CHANGES OF MIGRATION PATTERNS AND SPATIAL EXPANSION OF BATS (*CHIROPTERA*) AS A REFLECTION OF ADAPTATION TO THE EXISTENCE IN URBAN LANDSCAPE

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Adaptations patterns of four bat species (Common noctule *Nyctalus noctula* Schreber, 1774, Parti-coloured bat *Vespertilio murinus* Linnaeus, 1758, Kuhl's pipistrelle *Pipistrellus kuhlii* Kuhl, 1817, Savi's pipistrelle *Hypsugo savii* (Bonaparte, 1837)) to the existence in urban landscape have been investigated in the western part of Ukraine. The species represent two groups that differ both by the origin and nature of adaptations to urban environment. Long-distance migrants, *N. noctula* and *V. murinus,* have adapted to wintering in temperate latitudes due to settlement and hibernation in concrete block buildings in large cities. They show noticeable seasonal change of behaviour that can be caused by global climatic processes.

All the recorded hibernation shelters of these species were located in buildings of Lviv city. They were situated mainly in the 12-storey concrete block houses, in the narrow cracks between buildings and behind the concrete wall decor.

Activity of *N. noctula*, including hunting, was observed almost throughout all the winter in Lviv city. Intensity of flight activity is positively correlated with average daytime temperatures. Flying individuals were observed generally at temperatures above 0 ºC. In the days when the average temperature was below -10 ºC, flights of bats have not been fixed, except of occasional social calls in the shelters.

Urbanization caused a loss of typical natural bat shelters, but at the same time it provided favourable alternative topical and trophic habitats. Hibernation torpor of bats is often not stable in underground shelters, especially in urban conditions. Winter activity of individuals flying near entrance to the hibernation shelter was described with visual observations.

Species belonging to the Mediterranean type of fauna: *P. kuhlii* and *H. savii*, have demonstrated a considerable range of expansion in the northern direction. The expansion of these species can be also a result of their synanthropization. Being originally the bats of rocky areas, today they have become the typical species of urban areas creating the colonies mainly in the cracks of various buildings and hunting usually over water and near street lamps. Today, *P. kuhlii*, especially, demonstrates one of the highest rates of synanthropization process among European bats.

The current expansion of these bat species has evolved through adaptation to their settling mainly in concrete buildings (which appeared in the last few decades) to survive the strong winter conditions, because only relatively large cities can provide comfort shelters for bats with optimal microclimatic characteristics. The adaptation of bats is stipulated by the use of cracks and crevices in multi-storey buildings as an alternative to natural rock clefts which are typical places for their settlements, including many Mediterranean species.

Key words: Chiroptera, adaptation, urban environment, Ukraine

Anthropogenic transformation of the landscape often leads to the creation of new types of habitats with rather peculiar characteristics. Question concerning reactions of some groups of fauna to intensification of anthropogenic pressure on their habitat

and different degrees of its transformation was widely highlighted in the scientific literature. Some species are able to adapt successfully to changing environmental conditions and occupy the new habitat types (Lancaster, Rees, 1979; Luniak, 2004; Pickett et al., 2011; Seress, Liker, 2015 etc). In particular, species-generalists are characterized by a wide range of tolerance and can settle in urban areas, where they find suitable climate, topical and trophic conditions; it concerns even suboptimal conditions of large cities, which may contribute to the growth of their populations in some cases (Erz, 1963; Sachanowicz, Wower, Bashta, 2006; Uhrin et al., 2016). Species-specialists which appear in the transformed environment, occupy mainly the habitats similar to natural ones (Adams, Dove, Franklin, 1985). However, this phenomenon is mostly not caused by actual adaptation of bats, but appears only because of a certain degree of their behaviour strategies plasticity.

With increasing of urban environment transformation some bat species have adapted to occupy anthropogenic structures such as buildings or bridges (Bashta, Chymyn, 2011). Eventually, some species settle almost exclusively in these structures (eg., *Eptesicus serotinus* Schreber, 1774, *Plecotus austriacus* (Fischer, 1829) (Bashta, 2010 a).

To understand the causes and courses of the appearance of such adaptations, it is important to study bat species, which demonstrate the tendencies to successful adaptation to living in urban landscape. In recent decades, such trends are the most clearly showed by four bat species in Ukraine (Common noctule *Nyctalus noctula* Schreber, 1774, Parti-coloured bat *Vespertilio murinus* Linnaeus, 1758, Kuhl's pipistrelle *Pipistrellus kuhlii* Kuhl, 1817 and Savi's pipistrelle *Hypsugo savii* (Bonaparte, 1837)).

