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Population Size Determination Using Photographic Estimation for The Conservation of Cave Nectar Bat (*Eonycteris spelaea*) at Gunung Reng, Kelantan, Malaysia

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Abstract: The cave nectar bat, *Eonycteris spelaea*, is one of the three fruit bats in mainland Southeast Asia that roost in caves, unlike other fruit bats roosting in the forest. This bat species is an important pollinator for many plant species, including economically important crops including durian, petai and jackfruit. Hence, this study was conducted to determine the population size of cave nectar bat (*Eonycteris spelaea*) at Gunung Reng, Kelantan, Malaysia, since no information was recorded for conservation purposes. We determined the bat population size using the photographic estimation method at the 13 *E. spelaea* roosts (5 times per roost) found inside Gunung Reng for 20 days (4-30 August 2019). Our bat population size estimate resulted in about 207 to 344 individuals of *E. spelaea* ($F(4,0) = 5.66$, $p\text{-value} < 0.05$). This estimate is a relatively modest population size of bats in an isolated limestone karst surrounded by human-dominated habitats. Though *Eonycteris spelaea* is listed as Least Concern in the IUCN Red List, it is an important bat species ecologically and economically, contributing to the fruit agriculture economy in Jeli, Kelantan. Future studies should incorporate a combination of bat census techniques with long term planning in mind to completely understand the population dynamics of this paramount bat species.

1. Introduction

Bats belonging to the order Chiroptera are the only mammals capable of flight, a very diverse group accounting for 20% of mammal species worldwide and about 50% of mammal species living in tropical forest [15]. In Peninsular Malaysia alone, there are about 110 species of bats documented, all occupying various niches and serving ecological purpose which contributes to the health of the ecosystem and indirectly support our economy through pollination, seed dispersal and pest control



[10,15]. There are two bat families that play important roles in plant pollination which are family Pteropodidae from the Paleotropics and Phyllostomidae from the Neotropics [13]. Pteropodid bats pollinate plants from about 168 species while phyllostomid bats pollinate flowers of approximately 360 species [6]. At least 31 known Malaysian plant species depend heavily on bats for pollination [10].

One bat species in Malaysia is a major pollinator for not only wild plants but also many economically important crops is *Eonycteris spelaea*, the cave nectar bat [3,13]. These crops include *Musa* spp. (banana), *Artocarpus heterophyllus* (jackfruit), *Durio zibethinus* (durian), and *Parkia* spp. (petai) [3,16,26]. *E. spelaea* is a nectarivorous bats (feeds on nectar from flowers) that have a widespread distribution across South Asia and Southeast Asia, examples in the country includes Merapoh, Pahang and Pulau Perhentian Kecil, Terengganu [1,2,15]. This bat species is one of the three fruit bats in mainland Southeast Asia that roost in caves, unlike other fruit bats roosting in the forest [7]. One such large colony of *E. spelaea* in Palawan consist of 50,000 individuals [27]. Their economic contribution cannot be denied as durian fruit export in 2018 brought in revenue of USD 500 million (Thailand), USD 17 million (Malaysia) and USD 21,000 (Indonesia) [21].

Unfortunately like a broken record, many of Malaysian bat species are at some risk of extinction mainly due to habitat loss, habitat fragmentation and hunting [10,25]. Caves which are synonymous with bats faces direct human disturbance primarily limestone quarrying that is increasing at an alarming rate in Southeast Asia compared to other tropical regions [4,8]. This trend is particularly concerning as *E. spelaea* require caves as their roosting site [17]. Bats use the caves as a a permanent shelter from incompatible weather conditions and to protect themselves from predators by aggregating in large numbers [4].

The populations size of a species changes based on several factors; birth, death, immigration and emigration. A stable population is favourable in maintaining the ecosystem balance as the species are able to perform their role in the ecosystem [12]. Anthropogenic disturbance made the bats vulnerable and prone to population decrease [24,29]. One example is with forest fragmentation which caused the declining species richness and relative abundance of small mammals in disturbed areas [28]. In light of the declining bat population in the country, we have conducted a photographic estimation method to determine the population size of *Eonycteris spelaea* inside Gunung Reng, Jeli, Kelantan, Malaysia. Above all, it is hoped that the population size data from this study will be used for the conservation of this species and further highlights their contribution of pollinating plants.

2. Materials and Methods

2.1 Study Area

The sampling site is located at Gunung Reng (main entrance: 5°42' 54.83"N 101°44' 43.46"E) which has a sizeable colony of *E. spelaea* and other bat species. A previous small mammal diversity study recorded 17 species of bats in which six were fruit bat species and 11 were insectivorous bat species [9]. Gunung Reng is a spectacular isolated limestone outcrop located close to the East West Highway in Jeli district in western Kelantan, Malaysia. Nowadays, the Gunung Reng area is repurposed as a family recreational area complete with facilities at the foot of the hill, a river (Sungai Pergau) for picnics plus offering caving and hiking activities for visitors. The primary economic activity in the vicinity of the sampling site is agriculture in which many villagers work on fruit orchards particularly durian. There are several plant species adapted to the karst landscape of Gunung Reng limestone hill including like *Begonia curtisii*, *Microcos antidesmifolia* and *Peperomia kotana* [5]. Figure 1 shows the main entrance of the cave at Gunung Reng, Jeli, Kelantan, Malaysia.



