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Bats on forest islands of different size in an agricultural landscape

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Abstract. The species composition and relative density of bats were compared in forests of various sizes occurring as "islands" in the agricultural landscape of central Poland. The following island categories were distinguished: very small (0.3–0.7 km^2), small (1.0–1.5 km^2), medium (2.0–3.5 km^2) and large (approx. 18 km^2). Bats flying over lanes were caught at 34 mist net stations in 13 islands at the end of June and beginning of July (period I) and again at the end of July and beginning of August (period II). Twelve species of bats were recorded (*Plecotus auritus*, *Eptesicus serotinus* and *Barbastella barbastellus* were the dominant species), and the number of species in specific categories of islands ranged from 8–9, except in the very small islands, where only 4 species were confirmed. Species diversity rose with the size of the islands. *Nyctalus leisleri* and *Myotis mystacinus* were caught only in the large island. The frequency of *B. barbastellus* and *Nyctalus noctula* clearly increased with island size as opposed to *E. serotinus* and *P. auritus*. The relative density (mean numbers of individuals caught at one location on one night) during period I increased with island size from very small (1.8) to large (8.1), while during period II, the highest values were achieved in the medium-sized islands (13.4). The mean number of species for one location and night rose in a similar manner. Forest fragmentation to very small units of less than 1 km^2 in size negatively influences bat ensembles.

Key words: Chiroptera, forest fragmentation, agricultural landscape

Introduction

Deforestation and forest fragmentation are elemental factors affecting species diversity and numbers of many animal communities. Areas covered by trees are the main foraging sites for a number of bat species (Walsh & Harris 1996, Lesiński et al. 2000). Open areas of arable fields and meadows are rather avoided (Gaisler & Kolibáč 1992, Rydell et al. 1994, Lesiński et al. 2000). Consequently, a limiting factor could be a decrease in the size of suitable foraging areas as a result of deforestation. Additionally, small forests do not provide appropriate environments for bat species most strongly associated with forests (limited number of roosts, lower diversity and age of tree species). However, bats live in many ecosystems and have a relatively high ability to move about. For bat species able to travel several kilometers to foraging areas, forest fragmentation should be a less important than for those species that experience open fields and meadows as barriers.

Studies conducted on very isolated islands at sea (Ahlén 1983, Wiles et al. 1989, Pedersen et al. 2003) show that bats are also affected by some of the relationships resulting from the MacArthur & Wilson's (1967) general theory of island biogeography. However, one should not expect similarly strong dependencies in an agricultural landscape, as forest islands are additionally connected by corridors of small water courses, tree alleys and human settlements. These enable bats to change location (Limpens & Kapteyn 1991), and even some of the least mobile species can move between these islands in a fairly short amount of time (most likely this is also realized during seasonal migrations to wintering areas).

In the studies conducted to date, not much attention has been paid to the influence of the size of wood lot and forest sizes on bats present within them. In the forests of Paraguay, the greatest species diversity of bats was found in landscapes of average level of forest fragmentation (Gorresen & Willig 2004). In southern Mexico the highest species richness was noted in forest stands of area up to 80 ha and mosaic of forests and arable fields as compared to a dense forest (Estrada & Coates-Estrada 2002). In Sweden, among areas with a great degree of incongruity and small woodlots 0.1 to 98.7 ha. in size, the number of bat species was not strictly dependent on lot size nor its isolation, but, above all, on the character of the environment (de Jong 1995). The species most sensitive to forest fragmentation were found to be *P. auritus* and *Myotis brandtii* (Eckman & de Jong 1996). A similar study conducted in Mexico on small forest islands (up to 50 ha) did not show differences in species richness and diversity of bats in relation to forest size (Montiel et al. 2006). In North America, clusters of trees and small forest stands were studied in relation to their distance from the edges of continuous forests, and confirmed differences based on the hunting strategies of specific bat species (Swystun et al. 2001, Hogberg et al. 2002).

Such studies have rarely been conducted on larger forest islands of various sizes. In eastern Poland it was shown that even a relatively small forest complex of about 60 km^2 can serve as a habitat for 14 out of the 17 potentially possible bat species found in this part of Poland (Sachanowicz & Krasnodębski 2003). One could expect that the number of bat species and their position in the dominance structure are dependent on forest size, considering the differences in habitat requirements of specific species and their ability to travel. Thus, the use of small forests could be more dependent on the surrounding environment and be characterized by higher numbers of synanthropic species. The purpose of this study is to investigate the assumptions presented above.