Materials and Methods

The area of research covers mainly the cities of the western part of Ukraine, in particular, Lviv city. Fragmentary studies have been also conducted in other cities of Ukraine: Uzhhorod, Mukachevo, Berehovo (Transcarpathian region) etc. The main sample plot (1 km²) was situated in the so-called "sleeping" district (Sykhiv microdistrict) of Lviv city which is constructed of concrete panel and brick houses. Green plants (trees and shrubs) are presented fragmentary. The research has been conducted using the methods of route investigation and ultrasonic detection.

Searching the bat shelters was performed by visual inspection and acoustic registrations, also the search of traces of vital activity of these animals was conducted. The emergence of individuals and their flight activity were recorded using detectors D-240x (Pettersson Elektronik AB) and Batcorder (ecoObst GmbH), as well as visually. Recorded bat calls were analysed by the software "BatSound" and "bcAnalyze".

The sonar signals of bats have been used as the activity measurement. *N. noctula* ultrasonic signals are characterized by a peak frequency of about 18-26, *V. murinus* – about 23-26, *P. kuhlii* – 36-40, *H. savii* – 31-36 kHz.

Results and Discussion

According to different behaviour features and adaptation types, two pairs of species have been determined – *N. noctula* / *V. murinus* and *P. kuhlii* / *H. savii*.

Common noctule *Nyctalus noctula*

Nyctalus noctula is one of the biggest and one of the most numerous migratory bat species in Ukraine. However, despite the significant number of publications on the biology and behaviour of the species (SluiterSluiter, Voute, Heerdt, 1973; Gaisler, Hanak, Dungel, 1979; Bihari, 2004; Vlaschenko A., Vlaschenko P. 2006; Bashta, 2011 etc.), many aspects of its ecology and behaviour features are still unclear.

Nyctalus noctula is primarily forest species, which is now adapted to settling in urban landscape, in particular – in different parts of buildings, mainly in the crevices of concrete panel houses (Bashta, 2008). Today records of hundreds of individuals of this species inhabiting fairly small area in some part of the urban environment become common.

New behaviour aspect, devoted to *N. noctula* hibernation, is studied rather poorly, because the species hibernates usually in regions that are characterized by significantly milder climatic conditions during a winter. These regions are situated in the southern and south-western part of the range, what is confirmed by the results of bats ringing (Hutterer et al., 2005). However, there are quite a few data concerning winter activity or winter time budget of *N. noctula* in Ukraine. Research in other countries can allow us to make some comparisons of the species behaviour in different conditions.

Nyctalus noctula is a long-distance migrant species (farthest flight is 1,600 km; Panyutin, 1968). Departure to wintering areas begins mostly in late July – early August in our latitudes. Late-summer appearance of a large number of Noctule individuals in hollow trees in the "Prypiat'-Stokhid" National Park (Western Polissia, data of the author) confirms this process. In the southern Ukraine, the mass emergence of migratory flocks of this species was noted mostly for the period from mid-August to October, sometimes until November and December, and a large number of spring migratory bats appeared in mid-March (Abelentsev, Pidoplichko, Popov, 1956). The latest records of adult females were found here in late September, and the males in mid-October.

It seems to be, that migration paths of *N. noctula* runs through Ukraine from Belarus and possibly the south-western Russia. Autumn migrations from the northern and central parts of Ukraine are southwards, to the Crimea and the Black Sea, further along the Black Sea to Romania and Bulgaria, and possibly across the Black Sea to Turkey or eastwards along the Azov Sea coast. Thus, the bats which had been ringed in Voronezhskyi zapovidnyk, were found later in Bulgaria in winter (Panyutin, 1968).

In Eastern and Central Europe, *N. noctula* wintering areas are still poorly studied. Supposedly, from the western part of Ukraine it migrates in the south-

western and southern directions, which is, to some extent, supported by bat ringing results. Thus, the bat which had been ringed in the Bialowieza Forest, was caught later at the foothills of the Carpathians. There is some evidence of the southwest direction of autumn migrations of this species: the bat, which had been ringed in the Voronezhkyi zapovidnyk, was caught in Rudnyky village of Lviv region (Krochko, 1988). Probably, some individuals from the west-Ukrainian populations hibernate in the Transcarpathia (Krochko, 1992).

