n a (a shelf under the entrance was added) were used. Internal dimensions of the boxes were as follows: 40 cm × 13 cm × 4 cm, with entrance 15.5 cm × 1.5 cm and walls 2 cm thick. In April 1998, 102 boxes were installed in three study plots (34 boxes per plot):

1. Fertile beech forest *Galio odorati-Fagetum*. Tree stand consisting almost exclusively of 80-year old beeches *Fagus sylvatica*, with almost complete lack of undergrowth.

2. Acidophilous oak-beech forest *Fago-Quercetum petraeae*. 150-year old tree stand, built up mainly of oak *Quercus robur,* beech *Fagus sylvatica* and Scotch pine *Pinus sylvestris*. Locally dense undergrowth consisting of broadleaved species.

3. Suboceanic fresh pine forest *Leucobryo-Pinetum*. Treestand built up almost exclusively of Scotch pine *Pinus sylvestris* (age 50–70 years), with an almost complete lack of undergrowth.

In 1998, boxes were checked every ten days from 02.07 (two months after fixing the boxes) to 09.09, when bats appeared to leave the boxes entirely. In 1999 boxes were controlled every two weeks from 24.04 to 23.06 and every ten days from 07.07 to 12.09, when no bats were recorded in the roosts. Plot no. 1 was not checked up after 09.06.1999, because no bats (or their droppings) were found there during the first 13 months of the study. All three plots were controlled again on 11-12.08.2001. Plot 3. was additionally controlled twice in July–August 2000.

Bats found in boxes were captured (under license of the Ministry of Environment No. Opog. 4201/173/98), their species, sex and age were determined. The relative density of bats (the number of bats per 100 boxes) was calculated (K a s p r z y k & R u c z y ń s k i 2001). The number of wasp (Vespidae) nests, occurence of other invertebrates (only qualitatively) and any damage of boxes by woodpeckers (Picidae) were also noted.

Results

Two bat species, *Pipistrellus nathusii* and *Plecotus auritus*, inhabited boxes, roosting both solitarily and in groups (harems of *P. nathusii*). The peak of their occupancy occurred between the 3rd decade of July and the 1st half of August each year. The highest number of bats (N_b) (Fig. 1) and the highest number of boxes occupied (N_o) (Fig. 2) were noted in the pine forest.

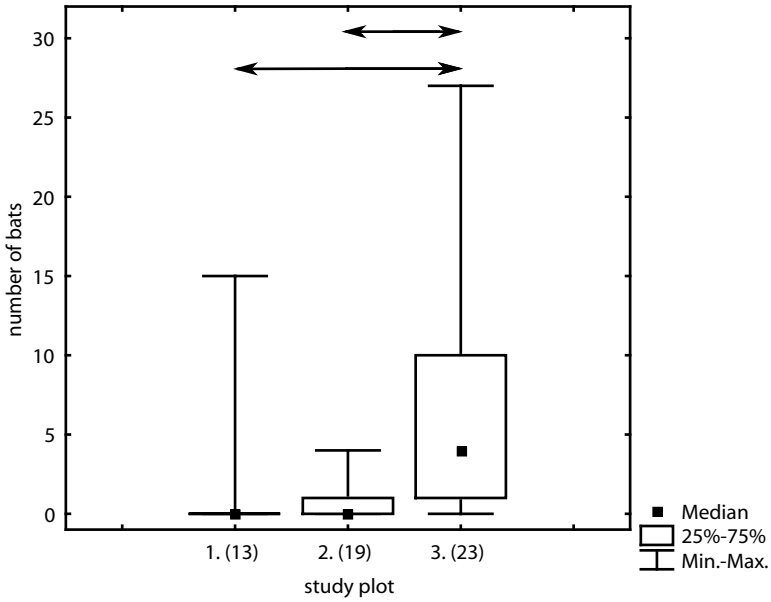

Fig. 1. The number of bats (per control) occupying boxes in study plots. 1. beech forest (80 year old), 2. oak-beech forest with pine (150 year old), 3. pine forest (50–70 year old). The sample sizes (number of controls) are given in brackets. Arrows indicate significant difference at $p < 0.001$.