Figure 1. Main cave entrance of Gunung Reng, Jeli, Kelantan, Malaysia

2.2 Methodology

This study was conducted for 20 days (4-30 August 2019) inside Gunung Reng. 13 roosts of *E. spelaea* was identified by looking at the eye shine on the cave ceiling as only fruit bats have eyes large enough to reflect lighting while we cannot see the eyes of insectivorous bats nor properly take pictures of these mobile small bats in the dark cave [22]. *Eonycteris spelaea* is the only fruit bat species captured at Gunung Reng that roost in caves, thus their species identification at the roost were confirmed in great confidence. Besides, other insectivorous bats inside Gunung Reng roost at other parts of the cave and do not share their roosts with *E. spelaea* [7].

We used photographic estimation method and take pictures at each roost five times every day for the duration of this study. For each shoot, we took roughly 1 to 3 minutes at every bat roost to minimize the disturbance towards *E. spelaea* colony. The camera was set up to flash feature for white balance mode. The dark cave conditions inside Gunung Reng often times need lighting help from torch light and head lamp when taking the roosts picture. The setting of the DSLR camera was ISO-1800, shutter speed (f/14-f/22) and low aperture number.

The bat population size estimate was calculated based upon the number pair of eyes of bats in the taken pictures. Each picture that has been drawn grids to standardize the calculation process of individual bats. The pictures were edited using the Zeke filter to made the bat eyes in the pictures clearer and easier to count. The total number of bats in 13 roosts were added for each shoot. Next, we compare and average the total amount of bats present between the five shoots of roosts for one day of fieldwork. This calculation is repeated for 20 days for the whole duration of this study. The estimation of population sizes of bats was done using repeated measures ANOVA, with the test related groups criteria.

3. Results and Discussion

1300 pictures of *Eonycteris spelaea* were taken during the whole period of this study. The number of *E. spelaea* was counted from the pairs of eyes. How the picture of bat roost looks like can be seen in Figure 2 which is the image of roost number 8 on day 15. The lowest range number of bats per shoot is shoot 4 (101-394 bats) while the highest range per shoot is during shoot 2 (107-527 bats). The total number of bats in every roost for 5 shoots per day is shown in Figure 3. The lowest number of bats ever recorded is 70 while the highest number of bats is 527. The average total number of bats for each shoot is as

follows: 290.05 ± 25.01 (shoot 1), 291.1 ± 25.05 (shoot 2), 256.7 ± 256.7 (shoot 3), 250.1 ± 19.99 (shoot 4) and 245.75 ± 245.75 (shoot 5) respectively. The standard deviation for the means of all shoots are 111.85, 112.04, 89.92, 89.42 and 81.75 respectively. We opted to calculate the total number of bats per shoot for the whole population instead of totalling each roost size is due to the fact that bats are very mobile and can fly from one roost to another, making it harder to estimate roost size.



Figure 2. Picture of roost number 8 on day 15. Notice the light spots on the cave ceilings; those are bat eyes.

