

Flight activity and habitat use of four bat species in a small town revealed by bat detectors

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A b s t r a c t. The aim of our study was to assess the seasonal and overnight changes in the flight activity and habitat use of four bat species under the conditions of a sub-mountain town by a detector monitoring. The urban habitats visited from May until October 1998 – 2000 were divided into three categories: gardens (illuminated or non-illuminated gardens and larger groups of trees), urban habitat (old and new buildings in suburbs and downtown), and water (streams and ponds). Only for *Myotis daubentonii* was a statistically significant increase in flight activity recorded between the lactation and post-lactation periods. The highest activity of *M. daubentonii* was recorded in the vicinity of water bodies. The activities of *Pipistrellus pipistrellus* and *Nyctalus noctula* were similar in relation to the habitats. Only in *Eptesicus serotinus* was the activity recorded per habitat type not significantly different. The changes of activity of *P. pipistrellus* had a bimodal character with the first peak in the 5th and the 6th ten-minutes and the second in the 12th ten-minutes. In *N. noctula*, activity was characterized by commuting over the urban habitats during the first 0.5 h. Relatively high activity was recorded in *E. serotinus* during the first 0.5 h in gardens.

Key words: Chiroptera, urban habitat, flight activity, bat detector, *Myotis daubentonii*, *Pipistrellus pipistrellus*, *Nyctalus noctula*, *Eptesicus serotinus*

Introduction

Urban habitats represent a specific segment of the landscape, which is used with different intensity by various mammal species. Some highly synanthropic bat species have adapted well to urban habitats. Towns and villages offer them not only plenty of diversified foraging areas, but also many suitable shelters (K u n z 1982, R y d e l l et al. 1996). Their utilisation by summer nursery colonies and by solitary individuals enables many bat species to extend their ranges mainly in the temperate zones (K u n z 1982).

Even though it is well known that many bats use buildings, chiropterological investigations of towns have been undertaken until recently. The knowledge of flight activity of the bats in urban areas has long remained scant and has had to rely on occasional findings. Bat research in urban habitats became more intensive due to the fast development of ultrasound detector use for the monitoring of bat activity. In the beginning, most field studies dealt with the distribution of various bat species in European cities (Berlin – H a e n s e l 1992, London – H o o p e r 1981 and M i c k l e b u r g h 1987, Leipzig – S c h o b e r & M e y e r 1995, Wien – S p i t z e n b e r g e r 1990, Oldenburg – S c h r ö d e r & W a l t e r 2002) and the requirements and/or flight activity of bats in urban habitats

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(Walsh & Harris 1996 a,b; Kurta & Teramino 1992, Vernier 1989). However, much more information from detector studies has been obtained in other habitat types (woodland - DeJong 1994, Krusic et al. 1996, Grindal & Brigham 1999; farmland – Gaisler & Kolibáč 1992; riverine – Racey et al. 1998, Vaughan et al. 1996).

A pioneer work about bat ecology in cities was published by Gaisler (1979), who recorded visually without bat detectors the initial flying activity of bats in the city of Brno. Trained observers distinguished four size categories of bats. The later acoustic monitoring using bat detectors (Gaisler et al. 1998) compared data obtained under the same conditions and along the same transects, and the habitat preference of selected bat species was analyzed.

The main goal of our study was to assess the seasonal and overnight changes in the flight activity and habitat use of four bat species in a sub-mountain town.

Material and Methods

A bat detector (Pettersson Elektronik D200 – heterodyning) was used for the monitoring of ultrasound bat calls within the town of Jablonec nad Nisou from May until October in 1998 – 2000 (cf. Schröder & Walter 2002). The visited urban habitats were divided into three categories: gardens (illuminated or non-illuminated gardens and larger groups of trees), urban habitat (old and new buildings in suburbs and downtown), and water (streams and ponds). These habitats were regularly cycled during three consecutive nights of monitoring. In addition, the habitats were visited in arbitrary sequence later at night.

