Research Article

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Influence of Tourists on the Summer Bat Colonies in the Devetashka Cave, Bulgaria

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Abstract: Microchiropteran bats, in particular cave dwellers, are adversely affected by human activity. In this connection, we assessed the state of the bat colonies in relation to tourist abundance and behaviour in the Devetashka Cave, Bulgaria. The cave is of European importance for bat conservation and houses more than 10,000 bats in the summer. However, during the weekends it is subject to an enormous tourist flow consisting of 500–1000 persons per day. In order to estimate the tourist factor, the number of people, whether flashlights and photoflashes were used and the maximum noise produced were recorded during observation sessions. Bat abundance, activity and adult and juvenile mortality were recorded in order to track the condition of the bat colonies. We discovered a strong positive relationship between the number of visitors to the cave and bat mortality ($r = 0.569$, $P < 0.05$). Light was the tourist factor with highest negative influence on the colonies. The extent of tourist influence on the bats is discussed and necessary measures to reduce it are suggested. Cave tours will need a special consideration, so that they can be designed to minimize as much as possible the detrimental effect human activity has on bats, thus the visitation regime of the Devetashka Cave will be revised based on the findings of this study.

Key words: bats, cave, human, anthropogenic, influence

Introduction

Caves are some of the most important habitats for bats, whether that was as a shelter, hibernation site or a reproduction site. Bats on the other hand are a main source of energy through nutrients for the other inhabitants of the caves (Vandel 1965, Gunn 2004, Biswas 2009, 2010). Even though bats are beneficial to ecosystems around the world, and are often keystone species, it is estimated that 3.5% of the world's bat species are either extinct or endangered (IUCN 2016). Most of the scientific research of cave bat species worldwide (Wilkinson & Boughman 1998, Wilkinson & South 2002, Berková & Zukal 2006, Meteyer *et al*. 2006), and in Bulgaria, focuses on the physiology, ecology and taxonomy of the bats (Pandurska & Beshkov 1998, Schunger *et al*. 2004, Pandourski & Karaivanov 2007). Data of the anthropological influence on cave bats and the impacts of tourism in particular are scarce. According to Duffus & Dearden (1990), wildlife tourism includes three dimensions: (1) consumptive (hunting, fishing, etc.); (2) low consumptive (zoos, aquariums, etc.); and (3) non-consumptive (wildlife watching, photography, etc.). Although some bat species respond well to tourism initiatives, other species, such as some cave-roosting bats, are vulnerable to disturbance in their roosts, especially during hibernation and the breeding season (Thomas 1995). In this relation Speakman *et al.* (1991) establish that the direct sources of disturbance (catching the bat) as well, as the non-tactile disturbances (flashlights, photoflashes, noise) lead to loss of energy during the hibernation period. Even more, during hibernation, human disturbance can exacerbate weight loss, resulting in mortality (Johnson *et al.* 1997, Tuttle 1994). Comparing the abundance of bats in two caves at the Kanger Valley National Park in India, which have become a major tourist

attraction, with data from previous years, Biswas *et al*. (2011) discover that there is a significant decrease in bat numbers. Alterations in bat behaviour due to a summer music festival are reported by Shirley *et al*. (2001) with a *Myotis daubentonii* colony in North England, as well as, tourist-related effects were reported over the breeding colonies of *Corynorhinus rafinesquii* in a rock shelter in Kentucky. Thomas (1995) also establishes that hibernating *Myotis lucifugus* and *Myotis septentrionalis* in an abandoned mine hibernaculum in Windsor, Quebec, are sensitive to non-tactile human disturbance. Even more direct observations of the behaviour of disturbed cave bats can be found in the study of Mann *et al*. (2002). They investigate the behavioural reactions of a breeding colony of around 1000 *Myotis velifer* to experimental tours of the cave. It is established that light intensity is the most significant factor, with highest bat activity observed in strong white light. The number of bat take offs and landings is also influenced by whether the tourists were talking. There are no similar studies in Bulgaria. The combination of easy access to most major bat caves in Bulgaria and the lack of knowledge on this subject make such research critical to bat conservation, which is also the case with the Devetashka Cave.

The cave is home to 15 bat species, whose total abundance reaches over 10 000 individuals in the summer and 35 000 in the winter (Petrov 2014). Because of its attractiveness and easy access, the Devetashka Cave is one of the 100 national tourist sites and its importance as a regional attraction is constantly increasing. In the last few years the number of visitors varies around 500–1000 persons per day. The increasing popularity of the cave inevitably leads to an increase in the tourist flow and thus an increase in the related influence over the bats. Under a specifically high negative influence are the summer bat colonies, because the reproductive season of the bats coincides with the busiest tourist period (May – August). In this relation, the purpose of this study is to investigate the influence of the tourists on the abundance, mortality and activity of the summer bat colonies in the Devetashka cave. Based on the revised literature and available data on the subject, it can be presumed that the flow of visitors has a significant influence over the bat colonies in the cave.

