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Seasonal Dynamics of Occupation of Bat Boxes by Bats in Forests of South-western Poland

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Abstract: Phenology of occupation of summer artificial roosts (boxes) by bats was studied in forests of south-western Poland. Surveys were performed since March till November in 2001–2005. The aim of the study was to show quantitative and qualitative seasonal variation in occupation of roosts by bats in forests. Ten bat species were noted. Most numerous were *Myotis nattereri* (51.5% of all individuals), *Plecotus auritus* (27.9%), *Myotis myotis* (9.6%), *Pipistrellus nathusii* (6.6%) and *Nyctalus noctula* (3.6%). The remaining species (*Myotis mystacinus*, *Myotis brandtii*, *Nyctalus leisleri*, *Eptesicus serotinus* and *Pipistrellus pygmaeus*) constituted less than 1% of all noted bats. The percentage of occupation of boxes varied between March and November (with maximum in the second half of this period) as did the density of individuals (with maximum in July or August). Differences in the number of bat species recorded in boxes were also observed in each phenological season.

Key words: Chiroptera, summer roosts, forest habitat, Central Europe

Introduction

Summer day roosts of bats provide protection from unfavourable weather conditions and predators, enable mating, breeding young and maintaining proper body temperature. Selection of appropriate day roosts in various periods of bats' life is one of the basic factors determining survival of these mammals, and availability of proper roosts can increase the size of bat populations (McComb & Noble 1981, Kunz 1982). Location and ease of access to bat boxes substituting natural roosts (tree holes) in the period of bats activity allow for carrying various studies on the ecology of these mammals (Benzal 1991, Gerell-Lundberg & Gerell 1994, Ciechanowski 2005, Dondini & Vergari 2009). Only a few such studies dealt with the question of phenology (seasonal dynamics) of the roosts occupation by bats and usually gave incomplete data (Haensel & Näfe 1982, Heise 1983, Taake & Hildenhagen 1989, König & König 1995, Dolsch 2003, Vergari & Dondini 2011).

The aim of the present study was to check whether quantitative and qualitative seasonal difference exists in the occupation of artificial roosts by bats in forests of south-western Poland.

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Materials and Methods

The study was carried out in forests of Milicka Valley in south-western Poland (Fig. 1). The research area covered about 450 km^2 (between 51°33'49.82" N / 17°46'25.75" E in the north, 51°24'27.98" N / 17°41'24.17" E in the south, 51°28'11.41" N / 17°33'24.62" E in the west and 51°30'40.7" N / 18°01'37.89" E in the east), at altitude of c. 150 m. Areas covered by systematic surveys were overgrown by Scots pine *Pinus sylvestris* Linnaeus, 1753 and dominated by communities of the alliance *Dicrano-Pinion*: subatlantic fresh pine forest *Leucobryo-Pinetum* and subcontinental lichen Scots pine forest *Cladonio-Pinetum* (Brzeg 2001). Most of the study area was located in two Natura 2000 areas, *Dolina Baryczy* (PLB020001) and *Ostoja nad Baryczą* (PLH020041). Tree stands in the age of 40–70 years dominated in areas where boxes for bats were hanged. Forest management was not intensive, and in the State Forests was based on forest management plans designed for a 10-year period. The forest management was conducted in accordance to the following rules: the preservation of forest stability, sustainable development and nature conservation. It was recognised by international certificates (FSC, PEFC) (Duda 2019). Mean year air temperature in the study area was 8ºC, with July being the warmest month, with mean temperature of 18ºC; January was the coldest month, with mean temperature of –2ºC and few days with frosts. Maximum summer temperatures reached 28–30ºC. Mean annual sum of precipitation in the Milicka Valley was c. 600 mm (Mielcarek et al. 1991).

Boxes were surveyed in 2001–2005 once a month since early spring (March) till late autumn (November). The number of boxes regularly surveyed varied in the study years: 2001 – 72, 2002 – 123, 2003 – 172, 2004 – 153, and 2005 – 196. Boxes for bats of the type Issel (Haensel & Näfe 1982) were slightly modified as to their size and the opening. Internal box dimensions were 35 x 15 x 10 cm. Boxes in the study area were hanged at a height of 2.5–3.5 m. During surveys, bats were identified to species and the number of individuals of each species was estimated.