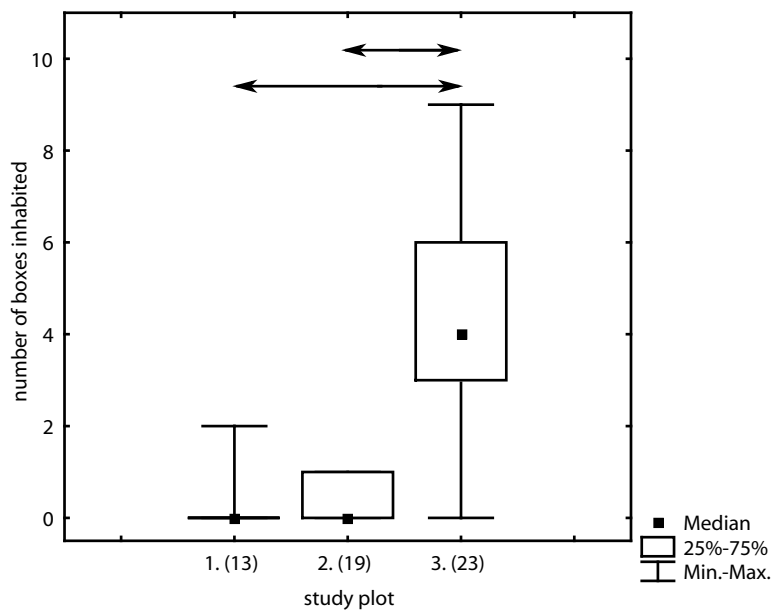

Fig. 2. The number of boxes (per control) occupied by bats in study plots. 1. beech forest (80 year old), 2. oak-beech forest with pine (150 year old), 3. pine forest (50–70 year old). The sample sizes (number of controls) are given in brackets. Arrows indicate significant difference at $p < 0.001$.

The occupation of boxes in broadleaved forests was much lower and appeared much later. The unusually high maximum relative density of bats in beech forest (Table 1) was a result of finding a *P. auritus* colony on 12.08.2001 (possibly a nursery). The number of bats differed significantly among study plots (Kruskal-Wallis test: $H = 24.84$, $df = 2$, $N = 55$, $p = 0.001$), as well as the number of boxes occupied ($H = 28.22$, $df = 2$, $N = 54$, $p < 0.001$). Comparisons of particular plots with Dunn test showed significant differences in these parameters between the pine forest and the beech forest (N_b: $Q = 4.18$, $p < 0.001$; N_o: $Q = 4.13$, $p < 0.001$), as well as between the pine forest and the oak-beech forest (N_b: $Q = 4.17$, $p < 0.001$; N_o: $Q = 3.99$, $p < 0.001$), but not between both broadleaved forests (N_b: $Q = 0.44$, $p > 0.5$; N_o: $Q = 0.54$, $p > 0.05$).

The nesting of birds (treecreeper *Certhia familiaris*) was recorded in only one box (in the beech forest). Three boxes (2.9%) were destroyed by woodpeckers. Nests of Vespidae (wasps *Dolichovespula* spp., hornets *Vespa crabro*) appeared in boxes in the second year after the boxes were hung up. In total, 14% of boxes contained nests of these insects. Boxes in the beech forest were inhabited (after two months) by numerous non-vespid invertebrates: gastropods (slugs Limacidae, snails: Clausilidae and Helicidae – *Cepaea* spp.), insects (mainly moths Lepidoptera, but also flies Diptera and beetles Coleoptera, including *Carabus* spp.), spiders Aranei, harvestmen Opiliones, centipeds Chilopoda and woodlice Isopoda. Only single spiders, moths and gastropods occupied boxes located in the pine and the oak-beech forests (Table 1).

Table 1. Occurrence of bats and invertebrates in study plots. 1. beech forest (80 year old), 2. oak-beech forest with pine (150 year old), 3. pine forest (50–70 year old). Values of relative density (RD) are given in number of bats per 100 boxes.

Parameter		Study plot		
		1	2	3
Mean RD per control	*Pipistrellus nathusii*	0.2	0.9	36.0
	Plecotus auritus	3.2	0.9	0.5
Maximal RD	*Pipistrellus nathusii*	2.9	11.8	79.4
	Plecotus auritus	41.2	2.9	2.9
Time from the installation of boxes to the inhabitance by bats (months)		>13	12.8	2.3
Number of wasp nests		5	4	3
Abundance of non-vespid invertebrates		++++	++	+

Discussion

The observed much higher bat occupation of boxes located in the coniferous forest could be associated with a lack of availabity of natural roosts (tree holes, crevices and loose bark). The number of such roosts was much higher in broadleaved forests (Limpens & Bongers 1991), so bats do not have to use artificial shelters there. In pine plantations, bird and bat boxes are often the only accesible roosts, which results in high levels of occupation, often in a very short time after the installation of boxes. The low number or even the lack of bats in boxes located in old deciduous trees tands may lead to errorneous conclusions in evaluation of a forest's importance for bats. Krzanowski (1961) controlled over 300 bat boxes

in the Białowieża National Park for three years, however he did not find any bats. He concluded that the Białowieża Primeval Forest was very poor in these animals. Later studies based on mist-netting and ultrasound detection showed that the bat fauna of this area was rich, both in qualitative and quantitative aspects (R a c h w a l d 1995, R a c h w a l d et al. 2001), however it was associated with the wide use of natural shelters (R u c z y ń s k i & R u c z y ń s k a 2000, R u c z y ń s k i & B o g d a n o w i c z 2002).