Records of *N. noctula* hibernation have been known from the urban areas at Western Europe since the nineteenth century (Kolenati, 1859), but the mass wintering has been discovered only recently. In recent decades, the hibernation bats were found in urban landscape of many Central European countries (Postawa, Galosz, Woloszyn, 1994; Zahn, Clauss, 2003 etc.), including Ukraine. Appearance of hibernating Noctules mainly in large cities may indicate an increase of the synanthropization degree of the species (Bashta, 2000, 2008; Tyshchenko, Godlevska, 2008; Vlaschenko A., 1999).

The first known record of hibernating *N. noctula* in Lviv was in 1999, when two males were found in the cellar (Bashta, 2000). However, a large winter colony was detected firstly in winter of 2006-2007 (Bashta, 2008). The next winter (2007-2008) an increase of the number and frequency of detection of *N. noctula* hibernation aggregations (n=18) was observed. The number of individuals in such aggregation varied from 25 to 300.

The territory of Ukraine traditionally belonged to the "reproductive" area of *N. noctula*. In Russia (Povolzhia) the northern boundary of "reproductive" part of the range lied slightly below the area of Samarska Luka (about 40ºN). Eastwards it runs around semi-desert of Volga-Ural watershed to the middle part of the Ural river; the west boundary is shifted to the latitude of Volgograd city (Smirnov et al., 2010). That is, the East European "reproductive" area of the species was isolated from the wintering area by a wide strip of open landscapes, in contrast to the western part of the population.

Wintering of bats within the area of its "reproductive" summer occurrence is a quite common phenomenon in Western Europe and several countries of Central Europe, which have relatively mild temperate climate in contrast to the middle zone of Eastern Europe. Wide overlapping of the *N. noctula* wintering area with "reproductive" one was known only in regions westward and south-westward of the Oder river (Schmidt, 1998; Harbusch, Engel, Pir, 2002; Zahn, Clauss, 2003 etc). Supposedly, it is caused by the influence of warmer Atlantic air masses.

However, the facts of *N. noctula* hibernation in the climatic "risk" zone of the distribution area have been known from the earlier times (Strelkov, 2002). Thus, in the late 90's of the last century and in 2004 the hibernating bats were found at the latitude of Astrakhan' city (Kozhurina, Gorbunova, 2004). Hibernating *N. noctula* was found in areas isolated from the main areas of winter stay in Lviv (Bashta, 2000) and Kharkiv cities (Vlaschenko A., 1999) in 90th. In Central Europe, similar records are known from the Baltic coast (Postawa, Galosz, Woloszyn, 1994) and from some

cities in central Poland (Szkudlarek et al., 2002). All the above mentioned findings are located far away from the nearest areas of *N. noctula* wintering at about 500 km and more.

Hibernation shelters of *N. noctula*. Natural hibernation shelters of the species are situated mainly in hollow trees, what is known from Western Europe (Schober, Grimmberger, 1998) and the Caucasus (Gazaryan, 2002) and in building crevices in Southern Europe (Georgiev, Stoycheva, 2006). In the Transcarpathia the Noctules also can probably hibernate in tree hollows, and before significant fall of temperature they migrate to the city buildings of plain part of the region (Abelentsev, Pidoplichko, Popov, 1956).

In Russia, near Samarska Luka, *N. noctula* was found in the cave (Smirnov et al., 2010) that is quite rare for this dendrophilous species. Some records of hibernating individuals are known from caves in the western Ukraine (Krochko, 1966). Significantly more findings of hibernating animals are recorded from the rock cracks (Kuzyakin, 1950; Gaisler, Hanak, Dungel, 1979; Gebhard, 1983-1984; Manfred, 1989; Harbusch, Engel, Pir, 2002).

All the recorded 18 hibernation shelters of *N. noctula* were located in buildings of Lviv city. They were situated mainly in the 12-storey concrete block houses, in the narrow cracks between buildings and behind the concrete wall decor. Two colonies were located in cavities under the window sills.

The largest number of occupied shelters was found during the days with the highest temperature (over +5 °C), which was caused by enhanced call activity of individuals in shelters. In colder days (with temperatures below -10 °C), bats were probably in torpor (to save energy) and social behaviour was not recorded in majority of shelters.

A half of shelters were found only once, which may indicate its temporary use, and, probably, less favourable conditions for bat hibernation. During the next years the number of discovered shelters ranged between 4 and 9 at the sample plot. They located at the height of 8-25 m. In contrast to the research results of Z. Bihari (2004), an altitude preference of shelter locations was not found.

Different degrees of association of bat individuals to specific shelters are probably caused by various internal microclimatic and other conditions (e.g., the internal volume of cavity in the structure, which enables settlement of larger colonies).