Percent of occupation of boxes by bats in subsequent months was calculated as well as coefficient of domination of particular species according to equation: $D = (N_i/N)100$, where N_i – the number of individuals of the i-th species found in boxes and N – the number of individuals of all species found in boxes. The frequency of occupation of boxes by each bat species was also calculated with equation $F = (n_a/n)100$, where n_a – the number of boxes where species „a" was noted and n – the number of all surveyed boxes. Seasonal variability of indices of box occupation was estimated using Kruskal-Wallis H test with post-hoc Dunn's test at significance level p=0.05. Calculations were performed with the Statistica 13.3 (TIBCO Software Inc.).

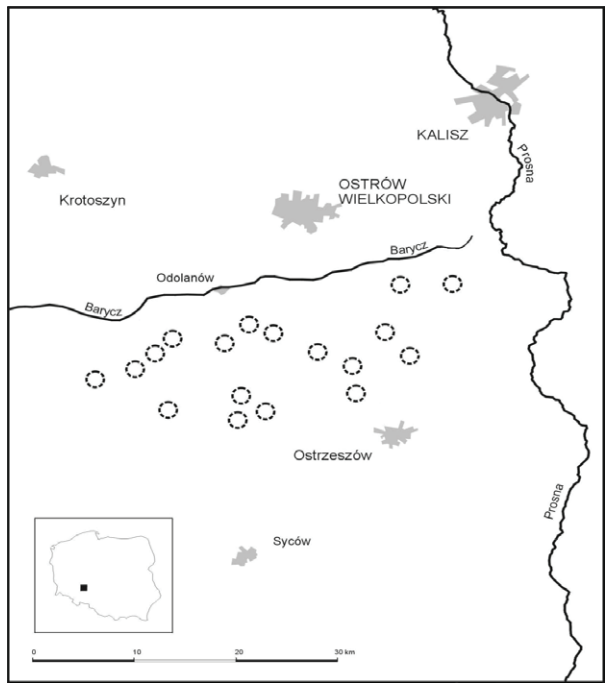

Fig. 1. Study area in south-western Poland. ◌ – sites where bat boxes were surveyed, grey patches – towns, black lines – rivers.

Results

There were ten bat species inhabiting boxes in the study area in 2001-2005: greater mouse-eared bat *Myotis myotis* (Borkhausen, 1797), Natterer's bat *Myotis nattereri* (Kuhl, 1817), Brandt's bat *Myotis brandtii* (Eversmann, 1845), whiskered bat *Myotis mystacinus* (Kuhl, 1817), brown long-eared bat *Plecotus auritus* (Linnaeus, 1758), common noctule *Nyctalus noctula* (Schreber, 1774), lesser noctule *Nyctalus leisleri* (Kuhl, 1817), serotine bat *Eptesicus serotinus* (Schreber, 1774), Nathusius' pipistrelle *Pipistrellus nathusii* (Keyserling et Blasius, 1839) and soprano pipistrelle *Pipistrellus pygmaeus* (Leach, 1825).

M. nattereri dominated (over 50% of all noted bats) in the total number of bats found in every-month surveys in pine forests. High percent

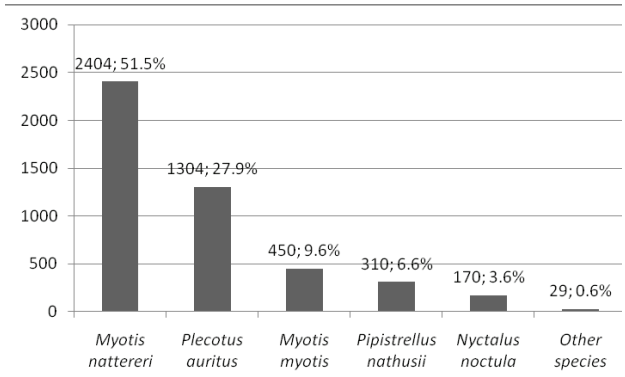

Fig. 2. Domination structure of bat species found during surveys of boxes in 2001–2005. The total number of surveys was 6,098. For each species, the number of individuals and the percent contribution are presented.

of domination was also noted for *P. auritus* (about 28%) then *M. myotis* (9.6%), *P. nathusii* (6.6%) and *N. noctula* (3.6%). Other species constituted less than 1% of all bats found in the study period (Fig. 2).