Materials and Methods

The research was conducted in central Poland, in the western Mazovian region near the city of Płońsk. The woodiness of this lowland area is about 10%. Forests take the form of many "islands" surrounded by an extensive agricultural landscape. For this study 13 various sized islands were chosen: five very small (0.3–0.7 km^2 in size), four small (1.0–1.5 km^2), three medium (2.0–3.5 km^2) and one large (18 km^2 – Fig. 1).

Most of the forests studied grow in fertile habitats. These are mixed woods or deciduous forests, and in just a few places made up exclusively of evergreens. Pine is a frequent species, but oak and spruce make up a large proportion of the tree stand. Pines comprise the greatest proportion of tree species in the very small islands. Thermophilous oak forests *Potentillo albae-Quercetum* are found locally, especially in the large and medium-sized islands, and a large fragment of marsh forest exists in one of the small islands. The tree stand is mature in

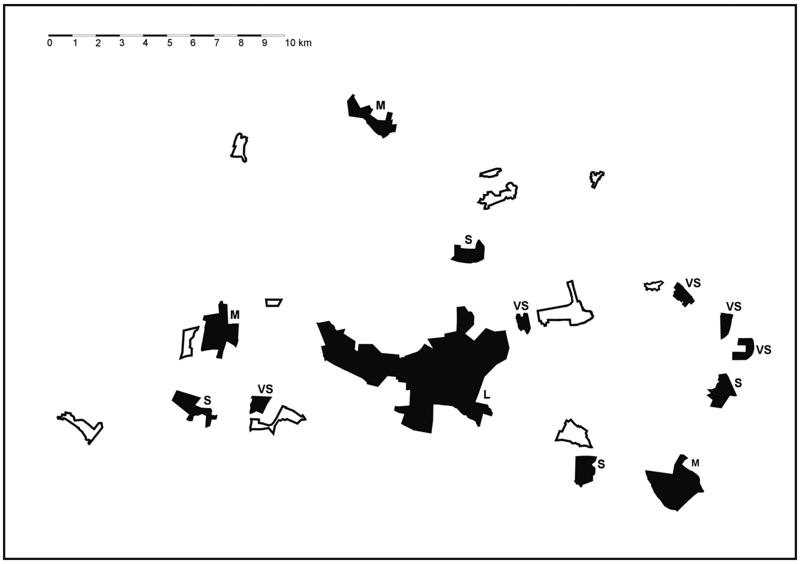

Fig. 1. Distribution of the forest islands in study area (the forest islands under study are marked in black). L – large, M – medium, S – small, VS – very small.

most cases, often over 100 years old, with a rich layer of young trees and undergrowth. Clear cuts are rare, approaching a dozen or so hectares in size in the large island only.

Bats were captured in mist nets set up along forest roads. A standard mist net station consisted of three nets set up near an intersection of lanes. The size of the nets was large enough to block the path of the lane (dimensions: 4–10 x 2.5 m). Captures took place from sunset to dawn. When a bat was caught, information about the species, sex and age, as well as the time of capture was recorded, and it was then released. Bats were captured in two periods: (I) June 26 – July 4 and (II) July 29 – August 5, 2004. Mist net stations were set up at 34 sites, a total of 59 capture sessions were conducted, and most of the sites were used during both periods. The number of locations by the island size category was similar and ranged from 13 to 17. There were slightly more locations included in the study during period II (Table 1). In period I, a total of 133 bats were caught (131 were identified to species), while in period II, 268 bats were caught (265 were identified to species).

Simpson's index was used to describe species diversity:

$$S = 1 - \sum p_i^2,$$

where i = from 1 to n, p_i – proportion of individuals of a specific species in the ensemble, n – number of species in the ensemble.

The differences in the share of each species found in the various sized islands and other proportions were compared using the χ^2 test (with the Yates' correction if one number at least

Table 1. Number of stations where bats were netted.

Study period	Large island	Middle islands	Small islands	Very small islands	Total
June/July	7	7	6	6	26
July/August	10	8	7	8	33

was lower than 5). Species richness and relative density of bats caught at specific trapping stations in forest islands of various sizes were compared using the two-way ANOVA.