The temperature averaged around 4 °C in one of the studied shelters (the only one where it was available to determine temperature parameters) and it was quite stable during the winter. Despite the entrance proximity and relatively small depth, the temperature was always above zero in the crevice.

In the north-western Caucasus (Gazaryan, 2002) and the northeast Kazakhstan (Butovsky, 1974), where the species wintering is known in tree hollows and wall cavities of concrete buildings, respectively, the bats hibernated in more severe conditions. These researchers have found out that the short decrease of external air

temperatures till -10 and -15 °C, and till -3 °C in the shelters does not lead to the death of bats. D. Smirnov et al. (2010) indicated that decrease of temperature even to -7 °C inside the shelter did not affect the wintering of bats.

Some shelters were found in low buildings (2-3 storeys), located in the city centre. Choice of shelters could depend mainly on their availability in block buildings (Gaisler, Hanak, Dungel, 1979), as well as the specific microclimatic features of cavities. The most numerous and the most stable shelters in time were usually located in cosy courtyards or parts of buildings, closed from the prevailing wind.

The activity of bats during hibernation period. The phenomenon of bat activity in hibernation period was found in some other species too: Greater horseshoe bat *Rhinolophus ferrumequinum* (Schreber, 1774) (Park, Jones, Ransome, 1999), Daubenton's bat *Myotis daubentonii* (Kuhl, 1817) (Daan, 1973), Natterer's bat *Myotis nattereri* (Kuhl, 1817) (Lubczyz, Nagel, 1995). Some researchers (Daan, 1973; Nagel A., Nagel R., 1994) have found out that bat winter activity is characterized by uneven dynamics with relatively high activity in late autumn, later decline and rising again at the end of the hibernation period. Some species are quite active in the winter both during the day and night (Thomas, 1995). The difference in bat activity is rather connected with the general physiological state of individuals, local climatic conditions and the availability of prey.

Feeding is a derived phenomenon of winter bat activity that needs bat awakening and seems to be synchronized with dusk. Twilight is the most favourable time for feeding, since darkness gives the possibility to fly out from hibernacula at higher external air temperatures than in other period of the night. In the case of successful hunting, the prolonged nocturnal activity of individuals was observed.

Activity of *N. noctula* in Lviv city, including hunting, was observed almost throughout all the winter; similar was found in some areas of Northern and Western Europe (Zahn, Kriner, 2014). Intensity of flight activity is positively correlated with average daytime temperatures.

In the days when the average temperature was below -10 ºC, flights of bats have not been fixed, except of occasional social calls in the shelters. Larger number of records was noted in the days with the average daily temperature above 0 ºC. Individuals were usually flying in a short distance between buildings within the courtyard. Nights of highest *N. noctula* activity were windless or slightly windy. Frequently, steep turns of bats allowed suggesting that they preyed on insects. Bat ultrasound signals also include signals accompanying the attack on prey (so-called, "buzz"), which confirmed the hunting winter bat activity, and the availability of prey.

Parti-coloured bat *Vespertilio murinus*

Vespertilio murinus occurs in central Europe and Asia, between 35 and 61ºN. It is distributed in almost all the landscapes, including agricultural and urban areas (Rydell, Baagøe, 1994). However, the numerous observations of this species are known beyond this area, including fairly remote regions like the British and the Faroe Islands and northern Scandinavia (Baagøe, 1999). Only migratory populations

of *V. murinus* are known in the most of European countries; there are restricted data or no data at all about sedentary ones.

Vespertilio murinus belongs to the long-distance migrants. The farthest known flight of this species was 1440 km (Masing, 1989). The western and south-western directions of seasonal autumn migrations are prevailing. Thus, the individual, which had been ringed in Bialowieza Forest, was caught in Romania (Kurskov, 1981).

This species hibernates mainly in the overground shelters; some records of hibernating specimens were known in the ventilation shaft building (Rydell, Baagøe, 1994; Baagøe, 1999).

The typical feature of *V. murinus* males' behaviour is making of loud and audible calls (for humans) in the mating season. It happens during demonstration flights that occur usually near tall buildings. Peak of male call activity is observed mostly in mid-October and it is fairly stable from year to year, suggesting that most of these males are distant migrants.

By the end of October the demonstration signal intensity is usually going down, probably because the majority of migrants leave the area of study. However, some individuals are staying till the frost weather, sometimes till the end of November, which is an indirect confirmation of their wintering in the city.