The flight activity of only four selected bat species was registered i.e. *Myotis daubentonii* (Kuhl, 1819), *Pipistrellus pipistrellus* (Schreber, 1774) – 45 kHz phonic type, *Nyctalus noctula* (Schreber, 1774) and *Eptesicus serotinus* (Schreber, 1774). The method of fixed and non-fixed detector points was used due to the fragmentation of the selected habitats (linear transects are inapplicable in urban habitats for this reason). The monitoring started 10 minutes after sunset and continued until midnight. Each observation lasted 10 minutes and at the beginning the detector was tuned up and down between 15 and 60 kHz. After having heard a signal, the observer tuned to optimum frequency and recorded the duration of the time interval during which the bat signals were heard (McAney & Fairley 1988a, Von Zahn & Maier 1997). When bats were no longer heard, the frequency was again tuned in all intervals. The activity was noted as commuting flights or foraging.

Fixed points (23 different points, only one in each habitat) were used for the study of seasonal activity dynamics (Furlonger et al. 1987). The monitoring was always conducted during three consecutive nights within a period of about three weeks. Data from 14 three-day observations (42 days) were used with the shortest period between them being 12 days (July 1999) and the longest 35 days (June 1999). The year was divided into four parts with respect to the reproduction period: pregnancy (until June 15), lactation (from June 16 until July 13), post-lactation (from July 14 until August 11) and migration (after August 11). There is some risk of pseudoreplication in the activity frequency data recorded within a 10 minute period (e.g. one single bat could have produced all records from one sampling period). This pseudoreplication is not important, because the activity unit we used is not a number of foraging bats, but the level of total activity in one 10 minute period.

The bat activity at the non-fixed points was analyzed for overnight changes in its level. Three points each were randomly selected from urban and water habitats and two from

gardens (8 points total). The selection of points was limited only by their mutual minimal distance of 100 meters (R a c h w a l d 1992). The field observations were carried out during nine days in July and/or August in all three years (27 days total). During one night, all habitats were visited, and their order was regularly changed every day. Table 1 contains pooled data from the studied habitats.

The statistic software JMP (S A S Institute 1995) and Statistica for Windows 5.0 were used for data analysis. The level of bat activity was assessed primarily as the number of individual minutes in which bat ultrasound signals were detected (M c A n e y & F a i r l e y 1988b). This number was converted into the relative activity i.e. number of positive minutes per 60 minutes of monitoring. Bonferroni Correction was applied if multiple tests were used for the same data set. The changes in flight activity during the season and differences in habitat use were tested using contingency tables (Chi-square Test) and the Median Test, respectively. The Willcoxon Paired Test was used to check the changes in bat habitat use during the season and the differences in activity between the years. The non-parametric Mann – Whitney Test and the Spearman Correlation Coefficient were used to compare the changes in flight activity during the night. The activity in different habitat types was tested by the Median Test.

Table 1. The material (positive minutes) obtained in the different habitats (A-gardens, B- buildings, C-watersides).

Habitat	Season observation			total	Overnight observation			total
	A	B	C	Σ	A	B	C	Σ
<i>Myotis daubentonii</i>	59	5	277	341	2	2	414	418
<i>Pipistrellus pipistrellus</i>	169	94	236	499	92	56	172	320
<i>Nyctalus noctula</i>	53	125	138	316	90	85	54	229
<i>Eptesicus serotinus</i>	67	51	49	167	42	27	39	108
Total positives	348	275	700	1323	226	170	679	1057
Total minutes	730	1050	1030	2810	480	510	510	1500

Results

Seasonal changes

There were no between-year differences in the level of activity and habitat use (Table 2) and therefore the data were pooled for subsequent analyses.

All species were recorded during all reproduction periods, and there was no significant difference in the total activity of *P. pipistrellus*, *N. noctula* and *E. serotinus* during particular periods (pregnancy, lactation, post-lactation, migration). The only statistically significant

Table 2. Between-year differences in the level of activity and habitat use (Chi – square Test, P<0.05).

