TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2017) 41: 530-548
© TÜBİTAK
doi:10.3906/zoo-1602-51

Year-round monitoring of bat records in an urban area: Kharkiv (NE Ukraine), 2013, as a case study

Kseniia KRAVCHENKO[1,*], Anton VLASCHENKO[1], Alona PRYLUTSKA[1], Olena RODENKO[1,2], Vitalii HUKOV[1], Volodymyr SHUVAEV[1]

[1]Bat Rehabilitation Center of Feldman Ecopark, Lesnoye, Kharkiv, Ukraine
[2]Faculty of Biology and Environmental Protection, University of Silesia, Katowice, Poland

Received: 23.02.2016 • **Accepted/Published Online:** 21.11.2016 • **Final Version:** 23.05.2017

Abstract: This study presents information about the year-round phenology of bats of temperate zones in a city area for the first time. In total, 967 individuals of 5 bat species (*Nyctalus noctula* [87.5%], *Eptesicus serotinus* [10.6%], *Pipistrellus kuhlii* [0.8%], *Vespertilio murinus* [0.9%], and *Plecotus auritus* [0.1%]) were recorded during 2013 in Kharkiv. The population structures of temperate bat species are complex; segregation of sex and age groups varies spatially and seasonally. Most of the bats (88%) were collected during the hibernation period (January–March and November–December) and the autumn invasion (August–mid-September). The breeding period saw a lower number of bats collected, making up 0.5% of records (May–July). The degree of tolerance to urbanization is species-specific. The bats were found indoors (68.6%), between window frames (26.6%), outdoors (2.8%), in basements (1.05%), and on balconies (0.95%). Bats of temperate latitudes inhabit big cities in significantly increasing numbers in winter, spring, and autumn. They avoid urban areas in both the breeding period and the period of fat-store accumulation before hibernation.

Key words: Bats, Ukraine, Kharkiv, monitoring, urban ecosystem, bat phenology

1. Introduction

There have been many recent publications about different aspects of bat ecology in urban areas, such as the impact of light pollution (Stone et al., 2015; Hale et al., 2015), bat activity in relation to insect richness (Avila-Flores and Fenton, 2005; Muller et al., 2012; Oliviera et al., 2015), and features of habitat selection obtained by acoustic surveys (Vaughan et al., 1997; Russo and Jones, 2003; Dixon, 2012). The main factors that shape bat presence in particular habitats are prey abundance and roost availability (Kunz and Fenton, 2006). Furthermore, it is known that ecological plasticity is variable both among species (Gaisler et al., 1998; Duchamp et al., 2004) and within sex and age groups (Senior et al., 2005). The degree of tolerance of species in response to urbanization varies between specialists and generalists (McKinney, 2008). The basic theories of sex and age spatial segregation are founded on the phenomenon of higher energy costs for females during pregnancy and lactation than for males during the corresponding times (Racey and Speakman, 1987; Kunz and Fenton, 2006; Van Toor et al., 2011). As a consequence, females ultimately require habitats that offer higher prey availability and warmer roost microclimate conditions (Barclay, 1991; Hamilton and Barclay, 1994).

However, data concerning the demographic structure of bat populations and their year-round phenology in urban areas are quite limited (Coleman and Barclay, 2011; Ancillotto and Russo, 2015). Noninvasive methods (such as acoustic surveys) do not provide such information due to methodological limitations (Van Toor et al., 2011). Moreover, in most cases the data about individual bat records within city areas amount to tens of individuals per year (Stoycheva et al., 2009; Cermakova and Zieglerova, 2014; Zahn and Kriner, 2016). Such a small number of samples is not sufficient to allow valid conclusions to be drawn about the year-round relationships of bats to the city area. Nonetheless, due to the irreversible processes of urbanization and natural habitat loss, the city area becomes, by obligation, an increasingly important factor in the landscape of the time and spatial population structure of some bat species (Francis and Chadwick, 2012). At the same time, the city environment hides emergent peculiarities that are often determined by anthropogenic factors, such as the unpredictable disturbance of bat aggregations by people, including the destruction of their roost cavities in built-up areas, the sudden termination of access to newly discovered roosts through open windows and balconies, the potential repair of suitable roosting crevices and holes

* Correspondence: shusha.kravcheneo@gmail.com

in buildings, and threats from synanthropic predators (e.g., cats, birds) (Ancillotto et al., 2013; Voigt et al., 2016). Clarification of the effects that city environmental features have on bats is critical in order to guide and advise proper conservation strategies for supporting bat biodiversity in city areas.

In the city of Kharkiv, we have a unique situation where bats can be collected by bat specialists in abundance. Since 1999, when continuous bat monitoring started in Kharkiv (Vlaschenko, 1999), it has become easy to collect more than 100 bat individuals per year (Prylutska and Vlaschenko, 2013). In 2013, a special Bat Rehabilitation Center was founded (www.bat-kharkov.in.ua) and a unified bat rescue call-center was opened in order to start gathering information about human–bat conflicts. The resulting bat educational and public awareness activities that followed allowed us to collect nearly 1000 bats in 2013, which were accidentally found by citizens. With these data, we want to demonstrate several aspects of bat natural history in city areas, in light of seasonal changes in the temperate continental climate of northeastern Ukraine.

The objectives of the paper are: 1) to demonstrate the seasonal changes in the structure of bat assemblages using occasional finds, 2) to show the spatial distribution of bats in urban areas and to summarize the record types, 3) to describe the sex and age structure found during different seasons, 4) to show year-round body mass dynamics for two common species, and 5) to show mortality rates and summarize the causes of deaths and injuries.

2. Materials and methods

2.1. Study area

Kharkiv (Kharkov: transliteration from Russian) is located in northeastern Ukraine (50°0′N, 36°15′E, 135 m a.s.l.), 30 km inland from the border with the Russian Federation. The city was founded in 1654; it now has a population of 1.5 million inhabitants and covers 350 km^2. Three small rivers flow through Kharkiv from north to south (Figure 1). Kharkiv

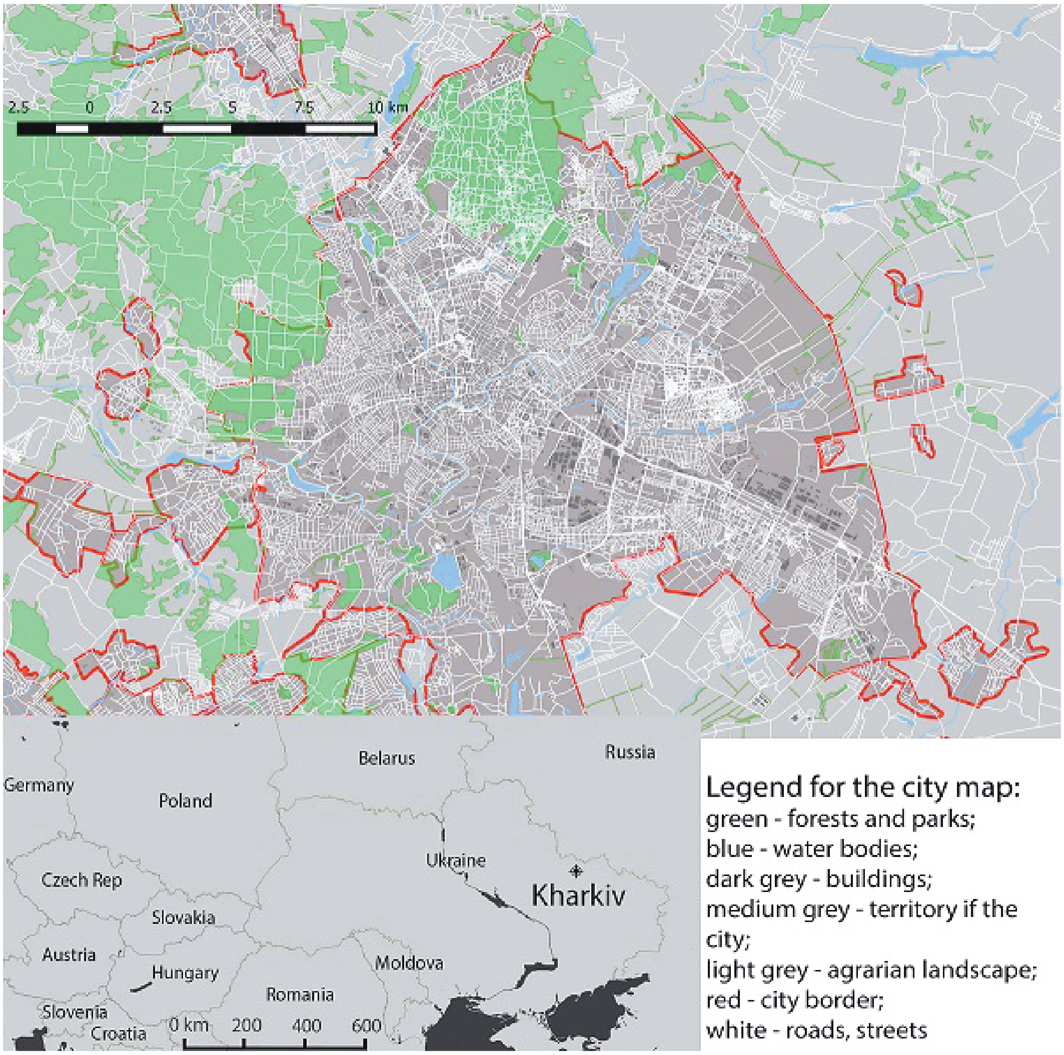

Figure 1. Location of Kharkiv on the map of Europe, and a general view of the city area.

is located in a forest–steppe nature zone with temperate continental climate conditions. The mean annual temperature in Kharkiv is 7.5 °C; the isotherm of January is –7 °C and the absolute minimum is –35.6 °C. The July isotherm is 21 °C and the absolute maximum is 38.9 °C. Annual precipitation does not exceed 540 mm (Golikov et al., 2011).

2.2. Division of the year's seasons

For studying bats, the yearly cycle can be divided into the following periods: phenological periods, calendar months, or bat life cycle periods. The year-round cycle of 2013 was divided into phenological periods based on the data on average daily temperature in Kharkiv (Figure 2). Phenological winter finished on 29 March. Spring, marked by the period following the end date of a stable rise of daily average temperatures above 0 °C, started on 30 March and ended on 26 April. Summer lasted from 27 April and finished on 3 September (the period after the date of the stable rise of daily average temperature above 15 °C to the date of the fall of daily average temperature below 15 °C). Autumn was from 4 September to 2 December (the period of daily average temperature fall from 15 °C to 0 °C). Winter started on 3 December (Figure 2). The division of the year by months follows the Gregorian calendar. The year divided by bat life cycle is based on both previous data and the results of the current study (Vlaschenko, 2006; Gukasova and Vlaschenko, 2011). The first hibernation period studied (Hibernation 1) in 2012–2013 ended on 29 March and matched the end of the phenological winter. The period of spring migration continued until the end of April, and the three following calendar months (May, June, and July) were the breeding season. The autumn invasion occurred from 1 August to 12 September (Figure 2). We named the period between the autumn invasion and the new hibernation period (2013–2014) "autumn silence", because a minimal number of bats were detected by citizens at that time. It ran from 13 September to 2 December. Accordingly, the second hibernation period studied (Hibernation 2) in 2013–2014 started after 3 December.

2.3. Accidental bat findings and measurements

Information about findings of individual bats or of groups of bats was reported by citizens through the call-center of the Bat Rehabilitation Center of Feldman Ecopark. The Rehabilitation Center worker delivered the bat (or bats) from the place of the find to the Bat Rehabilitation Center for further attention: watering and/or feeding (if necessary), measuring, and banding. Bats without injuries were released the same day in the evening (during the warm season of the year). Bat carcasses were also collected and recorded. Wherever possible, all the parameters that would be taken for live bats were estimated for carcasses, too.