Results

Twelve species of bats were found in the forest islands under study. Very small islands exhibited the greatest differences of this factor among all the categories of forest island size. They were characterized by a paucity of species (only four), while eight species were confirmed in small and medium-sized islands, and nine in the large island (Table 2). *N. leisleri* and *M. mystacinus* were confirmed in the large island only, *M. myotis* only in a medium-sized island, *P. nathusii* only in a small island. Very small islands also deviated from the other size categories in terms of species diversity. The S index was barely 0.56, while it was 0.80 in the large island.

Table 2. Number of species and species diversity of bats caught on forest islands of various sizes.

Characteristics	Island size			
	Large	Middle	Small	Very small
Number of species	9	8	8	4
Species diversity – S	0.80	0.76	0.70	0.56

The most numerous species in the studied ensemble were *P. auritus*, *E. serotinus* and *B. barbastellus*. The small proportion of *Myotis* species is notable (under 10%), as well as *Pipistrellus* – represented by only one individual. Differences in the species dominating the netted bats were noted during both study periods. In June–July, the most frequent species were *B. barbastellus* (35.9%) and *P. auritus* (34.4%), while in July–August – *E. serotinus* (30.6%) and *P. auritus* (27.9%). A distinct increase in numbers of *E. serotinus* was recorded between period I and II among the caught bats, from 13 to 81 individuals out of 131 bats

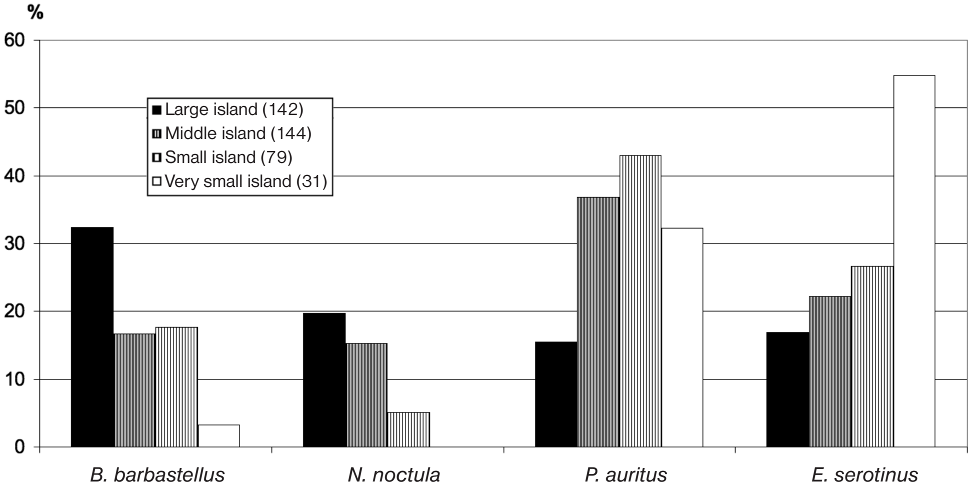

Fig. 2. The proportion of selected bat species in forest islands of various sizes (sample size is given in parentheses: number of individuals identified to species).

in total identified in period I and 265 identified in period II – a difference found to be statistically significant (χ^2=20.6, d.f.=1, p<0.001). *N. noctula* exhibited a similar increase: from 8 to 46 individuals, also a statistically significant difference (χ^2=9.4, d.f.=1, p<0.001).

The most numerous species found (*P. auritus, B. barbastellus, E. serotinus, N. noctula*) exhibited a dependence between their percent in the ensemble and the size class of the forest (χ^2=64.7, d.f.=12, p<0.001). As the size of the forest island increased, a notable increase occurred in the number of *N. noctula* and *B. barbastellus*, while an inverse relationship was seen for *E. serotinus* and *P. auritus*. The latter, however, showed a weak dependence – its numbers were decidedly lower in the large island than in the remaining ones (Fig. 2).

The mean number of individuals caught in one location at the end of June/beginning of July declined as the area of the island decreased. In the research conducted a month later, this index increased in all the separate categories of island size. At the end of July/beginning of August, the mean number of bats caught at one location rose, starting from very small islands to medium ones, where it attained a maximum value of 13.4 individuals. No greater increases in the relative density of bats were confirmed in the large island during this period. Similar differences and trends were noted in the analysis of the mean number of species (Table 3).