species/ habitat	<i>Myotis daubentonii</i>	<i>Pipistrellus pipistrellus</i>	<i>Nyctalus noctula</i>	<i>Eptesicus serotinus</i>
garden	$\chi^2 = 2.42, P = 0.79$	$\chi^2 = 8.58, P = 0.79$	$\chi^2 = 6.53, P = 0.26$	$\chi^2 = 8.99, P = 0.34$
building	$\chi^2 = 0.35, P = 0.84$	$\chi^2 = 9.19, P = 0.42$	$\chi^2 = 16.32, P = 0.09$	$\chi^2 = 9.44, P = 0.40$
water	$\chi^2 = 13.19, P = 0.36$	$\chi^2 = 12.29, P = 0.20$	$\chi^2 = 10.74, P = 0.47$	$\chi^2 = 13.05, P = 0.07$
total	$\chi^2 = 12.71, P = 0.39$	$\chi^2 = 13.42, P = 0.34$	$\chi^2 = 15.15, P = 0.23$	$\chi^2 = 17.65, P = 0.06$

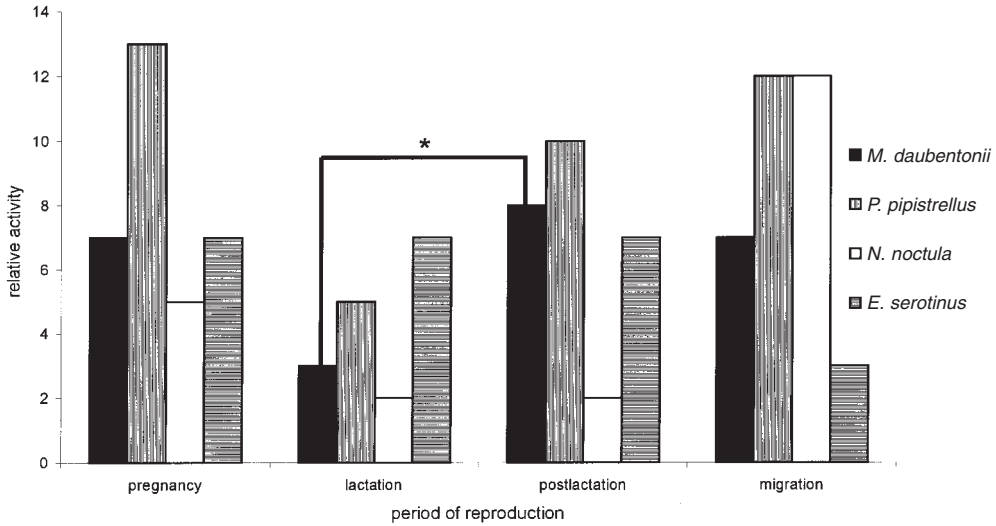


Fig. 1. The changes of bat activity in the parts of the reproduction period; * (χ^2 , $P < 0.05$).

increase in flight activity was recorded between lactation and post-lactation in *M. daubentonii* ($\chi^2 = 39.99$, $P = 0.021$) (Fig. 1).

The pattern of flight activity of particular species was different when habitat types were compared. The highest activity of *M. daubentonii* was recorded in the vicinity of water bodies. On the contrary, it was very low in urban habitats, where records of commuting flights dominated. Nevertheless, there were statistically significant differences in the level of activity in all cases analyzed (Table 3).

The activities of *P. pipistrellus* and *N. noctula* were similar in relation to the habitats. Both species flew less in urban habitats than in the other habitats under study (water and gardens), in which the recorded activity was at the same level. For *N. noctula* and *E. serotinus* the activity recorded per habitat type was not significantly different (Table 3).

Table 3. The seasonal changes of flying activity in the studied habitats (Willcoxon Paired Test, Bonferroni Correction, $P < 0.0042$).

species	building x garden	building x water	garden x water
<i>M. daubentonii</i>	Z = 3.05, P = 0.002	Z = 4.47, P < 0.001	Z = 2.77, P = 0.006
<i>P. pipistrellus</i>	Z = 3.34, P = 0.001	Z = 3.06, P = 0.002	Z = 0.06, P = 0.954
<i>N. noctula</i>	Z = 2.14, P = 0.033	Z = 2.40, P = 0.016	Z = 0.80, P = 0.422
<i>E. serotinus</i>	Z = 2.03, P = 0.043	Z = 2.49, P = 0.126	Z = 0.04, P = 0.965

Overnight changes

Timing of activity

The changes in the level of flight activity of bat species in the course of the night were statistically different (Mann-Whitney Test, $Z = 94.76$, $P = 0.012$). The relative activity of two

species (*M. daubentonii* and *N. noctula*) correlated positively with the order of ten-minute intervals after sunset (Sp = 0.16, P < 0.010, n = 150 and Sp = 0.26, P < 0.001, n = 150, respectively).