Targeted bat collection was undertaken in two large buildings in the city center, where there are numerous winter aggregations of bats. In the first building, called "Derzhprom", workers (night watchmen) caught the bats, which were stuck in the building, and put them into cardboard boxes and then called the Bat Rehabilitation Center. Bat Rehabilitation Center staff or volunteers then visited the building and took the bats back to the center in the boxes (or took the bats out of the boxes, and brought them back to the center in bags). The boxes were left in cool conditions at the building (15–18 °C); bats stayed in the boxes for no longer than half a day. From time to time, we (the authors) also visited the building for collecting, catching, and handling bats inside the building. We noted the number of the floor and porch (building section) where the bat was found for each record, if it was known. We also observed the basement of the building at irregular intervals and collected any bat carcasses. The

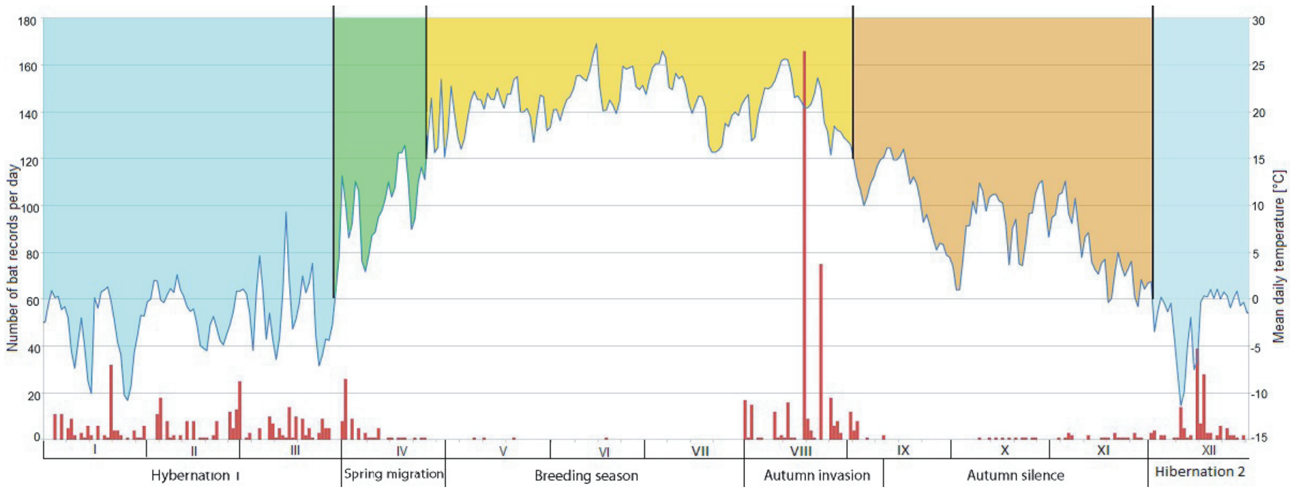

Figure 2. Daily average temperature in Kharkiv during 2013. Division of the year by phenological periods (blue – winter, green – spring, yellow – summer, orange – autumn), and periods of the bat life cycle; total number of bat records in a day (red columns). I-XII - months of the year.

second large building is at V. N. Karazin Kharkiv National University, where bat monitoring has been carried out for years (Vlaschenko, 2011). In the V. N. Karazin University building, bats frequently get trapped in windows during the autumn invasion (up to 200 individuals in one window). Additionally, acoustical transects using ultrasound detectors (Pettersson D200 and D240X) were carried out near the buildings during the year to check if any bats were present in the buildings.

The following classification was used to describe the type of location in which a bat was found, in relation to a building: 1) outdoors; 2) indoors, above ground level (all bats found in different indoor locations were grouped together here; e.g., rooms, apartments, corridors, halls, sunrooms); 3) on a balcony; 4) in a basement; 5) between window frames.

All bats found within the city were identified to species level where possible. Only the records where identification was possible to species level are included here. Sex, age, and reproductive status were evaluated. Forearm length and weight (by digital scale to 0.1 g) were also measured. A full list of the bats recorded is presented in Appendix 1.

We used 2 age group classifications: ad = adult (specimens older than 1 year), and first-year individuals (specimens younger than 1 year). Specimens of an unclear age were classified as uncertain (un). For age identification in females, we used the following characteristics: 1) size and shape of the nipples; 2) color (Kozhurina and Morozov, 1994) and wear of canine teeth (Gazaryan and Kazakov, 2002). Females with protuberant nipples (1 mm or more in diameter) and milk-white, abraded canine teeth were ranked as adults. Females with flat and pink nipples and pinkish, sharp canine teeth were ranked as first-year individuals. Females with combined or uncertain age characteristics were classified as uncertain. The age of males was classified using the following criteria: 1) color and intact state of canine teeth; 2) size and position of testes and epididymis. Males with milky-white and worn canine teeth, big testes (from 7 × 4 mm or more), and distended, filled epididymis were ranked as adults. Males with pinkish and sharp canine teeth, small testes, and small, undistended epididymis were ranked as first-year individuals. Males with combined or uncertain age characteristics were classified as uncertain.

All bats were also banded with 1 of 3 sizes of special bat ring marked "Kiev, Ukraine", manufactured by Aranea, Poland (Vlaschenko, 2012).

2.4. Status of found bats

Bats were found both alive and dead. Live individuals were divided into three groups: 1) "healthy"—completely healthy bats (with no fresh injuries or external trauma, etc.); 2) "insignificant injuries"—bats with injuries that were insignificant in terms of effect on their ability to live, which included dry wing edges, less than 1-cm tears in membranes, broken toes, a broken first finger on a wing or 1 or 2 broken nonfirst fingers of a wing, or soiling by oil products; 3) "significant injuries"—bats sustaining traumas that were nonsurvivable because they prevented free flight and foraging, e.g., broken forearm(s) and/or leg(s), gap(s) in membranes, or injuries to the head or the body.

Bat carcasses and significantly injured bats were further classified by the cause of death and injury (if possible). We specified such causes as: 1) directly killed or injured by people; 2) indirectly killed or injured by people; 3) death after exhaustion; 4) death after fouling by oil products (e.g., by machine oil for elevator mechanisms); 5) killed or injured by a cat; 6) death as a result of becoming trapped in a window; 7) uncertain cause. The other category often presented in papers (Russo and Ancillotto, 2014) is "killed or injured by a bird". However, we had no cases of found bats having been attacked by birds in this study. Bats that died in private flats in boxes (as a result of induced artificial hibernation) were counted as having been killed by people indirectly.

2.5. Bat rehabilitation

During the warm period of the year, bats without injuries were released in the evening. Individuals with injuries were brought to a veterinary professional and were treated if possible. During the cold part of the year, found bats were kept in rehabilitation (Prylutska et al., 2014). Bats with sufficient body mass were watered and induced into artificial hibernation by the lowering of the ambient room temperature to mimic outdoor winter temperatures. Those with an insufficient body mass and with injuries were fed over various time periods. On 7 April 2013, all bats that had survived were released into the wild in the forest outside Kharkiv. All methods were ethical and respectful of animal welfare and the conservation of protected species, according to Sikes and Gannon (2011).

2.6. Statistical analysis

A "bat per day" (b/d) index was used for estimation of the abundance of bat records taken in the city in 2013. The total number of bats found in each month (N_d) was divided by the number of days (D) in the month: ($b/d = N_d/D$). The statistical calculations were carried out using R software (www.r-project.org; version R i386 3.1.1, R Development Core Team, 2014). The relationship between the number of records and winter temperatures was tested using the Spearman rank correlation test.

The sex ratio of abundant species in the sampled populations was estimated by analyzing deviations from a 1:1 ratio using the Fisher exact test. The impact of sex, age, and month parameters on the body mass of individuals was estimated with a linear regression model. The body mass data were tested for normality using the Shapiro–Wilk test. The effect of sex and month found on body mass was examined in two age classes of *Nyctalus noctula* using one-way ANOVA with the Tukey post hoc test. For comparison of the proportions of the different species among the individuals found alive or dead, a two-tailed Z-test was used. For comparison of the sex and age ratios within groups of dead and living individuals, the two-tailed Z test was also used. To analyze similarities in bat mortality by month, k-mean cluster analysis was performed. The distribution maps were built using QGis software (http://qgis.org/en/site; version 2.10.1, Development Team, 2015).

3. Results

A total of 967 individuals of 5 bat species (*Nyctalus noctula*, *Eptesicus serotinus*, *Pipistrellus kuhlii*, *Vespertilio murinus*, and *Plecotus auritus*) were recorded during 2013 in Kharkiv. The list of all recorded bats is presented in Appendix 1 with the record date and sex and age status. The most abundant species was *N. noctula* (n = 846; 87.5%), followed by *E. serotinus* (n = 103; 10.6%). The next two species, *P. kuhlii* (n = 8; 0.8%) and *V. murinus* (n = 9; 0.9%), were found rarely. *P. auritus* was recorded only once.

3.1. Seasonal changes in the structure of bat assemblage

Most bats (88%; n = 857) were collected during the hibernation period (January–March and November–December) and the autumn invasion (August–mid-September) (Table 1). The breeding period saw the lowest number of bat discoveries, making up only 0.5% of all records (May–July). The peak period of bat findings, according to our b/d index, was during the autumn invasion; the b/d index then measured 8.77. The lowest b/d index was noted during the breeding period at 0.04 (Table 1).

As for species composition in the city, *E. serotinus* was present in the city all year, and *N. noctula* was found in all periods except for the breeding period. *Pipistrellus kuhlii* was not recorded during the breeding season and the autumn invasion. *Vespertilio murinus* was recorded during the autumn invasion and autumn silence periods, and *P. auritus* was noted only during hibernation. During the autumn invasion, the first bat species that appeared in numbers in the city was *E. serotinus* (see Appendix 1), followed by *N. noctula*. Within large groups of *N. noctula*, one or two individuals of *E. serotinus* were also present (Appendix 1). During the autumn silence, almost all bats disappeared from the city area, returning for hibernation in November (Figure 2).

The end of hibernation in spring 2013 coincided with the end of phenological winter (Figure 2; Appendix 1). The last numerous bat discoveries occurred on 2 April; after 10 April, only single individuals were found (Appendix 1). The last record of *N. noctula* occurred on 25 April. The return of cold weather in the first part of April (Figure 2) did not account for the increase in bat records. Nevertheless, the warm period of calendar summer and the period of autumn invasion started exactly on 1 August (Figure 2), when the first record of *N. noctula* occurred. In the first half of the month, *E. serotinus* was predominantly found (66.2%), while in the second half *N. noctula* was predominantly found (98.9%) (Appendix 1). The arrival of phenological autumn on 4 September coincided with a decrease in bat records, and the last bat (*N. noctula*) was found on 12 September (in the period of autumn invasion) (Appendix 1). Bats started to be recorded again at the beginning of October, after the first days of daily near-zero average temperatures (Figure 2). These were *E. serotinus*, *P. kuhlii*, and *V. murinus*. The first record of *N. noctula* occurred at the end of the month only (Appendix 1). Six of the nine records of *V. murinus* occurred in October (Appendix 1). After phenological winter started

Table 1. Number (n) and proportion (%) of bat species records during different periods of the bat life cycle in Kharkiv, 2013, and the values of the b/d index.

Species	Hibernation period 1, 01.01.13–29.03.13; 2, 03.12.13–31.12.13	Spring migration 30.03.13–30.04.13	Breeding period 01.05.13–31.07.13	Autumn invasion 01.08.13–12.09.13	Autumn silence 13.09.13–02.12.13
N. noctula	n = 433/92%	n = 57/83.8%	_	n = 334/86.6%	n = 22/59.4%
E. serotinus	n = 33/7%	n = 8/11.7%	n = 5/100%	n = 49/12.7%	n = 8/21.6%
P. kuhlii	n = 4/0.8%	n = 3/4.5%	_	_	n = 1/2.7%
V. murinus	_	_	_	n = 3/0.7%	n = 6/16.3%
P. auritus	n = 1/0.2%	_	_	_	_
Total	n = 471	n = 68	n = 5	n = 386	n = 37
b/d index	1- 3.85; 2- 4.55	2.36	0.04	8.77	0.46

on 3 December, the number of bat records did not increase significantly (Figure 2). The first two peaks of records coincide with two periods of temperature drops at the beginning of December (Figure 2). However, there was almost no correlation between daily mean winter temperatures and the number of bat records (Spearman rank test: $r_s = 0.06$, $P < 0.001$).

3.2. The spatial structure of found bats

The distribution of bats found is presented in Figures 3, 4a, and 4b.

The three seldom-recorded species (*P. kuhlii*, *V. murinus*, and *P. auritus*) were found only as single individuals (Appendix 1), and therefore their concentrations across the city area could not be mapped. However, the single record of *P. auritus* was from the southern periphery of Kharkiv, which is an important finding (Figure 3). In contrast, *P. kuhlii* and *V. murinus* were found both in the city center and on the peripheries (Figure 3).

The records of *N. noctula* were concentrated in the center of Kharkiv (Figure 3) in two buildings. Of all of the records of *N. noctula*, 51% (n = 431) originated in the Derzhprom building and 29% (n = 253) were from the V. N. Karazin University building.

The records of *E. serotinus* are displayed on heat maps (Figures 4a and 4b). The location concentrations of the species were different in the autumn invasion and autumn silence periods (Figure 4a) compared to the hibernation period (Figure 4b).