Table 3. Mean number of individuals and mean number of species caught per given station and night (± standard deviation) in relation to the forest island size (only stations where netting took place in both study periods were taken into consideration). The number of stations is shown in parentheses.

Study periods	Large island (7)	Middle islands (6)	Small islands (6)	Very small islands (6)	Differences
		Number of individuals			
June/July	8.1±7.2	6.3±4.9	4.3±2.4	1.8±1.7	$F_{3,50}$=3.5, P<0.05
July/August	8.7±10.9	13.4±8.6	7.6±5.1	2.5±2.0	
		Number of species			
June/July	2.4±1.9	2.3±1.5	2.0±0.9	1.2±0.8	$F_{3,50}$=4.0, P<0.05
July/August	2.8±1.7	3.6±0.9	2.9±1.6	1.4±1.1	

Table 4. Differences in the number of individuals netted at the same station in period II in comparison to period I of the study. The number of stations is shown in parentheses.

Islands	Number of stations with			Difference (individuals)	Percentage increase
	more individuals	same number of individuals	fewer individuals		
Large (7)	5	0	2	+12	21.1
Middle (6)	5	0	1	+46	117.9
Small (6)	4	0	2	+19	73.1
Very small (6)	4	2	0	+8	72.9

Table 5. Sex ratio ♂♂ : ♀♀ of bats recorded during two study periods – comparisons: observed versus expected 1 : 1, large island versus other islands.

Study period	Observed	Expected	Difference d.f.=1	Large island	Other islands	Difference d.f.=1
I	33 : 93	63 : 63	χ^2=15.1, P<0.05	11 : 29	22 : 64	χ^2=0.1, NS, P>0.05
II	89 : 154	121.5 : 121.5	χ^2=8.9, P<0.05	24 : 56	65 : 98	χ^2=2.3, NS, P>0.05

When comparing the number of bats caught at the same locations for both periods of the study, an increase was noted in most cases, with the relatively lowest percentage of increase occurring in the large island, and the highest in the medium-sized islands (Table 4). The presence of young individuals is partly the cause of this observed increase. Their share the total number of bats caught during the second period when young individuals started to fly was 17.1% (N=251). Among dominant species only in *N. noctula* the proportion of young to adult bats (18 : 27) did not differ from expected 1 : 1 – in this species usually two young are born per female (χ^2=0.9, d.f.=1, p>0.05). Significant differences from the expected proportion 1 : 2 (one young per female) were obtained in *E. serotinus* 7 : 70 (χ^2=13.6, d.f.=1, p<0.001), *P. auritus* 9 : 59 (χ^2=7.7, d.f.=1, p<0.05) and *B. barbastellus* 2: 33 (χ^2=6.9, d.f.=1, p<0.05).

Females prevailed in the sample of netted bats in both study periods. No difference was observed between the sex ratios recorded in the large island versus lesser islands (Table 5). All individuals of *M. daubentonii* (12) appeared to be males while *M. mystacinus* (6) and *M. myotis* (3) – females.

Discussion

Through the use of various study methods, 15 bat species were confirmed in the large forest complex of Kampinos National Park (about 200 km^2 in size), about 10 km south of the study area (L e s i ń s k i 2003). This is almost the entire representation of the bat fauna for this part of Poland. While *Vespertilio murinus*, *Pipistrellus pipistrellus sl*. and *Myotis dasycneme* were confirmed in the Kampinos Forest, they were not observed in the forest islands under study. *M. dasycneme* is probably absent from the study area due to its distance from larger bodies of water. This factor also accounts for the infrequent presence of *M. daubentonii* represented only by males which can use foraging areas more distant from waters (E n c a r n a ç ã o et al. 2005). The remaining species could be so rare, that the relatively short study period did not enable their discovery, or perhaps they are present at different times of the year during migration (*V. murinus*).