A rapid onset of *M. daubentonii* activity was registered during the first 30 minutes (χ^2 , P = 0.006). Its level fluctuated during subsequent intervals, but it was relatively high all the time (Fig. 2) and only the decrease between the 10th and the 12th ten-minute interval was statistically significant (χ^2 , P = 0.016). In *N. noctula* activity increased later, i.e. from the 10th to the 13th ten-minutes (χ^2 , P = 0.001) in the second half of the monitoring. During the 5th and 6th ten-minutes, relatively higher commuting activity, which could be associated with flight to foraging areas was recorded. Typical early emergence was not registered.

In spite of important fluctuations, the activity of *P. pipistrellus* was negatively correlated with the order of ten-minute intervals (Sp = -0.11, P = 0.001, n = 1500). The changes of activity had a bimodal character with the first peak in the 5th and the 6th ten-minutes (increase of activity χ^2 , P = 0.002) and the second in the 12th ten-minutes (χ^2 , P = 0.016).

The only statistically insignificant correlation between the relative activity and the order of ten-minutes was observed in *E. serotinus* (Sp = 0.01, P = 0.799, n = 1500). Generally, the relative activity of *E. serotinus* was lower than that of other bat species under study.

Habitat use

Habitat use in each 0.5 h time interval after sunset was registered in three general categories of habitats – garden, urban habitat and water bodies. The difference in total level of activity in particular habitats, tested by means of the Median Test, was only insignificant in *N. noctula* (H = 0.99, P = 0.609, n = 153). In all other species, i.e. in *M. daubentonii* (H = 110.26, P < 0.001, n = 153), *P. pipistrellus* (H = 8.66, P = 0.013, n = 153) and *E. serotinus* (H = 6.50, P = 0.039, n = 153), the activities recorded per habitat type were significantly different.

M. daubentonii was almost exclusively recorded at water bodies during the night (Fig. 3), appearing there right at the beginning of the night (χ^2 , P < 0.001). Very low foraging and commuting activity (2 positive min. per 60 min. of monitoring) was registered in gardens at the end of the studied part of the night. High activity of *P. pipistrellus* in gardens (commuting and foraging) and urban habitats (mostly commuting) during the first 0.5 h after sunset reflects most probably the use of shelters in their vicinity. The increase of activity at water habitats was significant during the second 0.5 h after the sunset (χ^2 , P < 0.001) and decreased continuously thereafter (χ^2 , P < 0.001). In *N. noctula*, activity was characterized by commuting over the urban habitats during the first 0.5 h. Foraging activity of this species was recorded later. Relatively high activity was recorded in *E. serotinus* during the first 0.5 h (gardens). Nevertheless, considerable migration among all types of habitats occurred during the night (Fig. 3). Only the decrease in use of urban habitats between the 3rd and the 4th 0.5 h was significant (χ^2 = 51.72, P < 0.001).

Discussion

Seasonal changes

Seasonal changes of activity are mainly influenced by the changes in prey supply (quality and accessibility). Prey is more accessible during short peaks of abundance – swarming (during the warmest periods of the year). These changes in prey density are different in various