Materials and Methods

Research period. The study was conducted in the Devetashka Cave (N43.233719, E24.885422) over the months May, June and July 2016. The field observations were conducted every second week: 1. on Saturday and Sunday, as these were the busiest for tourist flow days and 2. on Monday, so that there is a control "quiet" day, when there are very few visitors or there are none. The length of the field day was 8 hours. Bat data collection was twice a day – before the visitor flow begins (08:30 h) and around the end of the tourist day (after 16 h). This approach was selected, so that the state of the bat colonies can be estimated before and after the human factor.

The tourist observations were conducted around two spots – the entrances of the Dry and the Water Gallery (Fig. 1). Data for the actions of the tourists was collected in observational sessions of 30 minutes each, with 5 minutes time after each session, so the observer can relocate to the other gallery. There were 10 sessions per day in total, five sessions for each gallery.

Bats in the Devetashka Cave. The Devetashka Cave is among the three most important bat shelters in Bulgaria. According to data from recent years, the cave is used as a hibernaculum by more than 35 000 bats of 5 species. In the summer the bat abundance can vary between 5000–10,000 individuals of 12 bat species (*Hypsugo savii, Miniopterus schreibersii, Myotis blythii, Myotis capaccinii, Myotis daubentonii, Myotis emarginatus, Myotis myotis, Myotis nattereri, Nyctalus noctula, Rhinolophus euryale, Rhinolophus ferrumequinum, Rhinolophus mehelyi*) (Petrov 2014, 2015).

Previous research shows that the upper Dry Gallery is the roosting site for the breeding *Myotis myotis* and *Myotis blythii*, whose abundance in recent years has been around 2500-3000 individuals. A mixed colony of around 500 individuals of *Rhinolophus euryale, Rhinolophus ferrumequinum* and *Rhinolophus mehelyi* is often observed in the Dry Gallery and sometimes in the high ceiling cavities of the Water Gallery. The abundance of *Miniopterus schreibersii* varies between 2000 and 6000 individials. They can be found in both Dry and Water Gallery. Data for the reproductive colonies of *Myotis daubentonii, Myotis emarginatus, Myotis nattereri, Hypsugo savii* and *Nyctalus noctula* is too scarce. We only know that their colonies are located in the inaccessible dark crevices of the highest ceilings near the galleries' entrances (Petrov 2014).

Assessment factors. 1. Two main factors of the state of the bats were considered during the evaluation of the tourist impact – relative abundance and mortality. The bats relative abundance was estimated in two ways: through direct count of individual bats and bats in small groups, and through photo count of the larger colonies. The abundance was recorded