This study shows that a relatively high number of bat species occurs in small forest complexes of about 1 km^2 in area. Smaller areas do not give a suitable habitat for forest bats. For example, in strictly forest species – Bechstein's bat *Myotis bechsteinii* a maternity colony of 20 females needs an area no less than 2.5–3 km^2 (M e s c h e d e & H e l l e r 2003). However, an increase in forested area to 18 km^2 did not cause a clear increase in species diversity on forest islands under study. This is most likely due to the eurytopic characteristics of most European bats. In the case of *N. leisleri* strong dependence on forests, where its foraging and shelter habitat is located (B o g d a n o w i c z & R u p r e c h t 2004, R u c z y ń s k i & B o g d a n o w i c z 2005), was confirmed in this study. On the other hand, *M. mystacinus*, recorded only on the large island, seems to be more eurytopic. For example, it is known to roost in buildings (S a c h a n o w i c z & R u c z y ń s k i 2001). *B. barbastellus* can also be categorized as a forest species, as its share in the ensemble and relative densities were clearly positively dependent on the size of the forest. It confirms its strong relationship to wooded habitats (R y d e l l & B o g d a n o w i c z 1997, S i e r r o 1999, G o m b k ö t ö 2003, M e s c h e d e & H e l l e r 2003, S i e r r o 2003). This also pertains to *N. noctula*, but to a lesser degree. This species uses forests for shelter, while its foraging areas can be located far beyond the woods (K r o n w i t t e r 1988).

The very low numbers of *Pipistrellus* species in the study area is more difficult to explain. This is even more puzzling given the presence of mostly deciduous forests in the area, which are much favored by these bats. A contributing factor is most likely the lack of larger water bodies, that *P. nathusii* and *P. pygmaeus* are especially attracted to (Beck 1994–1995, Barlow & Jones 1996, Barlow 1997, Vaughan et al. 1997, Lucan 2004).

Care should be taken when drawing conclusions from analysis of the species composition of the ensemble based on the study results. In particular, efforts should be taken to avoid comparisons of the frequency with which specific bat species occur in one particular category of forest island size. Bats differ in their foraging strategies, thus, in their use of forest lanes for this purpose. For such species as *B. barbastellus* and *P. auritus*, and to a lesser degree *E. serotinus*, wooded areas, especially forest lanes, are their main foraging sites (Entwistle et al. 1996, Sierro 1999, Lesiński et al. 2000). For other species these lanes serve primarily as flyways to their hunting areas – *N. noctula* being one of these.

The clear dependence of the abundance of bats flying over lanes and the number and diversity of species on the size of forest islands shows that larger forests could offer a richer and more diverse food base. Most likely this results from the presence of a greater variety of microhabitats, with the greatest numbers found in large forest islands. More diverse habitat with forest lanes and clearings increases efficiency of bat foraging (Grindal & Brigham 1999). An additional factor influencing the paucity of density and number of bat species in very small forest islands could be the lack of the typical forest roosts used by bats (tree holes, crevices in the tree bark). The conditions do not exist to support a full ensemble of forest bats, and most of the individuals appearing there most likely fly in from the surrounding anthropogenic environment. This is confirmed by the dominance of *E. serotinus* in the very small forest islands – one of the most synanthropic bat species (Catto et al. 1996). The strong influence of bordering built-up area on the occurrence of synanthropic species in the forest was also reported by Kaňuch & Krištín (2005). An eurytopic species – *P. auritus* (Swift 1998) – was found to be relatively insensitive to a decrease in size of forest complexes noted within the study area. However, forest fragmentation is not favorable for this species due to its weak echolocation sounds, and the problems it experiences in traveling through open terrain, observed in Swedish woods that are more fragmented than these in the study area (Eckman & de Jong 1996).

The seasonal differences observed during this study in the numbers of bats flying over the lanes can be explained by the opportunistic foraging of this group. The greatest differences were found in *E. serotinus* and *N. noctula*, for whom large beetles play a significant role in their diet (Beck 1994–1995). At the end of June/beginning of July, these bats probably focused their attention on the summer chafer *Amphimallus solstitialis* – a beetle very numerous at this time of year with concentrated flights occurring beyond the forest areas. At the end of July, a greater number of large beetles appeared in the forest itself (during this study, large numbers of sawyer beetles *Monochamus scutellatus* were noted flying along the lanes). Changing from one food source to another depending on its availability is a known characteristic of European bats, also, inter alia, of *E. serotinus* (Robinson & Stebbings 1993, Catto et al. 1994).

The additional appearance of bats inside the forest (*E. serotinus*), and, to a certain extend, a likely change in foraging sites (*N. noctula*), as well as the appearance of young individuals, can explain the increase in the number of bats captured at the same sites during the second period of the study. An additional factor to consider is the bats' increase in hunting activity within the forest itself.

