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Factors Affecting Activity Patterns of the Whiskered Bat *Myotis mystacinus* (Kuhl, 1817) (Chiroptera: Vespertilionidae) in the Western Carpathians, Poland

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Abstract: We applied radio-telemetry on 21 individuals (10 females and 11 males) to provide data on the temporal activity patterns of the whiskered bat (*Myotis mystacinus*) in the Carpathian Mountains (southern Poland). We tested whether sex, season and weather conditions affect their activity patterns in July-September. On average, whiskered bats left day roosts 18.9 minutes after sunset and returned to roosts 198.1 minutes before sunrise. The mean length of activity was 330 minutes (SE±25) per night. Bats were active mainly (85%) during the whole night; they rarely (15% of nights) interrupted foraging and returned to their roosts for 10-60 minutes. Their activity peaked between the 2nd and the 3rd hour after sunset, when 76% of individuals foraged. Duration of activity varied between sexes. In females, it was one hour longer and noticeably increased from July to August. Males, but not females, shortened their activity again in September. However, due to high individual variation, differences in activity patterns between sexes were insignificant. Mean night temperature (positive effect) and duration of rainfalls (negative effect) best explained the variation in whiskered bats' activity. Our study delivered further evidence of the importance of weather conditions for the foraging activity of insectivorous bats in temperate environments.

Key words: male and female bats, foraging activity, temporal variation, weather conditions

Introduction

Bats are a very diverse group of mammals (Wilson & Mittermeier 2019) with a profound impact on numerous natural processes (Kunz & Fenton 2005). The gravity of both ecosystem services and disservices delivered by bats to humans is widely recognised (Boyles et al. 2011, Puig-Montserrat et al. 2015, Letko et al. 2020). However, due to the nocturnal lifestyle of bats, their hardly accessible roosts and overall elusiveness, there are still insufficient data on some aspects of their ecology, which

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makes planning conservation and management activities quite challenging (Voigt & Kingston 2016, Frick et al. 2019).

In insectivorous bats, high energy demand connected with reproduction is reflected in the rapid increase of food consumption by lactating females (Anthony & Kunz 1977, Kurta et al. 1989). At the same time, male bats, which do not care for offspring, experience less physiological stress. Their energy demands increase in mid-summer due to the spermatogenesis and mating period (Encarnação et al. 2004a, 2004b, Becker et al. 2013). In consequence, noticeable discrepancies in flight activity among female and male bats are expected to occur (Wilkinson & Barclay 1997, Dietz & Kalko 2007). As weather conditions modify food availability for insectivorous bats, they must adequately alter their foraging activity (Racey & Swift 1985, Peng et al. 1992).

The whiskered bat (*Myotis mystacinus*) is one of the most common bat species in Europe (Dietz et al. 2009). This small insectivorous species seeks food mostly in cluttered habitats, i.e. forests, vegetation along banks of waters and patches of woods within farmlands (Kaňuch et al. 2008, Buckley et al. 2013, Kurek et al. 2020). It hibernates mainly in caves (Mysłajek et al. 2007, Piksa et al. 2013) but chooses buildings for roosting (Buckley et al. 2013, Kurek et al. 2020).

We used radio-telemetry to record data on the daily activity of the whiskered bat in a human-dominated fragment of the Polish Western Carpathians, where the species is especially abundant (Kurek et al. 2017, 2020). We tested whether sex, season and weather conditions affect their activity patterns in July-September.