An important reason for the disproportion occupancy of bat boxes in particular kinds of forest may be the differences in microclimate of particular plant communities. The temperature inside potential roosts is among the most important constraints influencing selection of boxes by bats (L o u r e n ç o & P a l m e i r i m 2004). Thus the microclimatic conditions in the surrounding external environment may be significant for them as well. J a r z e m b o w s k i et al. (1998) recorded a strong relationship of dynamics of habitat preference in *P. nathusii* to air temperature and humidity. This author suggests that *P. nathusii* uses boxes in drier and warmer biotopes (pine forests) with much more frequency while too high temperature and too low air humidity only cause migration of this species to other tree stands (beech and alder forests) in some years. Verification of this hypothesis is not easy, because very little data concerning the microclimate of different forest communities exist. Ż a r n o w i e c k i (1995) recorded only a very small difference in the relative air humidity between the oak-hornbeam forest *Tilio-Carpinetum* (81.7%) and the fresh pine forest *Peucedano-Pinetum* (81.6%) in the Białowieża Primeval Forest. Differences in the maximum daily air temperature between these tree stands were much higher, especially in summer. The oak-hornbeam forest was colder than the pine forest by about 2.5 °C (O l s z e w s k i 1995). However, microclimatic differences between broadleaved and coniferous tree stands in the Darżlubska Forest may be much sharper as a result of varied methods of forest management. This factor does not affect forest structure in analogous tree stands of the Białowieża National Park.

High air humidity in fertile deciduous forests can also indirectly reduce the occupation of boxes by bats by attracting some invertebrates to use the same shelters. Large slugs (Arionidae and Limacidae), if they occur in large numbers, can especially make boxes unattractive for bats by occupying these roosts and covering the internal walls with mucus and faeces. This efect was mentioned by M a y l e (1990), however no quantitative data documenting the phenomenon have been available up to now. It does not seem that uneven occupation of boxes by bats in particular types of forest was associated with the presence of wasp nests, although Vespidae are considered to be important competitors of bats (K r z a n o w s k i 1961, G e r e l l 1985) and rodents (J u š k a i t i s 1995) in occupation of nestboxes. However, there were only slight differences among studied plots in the occupation of boxes by wasps. The influence of bird-bat competition on the use of shelters by bats can be important both with respect to natural tree holes and their artificial counterparts, like bird nestboxes, as well as spacious bat boxes of Issel and Schwegler types (G e r e l l 1985). ”Fissure” boxes (e.g. Stratmann model) are often damaged by woodpeckers, which make holes in their frontal walls, although the number of boxes affected by them was relatively low in the present study. In heavily managed woodland in eastern Poland 4.3% and 29.3% of bat boxes were damaged by woodpeckers after 3 and 5 years respectively (S a c h a n o w i c z 2003). This phenomenon sometimes enables occupation of such boxes by small passerine birds, esspecialy treecreepers *Certhia* spp., usually nesting in stem crevices and under loose bark (C r a m p & P e r r i n s 1993). In northern Sweden, 8% of Stratmann bat boxes were occupied by birds (G e r e l l 1985).

To summarise, the utilisation of boxes by bats in the studied plots depended on several factors. In beech forest, unsuitable microclimate and numerous occurences of invertebrates (mainly slugs and araneids) in boxes made boxes unatractive to bats. In oak-beech forest, boxes were mostly dry and their occupation by invertebrates was much smaller; however this old (150 year old) tree stand offered probably many more natural roosts – tree holes. No such roosts occurred in a relatively young pine forest, where boxes were dry and almost free of gastropods. These factors favoured the intensive utilisation of boxes by bats.

The results of the study show that bat boxes can be an effective conservation tool only in some specific types of forest, especially those with the most uniform structure, shaped by management practices. Instalation of boxes should be carried out intensively only in this type of tree stand, saving the limited financial resources for bat conservation. However, it should be borne in mind that this practice cannot replace the protection of natural roosts.

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