3.3. Results of ringing

Recaptures were achieved for *N. noctula* only (Table 2). Ten individuals were recaptured (1.2% from all recorded *N. noctula*), with an equal sex ratio. Most of the recaptured bats had been ringed during their first year of life. The time interval before recapture ranged from 10 days (DT04962) to 2 years and 3 months (DT02271). In five cases, the bats were recaptured in the same buildings as previously, and in two cases the bats were recaptured in buildings close-by (<200 m away). In two cases, bats had moved 7.5 km (DT04311) and 1.5 km (DT02271) respectively from the city center to the periphery (Table 2). *N. noctula* individuals ringed in August during the period of autumn invasion (Table 2) were recaptured in August of the same and following years (DT04962 and DT04158), with two bats (DT04890 and DT06987) being recaptured in December of the same year. The bats (DT04492 and DT00955) ringed during one winter were recaptured during the next. Data on body weight of recaptured individuals illustrate some trends. Two individuals of *N. noctula* (DT06987 and DT04890), which were captured in August and then recaptured at the beginning of the hibernation period in the same year, increased their body weight, with the adult gaining more than the first-year

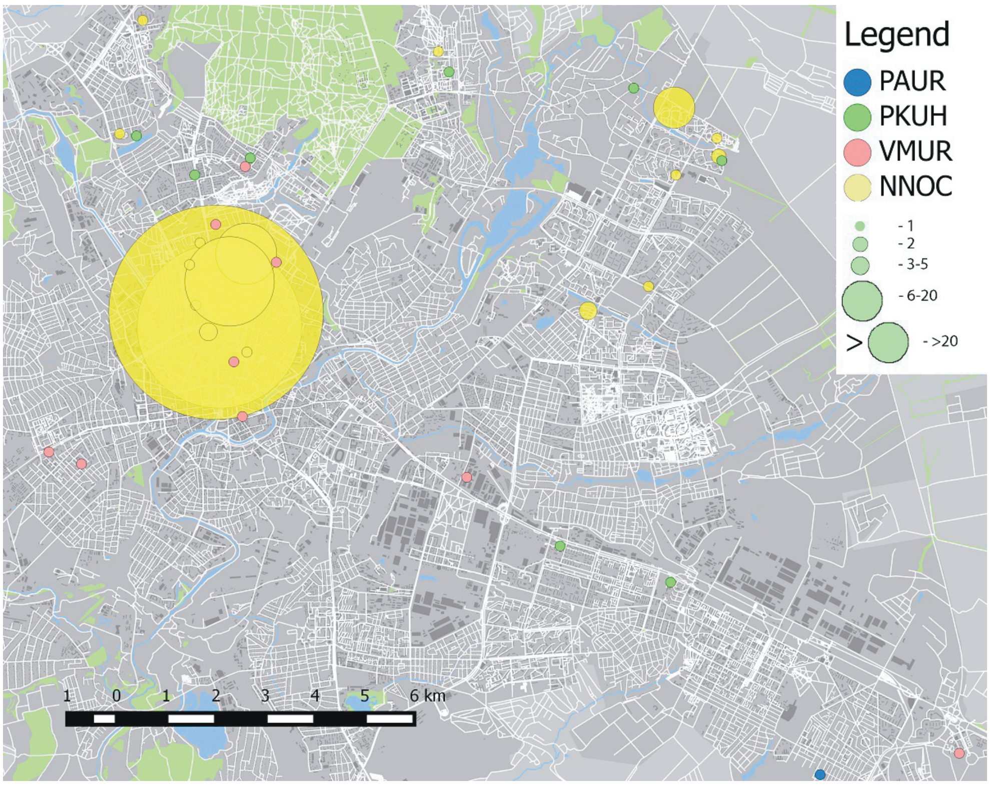

Figure 3. Spatial distributions of four bat species records throughout the year in Kharkiv. NNOC: *N. noctula*; PKUH: *P. kuhlii*; VMUR: *V. murinus*; PAUR: *P. auritus*.

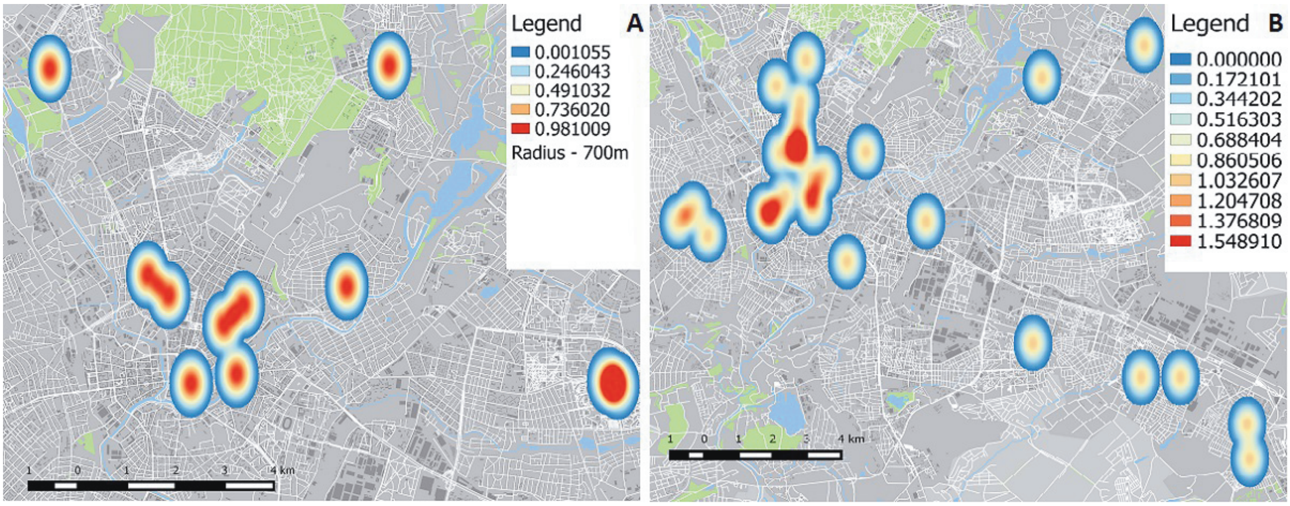

Figure 4. Spatial distributions of records of *E. serotinus* in Kharkiv. (a) The records in periods from 1 August to 2 December; (b) the records in winter, 1 January to 29 March and from 3 December to 31 December.

Table 2. List of recaptures of ringed *N. noctula* for 2013 in Kharkiv.

Ring number, sex, and age at time of ringing	Date of ringing and body weight (g)	Date of recapture and body weight (g)	Distance between the first and the second locations (m); time between recaptures (days or months)
DT00955 ♂ First-year ind.	2 Mar 2011 22.8	21 Jan 2013 26.4	0 m 22 months
DT04311 ♂ First-year ind.	20 Nov 2012 25.8	28 Mar 2013 18.6	7500 m 4 months
DT04668 ♀ First-year ind.	1 Mar 2013 22.7	21 Aug 2013 24.1	0 m 5 months
DT04962 ♂ First-year ind.	19 Aug 2013 21.8	29 Aug 2013 22.0	Unknown 10 days
DT04158 ♀ First-year ind.	11 Aug 2012 23.9	29 Aug 2013 28.2	0 m 12 months
DT02433 ♀ First-year ind.	9 Nov 2011 27.6	28 Oct 2013 22.9	200 m 23 months
DT04492 ♂ First-year ind.	7 Feb 2013 26.7	11 Dec 2013 29.6	0 m 10 months
DT06987 ♀ First-year ind.	19 Aug 2013 22.3	12 Dec 2013 25.1	200 m 4 months
DT02271 ♂ First-year ind.	14 Sep 2011 27.5	16 Dec 2013 29.1	1500 m 27 months
DT04890 ♀ ad	19 Aug 2013 22.3	18 Dec 2013 29.5	0 m 4 months

individual (Table 2). In most other cases, the body weight of the recaptured individuals was also higher than on their first date of capture (e.g., DT04158, DT00955, and DT04668). However, there were two individuals for which the opposite was true (DT04311 and DT02433) (Table 2).

To summarize the results of recapture: bats used the same buildings from year to year, and they arrived in the city in August, probably left at the beginning of autumn, returned at the end of autumn, and stayed there until the spring departure time.

3.4. Situations in which bats were discovered

Most of the bats (68.6%, n = 653) were found indoors. Fewer, but nonetheless significant, numbers of bats (26.6%, n = 253) were found between window frames. Far fewer (2.8%, n = 27) were found outdoors. Least of all, bats were found in basements and on balconies (1.05%, n = 10 and 0.95%, n = 9 respectively).

The only *P. auritus* was found in a basement during hibernation. A few discoveries of *P. kuhlii* occurred during the migration and hibernation periods and were mostly indoors, with one of each being found outdoors and in a basement. *Vespertilio murinus* was found indoors during the autumn invasion and outdoors during the autumn silence.

The most numerous species, *N. noctula* and *E. serotinus*, showed more varied distribution of discovery locations (Table 3). Both species were found most frequently indoors and between window frames. Bats found between window frames accounted for the largest percentage of bat discoveries during the autumn invasion period. *Eptesicus serotinus* was found more frequently on balconies than *N. noctula*, but it was not found in basements.

3.5. Sex ratio

The sex ratio was estimated for the common species *N. noctula* and *E. serotinus* in the months in which these particular species were noted.

Among adult individuals, the *N. noctula* sex ratio did not differ from 1:1 during the winter months and during March, April, and November (Fisher exact test, P > 0.05). In August and October all found individuals were females (Figure 5). Among the first-year individuals of *N. noctula*, the sex ratio was significantly different from 1:1 in January and February (Fisher exact test, P < 0.05), with male dominance (Figure 6).

When the adult and first-year individuals of *E. serotinus* were counted together, the sex ratio was not different from 1:1 (Fisher exact test, P > 0.05) in months in which both sexes were present. In February, May, June, September, and October, only male individuals were found (Figure 7).

3.6. The mortality of bats

In total, 39 dead individuals were found throughout the year, only 4% of the total number of bats found in 2013. The distribution of species was as follows: *N. noctula* (n = 28; 71.8%), *E. serotinus* (n = 9; 23.0%), and *P. kuhlii* (n = 2; 5.1%). The number of significantly injured individuals totaled 21 (*N. noctula* [n = 6; 28.5%], *E. serotinus* [n = 14; 66.7%], and *V. murinus* [n = 1; 4.8%]).

The proportion of *N. noctula* records among live individuals was significantly higher than among dead and injured individuals (Z score: –6.61, P < 0.05). At the same time the proportion of *E. serotinus* records among dead and injured individuals was significantly higher than that among live individuals (Z score: 6.34, P < 0.05). The proportions of *P. kuhlii* (Z score: 1.91, P > 0.05) and *V. murinus* (Z score: 0.56, P > 0.05) among dead and injured individuals were not significantly different from those among bats found alive.

The sex ratio in the group of live individuals of *E. serotinus* (32♀♀ and 40♂♂) was significantly different (Z score: 2.21, P < 0.05) from that in the group of dead or significantly injured bats (4♀♀ and 18♂♂). Within the dead-or-injured category, males were most abundant. The age ratio in the group of live individuals of *E. serotinus* (17 ad and 53 first-year individuals) was not significantly different (Z score: –1.46, P > 0.05) compared to those in the "dead-or-significantly-injured" group (5 ad and 6 first-year individuals).

Table 3. Division of types of records of *N. noctula* and *E. serotinus* during different periods of the bat life cycle in Kharkiv, 2013 (O – outdoors, I – indoors, Bl – balcony, Bs – basement, W – window).

Species	Type of record	Hibernation period 1, 01.01.13–29.03.13; 2, 03.12.12–31.12.12	Spring migration 30.03.2013–30.04.2013	Breeding period 01.05.13–31.07.13	Autumn invasion 01.08.13–12.09.13	Autumn silence 13.09.13–02.12.13	Total
N. noctula	O	n = 5/1.2%	n = 1/1.8%	-	n = 2/0.6%	n = 2/9.1%	n = 10/1.2%
	I	n = 388/90.4%	n = 56/98.2%	-	n = 126/38.0%	n = 18 /81.8%	n = 588/70.0%
	Bl	n = 2/0.5%	-	-	-	n = 1/4.5%	n = 3/0.4%
	Bs	n = 8/1.9%	-	-	-	-	n = 8/1.0%
	W	n = 26/6.1%	--	-	n = 204 /61.4%	n = 1/4.5%	n = 231/27.5%
E. serotinus	O	n = 6/18.2%	n = 2/33.3%	n = 1/25%	n = 2/4.1%	n = 3/42.9%	n = 14/14.1%
	I	n = 22/66.7%	n = 3/50.0%	n = 3/75%	n = 21/42.9%	n = 3/42.9%	n = 52/52.5%
	Bl	n = 5/15.2%	-	-	-	n = 1/14.3%	n = 6/6.1%
	Bs	-	-	-	-	-	-
	W	-	n = 1/16.7%	-	n = 26/53.1%	-	n = 27/27.3%

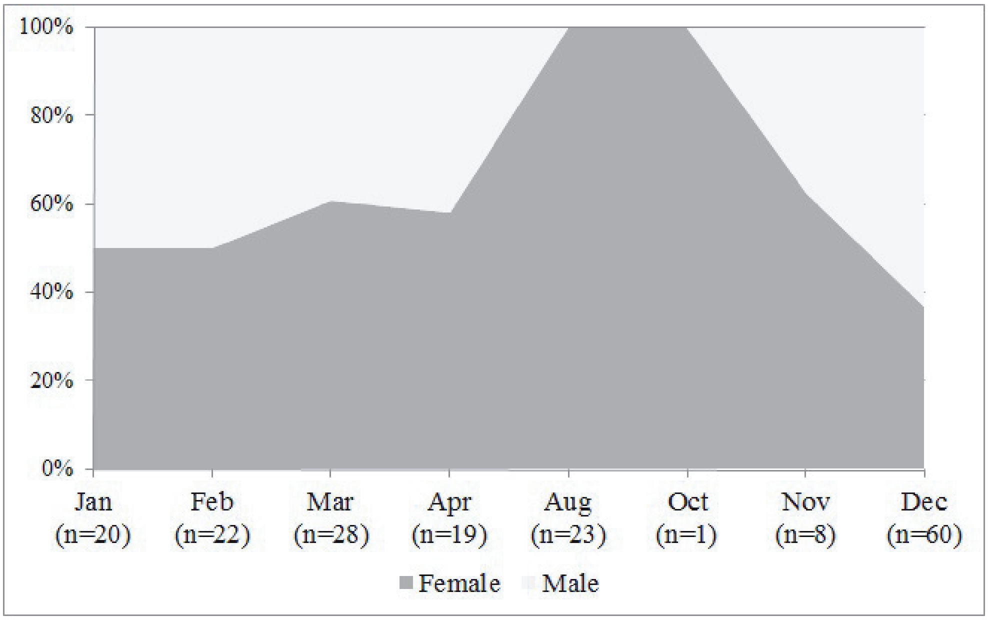

Figure 5. Sex ratio in adult individuals of *N. noctula* during 2013 in Kharkiv.