Percent of occupation of boxes by bats varied during the season (March–November). Data from 2001-2005 showed statistically significant difference ($H=25.9$, $d.f.=8$, $p=0.001$). In pair comparisons, statistically significant differences were found between July and November ($p=0.029$) and between August and November ($p=0.025$). The highest mean indices of occupation of boxes were noted from June till September (22.8-24.2%, see Fig. 3).

The density of individuals roosting in boxes also varied from spring till autumn ($H=28.0$, $d.f.=8$, $p<0.001$). Statistically significant differences in densities were noted between March and July ($p=0.042$), July and November ($p=0.014$) and between August and November ($p=0.025$). Mean densities of 100 individuals per 100 of boxes or higher were found since May till August (Fig. 4).

Kruskal-Wallis test revealed differences in the number of bat species noted in boxes during the study seasons ($H=30.5$, $d.f.=8$, $p<0.001$). Comparison of pairs showed statistically significant differences between March and July ($p=0.023$), June and November ($p=0.044$), July and November ($p=0.002$) and between August and November ($p=0.044$). From one to seven bat species were recorded during each survey (Fig. 5).

Bat species showed differences in phenology of box occupation. *M. nattereri* had the highest share in bat community (about 60%) in May and June. *M. myotis*, *P. nathusii* and *N. noctula* were more frequent in the second half of the study seasons, especially in August and September. *P. auritus* was noted relatively often in all months, and in the coldest months (March, November) it was the most numerous bat species (Table 1). Other species were recorded very rarely and usually in a short time period: *M. brandtii* in June and July (22 individuals in total), *N. leisleri* only in June (4 individuals), *M. mystacinus* in July (1 individual) and *E. serotinus* and *P. pygmaeus* in August (1 individual of each species).

Frequency of each species in boxes changed as well. A low percent of occupied boxes was noted during almost the whole season for: *M. nattereri* (maximum 3.7% in June), *N. noctula* (maximum 3.9% in September) and *P. auritus* (maximum 4.9%

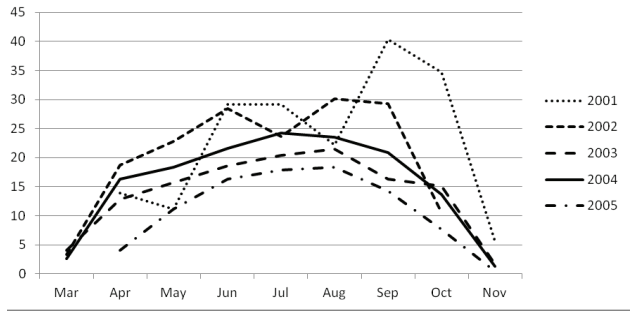

Fig. 3. Percent occupation of boxes by bats in each months in 2001–2005.

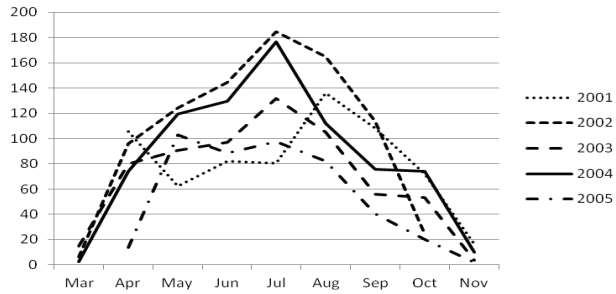

Fig. 4. Densities of bats roosting in boxes (number of individuals/100 boxes) in 2001–2005.

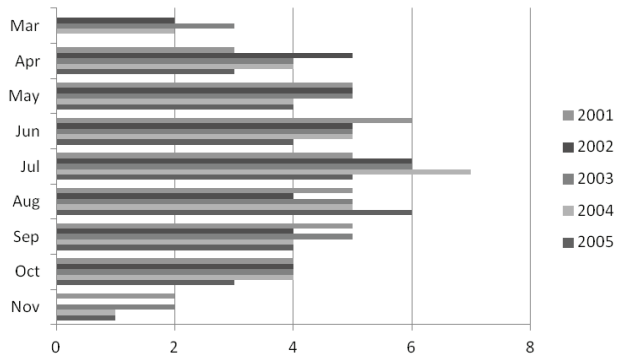

Fig. 5. The number of species found in boxes in each month in 2001–2005.