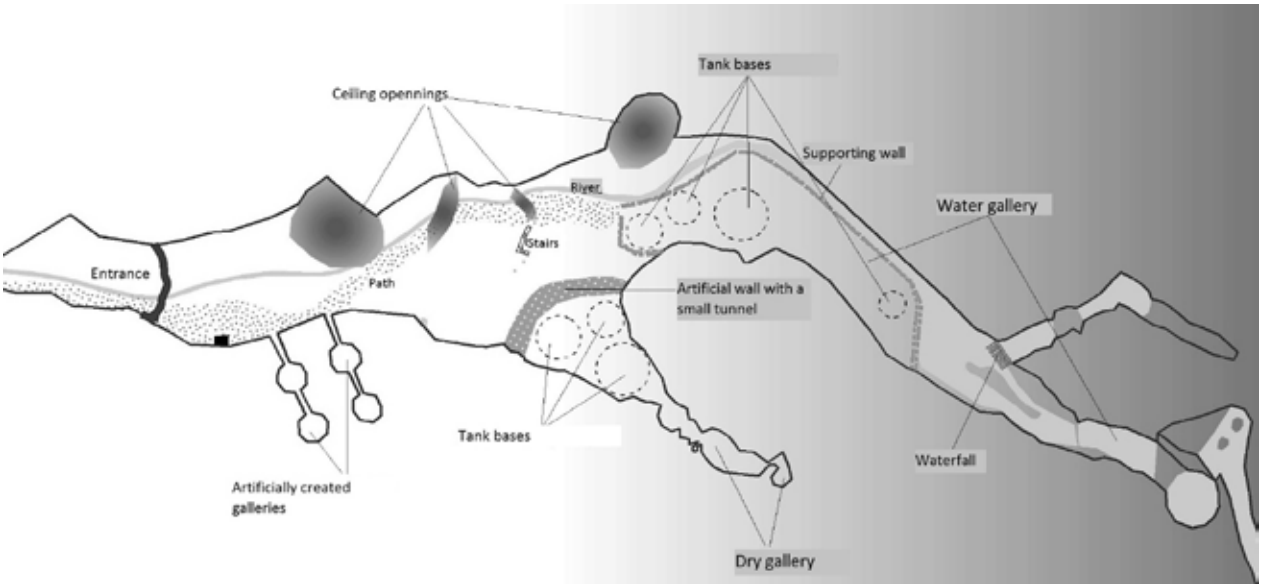

Fig.1. Map of the Devetashka Cave with marked objects and galleries

in total for all species. Noted was the movement of the colonies in the galleries. The abundance of the bats was recorded in the morning (08:30) and in the late afternoon, around 16 o'clock. In this manner it was ensured, that the natural increase in bat activity, as they are preparing to leave the shelter before sunset was excluded. The photos were taken with a D-SLR Canon camera set on a tripod. Only 1 photo of each colony was taken per count and the bats were under light for no more than 5-10 seconds, in order to bring the observer-related disturbance to the bats to a minimum. It must be noted that due to the structure and size of the cave, this method does not encompass all bats present in the cave and thus the estimated abundance can be considered relative. Similarly to the abundance, the estimated mortality was summed for all bat species. A count of the dead bats near every colony was taken in the morning and late afternoon, as the dead individuals were set aside in order to prevent a second count of the same bat on the next day. Temperature measurements were taken in each gallery as an additional abiotic factor.

2. In order to estimate the influence of tourists over the summer bat colonies in the cave, the following indicators were measured:

Time (in minutes) of a session, during which there were tourists in the gallery.

The number of photoflashes produced by tourists in a session. Included were only the photoflashes of photos taken near the entrance of the dark and semi-dark spots of the galleries or near a bat colony.

The maximum strength of the sound produced by tourists (through speaking, clapping, whistling etc.) for each session. Sound was measured with a decibel meter throughout the whole session and not more than 3 metres away from a tourist group.

Other actions or factors with a potentially negative influence on the bats. Here whether the visitors used a flashlight was considered, as a faint flashlight was categorized as 1 and a strong flashlight was categorized as 2.

Data on the total amount of tourists per day was provided by the parking guards who take entrance fees to the cave. Observation of the visitors' behaviour was conducted without influencing their behaviour in any way.

Statistical analysis of the data. By subtracting the morning abundance from the evening abundance, we established whether the number of the counted bats has increased or decreased during the day. The normal distribution of the data was tested with Shapiro – Wilks test. All tested variables - number of tourists per day ($P=0.058$); number of photoflashes per day ($P=0.053$); number of dead bats per day ($P=0.052$) and average noise level per day ($P=0.15$) followed a normal distribution. Thus, Pearson correlation was used to examine the relation between the number of tourists, and their activities, and the mortality of the bats. Data is presented as averages and standard errors. All data was analysed using Minitab version 17 statistical software.

Results

Throughout the study bat colonies from three genera were established – *Rhinolophus*, *Myotis* and *Miniopterus*. The dark zone of the Dry Gallery (more specifically – a higher spot, accessible through a

short, steep path) was the main region where large breeding colonies were found. The area is preferred for the raising of young, since the temperature there is considerably higher with around 1.5°C – 2°C, than the Water Gallery. The Dry Gallery, however, is also smaller and more open, which makes it easily accessible for the visitors. Even though, there was no significant correlation between the change in bat abundance and the number of tourists ($r = 0.333$; $P > 0.05$), there was a considerable trend of decrease in bats numbers on Saturday and Sunday compared to Monday (Fig. 2).

The established mortality for the study period was 525 bats of the genera *Rhinolophus, Myotis* and *Miniopterus*. Around 85% of the dead bats were either new-born babies or juveniles (5-10 days old). The adult bat mortality cannot be accurately estimated because of their high mobility. A lot of the dead adults were located away from the colonies.

Data from this study shows that the highest number of tourists is on Sunday, followed with a small difference by Saturday, while there were very few visitors on Monday (Fig. 3). The highest number of visitors was recorded on 12.06.2016 (Sunday) – 665 tourists. The lowest number of visitors was on 11.07.2016 (Monday) – 31 tourists.