Materials and Methods

Study area

The study area (70 km^2) was situated in fragments of the Silesian Beskid Mountains and Żywiec Basin (N49°40'01" E19°04'35") in the Western Carpathian Mountains (southern Poland). Climatic parameters of the area depend on the altitude, which varies from 250 to 1,257 m a.s.l. (Table 1) (Durło 2012). In the past, the foothills (<670 m a.s.l.) of the Western Carpathians were covered with broad-leaved forests with a dominance of oaks (*Quercus* ssp.), limes (*Tilia* ssp.) and hornbeam (*Carpinus betulus*). Mixed forests at the lower montane zone (670-980 m a.s.l.) consisted mainly of beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*) and fir (*Abies alba*), while in the upper montane zone (>980 m a.s.l.), the Norway spruce (*Picea abies*) prevailed. After centuries of human pressure, however, the landscape has changed dramatically due to deforestation, the development of agriculture and the expansion of human settlements. Nowadays, the foothills consist primarily of farmlands and built-up areas, with small patches of woods covering banks of watercourses and peaks of more prominent hills. Montane zones remain forested but the composition of tree species has changed. Modern managed stands are heavily dominated by Norway spruce (Grodzińska & Szarek-Łukaszewska 1997, Main-Knorn et al. 2009). Human population density (147 people/km^2, Statistics Poland 2018) is among the highest along the Carpathian Mountains.

Despite substantial human pressure, the biodiversity of the region is relatively high. The Silesian Beskid Mountains are protected as both a landscape park and a special area of conservation of the EU Natura 2000 network of protected areas (Niedziałkowska et al. 2006, Mysłajek et al. 2009, 2012, Rożen et al. 2013, Diserens et al. 2017). The study area offers suitable foraging areas and both summer and winter roosts for bats; thus, the local bat diversity is relatively rich, with the whiskered bat being one of the most abundant species well adapted to human-dominated landscape (Mysłajek et al. 2007, Kurek et al. 2017, 2020).

Radio-telemetry

We captured with mist-nets 33 individuals (15 females, 18 males) between June and September 2009-2011, but for the analysis, we used data obtained from 21 individuals (ten females, 11 males) as one bat spent most of the time in the roost due to rainfalls, while 11 individuals dispersed (see Kurek et al. 2020 for further details). We trapped bats with mist-nets erected mainly along banks of waters, near caves and breeding roosts. All individuals were subjected to genetic analysis based on mtDNA sequence, which confirmed the accuracy of the species identification (Bashta et al. 2011). We marked the captured bats with metal bands (Porzana, UK) and equipped them with radio-telemetric transmitters (BD-2N, Holohil, Canada or PIP4, Biotrack, UK), the mass of which (0.30 g and 0.39 g) corresponded to 4-7.8% of bat body mass, respectively. Transmitters were attached with surgical glue (Torbot, USA) on a shaved area between the shoulders. The examination of two individuals recaptured one year after the telemetry study proved that the transmitter dropped off when the fur had fully regrown.

Table 1. Characteristics of the climatic zones in the Western Carpathian Mountains (after Durło 2012).

Parameters	Altitude [m a.s.l.]			
	250–500	**501–750**	**751–1000**	**1001–1250**
Mean annual temperature (°C)	7.4	6.2	5.3	3.7
Annual precipitation (mm)	1000	1090	1250	1360
Durability of snow cover (days)	85	116	138	154