Table 1. Number of individuals (N) and domination of bat species (D – %) found in the study area in each month in 2001–2005.

Species	Mar	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov
	N	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N
Myotis nattereri	4	240	50.8	427	58.0	484	62.6	493	50.9	395	48.5	211	41.5	148	45.3	2
Plecotus auritus	30	187	39.7	232	31.0	192	24.8	257	26.5	140	17.2	122	24.0	123	37.6	21
Myotis myotis	0	21	4.4	44	6.0	54	7.0	52	5.4	116	14.3	129	25.3	34	10.4	0
Pipistrellus nathusii	0	1	0.2	8	1.1	28	3.6	128	13.2	130	16.0	15	2.9	0	0	0
Nyctalus noctula	5	23	4,9	28	3.9	1	0.1	27	2.8	31	3.8	32	6.3	22	6.7	1
Other species	0	0	0	0	0	15	1.9	12	1.2	2	0.2	0	0	0	0	0
Total	39	472	100.0	739	100.0	774	100.0	969	100.0	814	100.0	509	100.0	327	100.0	24

Table 2. Number of boxes occupied by bat species noted in the study area (N) and the frequency (F – %) in each months in 2001–2005.

Species	Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Myotis nattereri	2	0.4	21	2.9	22	3.1	27	3.7	21	2.9	24	3.3	15	2.1	17	2.4	5	0.2
Plecotus auritus	10	2.2	33	4.6	36	5.0	29	4.0	27	3.7	19	2.6	25	3.5	35	4.9	4	0.9
Myotis myotis	0	0	19	2.6	41	5.7	54	7.5	56	7.8	76	10.5	75	10.4	17	2.4	0	0
Pipistrellus nathusii	0	0	1	0.1	8	1.1	28	3.9	36	5.0	42	5.8	15	2.1	0	0	0	0
Nyctalus noctula	3	0.7	13	1.8	15	2.1	0	0.0	5	0.7	11	1.5	28	3.9	20	2.8	1	0.2
Other species	0	0	0	0	0	0	13	1.8	12	1.6	2	0.2	0	0	0	0	0	0
Total	15	3.3	87	12.0	122	17.0	151	20.9	157	21.7	174	24.0	158	22	89	13	10	1.3

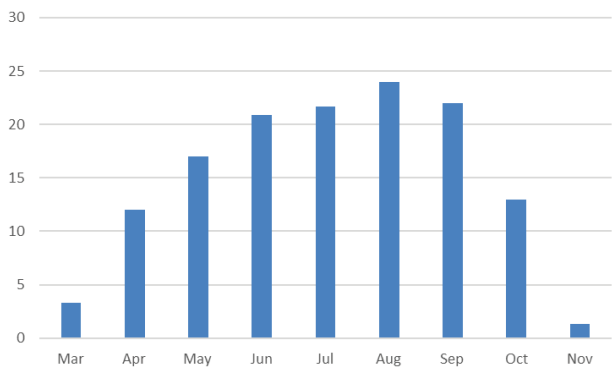

Fig. 6. Mean percent of boxes occupied by bats in particular months.

in October). A higher percent of occupied boxes was recorded for *P. nathusii* (maximum 5.8% in August), and *M. myotis* which occurred in the highest number of boxes (over 10%) in August and September (Table 2). Other species inhabited together a maximum of 1.8% of boxes.

The degree of occupation of boxes increased from March till August to achieve maximum value of 24%. The index values slightly exceeded 20% in June, July and September while in March and November it was below 5% (Fig. 6).

Discussion

Papers published so far aimed at bat occurrence in artificial roosts in forests of central Europe have mainly focused on diversity in occupation of different types of boxes (Haensel & Näfe 1982, Heise 1982, Taake & Hildenhagen 1989). They have not fully described seasonal variability of densities, domination and the degree of utilisation of such roosts by various species or have not presented the whole period of bats' activity (from occupation of boxes after hibernation to their leaving before next hibernation).