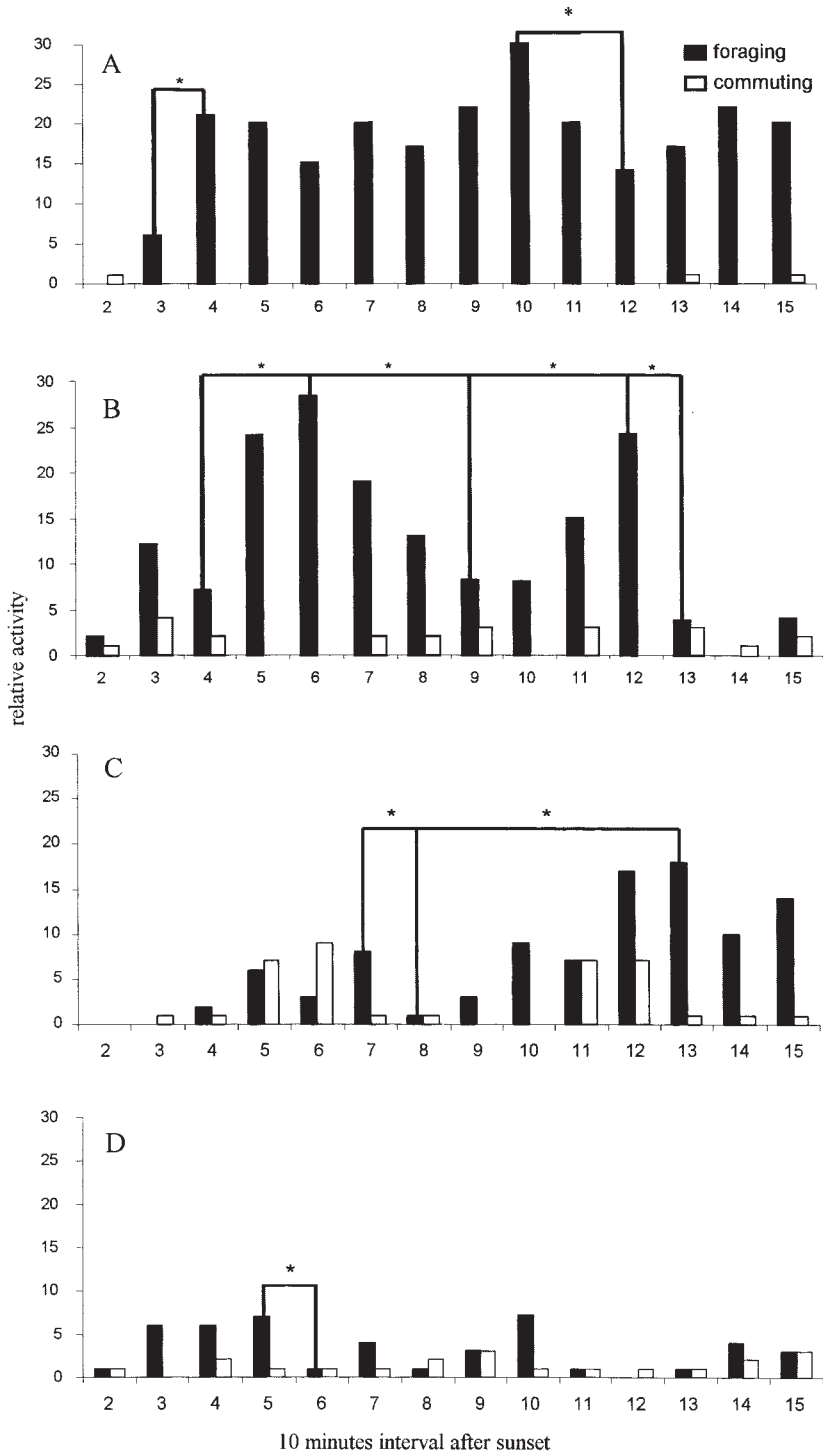


Fig. 2. The overnight changes in the level of flying activity. **A** – *M. daubentonii*, **B** – *P. pipistrellus*, **C** – *N. noctula*, **D** – *E. serotinus*; * (Mann – Whitney test, Bonferroni Correction, $P < 0.0042$).