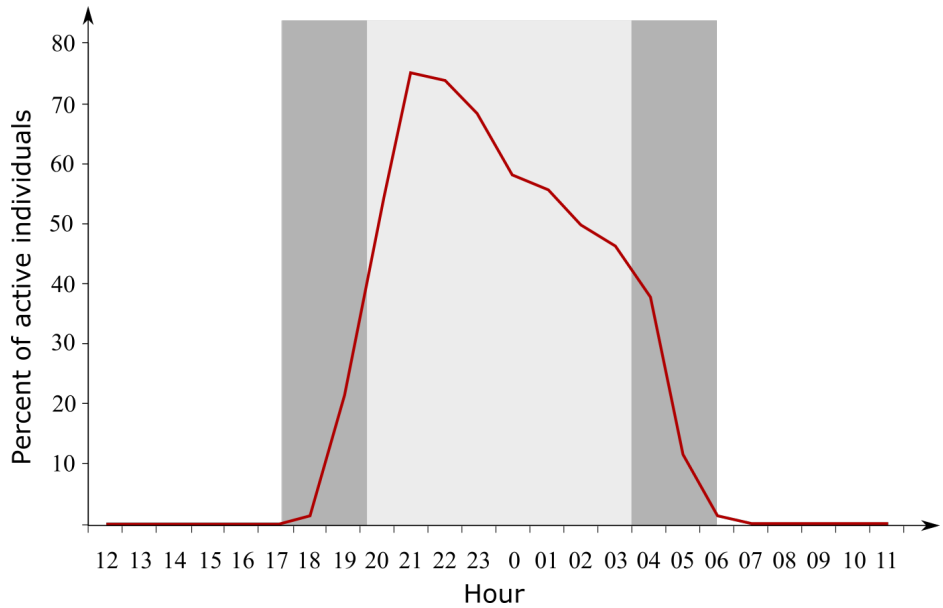

Fig. 1. Daily activity pattern of the whiskered bats in the Western Carpathians, Poland, revealed with radio-telemetry. Universal time (UT+1). Light grey indicates night hours, dark grey – seasonal changes in sunrise and sunset.

We tracked the marked bats with an antenna (RA-14, Telonics, USA or YAGI-AY/C, Titley Electronics, Australia) and VHF radio receiver (VR-500, Yaesu, Japan). The locations of the tagged bats were determined by triangulation with 2–3 fixes. We attempted to get bat positions at least every 15 minutes from dusk until dawn.

Research procedures were reviewed and approved by the 1st Local Ethical Commission for Animal Experiments in Warsaw (Poland), while the Regional Directorate for Environmental Protection in Katowice (Poland) granted a permit to capture and mark bats.

We applied the Mann-Whitney U test to reveal differences in the duration of activities between bats of different sexes and the G–test of goodness-of-fit to check for differences in their activity patterns. We also performed multiple regression analyses to assess the impact of temperature and rainfall on bat activity (Sokal & Rolf 1995).

Results

We observed the overnight activity of the whiskered bats for 96 individual-nights. Bats rarely stayed in roosts all night (8% of cases). For 73 individual-nights we recorded detailed night activity (without any gaps). Bats left their day roosts on average 18.9 minutes after sunset (SE±1.7, range 0-113, n=87 individual-nights). Males did it slightly earlier than females (mean 18.6, SE±2.3, range 0-63, n=43 and mean 19.3, SE±2.6, range 0-113, n=44, respectively), but the difference was statistically negligible (U Mann-Whitney test, W=974, NS). Whiskered bats returned to roosts on average 198.1 minutes before sunrise (SE±26.4, range 0-658). Males did it on average 96 minutes earlier than females (mean 239.4, SE±37.9, range 2-658 and mean 143.5, SE±33.2, range 0-578, respectively). Due to wide individual variation, this difference was marginally insignificant (W=371.5, p=0.053). Bats were mostly active during the whole night (71% of nights) and the return to roosts ended their foraging efforts, but sometimes (18% of nights), they interrupted foraging, came back to their roosts for 10-60 minutes and then left again. Such interruption of foraging was recorded nine times for females and four times for males.

From May to September, whiskered bats were active from 17.00 to 5.00 h (universal time; Fig. 1).

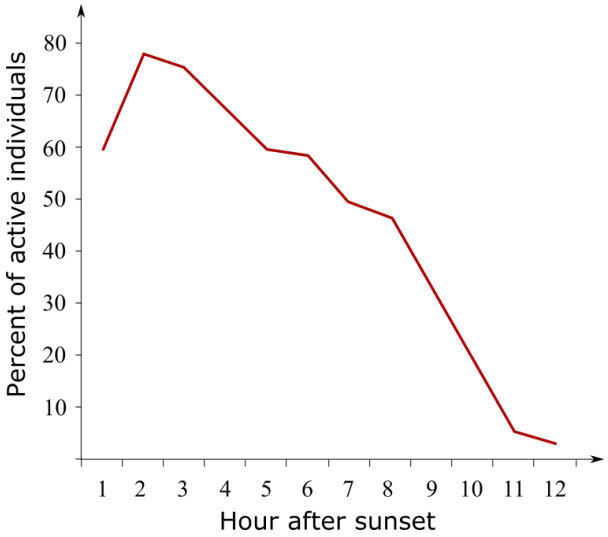

Fig. 2. Night activity pattern of whiskered bats in the Western Carpathians, Poland, revealed with radio-telemetry.