The results of this study show that forest fragmentation, though generally unfavorable for bats, does not cause a drastic decline in the number of species if the forests are not smaller than 1 km^2. Larger forests provide conditions for the relatively rich ensembles of these mammals. For such species as *E. serotinus*, *N. noctula* and *M. myotis*, who often travel several kilometers from day roosts to their foraging areas (Degn 1983, Kronwitter 1988, Catto et al. 1996, Robinson & Stebbings 1997), such forest fragmentation as seen in the study area does not constitute a barrier in traveling to foraging areas and dispersal.

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LITERATURE

Ahlén I. 1983: The bat fauna of some isolated islands in Scandinavia. *Oikos 41: 352–358*.

Barlow K.E. 1997: The diets of two phonic types of the bat *Pipistrellus pipistrellus* in Britain. *J. Zool. (London) 243: 597–609*.

Barlow K.E. & Jones G. 1996: *Pipistrellus nathusii* (Chiroptera: Vespertilionidae) in Britain in the mating season. *J. Zool. (London) 240: 767–773*.

Beck A. 1994–1995: Fecal analyses of European bat species. *Myotis 32–33: 109–119*.

Bogdanowicz W. & Ruprecht A. L. 2004: *Nyctalus leisleri* (Kuhl, 1817) – Kleinabensegler. In: Krapp F. (ed.), Handbuch der Säugetiere Europas 4, part. II. *Aula-Verlag, Wiebelsheim: 717–756*.

Catto C.M., Hutson A.M. & Racey P.A. 1994: The diet of *Eptesicus serotinus* in southern England. *Folia Zool. 43: 307–314*.

Catto C.M., Hutson A.M., Racey P.A. & Stephenson P.J. 1996: Foraging behaviour and habitat use of the serotine bat (*Eptesicus serotinus*) in southern England. *J. Zool. (London) 238: 623–633*.

Degn H.J. 1983: Field activity of a colony of serotine bats (*Eptesicus serotinus*). *Nyctalus (N.F.) 1: 521–530*.

Eckman M. & de Jong J. 1996: Local patterns of distribution and resource utilization of four bat species (*Myotis brandti, Eptesicus nilssoni, Plecotus auritus* and *Pipistrellus pipistrellus*) in patchy and continuous environments. *J. Zool. (London) 238: 571–580*.

Encarnação J. A., Kierdorf U., Holweg D., Jasnoch U. & Wolters V. 2005: Sex-related differences in roost-site selection by Daubenton's bats *Myotis daubentonii* during the nursery period. *Mammal Rev. 35: 285–294*.

Entwistle A.C., Racey P.A. & Speakman J.R. 1996: Habitat exploitation by a gleaning bat, *Plecotus auritus*. *Philosophical Transactions of the Royal Society of London, ser. B – Biological Science 351: 921–931*.

Estrada A. & Coates-Estrada R. 2002: Bats in continuous forest, forest fragments and in an agricultural mosaic habitat-island at Los Tuxtlas, Mexico. *Biological Conservation 103: 237–245*.

Gaisler J. & Kolibáč J. 1992: Summer occurrence of bats in agrocenoses. *Folia Zool. 41: 19–27*.

Gombkötö P. 2003: Die Sommerlebensräume der Mopsfledermaus (*Barbastella barbastellus*) in Bükkgebirge (Nordungarn). *Nyctalus (N.F.) 8: 544–547*.

Gorresen P.M. & Willig M.R. 2004: Landscape responses of bats to habitat fragmentation in Atlantic forest of Paraguay. *J. Mammal. 85: 688–697*.

Grindal S. D. & Brigham R. M. 1999: Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. *Ecoscience 6: 25–34*.

Hogberg L.K., Patriquin K.J. & Barclay R.M.R. 2002: Use by bats of patches of residual trees in logged areas of the boreal forest. *American Midland Naturalist 148: 282–288*.

de Jong J. 1995: Habitat use and species richness of bats in a patchy landscape. *Acta Theriol. 40: 237–248*.

Kaňuch P. & Krištín A. 2005: Factors influencing bat assemblages in forest parks. *Ekológia (Bratislava) 24: 45–56*.