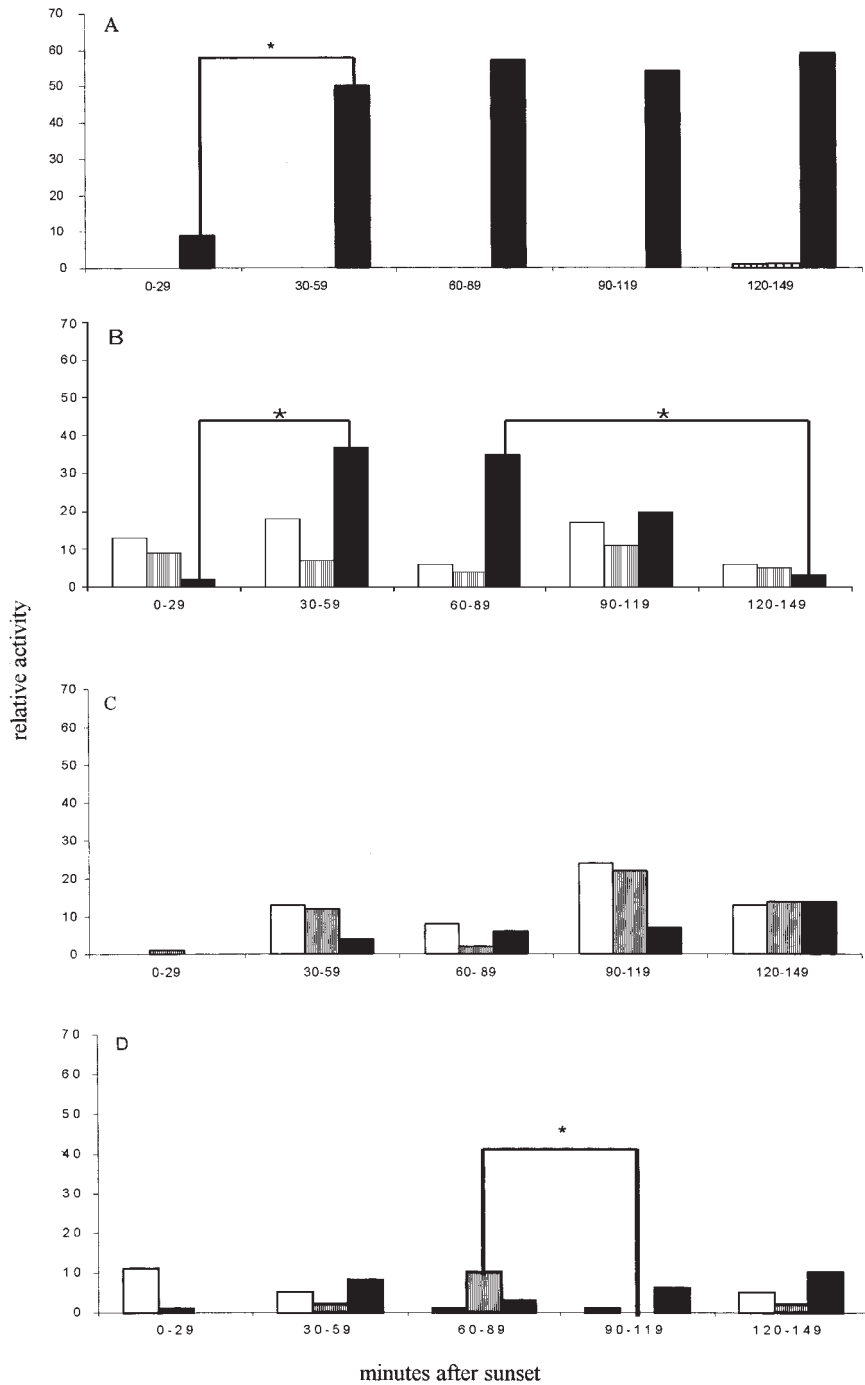


Fig. 3. The habitat use during first part of the night. **A** – *M. daubentonii*, **B** – *P. pipistrellus*, **C** – *N. noctula*, **D** – *E. serotinus*;* (Median test, $P < 0,05$).

habitats i.e. they also influence the changes in habitat use during the season (DeJong 1994, DeJong & Ahlén 1991).

In urban habitats, we registered a decrease in foraging activity of *M. daubentonii*, *P. pipistrellus* and *E. serotinus* (similarly observed for *E. nilssonii* by Rydell 1993) approximately 14 days before the births (in mid June). During the subsequent lactation period (the second half of June and the beginning of July) an increase in the activity level was recorded in the above-mentioned bat species. The weaning of young in the period of highest food supply (DeJong 1994, Catto et al. 1996) might be achieved by a modification of the length of foetus development (e.g. day lethargy). The activity of two species, i.e. *M. daubentonii* and *P. pipistrellus*, increased during the end of July in urban habitats presumably because of the young already foraging independently. This recorded increase in activity exactly corresponds to the period of maximum Diptera abundance (Anthony & Kunz 1977) between July of 13th and 22nd.