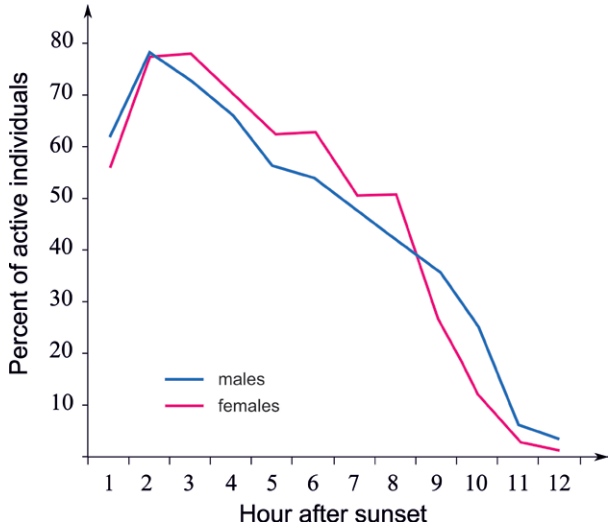

Fig. 3. Night activity patterns of male and female whiskered bats in the Western Carpathians, Poland, revealed with radio-telemetry.

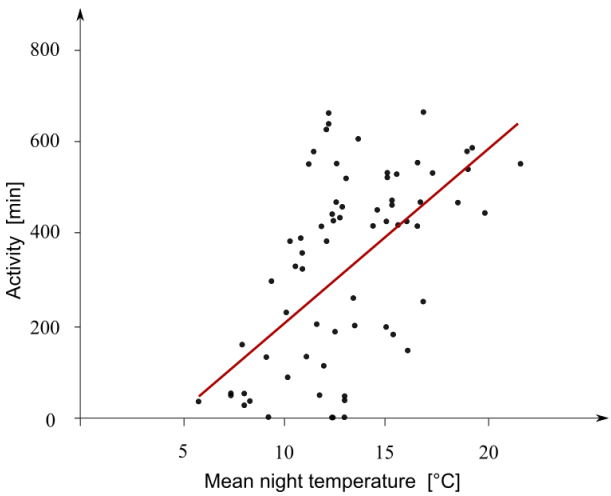

Fig. 4. Relationship between the length of activity of whiskered bats and mean night temperature in the Western Carpathians, Poland. Each point denotes one night of radio-tracking and individual male or female bat.

Their activity peaked during the 2nd and 3rd hour after sunset, when 76% of individuals foraged (Fig. 2). During the 7th-8th hour after sunset, only 47.5% of individuals stayed on the foraging grounds, while during the 12th hour after sunset, only 2.5% of them were still active. Such long foraging occurred only in September and accounted for 20% of nights during which we conducted radio-telemetry. Activity patterns varied between sexes (G test, G=506.8, $p<0.01$), being one hour longer in females (Fig. 3).

Overall, the mean length of the whiskered bat activity accounted for 330 minutes per night (SE±25 minutes). It substantially increased from 250 mins (SE±39, n=26) in July to 428 mins (SE±29, n=26) in August and then dropped to 310 mins (SE±55, n=23) in September. For females alone, however, the length of activity increased from 237 mins (SE±46, n=19) in July to 406 mins (SE±46, n=12) in August and stayed high also in September, when it averaged 456 mins (SE±92, n=6). At the same time, the activity of males increased from 284 mins in July (SE±76, n=7) to 458 mins (SE±38, n=14) in August and decreased in September to 259 mins (SE±63, n=17). Yet, due to high individual variation, those differences remained statistically insignificant.