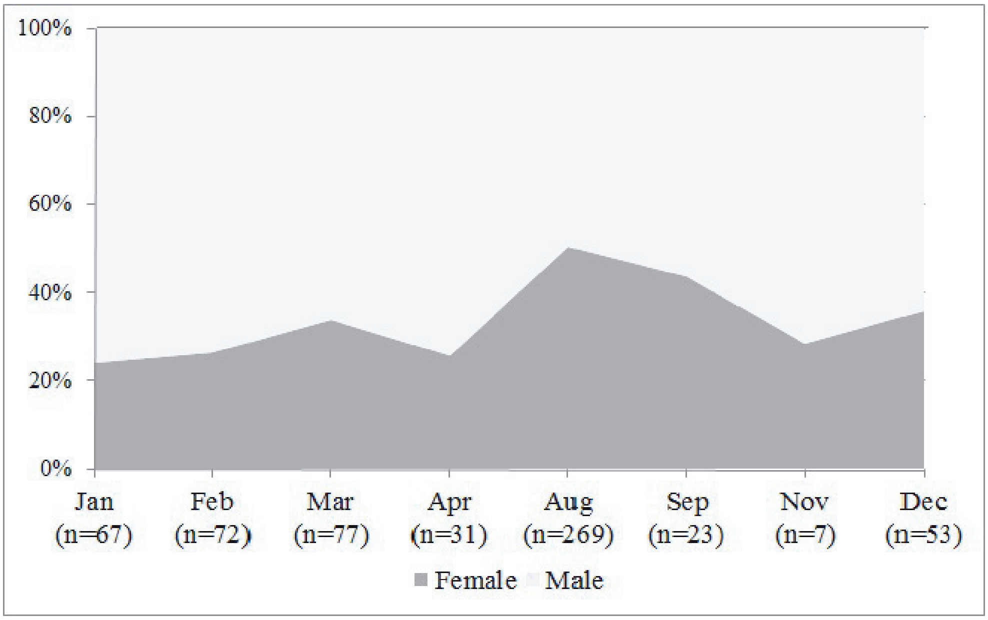

Figure 6. Sex ratio in first-year individuals of *N. noctula* during 2013 in Kharkiv.

The sex ratio in the group of "live" *N. noctula* (329♀♀ and 431♂♂) was not significantly different (Z score: 0.15, P > 0.05) from that in the group of "dead-or-significantly-injured" (10♀♀ and 14♂♂). The age ratio of adult to first-year individuals in the group of "live" individuals of *N. noctula* (167 ad and 556 first-year) was significantly different (Z score: –2.34, P < 0.05) from the age ratio within the group of "dead-or-significantly-injured" (7 ad and 7 first-year).

In Figure 8, the ratio of all recorded bats to dead-or-significantly-injured bats is presented. A main pattern to emerge for 2013 is that the number of "dead-or-significantly-injured" bats decreased significantly as the total number of individuals found increased. The minimum overall mortality occurred in August (Figure 8). In June and July, all *E. serotinus* individuals found had significant injuries or were dead (Figure 8). The months of phenological winter (January–March and December)

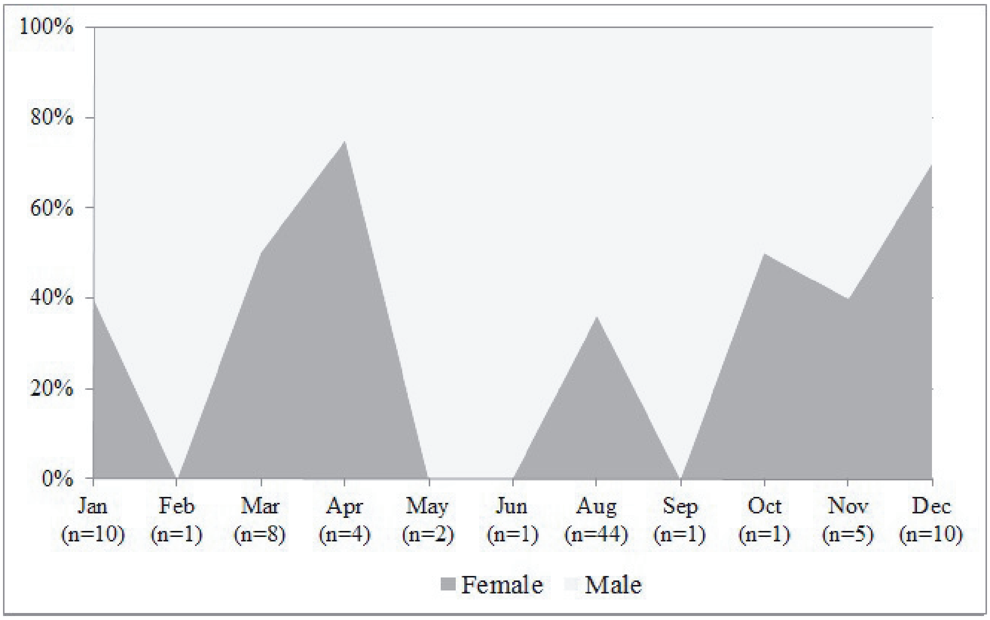

Figure 7. Sex ratio of *E. serotinus* for all age groups together during 2013 in Kharkiv.

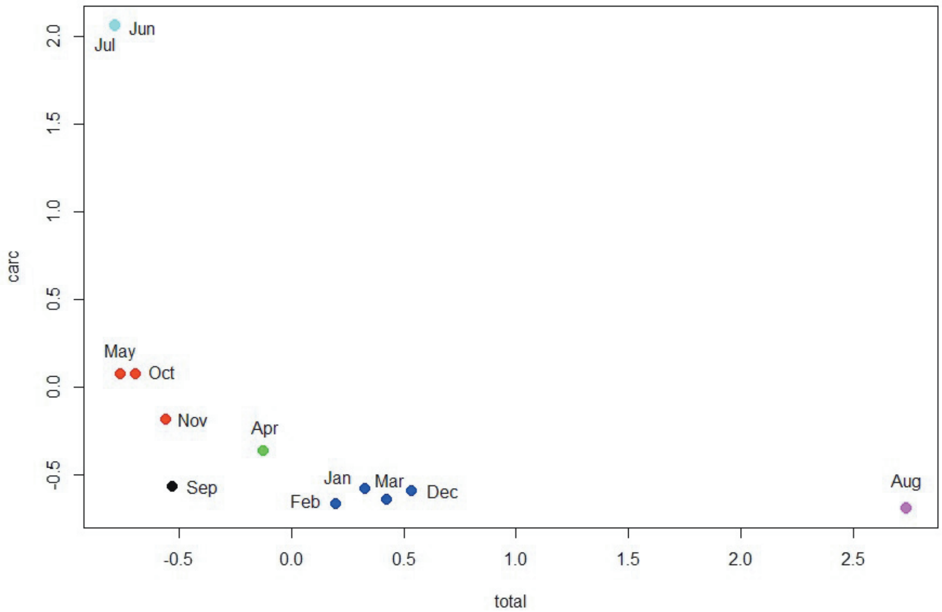

Figure 8. Relationship between the number of recorded bats and the percentage of those that were dead or significantly injured, as shown using k-mean clustering.

(Figure 8), the hibernation period, showed a stable mean mortality proportion between groups. Months of the "intermediate state" in the bat life cycle (April and September) had a median position in the cluster; October and November were classified as closer to May (Figure 8).

The causes of death and significant injury are presented in Figure 9. The proportions of cause-of-mortality types are approximately equal (excluding the "unidentified cause" group). In other words, there was no predominant type of mortality in the results for 2013.

3.7. Body mass dynamics

Of the three factors of month, age, and sex, only sex had no significant impact on the body mass of individuals of *N. noctula* (linear regression, intercept: 23.02, SE: 0.36, t value: 62.76, $P < 0.0001$). To consider this further, a comparison of body mass was conducted for the two age

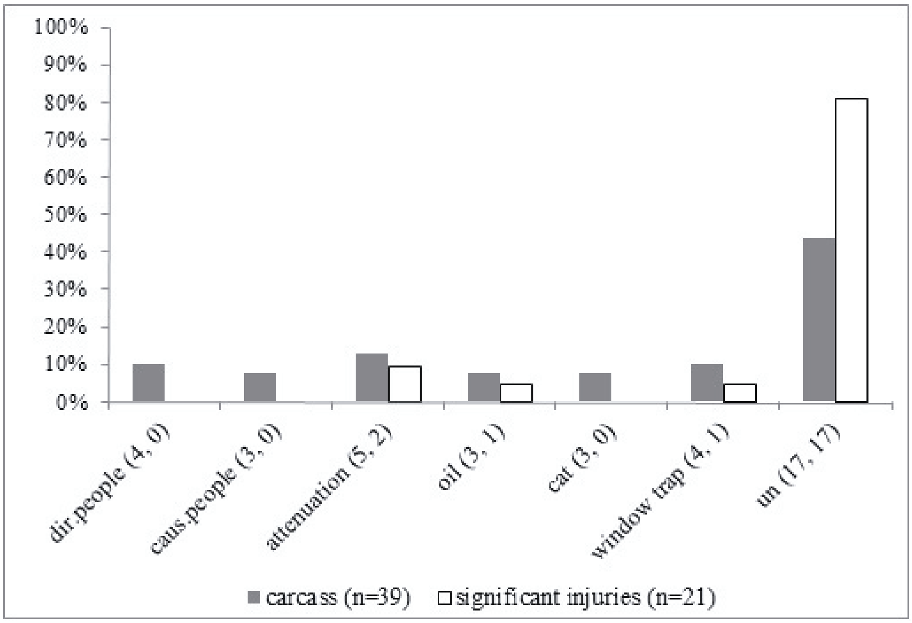

Figure 9. Comparative ratios of the causes of death or significant injury during 2013 in Kharkiv: dir. people – directly killed or injured by people; cas. people – indirectly/casually killed or injured by people; attenuation – death after exhaustion; oil – death after fouling by oil products; cat – killed or injured by a cat; window trap – death as a result of becoming trapped in a window; un – uncertain.

groups separately, with males and females being compared together. The body mass data were normally distributed (Shapiro–Wilk test, W = 0.98, P > 0.05).

The body mass dynamics of adult individuals of *N. noctula* over different months is presented in Figure 10. The results for first-year individuals are presented in Figure 11. For the adult individuals of *N. noctula*, body mass was significantly different between months (ANOVA, F: 6.41, P < 0.0001) (Appendix 2). Generally, a gradual decrease of average body mass from January until March was noted among adult individuals (~3 g), with an insignificant increase among females in April (~1.5 g). The highest mean values occurred in November. The absolute maximum was noted in December (32.9 g per ad) and the absolute minimum was in March (18 g per ad) (Figure 10). In addition, there were significantly higher mean values of body mass in November compared to August (~5 g).

The first-year individuals of *N. noctula* showed significantly different body masses between months (ANOVA, F: 10.45, P < 0.0001) (Figure 11; Appendix 2). January to April also saw a body mass decrease among the first-year individuals. However, the lowest average value of body mass was noted in April and the highest was in November. The absolute maximum was noted in December (03.12.2013, 32.5 g, female, first-year individuals) and the absolute minimum in February (05.02.2013, 17.1 g, male, first-year individual) (Figure 11). The body mass changes between August and November are lower compared to those among adult individuals (~2 g).

As for *E. serotinus*, the dataset was not large enough for a correct comparison between months. Therefore, we have simply presented the graphic visualization of the body mass data (Figure 12). The maximum body mass value was noted in November (24.11.2013, male first-year individual, 27.6 g), and the minimum was in January (10.01.2013, male first-year individual, 14.0 g).

4. Discussion

4.1. Seasonal changes in the structure of bat assemblages

The frequency and number of bat discoveries in the city area reflects, on one hand, the regularity with which bats frequent the urban environment, yet on the other hand, the environment in which they are found reveals their ecological predisposition to becoming trapped or negatively affected by city conditions. Uneven numbers of bat records during the annual cycle suggest irregular use of the city area by bats in temperate climatic conditions. The city contains the most bats during the autumn invasion (August–mid-September) and the winter (December–March) and the fewest bats during the breeding season (May–July) and the period of autumn silence (mid-September–October) (Table 1).