Reports based on long-term studies containing information on species structure of bat assemblages and its seasonal variability are not frequent. König & König (1995) presented data from western Germany on the dynamics of bat community roosting in boxes through three successive seasons. Due to local differentiation of bat fauna, the paper pertains mainly to species very rare in boxes in Poland (Kowalski & Lesiński 1994). Bechstein's bat *Myotis bechsteinii* (Kuhl, 1817), which has never been found in our study area, dominates in western Germany, and one of the subdominants was *N. leisleri* (see König & König 1995), which in our study constitutes less

than 1% of recorded bats. The only species frequent in boxes surveyed by König & König (1995) and in our study is *M. nattereri*. Phenology of occupation of boxes by this species is similar in Germany and in Poland, with the exception that the highest numbers of individuals have been noted in August in the former and in June in the latter country.

Phenology of the presence of bats in boxes in central Poland has been presented by Lesiński et al. (2009). The latter study has been performed during one season (a time period much shorter than in the present study) and has reported lower number of species and individuals. *Pipistrellus nathusii* has been revealed as the most frequent species in central Poland while, in the present study, it constitutes less than 7% of all bats. In both areas, the species is the most frequent in July and August.

Other papers presenting the phenology of bat occurrence in boxes in this part of Europe usually contain data on single species. Schmidt (1988, 1994) described phenology of occupation of boxes by *P. nathusii* and *N. noctula* in eastern Germany. He has also demonstrated the highest density of *P. nathusii* in summer (Schmidt 1994), which agrees with results from central Poland (Lesiński et al. 2009) and with data obtained in the present study. During this period, high concentrations of *P. nathusii* were also observed by Rachwald (1992) in northern Poland, while in southern Sweden numerous *P. pipistrellus* were found (Gerell & Lundberg 1985). Schmidt (1988) observed the highest density of *N. noctula* in eastern Germany in spring and autumn while in summer months the density was low. This suggests appearance of the species in the area while mating and during spring and autumn migrations between the sites of hibernation and breeding grounds. Results pertaining to *N. noctula* reported here indicate, however, relatively uniform though not frequent presence of this species during the whole season.

In central Europe during winter (December–February) bats inhabit roosts well isolated from the outdoor conditions like caves or anthropogenic underground roosts (Řehák & Gaisler 1999) while boxes in forests are occupied from spring till autumn (March–November) (Lesiński et al. 2009).

Based on our results, we may state that in early spring and late autumn the boxes are occupied only by *P. auritus* and *N. noctula*. These species are resistant to low temperature and they leave their winter roosts early and stay long in summer roosts (Harmata 1973, Sluiter et al. 1973). An increase of coefficients of box occupation in subsequent months from April to May (in spring) is associated with the arrival of thermophilous bats and with the formation of breeding colonies of some species. In the study area, main breeding colonies observed were those of *M. nattereri* and *P. auritus*. In the case of these two species, relatively high density in boxes during the whole season of activity at low number of occupied roosts was just caused by the presence of breeding colonies, where young individuals are born.

High species richness and relative density of bats in analysed roosts in late summer and early autumn (August–September) resulted from both presence of breeding colonies (despite the fact that the colonies decompose in this time) and appearance of species that mate in these months: *M. myotis, N. noctula, P. nathusii* (see Heise 1982, Schmidt 1984, 1988, 1991, 2001, Rackow & Haensel 2002, Jahelková & Horáček 2011). Noteworthy is the high number of boxes occupied by small groups of individuals of species mating in this time. Harems of *N. noctula*, *M. myotis* and *Pipistrellus* spp. described in the literature (Gerell-Lundberg & Gerell 1994, Schmidt 2003, Gebhard & Bogdanowicz 2004) are usually small.

Relatively high occupation of boxes and high species richness in autumn is probably an effect of the appearance of bats migrating through the study area and using boxes as transitory quarters. Seasonal occupation of boxes by migrating bats was reported from the Baltic Sea coast (Jarzembowski 2003) or near Bodensee Lake (Fiedler 1998). Moreover, for some periods of activity, boxes are probably occupied by single individuals, mainly males, which live solitarily outside the mating period (Kowalski & Ruprecht 1984, Schober & Grimmberger 1997).

In conclusion, considering results presented here and data in other studies from this part of Europe, one may conclude that the observed changes in occupation of boxes by bats are probably determined by two basic factors: the first, behavioural factor, associated with life cycle of bats, and the second, physical factor, associated with temperature of the roost and its surrounding.

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