Mean night temperature and duration of rainfalls best explained changes in the activity of whiskered bats (R^2=0.48, n=73, $sr^2_{Temperature}$=0.28, sr^2_{Rain}=0.20). Bats prolonged their activity with increasing temperature and shortened it during rainfall. Both factors explained 54% of female activity (R^2=0.54, n=33, $sr^2_{Temperature}$=0.24, sr^2_{Rain}=0.23) and 47% of male activity (R^2=0.47, n=40, $sr^2_{Temperature}$=0.33, sr^2_{Rain}=0.16). The temperature was the more important of the two factors (as evidenced by the semi-partial correlations squared sr2). The lowest temperature at which whiskered bats followed with radio-telemetry were active was 6°C (Fig. 4).

Discussion

The peak in the activity between the 2nd and 3rd hours after sunset was frequently recorded among various bat species (Kunz 1974, Taylor & O'Neill 1988; Zielinski & Gellman 1998). Bats usually stay active throughout the night, but their return to shelters can be initiated by bad weather conditions or the necessity to nurture offspring in the case of females.

For example, in Ireland, lactating female whiskered bats paused foraging and returned to roosts (Buckley et al. 2012). Our study showed that bats, when not forced by external conditions, foraged for the whole night and after having returned to the shelter, they rarely left it again. The exceptions were associated with lactating females, which paused activity to nurture offspring, as we assumed. In the Western Carpathian Mountains, whiskered bats were active on average for 5.5 hours (23% of the day) during 53% of nights. Studies conducted in Germany on females of Daubenton bats *M. daubentonii* showed similar results (60% nights; Encarnação et al. 2006).

The analysis of the seasonal pattern of whiskered bat activity on their foraging grounds confirmed the stable presence of this species in the Western Carpathians from spring (April) until the beginning of autumn (September). The noticeable decrease in the activity of females in the second half of July was most probably caused by parturitions and the necessity of intensive care for new-borns. Probably after parturitions, females did not forage and used their fat reserves. The peak in activity of females in the second half of June was parallel with lactation, when females intensively forage to sustain their higher energetic needs connected with nurturing their offspring. When offspring became self-reliant (in the second half of July), the number of females in foraging grounds decreased, probably because they were leaving the breeding areas. Adult males stayed active on foraging ground longer, from the second half of June until the first half of July, most likely caused by the need to accumulate energy for mating that started in the second half of July.

Ongoing global climatic changes affect various aspects of bat ecology (Costa et al. 2018, Haest et al. 2020, De Bruyn et al. 2021). Our study delivered further evidence of the importance of weather conditions for the foraging activity of insectivorous bats in temperate environments. The main factors shortening the time bats stayed foraging were low temperatures during the night and prolonged rainfalls. Bats are affected by low temperatures directly due to the unfavourable ratio between mass and surface of their bodies and indirectly, as they forage on ectothermic prey, the activity of which is heavily affected by weather conditions (Humphrey et al. 1977, Anthony et al. 1981, Grindal et al. 1992, Lewis 1993). Rainfalls may influence bat activity by accelerating heat deprivation (Tuttle & Stevenson 1982), disrupting echolocation (Griffin 1971) and decreasing the number of flying insects (Anthony et al. 1981). Our study showed that bat activity was terminated when temperature dropped below 6°C. Such mean temperature during the night may be a crucial factor initiating bat hibernation.

Conclusions

Our study provides further evidence of the impact of weather conditions on night activity patterns of insectivorous bats in temperate environments. The full effect of changing weather parameters on bat fitness requires further investigation, including different bat species and populations. This information is essential for guiding conservation efforts in light of ongoing climate change and for preserving the ecosystem services provided by bats (Festa et al. 2023, Russo et al. 2024).

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