Out of 12 species of bats in the Kharkiv region (Vlaschenko, 2006, 2011), only 5 were recorded within

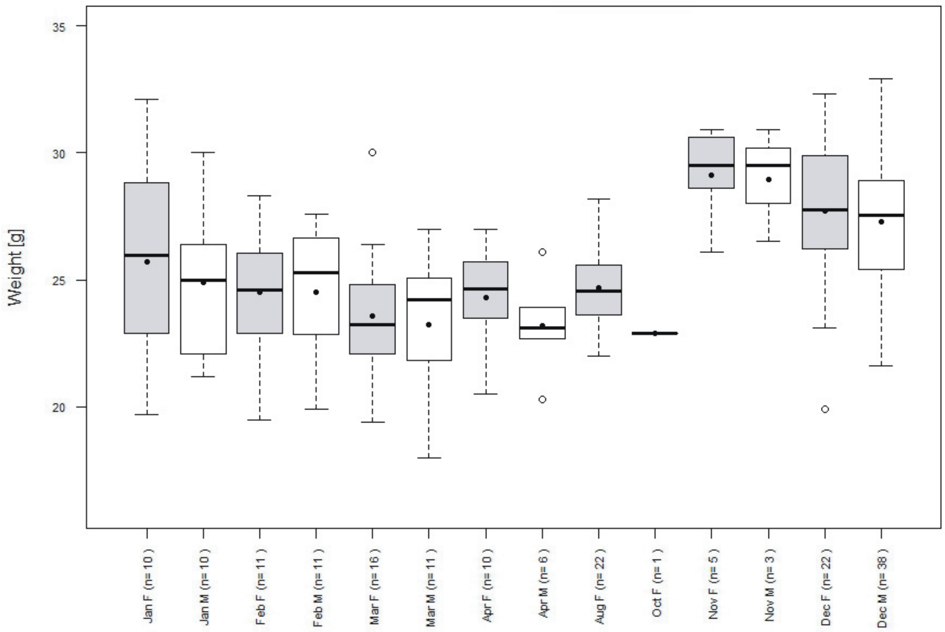

Figure 10. The body mass dynamics by month of adult individuals of *N. noctula* during 2013 in Kharkiv. F – ♀♀, M – ♂♂ (black dot – mean value, line – median value, whiskers – min and max values, open dot – outlier).

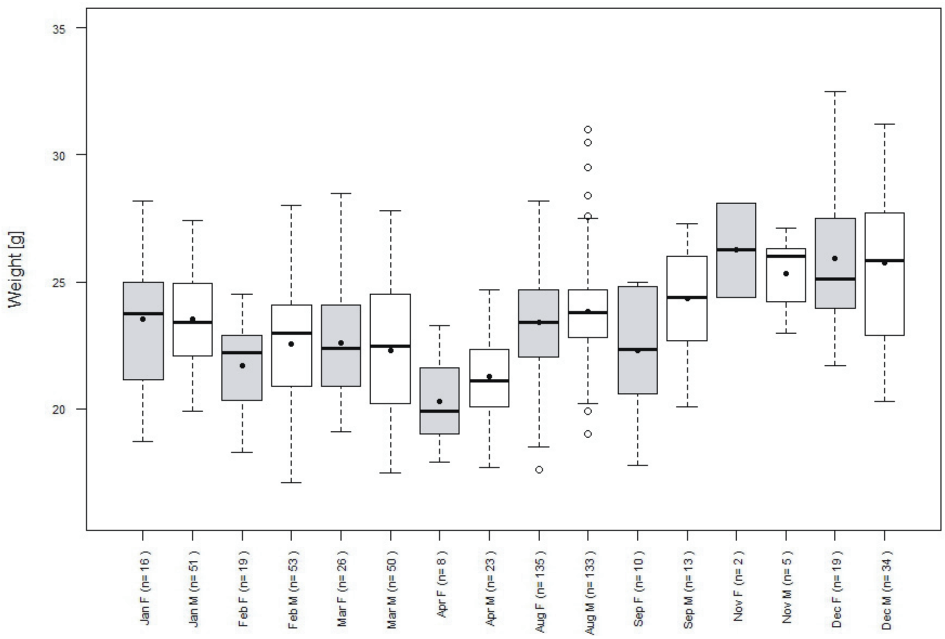

Figure 11. The body mass dynamics by month of first-year individuals of *N. noctula* during 2013 in Kharkiv. F – ♀♀, M – ♂♂ (black dot – mean value, line – median value, whiskers – min and max values, open dot – outlier).

the city area by way of occasional discovery by citizens. The diversity decrease in urban areas compared to natural areas is common for bat populations in temperate zones (Coleman and Barclay, 2012). The full list of bat fauna of the region includes mostly forest-dwelling species that breed in woodland landscapes (Vlaschenko and Gukasova, 2009a, 2010). Moreover, none (neither forest-dwelling nor house-dwelling) are confirmed as breeding in the city area due

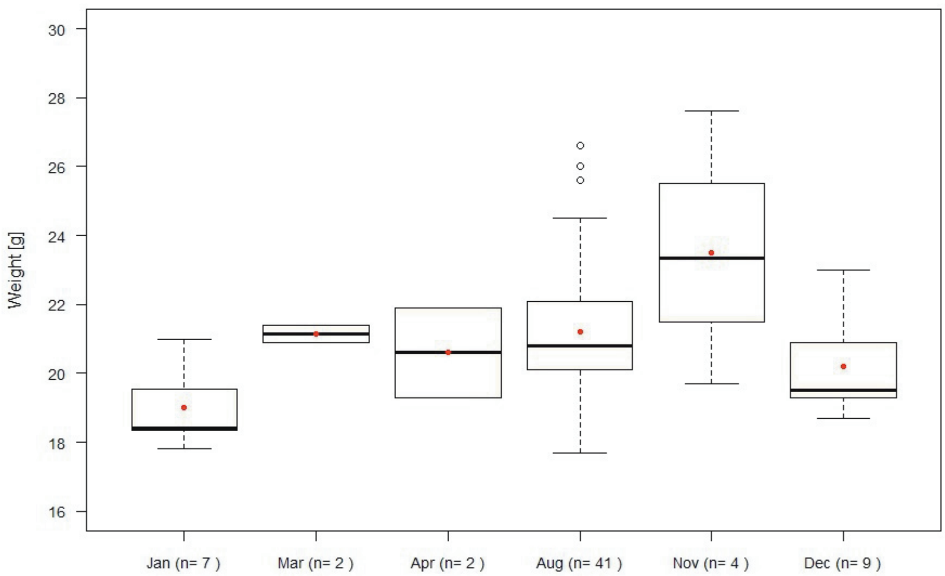

Figure 12. The body mass dynamics by month for all *E. serotinus* during 2013 in Kharkiv. F – ♀♀, M – ♂♂ (red dot – mean value, line – median value, whiskers – min and max values, open dot – outlier).

to an absence among the records of pregnant or lactating females, as well as newborn pups or juvenile individuals. Thus, during the breeding time from May to July, only adult males of *E. serotinus* were recorded in the city area as a result of occasional discovery by citizens. However, *P. kuhlii* is known to be a sedentary synurbic species (Ancillotto at al., 2015) and has been found to breed on the outskirts of Kharkiv (Vlaschenko, 2006), as well as in small settlements in central Ukraine (Bilushenko, 2013). Ancillotto et al. (2015) described how newborn pups of *P. kuhlii* are of such abundance in city areas that they are often found by citizens in Italy. Limitations of the results we obtained regarding *P. kuhlii* could be a result of the methods available to us for gathering information as 2013 was the first year of operation for the bat rescue call center, and information about it was not yet thoroughly shared with citizens. As a result, it could be that fewer *P. kuhlii* discoveries were reported to us than occurred. Moreover, the lower level of ecological education of citizens in Ukraine compared to that of other European countries could be a factor. However, the lack of *P. kuhlii* discoveries could instead reflect the higher fitness of this species in urban conditions compared to other species, which manifests as a better ability to avoid urban hazards. Nevertheless, all sex and age groups (except first-year males, possibly due to the small number of records in general) of this species were found within the city area outside the breeding season. For these reasons, we assume that the ratio of *P. kuhlii* records, as obtained by occasional discovery by citizens, does not reflect its true relative abundance compared to other species found in Kharkiv. To further improve the estimation of relative abundance of this species within the city area in the future, additional methods should be used, such as mist-netting and/or acoustical monitoring.

In contrast to *P. kuhlii*, the other sedentary species, *E. serotinus*, was confirmed as present year-round in Kharkiv. However, sex/spatial segregation among the population did occur during the breeding season. The females apparently left the city core for the outskirts from May to July, as only males were found within the city area at this time. We can assume that the summer conditions of Kharkiv are therefore not suitable for the breeding of *E. serotinus*. However, it appears that they readily exploit the city during the hibernation period, when *E. serotinus* was noted regularly. It is noteworthy that the sex ratio of *E. serotinus* had already returned to equal by August, the time of the autumn invasion, as the females and first-year individuals returned to the city area, having finished the lactation period.

The most frequently found species in Kharkiv is *N. noctula*. It is a typical tree-dweller during breeding, but it also readily occupies building cavities during hibernation (Lupicki et al., 2007; Dietz et al., 2009). It has a mixed (from local to long distance) migration strategy (Lehnert et al., 2014; Voigt et al., 2014; Gashchak et al., 2015) and has recently expanded its hibernation range northwards in East Europe (Vlaschenko, 2006; Godlevska, 2015). The presence of this species in the city is mostly associated with autumn migration, swarming, and mass hibernation. All sex/age groups of this species were found in the city at these times. It is noteworthy that during January and February, males were dominant among first-year individuals. We assume that this reflects the differences that sex and age have on the process of gaining fat stores, as first-year males may accumulate the required stores more slowly and have fewer stores overall (McGuire et al., 2009). As most of the records are from the Derzhprom building, which is the hibernation site, it is possible that the higher number of active first-year males found inside the building reflects their premature arousal due to watering needs or due to exhaustion (Kunz, 1974; Kokurewicz and Speakman, 2006). According to data obtained by Gazaryan (2002) on dead individuals of *N. noctula* found during hibernation in tree hollows, males formed the majority of dead bats. Furthermore, male-centered mortality occurs in some species due to higher energy expenditures in mating activity (Gerell and Lundberg, 1990; Jonasson and Willis, 2011). Therefore, the higher activity of male *N. noctula* seen here during January and February could be a consequence of winter mating activity (Kozhurina and Morozov, 1994; Gebhard, 1995). However, the body mass of first-year males in this study was not significantly different from that of females. Nevertheless, a further explanation could be that individuals of both sexes that had surpassed the threshold body mass value for hibernation (between 22.5 and 24 g) were, as a result, predisposed to higher winter activity instead of more continuous hibernation.

No specimens of *N. noctula* were found during the breeding period within the city area; however, the nearest small breeding colonies were registered on the city outskirts, 5–10 km from the city center (Vlaschenko et al., 2015). Thus, *N. noctula* avoided staying in the built-up city area for breeding.

The records of *V. murinus* during the autumn invasion and autumn silence relate to migration and hibernation patterns already seen in this species in the area of Kharkiv (Vlaschenko, 2011).

The temporal bat population segregation pattern emerging from our results could be summarized as follows: all species noted in Kharkiv use the urban area during the autumn invasion (migration) and hibernation periods, and they avoid urban areas in periods of breeding and prehibernation hyperphagia.

4.2. The period of bat absence

The greatest bat absence from the city area occurs in the first half of the autumn silence (mid-September–October) (Figure 2). During this time, the city area becomes almost empty as indicated by bat records. Single individuals of *E. serotinus*, *V. murinus*, and *P. kuhlii* were found, but no records of *N. noctula* were made from 13 September to 26 October from either registered records of bats found by citizens or by call detection with ultrasound detectors. Even the roost sites preferred by *N. noctula* during the autumn invasion and hibernation (the Derzhprom and university buildings) remained empty during this time. As *N. noctula* is a migratory species, it is possible to assume that the described rapid appearance of this species in the city area in August followed by its sudden disappearance in the second part of September is a result of migration movements, which can take place in several waves (Hill and Hüppop, 2008). However, the repeated discoveries of ringed individuals in August, and then again in November and December (Table 2), point to the presence of the same bat aggregations in the area at these two different times (Vlaschenko, 2012). This gives the impression that active reaggregation and possible swarming of *N. noctula* takes place in Kharkiv in August, followed by the bats leaving the city for a short time before returning again in November. By December, they have already occupied the hibernation sites. This statement supports the fact that we found higher body masses in recaptured individuals in November and December compared to August (Table 2). In August, the average body mass of adult and first-year individuals amounted to less than 25 g, which is not enough to see them through the winter (Figures 5 and 6) (Prylutska et al., 2014; Rodenko et al., 2014). However, in November and December, individuals were significantly heavier, with an average body mass of 28–30 g among adults and 25–26 g among first-year individuals. The repeated recapture in December of several ringed individuals from previous years further supports the hypothesis that they return to Kharkiv for hibernation (Table 2). The behavior of *N. noctula* during the period of autumn silence could still be questioned: are they actively swarming and showing first-year individuals further places available for hibernation, and then leaving to gain fat resources? To add to the mystery, it is unknown where they move to in late September and October to gain additional fat resources. The period of prehibernal fat accumulation is a difficult part of the bat's life cycle. As the drop in temperature during autumn decreases insect-food availability (especially aerial insects) (Speakman and Rowland, 1999), bats are simultaneously faced with a need to increase food intake in order to accumulate adequate fat resources to survive winter. The current hypothesis for the mechanism of prehibernal fat-store depositing is that bats choose colder roosts, spend more time in torpor, use accordingly less energy, and therefore accumulate the required fat resources (Speakman and Rowland, 1999; Kokurewicz and Speakman, 2006). As alluded to earlier, we have no idea where *N. noctula* moves to for foraging in the period of autumn silence; it could be the city periphery or the forest areas in the region, or they could even make short movements further south. Autumn in the continental climate conditions of the Kharkiv region is cold and rainy, and we assume that insect availability is quite limited, especially for aerial hunters as large as *N. noctula*. The overall picture of temperature dynamics for the year in Kharkiv is presented in Figure 2. If we hypothesize that

N. noctula moves southwards from Kharkiv during the autumn silence, it means that there is an inverted south–north direction of migration in November. This idea contradicts the general view of the migratory direction of European long-distance migratory bats in early winter: in summer–autumn, they move from the northeast to the southwest, doing the reverse only in springtime (Hutterer et al., 2005). Therefore, the return of *N. noctula* to the city in November suggests they are going against the normal trend by making northerly movements at this time of year. However, for many species of *Myotis* bats, it is known that the migration direction is actually often not connected with a north–south axis, but is instead dependent on the disposition of the nearest suitable hibernacula (Rogowska and Kokurewicz, 2007). Therefore, this latter trend could be a better indication of what is influencing the migratory movements of *N. noctula* in winter. As with the *Myotis* example, their migration could follow biotic factors, such as the availability of good insect sources not far from the city, rather than the climate trends. If our future investigations show that *N. noctula* indeed remains more northerly in winter, it will necessitate a change of the migration status of *N. noctula* and an expansion of their winter range northwards (Vlaschenko, 1999; Strelkov, 2002; Rodenko et al., 2014; Godlevska, 2015), as a consequence of a complex adaptation of this species' behavior. It is possible that with warming winters (Godlevska, 2015), a warming of autumn temperatures is taking place, too, and these circumstances are allowing *N. noctula* to adapt to spending winters at more northerly latitudes.