Thus, like *N. noctuls*, this species has adapted to hibernation in urban landscape. Many facts have been accumulated recently to confirm the data about its wintering in urban areas within the main part of the "reproduction" area (Strelkov, 2001). A few facts of *V. murinus* wintering are recorded also in Lviv city. Namely, hibernation colonies were found in the cracks of multi-storey block buildings in December 2008. Two discovered colonies numbered about 30 and 15 individuals, respectively.

Vespertilio murinus hibernates in buildings, but not in underground cavities (which are usually checked regularly by scientists), so only a few records of this species in winter are known by this time. Records of *V. murinus* in the cities of Ukraine (Tyshchenko, Godlevska, 2008; Bashta, 2009) and other countries, such as Lithuania: Vilnius (Baranauskas, Grikieniene, Masing, 2006), Latvia: Riga (Šuba, Vietniece, Pētersons, 2010), Belarus: Minsk (Shpak, 2012) and Russia: St. Petersburg (Bogdarina, 2006) show that the species is adapting to the wintering in urban environment in all the Eastern Europe area.

Kuhl's pipistrelle *Pipistrellus kuhlii*

Pipistrellus kuhlii occurs in Western, Southern and Eastern Europe. This species is particularly interesting and exceptional among European bats, taking into account its extraordinary expansion intensity towards the north over the past decades. Being the species of Mediterranean fauna, it invaded the new, large areas, moving to the north during the past three decades. This process passed especially rapidly in Central and Eastern Europe, e.g. Hungary and Ukraine (Zahorodniuk, Nehoda, 2001; Szatyor et al., 2003; Bashta, 2010 b). Rapid expansion is characteristic for the species in Central and Eastern Europe (Sachanowicz et al., 2006).

Till the 90th of the XX century *P. kuhlii* was one of the rarest bat species in

Ukraine, whose distribution was limited to the Crimea and the north banks of Azov sea (Krochko, 1994). In 1998 the species has already reached the North of Ukraine (Kedrov, Sheshurak, 1999). Till the end of the first decade of the XXI century it has invaded almost the whole territory of Ukraine (Bashta, 2010 b).

Pipistrellus kuhlii, being originally the bat of rocky areas, today has become the typical species of urban areas creating the colonies mainly in the cracks of various buildings and hunting usually over water and near street lamps. Today, this species demonstrates one of the highest rates of synanthropization process among European bats. In this case, it can be comparable, probably, with Serotine bat *Eptesicus serotinus* Schreber, 1774 or Pipistrelle bat *Pipistrellus pipistrellus* (Schreber, 1774) (Bogdanowicz, 2004).

Today, the northern boundary of the *P. kuhlii* range runs along the north-western France through Switzerland, southern Germany, Austria, southern Czech Republic, Hungary, and Romania to the north, Ukraine and south-western Russia. Some records are also known from the south coast of England (Bogdanowicz, 2004). *P. kuhlii* was noted in the winter even in the most northern parts of the European range, in the cities of Saratov and Izhevsk, Russia (Ilyin et al., 2003).

The expansion of *P. kuhlii* in Central and Eastern Europe is favoured probably by the presence of large river networks that can serve as natural migrations routes. The first discovery of this species comes from the valleys of major waterways: Dnipro, Dnister, Prut, Danube, Tisa, etc. This hypothesis can be supported by a statement of distribution directions (north and west) and the fact that the resettlement was faster found in low-lying plains of the rivers network (Hungary and Ukraine) than in mountainous regions (Romania and mountainous parts of Slovakia and the Czech Republic), where migration can be difficult because of natural barriers (Carpathians).

In our opinion, the appearance of *P. kuhlii* may be expected in the south-eastern part of Belarus as well as in the south-western regions of Russia adjacent to the Chernigiv region of Ukraine, where the species was discovered in the last decade (Gavris, Kotserzhynskaya, 2002). The situation in Ukraine indicates that *P. kuhlii* became typical species of urban areas, which inhabits different types of buildings during all the year. Shelters have been noted mostly in the crevices of buildings. Features of winter ecology of species are still poorly understood.

Savi's pipistrelle *Hypsugo savii*

Hypsugo savii is a typical element of the Mediterranean fauna of southern Europe. As well as it was found in the Canary Islands, North Africa, most of the Mediterranean islands and the northern part of the Near East. It also occurs in the Caucasus, Western Turkestan, in the north of Afghanistan and Kashmir. Until recent years the north border of the species distribution area ran from the Pyrenees, through the Central Massif, the Alps, northern Pannonia in Hungary and Slovakia within the European area (Dietz, Helversen, Nill, 2007; Horáček, Benda, 2004; Masson, 1999).