Kronwitter F. 1988: Population structure, habitat use and activity patterns of the noctule bat *Nyctalus noctula* Schreb., 1774 (Chiroptera: Vespertilionidae) revealed by radio-tracking. *Myotis 26: 23–85*.

Lesiński G. 2003: Bats of the Kampinos National Park. In: Andrzejewski R. (ed.), *Kampinos National Park, vol. 1: 647–654 (in Polish with English summary).*
Lesiński G., Fuszara E. & Kowalski M. 2000: Foraging areas and relative density of bats (Chiroptera) in differently human transformed landscapes. *Z. Säugetierkd. 65: 129–137.*
Limpens H.J.G.A. & Kapteyn K. 1991: Bats, their behaviour and linear landscape elements. *Myotis 29: 39–48.*
Lucan R.K. 2004: Ecology of three pipistrelle species *P. nathusii*, *P. pipistrellus* and *P. pygmaeus* in S-Bohemia: habitat use and seasonal changes in activity. *Bat Research News 45(3): 131.*
MacArthur R.H. & Wilson E.O. 1967: The theory of island biogeography. *Princeton University Press, 203 pp.*
Meschede A. & Heller K.-G. 2003: Ecologie et protection des chauves-souris en milieu forestier. *Le Rhinolophe 16: 1–214.*
Montiel S., Estrada A. & Leőn P. 2006: Bat assemblages in a naturally fragmented ecosystem in the Yucatan Peninsula, Mexico: species richness, diversity and spatio-temporal dynamics. *J. Trop. Ecol. 22: 267–276.*
Pedersen S. C., Genoways H. H., Morton M. N., Johnson J. W. & Courts S. E. 2003: Bats of Nevis, northern Lesser Antilles. *Acta Chiropterologica 5: 251–267.*
Robinson M.F. & Stebbings R.E. 1993: Food of the serotine bat, *Eptesicus serotinus* – is fecal analysis a valid qualitative and quantitative technique? *J. Zool. (London) 231: 239–248.*
Robinson M.F. & Stebbings R.E. 1997: Home range and habitat use by the serotine bat, *Eptesicus serotinus*, in England. *J. Zool. (London) 243: 117–136.*
Ruczyński I. & Bogdanowicz W. 2005: Roost cavity selection by *Nyctalus noctula* and *N. leisleri* (Vespertilionidae, Chiroptera) in Białowieża Primeval Forest, eastern Poland. *J. Mammal. 86: 921–930.*
Rydell J. & Bogdanowicz W. 1997: *Barbastella barbastellus. Mammalian Species 557: 1–8.*
Rydell J., Bushby A., Cosgrove C.C. & Racey P.A. 1994: Habitat use by bats along rivers in north east Scotland. *Folia Zool. 43: 417–424.*
Sachanowicz K. & Krasnodębski I. 2003: Species composition and anthropogenic roosts of bats in the Łuków Forest. *Nietoperze 4: 27–38 (in Polish with English summary).*
Sachanowicz K. & Ruczyński I. 2001: Summer roost sites of *Myotis brandtii* (Eversmann, 1845) (Chiroptera, Vespertilionidae) in eastern Poland. *Mammalia 65: 531–535.*
Sierro A. 1999: Habitat selection by barbastelle bats (*Barbastella barbastellus*) in the Swiss Alps (Valais). *J. Zool. (London) 248: 429–432.*
Sierro A. 2003: Habitat use, diet and food availability in a population of *Barbastella barbastellus* in a Swiss alpine valley. *Nyctalus (N.F.) 8: 670–673.*
Swift S. M. 1998: Long-eared bats. *T & AD Poyser Natural History, London, pp. 182.*
Swystun M.B., Psyllakis J.M. & Brigham R.M. 2001: The influence of residual tree patch isolation on habitat use by bats in central British Columbia. *Acta Chiropterologica 3: 197–201.*
Vaughan N., Jones G. & Harris S. 1997: Habitat use by bats (Chiroptera) assessed by means of a broad-band acoustic method. *Journal of Applied Ecology 34: 716–730.*
Walsh A.L. & Harris S. 1996: Foraging habitat preferences of vespertilionid bats in Britain. *Journal of Applied Ecology 33: 508–518.*
Wiles G.J., Lemke T.O. & Payne N.H. 1989: Population estimates of fruit bats (*Pteropus mariannus*) in the Mariana Island. *Conservation Biology 3: 66–76.*