4.3. The "prehibernal" period

We originally divided the bat life cycle into 5 parts: Hibernation 1 and 2, spring migration, breeding, autumn invasion, and autumn silence. However, based on the results, we decided to split the autumn silence into two halves. The first half is still referred to as the autumn silence, and the second half, a period of slowly increasing bat records before hibernation, is called "prehibernal" (Speakman and Rowland, 1999). Marking the transitional dates from the autumn silence to the prehibernal period must be done cautiously with data just from 2013. On one hand, if the autumn silence is the period of almost absolute bat absence, it could be said to last from 13 September until 10 October (Appendix 1). On the other hand, we could use the sparse records of *E. serotinus*, *P. kuhlii*, and *V. murinus* after 10 October to mark the dates for the autumn silence, and then the first records of *N. noctula* to mark the beginning of the prehibernal period. The second variant is more correct in our opinion, but in general the validation of the periods of the bats' life cycle for those individuals inhabiting urban areas has to be tested over multiyear datasets. Some particularities of bat seasonal life in Kharkiv have been published earlier (Vlaschenko and Gukasova, 2009b; Vlaschenko et al., 2015), but detailed analyses have been carried out for the first time in the present study.

4.4. The spatial distribution of bats

The spatial distribution of bat records in Kharkiv during the periods of higher bat concentration is nonuniform. However, the concentrations of records in the northern and northeastern parts of Kharkiv alone could not demonstrate the preferences of the bats. The types of spatial distribution that could definitively point to bat preferences are as follows: first, the proximity of building estates to both industrial areas and one-story building areas; second, the access level of the citizens who found the bats to the Internet and other sources of information. Also noteworthy is that the forest-dwelling *P. auritus* was spotted only once on the southeastern edge of the city area, in the basement of a one-storied building, whereas synanthropic species such as *E. serotinus* and *P. kuhlii* were found uniformly across the city in different types of built-up areas. Our results suggest that the woodland-poor area of Kharkiv is unsuitable for *P. auritus*, whose species distribution is generally outside built-up areas (Entwistle et al., 1997). Most of the *N. noctula* discoveries occurred in two well-known hibernation locations for these species—circumstances that misrepresent the spatial uniformity shown in reality for this species within the city area (Figure 3). For example, it is known that *N. noctula* occupies blocks of flats located in the northeastern part of city. However, our results reveal the frequency of bat–human conflict and the predisposition of bats in these locations to become trapped in buildings due to features of building construction; therefore, the high concentrations of bats could be a byproduct of these conflicts, rather than a species preference for particular building types.

While classifying the places where bats were discovered, the possibility of bats remaining in that place, and therefore their possible future exposure to risk, was considered. All found and rescued bats were potentially at risk of death, because in 95% of cases, bats were found indoors or between window frames—situations from which they could not have found the way out by themselves. Furthermore, individuals found grounded or exposed outdoors were usually injured or weak from exhaustion. Individuals found on balconies were usually associated with hibernation or bats resting for the day, a situation comparable to being in a roost. Bats found in basements could either be assessed as being in a roost or in a trap, depending on whether the entrance to the basement was difficult to reach or rarely opened. The interior area of a basement is usually a trap for bats, since bats that have had to penetrate an inner door or window become trapped if they cannot find the way back through—for example, if these access points are subsequently closed or unexpectedly remain closed. The most dangerous situation for bats, however, is getting stuck between window frames. Since bats are very social animals, if one is trapped between window frames and emits distress calls, other individuals quickly arrive and also become stuck, since getting out again is almost impossible (Bihari, 1999; Vlaschenko, 2002; Godlevskaya and Kondratenko, 2004; Vlaschenko and Gukasova, 2009b).

It is interesting that *P. kuhlii* was observed within the city with visual or detector-enabled observations, despite it being relatively rare compared to *N. noctula* or even *E. serotinus*. This may be a result of behavioral tendencies of this species (Ancillotto et al., 2015), which allow it to benefit from city conditions with a lower risk of being negatively affected by them. Also interesting is that *E. serotinus* was found more frequently outdoors and on balconies compared to *N. noctula*, and was also found proportionately less frequently inside buildings. As the records of *N. noctula* were concentrated in two large buildings, this could influence the frequency of indoor discoveries of this species during the year, while the more frequent records of *E. serotinus* found on balconies may result from behavioral peculiarities as they attempt to find appropriate roosts. Furthermore, outdoor records of *E. serotinus* are often associated with an unhealthy or exhausted state of individuals.

4.5. The mortality rate vs. bat abundance

During year-round monitoring of bat records, we noted that significantly injured or dead individuals made up only 4% of the total number of records, which is significantly lower than we assumed would be the case from previous research (Vlaschenko et al., 2013). Obviously, this percentage cannot reveal the real bat mortality rate in the city, as many of the dead individuals would not be noticed and reported by people. The rescue operations provided by bat workers from the Bat Rehabilitation Center also mitigate the mortality rate. The number of bat mortality and injury cases was inverse to the total number of bat discoveries during the annual cycle. In other words, in periods with low bat density within the city area (at breeding time or the period of autumn silence), the frequency of bats found was very low and in most cases found individuals were dead or significantly injured, whereas during the autumn invasion and hibernation period, most of the individuals found were alive. Also noteworthy is the fact that the proportion of *E. serotinus* is higher among dead and injured individuals compared to those among live individuals. Within the category of dead or injured bats, individuals of *E. serotinus* males were dominant. This may be a result of natural selection within the city area, as males of *E. serotinus* were present here all year and therefore were more frequently exposed to the risks associated with city life. It is interesting that mortality and injury cases were not biased towards either sex group of *N. noctula*. However, there were equal numbers of dead or injured individuals found among the adult and first-year individuals of *N. noctula*, and there were unequal proportions of healthy individuals in both age group. This suggests that the emerging fatal properties of city conditions may affect all sex and age groups of this species.

4.6. Species-specific features of urban environment occupancy

With an ever-changing set of environmental conditions, the success with which species adapt depends on their ability to recognize and include the new elements of the surrounding reality into their life cycle, which is predetermined by previous natural history (Ducci et al., 2015). The lack of woodland, poor insect availability, high level of built-up areas, and temperate climate conditions of Kharkiv make it most comparable to karst highlands among the natural habitats that bats inhabit. Urban areas, like karst highlands, afford roosting variability (Lausen and Barclay, 2006; Baker and Harris 2007), but may not provide the required food supply (Threlfall et al., 2011). In natural conditions, such regions are often used by bats for hibernation and swarming (Piksa, 2008), but only specialized species are able to undertake their whole life cycle, including breeding, in such an environment (Alberdi et al., 2002). *Pipistrellus kuhlii*, for example, is a synurbic specialist across Europe (Ancillotto et al., 2015). This species is significantly expanding its range toward the northwest in Eastern Europe, where it successfully continues to colonize urban areas (Sachanowicz et al., 2006). It is likely that climate change, together with the growth in number of warming "city islands" and an absence of competitive species, allows it to occupy this niche. However, other species, such as *E. serotinus*, which has been recorded in Kharkiv since the 1930s (Vlaschenko, 2011), are still unable to breed in city conditions, despite these trends. The main limiting factor is probably the food supply. The processes of urbanization induced the decline in large insects from the order Lepidoptera (Conrad et al., 2006). According to this, *P. kuhlii*, which feeds on small moths (Whitaker et al., 1994), may actually be benefitting from these conditions, whereas some larger species are encountering prey availability as an increasingly limiting factor for city life. However, the most interesting example of current adaptation to city conditions is seen in a larger bat, *N. noctula*, in East Europe. *Nyctalus noctula* only started to hibernate in urban areas of East Europe about 20–25 years ago (Vlaschenko, 1999; Godlevska, 2015). As we see in the example of Kharkiv, *N. noctula* inhabits the city area in exactly the same way that species in the genus *Myotis* inhabit karstic regions, i.e. for swarming, migration movements, and hibernation. The Kharkiv region is 200–250 km from the southern border of the main breeding zone of this species in East Europe (Strelkov, 2002; Godlevska, 2015). The oak forests on the flood plains of the forest–steppe zone of the Kharkiv region are the habitat where this species is found in greatest abundance during the breeding season (Vlaschenko and Gukasova, 2010). Therefore, Kharkiv is predisposed to a mass autumn invasion of this species into the city area. However, it is known that during rapid changes of environment populations experience the highest mortality rates at the beginning of the adaptation processes (Solberg and Solberg, 1982). With a tendency for sedentary assimilation before hibernation, *N. noctula* becomes affected by the unpredictable, negative impacts of the city environment to a higher degree than the other species mentioned. Hence, the 846 *N. noctula* records made by citizens in Kharkiv in 2013 reflect 846 individuals that were trapped by different types of anthropogenic traps and that were involved in people–bat conflict. This is a large number, and it only represents those cases where people provided the information to the call-center of the Bat Rehabilitation Center. Indeed, the true number of bat–human conflict cases must be much higher, especially when the fact that winter records of this species were confirmed from tens of cities across the territory of Ukraine, the south of Belarus, and the southwestern part of Russia is taken into account (Godlevska, 2012; Prylutska and Vlaschenko, 2013). It therefore becomes clear that there is a problem with people–bat conflicts across these territories. In some cases, the bats found are delivered to the local bat specialist or zoo, but the bat-worker community is very small in these areas, with fewer than 100 specialists across East Europe. The Bat Rehabilitation Center in Kharkiv is the only working center in Ukraine, and as such it is insufficient to cover bat rescue activity for most of the country. This is why the creation and support of bat rescue centers in Europe is an essential requirement to support the adaptation of *N. noctula* and other species to city conditions (Racey, 2013).

Possible resolutions for bat–human conflicts include the further separation of bat roost cavities from human spaces by creation of a network of alternative roosts for hibernation, the provision of continuous bat monitoring, and a growth in bat-rescue activity. Only knowledge of species-specific natural histories in city areas, knowledge of the ways in which species use the conditions provided by the city, and assessment of the main risk factors that lead to negative consequences for species will allow us to provide effective wildlife management (Neubaum et al., 2007) and thus support biodiversity and conservation across the city area, and around the world.

Acknowledgments
We would like to thank our colleagues and friends Dr Julia Kuznetsova, Oleg Prylutski, Olexander Klochko, Anna Suvorova, and Kseniia Birkel and conscientious Kharkiv citizens for help in bat discovery and collection. Special thanks to Kate Vaughan Williams for English editing and helpful comments. The work of the Bat Rehabilitation Center was supported by the Olexander Feldman Foundation and partly by the EUROBATS Project Initiative "Kharkiv Bat Education Program, 2013–2014". The authors would like to thank two anonymous referees for their constructive comments, which helped to improve the manuscript.

References

Alberdi A, Aihartza J, Aizpurua O, Salsamendi E, Brigham RM, Garin I (2014). Living above the treeline: roosting ecology of the alpine bat *Plecotus macrobullaris*. Eur J Wildlife Res 61: 17-25.

Ancillotto L, Serangeli MT, Russo D (2013). Curiosity killed the bat: domestic cats as bat predators. Mamm Biol 78: 369-373.

Ancillotto L, Tomassini A, Russo D (2015). The fancy city life: Kuhl's pipistrelle, *Pipistrellus kuhlii*, benefits from urbanization. Wildlife Res 42: 598-606.

Avila-Flores R, Fenton MB (2005). Use of spatial features by foraging insectivorous bats in a large urban landscape. J Mammal 86: 1193-1204.

Barclay RMR (1991). Population structure of temperate zone insectivorous bats in relation to foraging behavior and energy demand. J Anim Ecol 60: 165-178.

Bihari Z (1999). Examination of bats straying into rooms. Myotis 37: 99-102.

Bilushenko AA (2013). The current status of Kuhl's pipistrelle *Pipistrellus kuhlii* (Chiroptera, Vespertilionidae) in the central forest–steppe of Ukraine. Vestn Zool 47: 343-349.

Cermakova V, Zieglerova D (2014). First record of *Hypsugo savii* in Prague and summary of winter records of *Pipistrellus nathusii* from Prague and close surroundings (Czech Republic). Vespertilio 17: 95-101.