In Ukraine, till the 1990s, this species occurred in the Crimea, namely on the southern slopes of the Crimean Mountains (Dulitsky, 2001). It was common species

in this part of the Crimea (Uhrin, Gazaryan, Benda, 2009), but there are no data on the species occurrence in lowland steppe habitats of the peninsula.

Taking into account the dynamics of *H. savii* distribution in Central Europe, its appearance was predicted in the Transcarpathian region and in the western part of Ukraine (Bashta, Potish, 2007). For the first time *H. savii* was noted here by using the ultrasonic detector in 2009 (Bashta, 2012). During 2009-2013 the sonar signals of the species were recorded at eight sites in settlements of different levels (e.g., towns of Mukacheve, Uzhhorod, Berehove) and their surroundings.

So, during the last twenty years the northern boundary of the *H. savii* range has shifted to latitude of 50°N and this species was noted in almost all the Central Europe area (Poland, Austria, Czech Republic, Hungary, Slovakia etc.). *H. savii* was also found in different parts of Germany (Adorf, Starrach, 2010; Skiba, 2010) and the UK (Fisher, 1998). However, these records were usually considered as indirect influence caused by man, not associated with the natural range expansion. They come from towns located near the sea coast, thus, transportation of individuals with the goods conveyed from the southern European ports can not be excluded (Uhrin et al., 2016).

The multi-storey concrete buildings of large cities are the main shelters both for hibernation and creation of reproduction colonies of the species (Danko, 2007). Thus, adaption to the settlement in the urban landscape promoted the expansion of this species in the northern direction.

Discussion

Hibernation during the winter season is a physiological adaptation for survival in unfavourable climatic conditions and it is a very important phenomenon for many insectivorous bats, especially in temperate climatic zone (McNab, 1982).

Urbanization caused a loss of typical natural bat shelters, but at the same time it provided favourable alternative topical and trophic habitats. Hibernation torpor of bats is often not stable in underground shelters, especially in urban conditions. Winter activity with visual observations of individuals flying near entrance to the hibernation shelter is described in the literature for the Big Brown bat *Eptesicus fuscus* (Beauvois, 1796) (Brigham, 1987), *Pipistrellus pipistrellus* (Avery, 1985) and *N. noctula* (Zahn, Clauss, 2003).

It was ascertained that *N. noctula* demonstrated a significant activity in the shelters during the winter, even at temperatures below 0 ºC (Zahn, Clauss, 2003). In many European cities this species occurs throughout all the year in recent decades, but it occupies the concrete block buildings mainly in autumn and winter (Gaisler, Hanak, Dungel, 1979; Bashta, 2008). Such activity is often accompanied by the consumption of food during the winter months.

A significant shift of the northern range boundary was observed for many species in Europe, mainly for those that are able to fly or characterized by considerable mobility, such as insects, birds or mammals (see., Balbontin et al., 2008; Drees et al., 2011; Arnold et al., 2012 etc). It is believed that such phenomena are related to recent

climate changes (Battisti et al., 2005; Uhrin et al., 2016).

Thus, a significant expansion of the range in the north direction is showed by two bat species that belong to the Mediterranean fauna type: *P. kuhlii* and *H. savii*. Concerning the *P. kuhlii*, the numerous records of this behavior type in different parts of the European range are described in the literature (Strelkov, 2004; Sachanowicz et al., 2006; Wawrocka, Bartonicka, Reiter, 2012 etc). Spatial expansion of *H. savii* in Central Europe was observed in the beginning of 1990s (Spitzenberger, 1997; Reiter et al., 2010).

This process may be caused by two contrary directed factors. On the one hand, anthropogenic transformation of bat habitats impels them to move in urban environment due to loss of typical shelters. On the other hand, urban environment provides them with favourable topical and feeding habitats, which are alternative to natural ones.

In general, the reasons of *P. kuhlii* and *H. savii* range expansion have not been ascertained yet clearly. There are two hypotheses for explaination of this phenomenon. In particular, it may be connected with the general changes in the environment caused by current climate change. Such changes in the distribution area of some species were predicted by some models of bat distribution changes in the case of global warming processes (Rebelo, Tarroso, Jones, 2010). In addition, it is assumed that the reaction to some climate change is more characteristic for individuals of the populations of the northern border area of species distribution range, in contrast to individuals from the southern part (Anderson et al., 2009).

The expansion of these species can be also a result of continuing synanthropization and synurbanization processes. This hypothesis is confirmed by some research results concerning settling of bats, in particular, *H. savii*, in newly occupied areas. More than 67% of the observations of the species individuals come from urban areas (Uhrin et al., 2016).