The trend in bat mortality follows closely that of tourist numbers. Highest mortality is established on Sundays, while on Mondays dead bats were rarely found (Fig. 4).

A significant, positive correlation was established between the bat mortality and the number of visitors ($r = 0.569$, $P < 0.05$), where, as the number of tourists increases, so does the number of dead bats (Fig. 5). The standard error of the estimate is 6.64, while the 95% confidence interval was 0.122 to 0.824. Of main interest was also how the use of white light influences the colonies. A significant, positive correlation was established ($r = 0.602$, $P < 0.05$) between the number of photoflashes used and the bat mortality (Fig. 6); the standard error of the estimate was 6.45, while the 95% confidence interval was 0.171 to 0.839. Naturally, the number of photoflashes is a derivative of the amount of tourists present and was increasing with the higher number of visitors. These relatively wide confidence intervals are most probably due to the small number of samples, as a longer sampling period would certainly improve on the confidence of the estimate.

The established noise levels varied in the range 65–80 dB. These relatively constant levels are most likely due to the high noise dispersion in the massive halls of the cave. There was no significant correlation between the noise levels and the bat mortality ($r = 0.456$, $P > 0.05$). Observations showed, however, that the visitors did not limit in any way the intensity level of their speech, as especially loud were children. A large part of the tourists were clapping, whistling and shouting in order to test the acoustics of the cave. An additional source of noise represented pets carried into the cave, especially dogs.

Temperatures in the galleries were relatively constant and varied only slightly related to time of

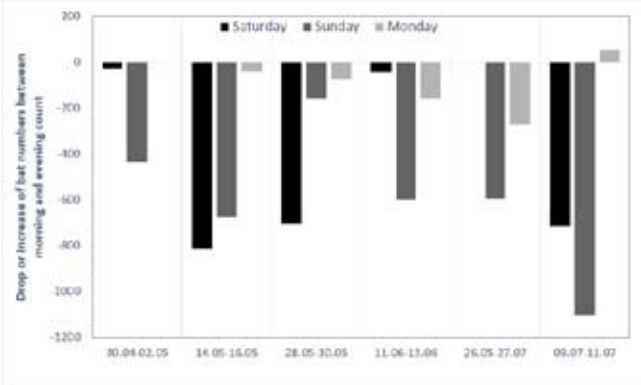

Fig. 2. Drop or increase in bat numbers per day, between the morning and evening count (morning number of bats subtracted from evening number of bats)

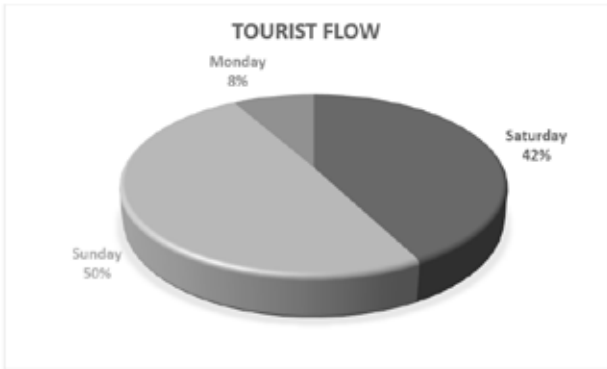

Fig. 3. Average visitor numbers of the cave on Saturday, Sunday and Monday

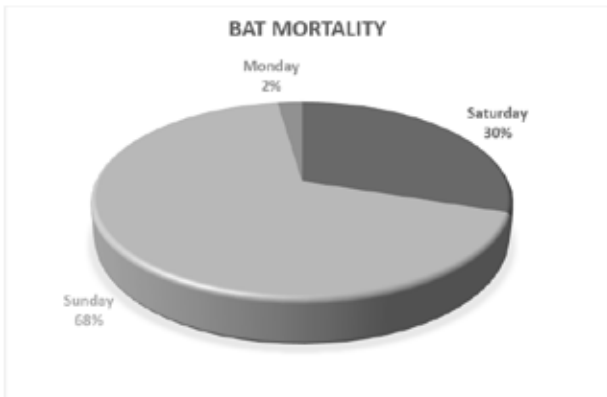

Fig. 4. Average bat mortality per day (from 8:30 h to 16:00 h) according to day of the week