Coleman JL, Barclay RMR (2011). Influence of urbanization on demography of little brown bats (*Myotis lucifugus*) in the prairies of North America. PLoS ONE 6: e20483.

Coleman JL, Barclay RMR (2012). Urbanization and the abundance and diversity of Prairie bats. Urban Ecosyst 15: 87-102.

Conrad KF, Warren MS, Fox R, Parsons MS, Woiwod IP (2006). Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. Biol Conserv 132: 279-291.

Dietz C, von Helversen O, Nill D (2009). Bats of Britain, Europe and Northwest Africa. 1st ed. London, UK: A & C Black Publishers Ltd.

Dixon MD (2012). Relationship between land cover and insectivorous bat activity in an urban landscape. Urban Ecosyst 15: 683-695.

Ducci L, Agnelli P, Di Febbraro M, Frate L, Russo D, Loy A, Carranza ML, Santini G, Roscioni F (2015). Different bat guilds perceive their habitat in different ways: a multiscale landscape approach for variable selection in species distribution modelling. Landscape Ecol 2015 30: 2147-2159.

Duchamp JE, Sparks DW, Whitaker JO Jr (2004). Foraging-habitat selection by bats at an urban–rural interface: comparison between a successful and a less successful species. Can J Zoolog 82: 1157-1164.

Entwistle AC, Racey PA, Speakman JR (1997). Roost selection by the brown long-eared bat *Plecotus auritus*. J Appl Ecol 34: 399-408.

Francis RA, Chadwick MA (2012). What makes a species synurbic? Appl Geogr 32: 514-521.

Gaisler J, Zukal J, Rehak Z, Homolka M (1998). Habitat preference and flight activity of bats in a city. J Zool 244: 439-445.

Gashchak S, Vlaschenko A, Eśtok P, Kravchenko K (2015). New long-distance recapture of a noctule (*Nyctalus noctula*) from eastern Europe. Hystrix 26: 59-60.

Gazaryan SV, Kazakov BA (2002). Ecology of noctule bat *Nyctalus noctula* on the North Caucasus and Ciscaucasia. Communication 2. Seasonal dynamics of sex and age composition. Plecotus et al. Pars Spec 2002: 83-88.

Gebhard J (1995). Observations on the mating behaviour of *Nyctalus noctula* (Schreber, 1774) in the hibernaculum. Myotis 32-33: 123-129.

Gerell R, Lundberg K (1990). Sexual differences in survival rates of adult pipistrelle bats (*Pipistrellus pipistrellus*) in South Sweden. Oecologia 83: 401-404.

Godlevska L (2015). Northward expansion of the winter range of *Nyctalus noctula* (Chiroptera: Vespertilionidae) in Eastern Europe. Mammalia 79: 315-324.

Godlevska LV (2012). Results of the work of the bat contact-center (Ukraine). Scientific Notes of Taurida V. I. Vernadsky National University, Biology, Chemistry 25: 12-20 (in Russian with English summary).

Godlevskaya EV, Kondratenko AV (2004). Death of bats in window-traps. Plecotus et al. 7: 97-99 (in Russian with English summary).

Golikov AP, Kazakova NA, Shuba MB (2011). Kharkovskaja oblast, Regionalnoje razvitije: sostojanije i perspektivi. Kharkiv, Ukraine: V.N. Karazin Kharkiv National University Press (in Russian).

Gukasova A, Vlaschenko A (2011). Effectiveness of mist-netting of bats (*Chiroptera*, *Mammalia*) during the non-hibernation period in oak forests of Eastern Ukraine. Act Zool Cracov 54A: 77-93.

Hale JD, Fairbrass AJ, Matthews TJ, Davies G, Sadler JP (2015). The ecological impact of city lighting scenarios: exploring gap crossing thresholds for urban bats. Glob Change Biol 21: 2467-2478.

Hamilton IM, Barclay RMR (1994). Patterns of daily torpor and day-roost selection by male and female big brown bats (*Eptesicus fuscus*). Can J Zoolog 72: 744-749.

Hill R, Hüppop O (2008). Birds and bats: automatic recording of flight calls and their value for the study of migration. In: Computational Bioacoustics for Assessing Biodiversity. Proceedings of the International Expert Meeting on IT-Based Detection of Bioacoustical Patterns. Bonn, Germany: BfN-Skripten, pp. 135-141.

Hutterer R, Ivanova T, Meyer-Cords C, Rodrigues L (2005). Bat Migration in Europe: A Review of Banding Data and Literature. Bonn, Germany: Federal Agency for Nature Conservation.

Jonasson KA, Willis CKR (2011). Changes in body condition of hibernating bats support the thrifty female hypothesis and predict consequences for populations with white-nose syndrome. PLoS ONE 6: e21061.

Kokurewicz T, Speakman JR (2006). Age related variation in the energy costs of torpor in Daubenton's bat: effects on fat accumulation prior to hibernation. Acta Chiropterol 8: 509-521.

Kozhurina EI, Morozov PP (1994). Can males of *Nyctalus noctula* successfully mate in their first year? Acta Theriol 39: 93-97.

Kunz TH, Fenton MB (2006). Bat Ecology. Chicago, IL, USA: University of Chicago Press.

Lausen CL, Barclay RMR (2006). Benefits of living in a building: big brown bats (*Eptesicus fuscus*) in rocks versus buildings. J Mammal 87: 362-370.

Lehnert LS, Kramer-Schadt S, Schönborn S, Lindecke O, Niermann I, Voigt CC (2014). Wind farm facilities in Germany kill noctule bats from near and far. PLoS One 9: e103106.

Lupicki D, Szkudlarek R, Cichocki J, Ciechanowski M (2007). The wintering of noctule bat *Nyctalus noctula* (Schreber, 1774) in Poland. Nietoperze 8: 27-38.

McGuire LP, Fenton MB, Guglielmo CG (2009). Effect of age on energy storage during prehibernation swarming in little brown bats (*Myotis lucifugus*). Can J Zoolog 87: 515-519.

McKinney ML (2008). Effects of urbanization on species richness: a review of plants and animals. Urban Ecosyst 11: 161-176.

Muller J, Mehr M, Bassler C, Fenton MB, Hothorn T, Pretzsch H, Klemmt HJ, Brandl R (2012). Aggregative response in bats: prey abundance versus habitat. Oecologia 169: 673-684.

Neubaum DJ, Wilson KR, O'Shea TJ (2007). Urban maternity-roost selection by big brown bats in Colorado. J Wildlife Manage 71: 728-736.

Oliveira LQ, Marciente R, Magnusson WE, Bobrowiec PED (2015). Activity of the insectivorous bat *Pteronotus parnellii* relative to insect resources and vegetation structure. J Mammal 96: 1036-1044.

Piksa K (2008). Swarming of *Myotis mystacinus* and other bat species at high elevation in the Tatra Mountains, southern Poland. Acta Chiropterol 10: 69-79.

Prylutska AS, Vlaschenko AS (2013). Material on the bat distribution on the base of results of contact-center in Kharkiv (2008–2012). Biological System 5: 532-537 (in Russian with English summary).

Prylutska AS, Vlaschenko AS, Kravchenko KA, Rodenko E (2014). Bat rehabilitation during winter in Kharkiv, Ukraine. In: Abstracts of the 23rd Polish Chiropterological Conference; 28–30 March 2014; Sypniewo, Poland.

Racey PA (2013). Bat conservation: past, present and future. In: Adams RA, Pedersen SC, editors. Bat Ecology, Evolution and Conservation. 1st ed. New York, NY, USA: Springer, pp. 517-532.

Racey PA, Speakman JR (1987). The energy costs of pregnancy and lactation in heterothermic bats. In: Symposia of the Zoological Society of London 57. Oxford, UK: Oxford University Press, pp. 107-125.

Rodenko EE, Kravchenko KA, Vlaschenko AS, Chepiznaja AJ, Suvorova AD, Prylutska AS (2014). The record of *Nyctalus noctula* in winter time in Poltava city (Ukraine). Plecotus et al. 17: 43-51.

Rogowska K, Kokurewicz T (2007). The longest migrations of three bat species to the “Nietoperek” bat reserve (Western Poland). Berichte der Naturforschenden Gesellschaft der Oberlausitz 15 (Supplement): 53-60.

Russo D, Ancillotto L (2014). Sensitivity of bats to urbanization: a review. Mammal Biol 80: 205-212.

Sachanowicz K, Wower A, Bashta AT (2006). Further range extension of *Pipistrellus kuhlii* (Kuhl, 1817) in central and eastern Europe. Acta Chiropterol 8: 543-548.

Senior P, Butlin RK, Altringham JD (2005). Sex and segregation in temperate bats. Proc R Soc Ser B-Bio 272: 2467-2473.

Sikes RS, Gannon WL (2011). Guidelines of the American Society of Mammalogists for the use of wild mammals in research. J Mammal 92: 235-253.

Solberg O, Solberg D (1982). Populacionnaja biologija i evolucija. Moscow, USSR: Mir (in Russian).

Speakman JR, Rowland A (1999). Preparing for inactivity: how insectivorous bats deposit a fat store for hibernation. P Nutr Soc 58: 123-131.

Stone EL, Harris S, Jones G (2015). Impacts of artificial lighting on bats: a review of challenges and solutions. Mamm Biol 80: 213-219.

Stoycheva S, Georgiev D, Pandourski I, Tilova E (2009). Bat diversity in two large towns of the Upper Thrace, Bulgaria (Chiroptera). Lynx NS (Praha) 40: 83-93.

Strelkov PP (2002) Material on wintering of migratory bat species (Chiroptera) on the territory of the former USSR and adjacent regions, Part 2. *Nyctalus noctula*. Plecotus 5: 35-56.

Threlfall CG, Law B, Penman T, Banks PB (2011). Ecological processes in urban landscapes: mechanisms influencing the distribution and activity of insectivorous bats. Ecography 34: 814-826.

Van Toor ML, Jaberg C, Safi K (2011). Integrating sex-specific habitat use for conservation using habitat suitability models. Anim Conserv 14: 512-520.

Vlaschenko AS (1999). Naxodka vechernitsyi ryizhei *Nyctalus noctula* na zimovke v Xar’kove. Vestnik Zoologii 33: 76 (in Russian).

Vaughan N, Jones G, Harris S (1997). Habitat use by bats (Chiroptera) assessed by means of a broad-band acoustic method. J Appl Ecol 34: 716-730.

Vlaschenko AS (2002). Finds of bats in the building of Kharkov National University. Bull Kharkov Univ 551: 212-216 (in Russian with English summary).

Vlaschenko AS (2006). Biogeocenological Role of Bats (*Mammalia*, *Chiroptera*) on the South Part of Forest-Steppe Zone. Kharkiv, Ukraine: Kharkiv National University (in Russian with English summary).

Vlaschenko AS (2011). Research history and list of records of bats (Chiroptera) in the Kharkov Region in the XIX and XX centuries. Plecotus et al. 14: 26-54 (in Russian with English summary).

Vlaschenko AS (2012). Results of bat (Chiroptera) ringing on the territory of the Kharkov region (2002–2012). P Nation Mus Nat His Khar 10: 31-41 (in Russian with English summary).

Vlaschenko AS, Gukasova AS (2009a). Development of method for the inventory of species composition and population structure of Chiroptera. Nature Reserves in Ukraine 15: 49-57 (in Russian with English summary).

Vlaschenko A, Gukasova A (2009b). Phenology of bat migration in Kharkov City (North-Eastern Ukraine). In: Abstracts of the 1st International Symposium on Bat Migration; 16–18 January 2009; Berlin, Germany.

Vlaschenko AS, Gukasova AS (2010). Bat (Chiroptera) fauna and structure of assemblage of projecting protected area “Yaremovskoe” (Kharkov region). Nature Reserves in Ukraine 16: 44-50 (in Russian with English summary).

Vlaschenko AS, Kravchenko KA, Gukasova AS (2013). New winter aggregation of *N. noctula* in cities of NE Ukraine: evolution step in anthropocene or ecological trap? In: Abstracts of 3rd International Berlin Bat Meeting: Bats in the Anthropocene; 1–3 March 2013; Berlin, Germany.

Vlaschenko A, Kravchenko K, Prylutska A, Gukov V, Suvorova A, Rodenko E (2015). Seasonal movement of bats in big city area (Kharkiv, NE Ukraine). In: Abstracts of 4th International Berlin Bat Meeting: Movement Ecology of Bats; 13–15 March 2015; Berlin, Germany.

Voigt CC, Lehnert LS, Popa-Lisseanu AG, Ciechanowski M, Estók P, Gloza-Rausch F, Görföl T, Göttsche M, Harrje C, Hötzel M et al. (2014). The trans-boundary importance of artificial bat hibernacula in managed European forests. Biol Conserv 23: 617-631.

Voigt CC, Phelps KL, Aguirre L, Schoeman MC, Vanitharani J, Zubaid A (2016). Bats in buildings: the conservation of synanthropic bats. In: Voigt CC, Kingston T, editors. Bats in the Anthropocene: Conservation of Bats in a Changing World. 1st ed. New York, NY, USA: Springer International Publishing, pp. 427-462.

Whitaker JO Jr, Shalmon B, Kunz TH (1994). Food and feeding habits of insectivorous bats from Israel. Z Saugetierkunde 59: 74-81.

Zahn A, Kriner E (2016). Winter foraging activity of Central European vespertilionid bats. Mamm Biol 81: 40-45.