However, it can be assumed that this phenomenon may be caused by some internal mechanisms in the population dynamics, but not be the answer, for example, on climate changes. Similar processes of northward expansion and colonization of new areas in the twentieth century are known for some synanthropic or relatively synanthropic birds like Eurasian collared dove *Streptopelia decaocto* (Frivaldszky, 1838), Syrian woodpecker *Dendrocopos syriacus* (Hemprich & Ehrenberg, 1833) (Hagemeijer, Blair, 1997). In any case, successful spatial expansion of *P. kuhlii* and *H. savii* in Europe could not happen without a high level of ecological, topical and trophic plasticity of these species. The most likely, the process of range expansion of *P. kuhlii* and *H. savii* is a result of joint influence of these factors.

Supposedly, changes in the seasonal behaviour of some other bat species can be also considerably caused by global climatic processes. This particularly concerns the *N. noctula* і *V. murinus*, which show the similar behaviour changes. Thus, one of the possible causes of wintering of this species in our latitudes may be softening the winter climatic conditions in recent decades in Europe. It may also be due to

later beginning of hibernation in some species that we observe, in particular in *V. murinus*. Thus, in 2016 this species showed a considerable flight activity until the middle of November to the beginning of a strong snowfall. During the monitoring the animals hunted actively in a day before a sharp declining of air temperature and snowfall. Undoubtedly, these individuals belong to the bat wintering group in Lviv city. Herewith, in a few days the species were found at the transect again, when the average daily temperature increased up to 5-8 °C.

Origin of species that were recorded during the autumn-winter period, remains unclear (they may be migrants or belong to the local sedentary population). Also it is assumed (Fleming, Eby, 2003) that both the choice of wintering regions and the availability of long-distance seasonal migrations can be a feature of some populations, but not for some species in general.

In the summer *V. murinus* is a relatively rare species for the territory of Lviv city and the Western Ukraine (Bashta, 2010 a). Timeframe stability of mass appearance of individuals of this species during the migration period suggests that they come from quite remote areas. The origin of migratory individuals can be determined by non-invasive methods, for example – analysis of stable isotopes (Rubenstein, Hobson, 2004).

Probably, there is a phenomenon described by P. Strelkov (2002) that some of *N. noctula* individuals (and, apparently, *V. murinus*) make the attempts to hibernate in a climatic "risk" zone. In cold winters, such attempts will probably lead to the elimination of animals, but in case of possible global warming or finding appropriate shelter for the wintering, they may contribute to settling the new hibernation areas and lead to the creation of sedentary populations.

Concrete block buildings are the temporary shelters during migration or important hibernacula for analyzed bat species almost everywhere in Europe. However, wintering of the bats in buildings may often cause the conflicts "bat-man" (noise, presence of excrements, penetration of bats in the apartments and stairwells).

So, today we observe a process of active adaptation of bat species, stipulated by the use of cracks and crevices in multi-story buildings as an alternative to natural clefts in the rocks that are typical shelters for bats, including many Mediterranean species. However, adaptation of forest species, *N. noctula*, to the settling in urban areas is an interesting and still unexplored phenomenon.

Thus, it seems, that current expansion of these species has evolved because of their ability to hibernation in urban areas using concrete multi-storey buildings, primarily to survive in the harsh winter conditions. The cities, in particular, with relatively large area, can provide the comfortable shelters with certain microclimatic characteristics (Arnfield, 2003). Such adaptation to living in urban environments promotes the conservation and efficient spending of energy reserves by bats and causes certain changes in their behaviour and some phenological aspects of their life (Neuweiler, 2000).

Conclusion

Increase of the degree of environment urbanization caused adaptation of some bat species to the settling in constructions of anthropogenic origin.

Long-distance migrants *Nyctalus noctula* and *Vespertilio murinus* have adapted to wintering in temperate latitudes due to settlement and hibernation in concrete panel buildings of large cities. They show visible seasonal change of behaviour patterns that can be caused by global climatic processes.

Species belonging to the Mediterranean fauna type, *Pipistrellus kuhlii* and *Hupsugo savii*, demonstrate a significant range expansion in the northern direction. The expansion of these species can be also a result of their synanthropization and continuing synurbanization processes.

There are two suggestions concerning the factors which caused this process. The loss of typical shelters, anthropogenic transformation of habitats impel the bats to move in urban environment. At the same time, urban environment provides them with favourable topical and forage habitats, alternative to natural ones.