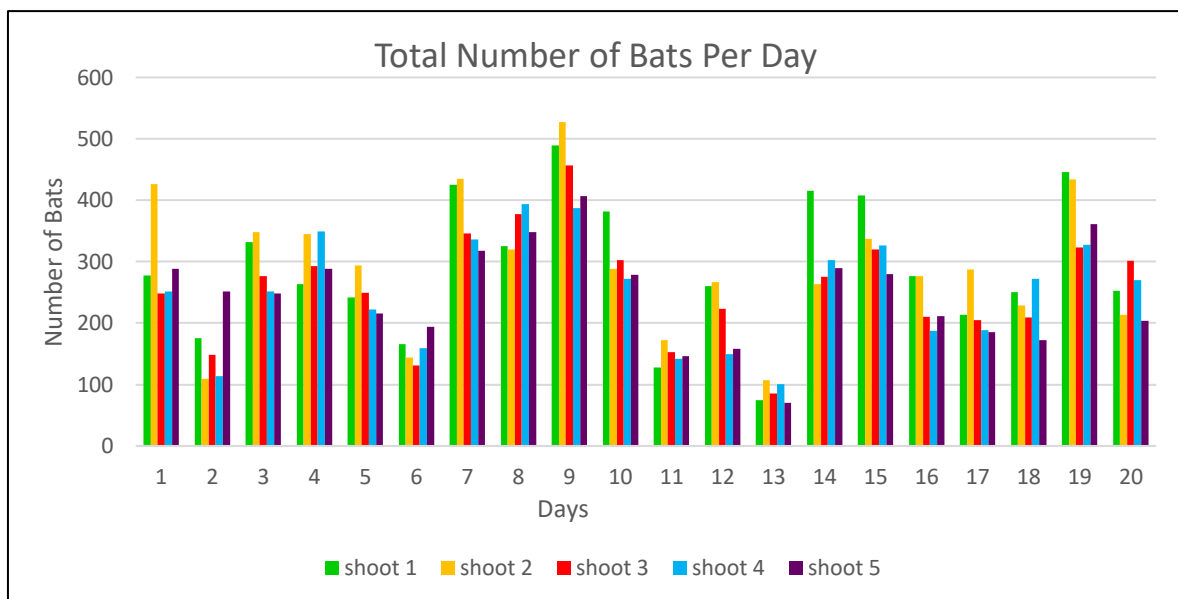


Figure 3. Graph bar chart for the total number of bats per day for 5 shoots of pictures

At the beginning of the fieldwork, the bats were quite disturbed by the lights used for photographic method. Hence, each picture taken requires a 2-3 minute gap to minimize the disturbance and allow the bats to familiarise with the lighting. Other measures that were taken to reduce disturbance towards the bats include less number of people in the field, keeping quiet and starting off with a dim light. These measures should have helped reducing the inconsistencies in the number of bats in our photographs and bat population estimate. As a result, our bat population size estimate resulted in about 207 to 344 individuals of *E. spelaea* ($F(4,0) = 5.66$, $p\text{-value} < 0.05$). Our population estimate takes account the assumption that the bats are readily observable at their roost and the bats will return to the same roost every day. Thus, we recommend comparing our method with advanced censusing methods like thermal imaging and reflectance infra-red imaging or using a combination of bat census techniques such as evening emergence count to better estimate bat population sizes [12].

207 to 344 *E. spelaea* individuals is a modest population size for an isolated limestone karst hill of only 200m in height. *Eonycteris spelaea* colonies vary in size, ranging from several dozens to thousands depending on the size of the karst landscape like caves, rock shelters & occasionally urban buildings [11]. Gunung Reng is one of the two naturally isolated limestone hills in the Jeli district alongside Gua Setir, hence the population decline of this bat species cannot be solely attributed to any threats towards the karst landscape itself [14,23]. Moreover, we have no past records for the bat population in Gunung Reng to infer that the population pattern here is in decline or stagnated except for the aforementioned small mammal study (bat sampling for 4 nights) in 2011 which only recorded 11 *E. spelaea* captures [9].

We also observed that there are roughly more bats in the roosts further into the cave where there is no illumination. However, this roost behaviour cannot be inferred as its roosting site preference as *Eonycteris spelaea* has been found roosting in areas within the cave, with partial illumination and absent illumination [30]. Anthropogenic disturbances might affect the bats moving further in as there are colourful lights at the main cave entrance of Gunung Reng.

Furthermore, there is also the lack of bat census studies in the country for comparison even though *E. spelaea* is widely distributed in the country. The Batu Caves in Selangor once recorded an estimate of 700,00 *E. spelaea* but this estimate was in 1967 [17]. Current studies in Batu Caves only mention the abundance of this bat species, possibly still in the thousands [19,20]. In any case, the comparison between Gunung Reng and Batu Caves in terms of bat population size may not be fully grounded even though both caves in an isolated limestone karst hill surrounded by a human-dominated setting as Gunung Reng is very much smaller (0.06 km²) than Batu Caves with 1.3 km² size [14].

While the status of *Eonycteris spelaea* is Least Concern on the IUCN Red List, the bat population in Gunung Reng should be monitored for the long term as there are other threats that could lead to the decline population such in the case of loss of foraging area due to forest fragmentation and continuous human disturbance from tourists entering the cave [18,29]. Therefore, further bat census monitoring should be conducted preferably for long term not only for bat conservation efforts but the community can gain much from the tourism at Gunung Reng and reap the benefits from the pollination services from *Eonycteris spelaea*. We would also like to suggest introducing bats to the community through talks, guided tours, bat emergence watching and other activities due to Gunung Reng is easily accessible so that everyone can appreciate these unsung heroes.

4. Conclusion

This initial bat population census using photographic estimation method managed to record the population size of *Eonycteris spelaea* between 207 to 344 individuals at Gunung Reng, Kelantan, Malaysia. This estimate is a relatively modest population size of bats in an isolated limestone karst surrounded by human-dominated habitats. Though *E. spelaea* is listed as Least Concern in the IUCN Red List, it is an important bat species ecologically and economically, contributing to the fruit agriculture economy in Jeli, Kelantan. Future studies should incorporate a combination of bat census

techniques with long term planning in mind to completely understand the population dynamics of this paramount bat species.

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