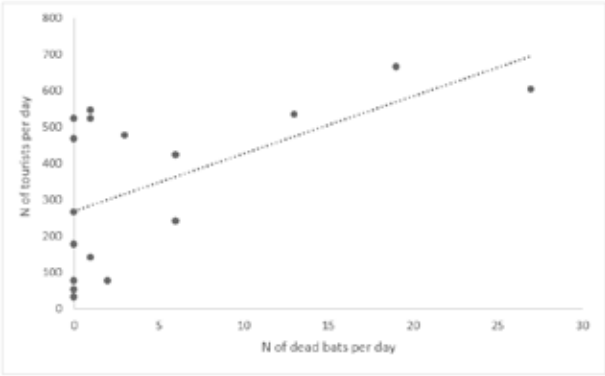

Fig. 5. Positive correlation between the daily bat mortality and the number of visitors to the cave per day

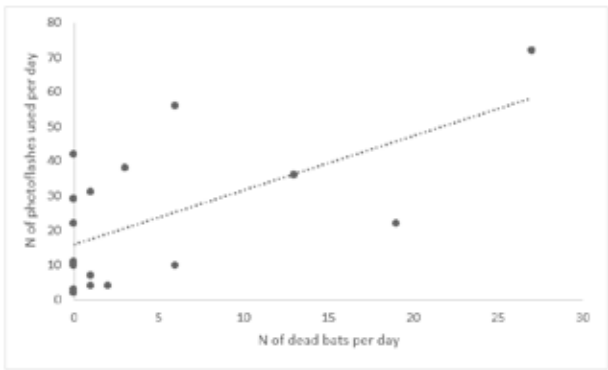

Fig. 6. Positive correlation between the total amount of photoflashes used per day and the daily bat mortality

the season. In the beginning of the study, end of April – beginning of May, the average daily temperatures were around 15°C in the Dry Gallery and 13°C in the Water Gallery. At the end of the study, the middle of July, the average daily temperatures were around 19°C in the Dry Gallery and 17.5°C in the Water Gallery.

Discussion

A more in depth research is needed to establish how the different types and intensities of noise influence the various species of bats.

Most probably the weather conditions did not have a strong influence over the bat mortality. During most of the field days the weather was sunny and warm, while it was raining on only 2 of the days. This suggests that there was a normal nocturnal activity of the bats and a small possibility of increased mortality due to bad weather conditions.

The observed colonies were at the expected from previous studies for these genera locations within the cave (Petrov 2014). Reproducing bats, which do not normally inhabit tight crevices, usually gather in large colonies at the ceilings of the cave, in spacious cavities of the rock. Bats choose such spots as they can house a large colony, but also trap heat and enhance the economy of the bats' metabolic processes (Kunz 1982). The higher heat needs of reproducing and roosting bats, also confirms why the observed in the Devetashka cave maternity colonies preferred the Dry gallery – which, as established by the temperature measurements is warmer. The fact that increased movement of the colonies between the galleries was observed and that there was a trend of decrease in bat numbers from morning towards the end of the day is a cause for concern. Such activity is not beneficial for roosting mothers or their young, as it is a loss of precious energy. The study of Burnet & August (1981) illustrates this as they investigate the energy and time budgets for day-roosting in a *Myotis lucifugus* maternity colony - 79% of the time is spent resting, 14% - grooming, 5% - active and only 1% is actually spent moving. Another possibility is for the colony to change roosts. This is also an unbeneficial outcome, since roost fidelity provides familiar high quality roosts and enhances social relationships. It has been specifically established that cave-dwelling bats prefer and benefit from roost fidelity (Lewis 1995).

Even though not significantly proven, the established results in the above study could as well relate to noise levels in the cave. Jones (2008) find that there is a negative influence of car traffic over feeding *Myotis myotis*. Bunkley *et al.* (2015) establish a negative effect of noise on the echolocational activity of bats outside their shelter. Few studies look into the direct tourism-related human influence on bats, but the established by our research correlation between the bat mortality and the number of visitors to the cave, is in accordance with the results of Biswas *et al.* (2011) that bat numbers decrease with increasing tourist flow. Our results indicated that white light is the most significant source of disturbance for bats. The study of Mann *et al.* (2002) also supports this conclusion. It becomes clear from the established results and analysis of the available literature on the anthropogenic influence on bat populations, that disturbance at their shelters and alteration and destruction of the environment have significant consequences.

Recommendations

Based on the established results of the influence of tourists on the bat colonies, the following recommendations are made to the respective authorities and institutions:

To physically limit the access to the Dry Gallery over the period 30 April – 1 August.

Prohibitive signs to be placed, banning the use of any light (photoflashes, flashlights etc.).

To limit the access of pets to the cave

To prohibit and control the noise levels near the entrances of the Water and Dry galleries.

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