The current expansion of these bat species has evolved through their adaptation to settling in concrete buildings to survive the harsh winter conditions. Relatively large cities can provide appropriate shelters with favourable microclimatic characteristics. To some extent, these places are alternative to natural shelters in rocks for settlement of bats.

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ЗМІНИ МІГРАЦІЙНОГО АЛГОРИТМУ ТА ПРОСТОРОВА ЕКСПАНСІЯ РУКОКРИЛИХ ЯК ВІДОБРАЖЕННЯ АДАПТАЦІЙ ДО ІСНУВАННЯ В УРБАНІЗОВАНОМУ ЛАНДШАФТІ

А.-Т.В. Башта

Адаптації чотирьох видів кажанів (вечірниці дозірної *Nyctalus noctula* Schreber, 1774, лилика двоколірного *Vespertilio murinus* Linnaeus, 1758, нетопира середземноморського або білосмугого *Pipistrellus kuhlii* Kuhl, 1817 і нетопира кажановидного або гірського *Hypsugo savii* (Bonaparte, 1837)) до існування в урбанізованому середовищі досліджували в західній частині України. Ці види представляють дві групи, що істотно різняться як походженням, так і характером адаптацій до урбосередовища. Дальні мігранти – *N. noctula* і *V. murinus*, адаптувалися до зимівлі в помір-

них широтах завдяки оселенню та гібернації в блочних будівлях великих міст. Вони проявляють очевидну зміну сезонних поведінкових стереотипів, яка може бути зумовлена глобальними кліматичними процесами.

Види, що належать до середземноморського типу фауни: *P. kuhlii* та *H. savii,* продемонстрували істотне розширення ареалу в північному напрямі. Експансія цих видів також може бути наслідком процесу їх синантропізації і триваючої синурбанізації.

Сучасна експансія цих видів кажанів розвинулася завдяки їх адаптації до поселення переважно у бетонних будівлях (які з'явилися в останні кілька десятків років) для переживання суворих умов зимового періоду, оскільки саме відносно великі міста можуть надавати кажанам комфортні схованки з оптимальними мікрокліматичними характеристиками. Процес адаптації досліджуваних видів зумовлений використанням тріщин і щілин у багатоповерхових будівлях як альтернативи розколинам у природних скелях, які є традиційними місцями поселення, зокрема, багатьох середземноморських видів.

Ключові слова: Chiroptera, адаптація, урбосередовище, Україна

ИЗМЕНЕНИЯ МИГРАЦИОННОГО АЛГОРИТМА И ПРОСТРАНСТВЕННАЯ ЭКСПАНСИЯ РУКОКРЫЛЫХ КАК ОТОБРАЖЕНИЕ АДАПТАЦИЙ К СУЩЕСТВОВАНИЮ В УРБАНИЗИРОВАННОМ ЛАНДШАФТЕ

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Адаптации четырех видов рукокрылых (ночница рыжая *Nyctalus noctula* Schreber, 1774, кожан двуцветный *Vespertilio murinus* Linnaeus, 1758, нетопырь Куля *Pipistrellus kuhlii* Kuhl, 1817, нетопырь кожановидный *Hypsugo savii* (Bonaparte, 1837)) к существованию в урбанизированной среде исследованы в западной части Украины. Эти виды представляют две группы, которые существенно отличаются как происхождением, так и характером адаптаций к урбосреде. Дальние мигранты, *N. noctula* и *V. murinus,* адаптировались к зимовке в умеренных широтах благодаря поселению и гибернации в блочных строениях больших городов. Они проявляют заметную смену сезонных поведенческих стереотипов, которая может быть обусловлена глобальными климатическими процессами.

Виды, принадлежащие к средиземноморскому типу фауны: *P. kuhlii* и *H. savii,* продемонстрировали существенное расширение ареала в северном направлении. Экспансия этих видов также может быть следствием процесса их синантропизации.

Современная экспансия этих видов летучих мышей происходит благодаря их адаптации к поселению в основном в бетонных строениях (которые появились в последние несколько десятков лет) для переживания суровых условий зимнего периода, поскольку именно относительно большие города могут предоставлять им комфортные укрытия с оптимальными микроклиматическими характеристиками. Процесс адаптации исследуемых видов обусловлен использованием трещин и щелей в многоэтажных строениях как альтернативы расщелинам в естественных скалах, которые являются традиционными местами поселения, в частности, многих средиземноморских видов летучих мышей.

Ключевые слова: Chiroptera, адаптация, урбосреда, Украина

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