Appendix 1. List of bat records in Kharkiv in 2013.

Abbreviations: Date of record: 04.01. – dd.mm. Bat species acronyms: NNOC – *Nyctalus noctula*; ESER – *Eptesicus serotinus*; PKUL – *Pipistrellus kuhlii*; VMUR – *Vespertilio murinus*; PAUR – *Plecotus auritus*. Symbols of sex and acronyms of age: ♀ – female, ♂ – male; ad – adult individual, sad – first-year individuals. For 1 individual we noted only 1 symbol of sex; for 2 or more individuals, we noted the number before the sex symbols. We divided sex and age groups of a species by commas, different species on one date by semicolons, and records on different dates by dots.

04.01. – NNOC 2♀♀ sad, ♀, 7♂♂ sad, un. 06.01. – NNOC 2♀♀ ad, 2♀♀ sad, 5♂♂ sad, un; ESER ♀ sad. 08.01. – NNOC ♀ ad, ♀ sad, 3♂♂ sad. 09.01. – NNOC ♀ sad, ♀, 2♂♂ ad, 5♂♂ sad. 10.01. – ESER ♀ sad, ♂ sad. 12.01. – NNOC ♂ ad, ♂ sad; ESER ♂ ad. 13.01. – ESER ♀ sad. 14.01. – NNOC ♀ ad, ♀ sad, ♀, ♂ ad, ♂ sad, ♂. 15.01. – NNOC ♂ sad; ESER ♂ sad. 17.01. – NNOC 3♀♀ sad, 3♂♂ sad. 19.01. – NNOC ♂ sad; ESER ♂ ad. 20.01. – PAUR ♀ sad. 21.01. – NNOC 3♀♀ ad, 5♀♀ sad, ♀, 5♂♂ ad, 11♂♂ sad, 5♂♂; ESER ♂ sad. 26.01. – ESER ♀ ad. 29.01. – ESER ♂ sad. 04.02. – NNOC ♀ ad, 2♀♀ sad, 2♂♂ ad, 4♂♂ sad, 2♂♂. 05.02. – NNOC 2♀♀ ad, 2♀♀ sad, 3♂♂ ad, 8♂♂ sad, ♂; PKUL ♂ ad. 07.02. – NNOC ♀ ad, 3♀♀ sad, 4♂♂ sad. 08.02. – NNOC ♀ ad. 09.02. – NNOC ♂ ad, ♂ sad. 11.02. – NNOC 2♂♂ sad. 13.02. – NNOC ♀ ad, 2♀♀ sad, 5♂♂ sad. 15.02. – NNOC 3♀♀ sad, 5♂♂ sad. 17.02. – ESER ♂ ad. 18.02. – NNOC ♂ sad. 19.02. – NNOC ♀. 21.02. – NNOC 2♀♀ ad. 22.02. – NNOC ♀ sad, 7♂♂ sad. 26.02. – NNOC 2♀♀ ad, 2♀♀ sad, 3♂♂ ad, 5♂♂ sad. 27.02. – NNOC 2♀♀ sad, ♂ ad, 2♂♂ sad. 28.02. – NNOC ♀ ad, 2♀♀ sad, ♂ ad, 9♂♂ sad. 01.03. – NNOC 5♀♀ ad, 9♀♀ sad, 2♂♂ ad, 9♂♂ sad. 03.03. – NNOC ♀ sad. 04.03. – NNOC 3♂♂ sad. 07.03. – NNOC ♀ sad, ♀♀, 2♂♂ sad. 10.03. – NNOC 3♀♀ sad, 7♂♂ sad. 11.03. – NNOC 2♀♀ ad, ♂ ad, 3♂♂ sad, ♂. 12.03. – ESER ♀. 13.03. – NNOC ♀ ad, ♀ sad, 3♂♂ sad. 14.03. – NNOC 2♂♂ sad. 15.03. – NNOC ♂ sad. 16.03. – NNOC 2♀♀ ad, 2♀♀ sad, ♀, ♂ ad, 7♂♂ sad; PKUL ♀ ad. 17.03. – ESER ♂ sad. 18.03. – NNOC 2♀♀ ad, 3♀♀ sad, ♀, 3♂♂ ad, ♂. 20.03. – NNOC ♀ ad, 2♀♀ sad, 2♂♂ ad, 4♂♂ sad. 21.03. – NNOC ♂ ad; ESER ♂ ad. 22.03. – NNOC ♀ sad, 2♂♂ sad; ESER 2♀♀ sad. 23.03. – NNOC ♂ sad. 25.03. – NNOC ♂ sad, ESER 2♀♀ ad. 26.03. – NNOC 3♀♀ ad, 2♀♀ sad, 2♂♂ sad, un; ESER ♂ ad. 27.03. – NNOC ♀ ad, ♀ sad, ♂ sad; ESER ♂; PKUL ♀ ad. 28.03. – NNOC ♂ ad, 3♂♂ sad; ESER ♂ sad. 01.04. – NNOC 3♀♀ ad, ♀ sad, 2♂♂ sad, 2♂♂. 02.04. – NNOC 4♀♀ ad, 3♀♀ sad, ♀, 5♂♂ ad, 14♂♂ sad. 04.04. – NNOC 2♀♀ ad, ♀ sad, ♀, 4♂♂ sad; PKUL ♀ sad. 06.04. – NNOC ♀ sad, ♂ ad, ♂ sad; ESER ♀ sad, ♂. 08.04. – NNOC ♀ sad, ♂ sad, un. 09.04. – ESER ♀ ad. 10.04. – ESER ♂ ad. 11.04. – ESER ♂. 12.04. – NNOC ♀ ad, ♀ sad, ♂ sad, 2 un. 15.04. – NNOC ♂ ad. 16.04. – NNOC ♀ ad. 18.04. – PKUL ♂ ad. 19.04. – PKUL ♀. 20.04. – NNOC ♂. 23.04. – PKUL ♀. 25.04. – NNOC ♂ ad. 26.04. – ESER ♀ ad. un. 04. – ESER ♂ ad. 11.05. – ESER ♂ ad. 14.05. – ESER ♂ ad. 23.05. – ESER ♂. 20.06. – ESER ♂ ad. un. 07. – ESER ♂ ad. 01.08. – NNOC 7♀♀, 4♂♂, 5 un.; ESER ♂ sad. 02.08. – ESER ♂ sad. 03.08. – ESER ♀ ad, 9♀♀ sad, ♂ ad, 4♂♂ sad. 05.08. – ESER ♂ ad. 06.08. – NNOC ♀ ad. 10.08. – NNOC ♀ sad, 3♂♂ sad; ESER ♀ sad, ♂ ad, 6♂♂ sad. 11.08. – NNOC un. 12.08. – ESER ♂ sad, ♂. 13.08. – ESER ♂. 14.08. – NNOC ♂ sad; ESER 3♀♀ sad, 11♂♂ sad, un. 15.08. – ESER ♂ sad. 16.08. – VMUR un. 19.08. – NNOC 17♀♀ ad, 80♀♀ sad, 69♂♂. 20.08. – NNOC 5♀♀ sad, ♂ sad, ♂; ESER 2♀♀ sad. 21.08. – NNOC ♀ ad, 3♀♀ sad. 22.08. – NNOC ♂ sad. 24.08. – NNOC 2♀♀ ad, 32♀♀ sad, 41♂♂ sad. 27.08. – NNOC ♀ ad, 8♀♀ sad, 8♂♂ sad, ♂; ESER ♂. 28.08. – NNOC 3♀♀ sad, 3♂♂ sad. 29.08. – NNOC ♀ ad, 2♀♀ sad, 5♂♂ sad. 30.08. – NNOC 2♀♀ sad, ♂ sad. 02.09. – NNOC 7♀♀ sad, 5♂♂ sad. 03.09. – NNOC ♀ sad, 3♂♂ sad. 04.09. – NNOC 2♀♀ sad, 5♂♂ sad; VMUR ♂. 07.09. – VMUR ♀. 12.09. – NNOC ♂; ESER ♂ sad. 11.10. – ESER ♂ sad. 14.10. – PKUL ♂. 16.10. – VMUR ♀ ad. 18.10. – VMUR ♂ sad. 20.10. – ESER ♀. 22.10. – VMUR ♂ sad. 24.10. – VMUR ♀ sad. 25.10. – VMUR ♂ sad. 27.10. – NNOC ♀. 28.10. – NNOC ♀ ad. 04.11. – NNOC ♀ ad. 06.11. – ESER ♂ sad. 07.11. – ESER ♀ ad, ♂ ad, ♂. 08.11. – NNOC ♀, ♂ ad. 13.11. – NNOC ♀ sad, ♂ ad. 17.11. – NNOC ♂. 18.11. – NNOC ♀ ad. 19.11. – NNOC ♂ sad. 21.11. – NNOC ♀ ad, ♀ sad, ♂ sad. 22.11. – VMUR ♀ ad. 23.11. – ESER ♀ sad. 24.11. – ESER ♂ sad. 25.11. – NNOC ♂ ad. 27.11. – NNOC 3♂♂ sad. 28.11. – NNOC ♀ ad. 29.11. – NNOC ♀ ad. 02.12. – NNOC 3♀♀ sad. 03.12. – NNOC 2♀♀ sad, 2♂♂ sad. 05.12. – NNOC ♀ ad, ♂ ad. 06.12. – NNOC ♀ ad, ♂ sad. 09.12. – NNOC ♂ sad. 10.12. – ESER ♀ sad. 11.12. – NNOC 4♀♀ ad, ♀, 6♂♂ ad, 3♂♂ sad. 12.12. – NNOC ♀ sad, 3♂♂ ad; ESER ♀. 13.12. – NNOC ♂ sad. 14.12. – NNOC ♂ sad; ESER ♀ sad. 16.12. – NNOC 6♀♀ ad, 3♀♀ sad, ♀, 21♂♂ ad, 7♂♂ sad, ♂. 17.12. – NNOC ♀, 3♂♂ sad; ESER ♀ ad, ♀ sad, ♂ ad. 18.12. – NNOC 5♀♀ ad, 7♀♀ sad, ♀, ♂ ad, 11♂♂ sad, 2♂♂; ESER ♀ sad. 19.12. – NNOC ♀ ad, ♀ sad, ♂ sad. 20.12. – NNOC 2♀♀ad, ♂ sad. 22.12. – ESER ♂ sad; PKUL ♀. 23.12. – NNOC ♀ ad, ♀ sad, 2♂♂ ad, ♂ sad; ESER ♂. 25.12. – NNOC ♀ sad, ♂ ad, ♂; ESER ♀ sad, ♂ ad. 26.12. – NNOC 2♂♂ ad. 27.12. – NNOC ♀ ad, ♂ ad. 28.12. – ESER ♀ ad. 30.12. – NNOC ♂ sad, ♂.

Appendix 2. Body mass differences.

The pairs among adult *Nyctalus noctula* that were significantly different by weight (Tukey post hoc test, P < 0.05): Mar ♀♀ – Nov ♀♀, Mar ♂♂ – Nov ♀♀, Mar ♂♂ – Nov ♂♂, Mar ♀♀ – Dec ♀♀, Mar ♀♀ – Dec ♂♂, Mar ♂♂– Dec ♀♀, Mar ♂♂ – Dec ♂♂, Apr ♀♀ – Nov ♀♀, Apr ♂♂ – Nov ♀♀, Apr ♀♀ – Dec ♀♀, Apr ♂♂ – Dec ♀♀, Apr ♂♂ – Dec ♂♂, Aug ♀♀ – Dec ♀♀, Aug ♀♀ – Dec ♂♂, Aug ♀♀ – Nov ♀♀.

The pairs among first-year individuals of *Nyctalus noctula* that were significantly different by weight (Tukey post hoc test, P < 0.05): Jan ♀♀ – Apr ♀♀, Jan ♂♂ – Apr ♀♀, Jan ♂♂ – Apr ♂♂, Jan ♂♂ – Dec ♀♀, Jan ♂♂ – Dec ♂♂, Feb ♀♀ - Aug ♂♂, Feb ♂♂ – Aug ♂♂, Feb ♀♀ – Dec ♀♀, Feb ♀♀ – Dec ♂♂, Feb ♂♂ – Dec ♀♀, Feb ♂♂ – Dec ♂♂, Mar ♂♂ – Aug ♂♂, Mar ♀♀ – Dec ♀♀, Mar ♀♀ – Dec ♂♂, Mar ♂♂ – Dec ♀♀, Mar ♂♂ – Dec ♂♂, Aug ♀♀ – Apr ♀♀, Aug ♀♀ – Apr ♂♂, Aug ♂♂ – Apr ♀♀, Aug ♂♂ – Apr ♂♂, Sep ♂♂ – Apr ♀♀, Sep ♂♂ – Apr ♂♂, Sep ♀♀ – Dec ♀♀, Sep ♀♀ – Dec ♂♂, Nov ♀♀ – Apr ♀♀, Nov ♂♂ – Apr ♀♀, Nov ♂♂ – Apr ♂♂, Dec ♀♀ – Apr ♀♀, Dec ♀♀ – Apr ♂♂, Dec ♂♂ – Apr ♀♀, Dec ♂♂ – Apr ♂♂, Dec ♀♀ – Aug ♀♀, Dec ♀♀ – Aug ♂♂, Dec ♂♂ – Aug ♀♀, Dec ♂♂ – Aug ♂♂.