Gaisler et al. (1998) described the peak of *P. pipistrellus* activity during the end of August and the beginning of September when the colonies are disintegrating. We registered the maximum of *P. pipistrellus* activity approximately at the same time, but the highest activity of bats (cca 30 % of minutes positive) in this period was observed by Zukal et al. (1997). This increase in the activity level at our locality was also influenced by increasing commuting flights during migrations (after the nursery colonies disintegration and the period of reproduction). We ascertained the peak of activity in *N. noctula* in September, similarly to Rachwald (1992), who studied this species in Poland. The peak of *E. serotinus* activity was observed earlier i.e. during July. In *E. serotinus*, the weaning of juveniles was relatively soon, during the first half of July. Therefore, this species was not detected in urban habitats in the end of August, and it is potentially visiting the hibernacula in the beginning of September.

Overnight changes

Timing of activity

Overnight changes in bat activity are closely related to seasonal fluctuations – the food supply and its accessibility changes rapidly. Activity can be limited to the beginning of the night when the abundance of diurnal prey is higher (Jones & Rydell 1994).

Seasonal changes in bat emergence and consequently in their arrival at foraging sites are manifested, as the change in the emergence is related to sunset (O'Shea & Vaughan 1977, Rydell 1993). The time of emergence is significantly correlated with the sunset (e.g. Gaisler 1963, Swift 1980) and its interspecific differences are related to foraging strategy and prey selection (Rydell et al. 1996). Insect abundance is highest during the evening, often even before bat emergence, and it declines towards midnight (Rydell 1992). The fast-flying *N. noctula* has been regularly seen foraging before sunset (Rachwald 1992), emerging earlier during the spring and autumn period than in summer (Gaisler et al. 1979). Nevertheless, we only registered the peak of *N. noctula* foraging activity in urban habitats 1–1.5 hours after sunset. Until that time, we recorded mainly the commuting activity of this species. We can assume that individuals of *N. noctula* are coming to the studied localities from the largest distances. Gaisler et al. (1998) also found later appearance of this species at the foraging areas in urban habitats, and they

explained this observation by the absence of suitable shelters in the surroundings of the foraging areas.

Many bat species with other foraging strategies avoid very early emergence in order to not be exposed to a high predation risk. These species are usually represented by slow flyers, hawkers and various gleaners (Ryde11 et al. 1996). Entwistle et al. (1996) and Ryde11 et al. (1996) found the approximate time of emergence of the slow hawking *P. pipistrellus* to be 35 minutes and 28 minutes after sunset, respectively. We observed high bat activity as soon as 20 minutes after sunset in urban habitats. Similar results were published for *E. serotinus* and *P. pipistrellus* by Gaisler et al. (1998), who recorded maximum activity during the first 0.5 h after sunset. On the other hand, Verboom (1998) found a synchronization of peak prey activity and *P. pipistrellus* foraging.

The bats spend certain amount of time on commuting flights to the foraging areas in urban habitats (viz. *N. noctula*), and there is a correlation between the emergence time after sunset and the distance between foraging area and shelter (Entwistle et al. 1996). Verboom (1998) concluded that the density of shelters and quality of foraging areas is low in comparison with the size of bat home range (distance effect), and Walsh & Harris (1996b) stated the necessity of balance between suitable foraging places and shelters.

E. serotinus came soon after sunset into the garden habitats. It is most probable, that this species finds a sufficient number of roosts in buildings within urban habitats. Fragmentation of *P. pipistrellus* and *E. serotinus* occurrence in the cities is related to a limited number of foraging areas and potential shelters (Hensel 1992). Ryde11 et al. (1996) registered the emergence of *M. daubentonii* as late as 1.5 hour after sunset, and late emergence of this species is also found in other published data (Jones & Ryde11 1994, Gaisler et al. 1998). We recorded *M. daubentonii* activity at foraging areas as early as 30 minutes after sunset and during the subsequent time period it did not show any substantial fluctuations. During the post-lactation period the problem of distance between roosts and foraging places could be complicated by the behaviour of some males who use farther foraging habitats. One of the possible explanations for this behaviour is to reduce the intra-specific competition risk for the yearlings (Entwistle et al. 1996).

Depending on species, bats forage approximately 80 % of the time spent outside of the roosts. The rest of time they are resting and/or eating prey in night roosts (Ryde11 1993, Kunz 1982). Females of *E. nilssonii* had regular rest in the same night roosts during the night (DeJon 1994). Generally, the activity of bats is divided into rest periods of various lengths alternating with foraging periods. Returns to the roosts continue all night but the majority is usually concentrated into the period before sunrise. Bimodal activity with two peaks was registered in *P. pipistrellus* during the first half of the night (similarly Vaughan et al. 1997) and partly also in *E. serotinus*, but its total activity was very low. The decrease of activity was probably influenced by the return of lactating females into the day shelters where they feed the young (Gaisler 1963, Swift 1980).

The timing of bat flight activity has another type of bimodal distribution when we look at the overnight distribution (O'Shea & Vaughan 1977, Vaughan et al. 1997). Most bat species have two peaks of activity, after sunset and before sunrise (Rachwald 1992). This bimodal model is not always evident in the higher latitudes where foraging around midnight occurs frequently (Ryde11 1993). The bimodality of overnight activity changes during the season depending on the reproduction cycle (Kunz 1982, O'Shea & Vaughan 1977) and on prey accessibility (Kunz 1982). It is much more

pronounced during the period of high energetic costs (lactation) than during the post-lactation period when the morning peak of activity is lower. Generally, it was found that bats consume about 60 % of their prey during the first half of the night and approximately 40 % during the second half but, Anthony & Kunz (1977) found that non-reproducing females caught 43 %, lactating females 28 % and pregnant ones only 19 % of their prey during the first 20 minutes, respectively. During the cooler periods the bimodal distribution of activity is missing because bats forage longer to maintain energy income. Bats also emerge later under cooler weather conditions (O'Shea & Vaughan 1977).

Habitat use

All habitat types under study were visited by flying bats but the habitats with higher prey density presumably were selected similarly to an open landscape (Walsh & Harris 1996a, Entwistle et al. 1996, Anthony & Kunz 1977). This preference changed during the night. In most studies, habitats associated with water were selected (Racey & Swift 1985, McAney & Fairley 1988b, Walsh & Mayle 1991, Hart et al. 1993, Rachwald 1992, Rydell et al. 1994, Rydell et al. 1996, Krusic et al. 1996, Zukal et al. 1997). McAney & Fairley (1988b) found a preference for covered water bodies and farmland during the first half of the night when the highest activity was registered. Vaughan et al. (1997) reported almost 70 % of positive records over water habitats.

M. daubentonii, which is found close to water habitats (Racey et al. 1998), also foraged around them in the town (Schroder & Walter 2002). The high energy requirements of this species could explain this strong selection (Kalko & Braun 1991). The preference was evident during the beginning and the end of the studied part of the night, whereas *M. daubentonii* flew in urban habitats during the middle part. Riverine habitats with many trees were also attractive for all studied bat species except *E. serotinus* in the city of Brno (Gaisler et al. 1998). In our study, *E. serotinus* changed its habitat preference during the night moving from gardens to urban habitats. Around midnight, it foraged in water habitats, which are especially important during the lactation and post-lactation periods when total prey density is rather low (Pokorny 1998).

In our study, water habitats were also frequently used by *N. noctula* before midnight. On the other hand, Rachwald (1992) reported the foraging of *N. noctula* in this habitat at the beginning of the night, i.e. at a time when we registered mainly commuting flights in urban habitats (similarly to Gaisler et al. 1998). The last species under study, i.e. *P. pipistrellus*, the most common species in Jablonec, also used the surroundings of water bodies with peak activity between 30 and 120 minutes after sunset, while Gaisler et al. (1998) reported its highest activity in old suburbs and villa quarters, both with gardens.

The selection for small water surfaces in town demonstrate their high attraction for bats. Therefore, enhancement and maintenance of water surfaces with riparian vegetation could be incorporated into advice to landowners concerning the conservation of the natural landscape mosaic and bat conservation.

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