Diversity and Population status of Bats in Pilikuttuwa ancient cave temple in the Gampaha District, Sri Lanka

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ABSTRACT

Due to two unique specializations - echolocation and flight, bats have become one of the most successful groups of extant mammals in the world. Pilikuttuwa rajamaha viharaya, an ancient meditation monastery complex is a one of best places for bats which gives protection in Sri Lanka. In the present study, we evaluate the species diversity and population status of bats in Pilikuttuwa ancient meditation monastery complex with regard to their roosting ecology. Six species of bats including *Taphozous melanopogon*, *Rhinolophus beddomei*, *Rhinolophus rouxii*, *Hipposideros galeritus*, *Hipposideros speoris* and *Megaderma spasma* were recorded with the following conservation status, four in Vulnerable and two in Least Concerned. *Taphozous melanopogon* was the most abundant, and had the largest population with the widest distribution at the study site. A Natural predator of bats, *Paradoxurus hermaphoditus* was recorded in one roosting site.

Key words: Chiroptera, Insectivorous, Roosting, Ecology, Dead specimen, Threatened

INTRODUCTION

Of the rich diversity of vertebrate fauna, bats are unique in being the only group of mammals that, like birds, has sustained true flight. Bats belong to the order Chiroptera and are the sole representatives of this order. One of the 26 orders of mammalia, Chiroptera includes 1117 species of bats of the world over in two unequal suborders - the Megachiroptera (consisting of 186 species of Old World fruit bats in one family) and the Microchiroptera (consisting of 931 species in 17 families) (Mickleburgh et al., 1992; Koopman, 1993; Srinivasulu & Srinivasulu, 2001; Hutson et al., 2001; Mickleburgh et al., 2002). Bats are nocturnal, and the suborders have evolved unique ways of navigating and foraging in the dark. The megachiroptera navigate by sight, with the exception of a few species that navigate using echolocation. The microchiroptera have solved the problems of avoiding obstacles and foraging in the dark by evolving an intricate system of echolocation or sonar. Echolocation is a system of orientation where animals use echo's of the sounds (acoustic signals) produced by the animal itself to perceive the environment (Fenton, 1984). Due to two unique specializations - echolocation and flight, bats have become one of the most successful groups of extant mammals in the world (Mickelborough et al., 2002).

In 1997, Bates and Harrison re-evaluated the taxonomic status of bats in the Indian subcontinent including Sri Lanka, using available museum specimens and the data was backed by some field collection. This work, considered to be the most up to date work on the taxa, states that 30 species of bats are deemed to exist in Sri Lanka, represented by 18 genera under 07 families (Srinivasulu *et al*., 2010). Although bats are known to roost in bizarre places, the general types of day roosts of bats found in Sri Lanka areTrees, among dry leaves, Caves, Buildings and crevices/cracks/ hollows in trees (Digana et al., 2000; Yapa et al., 2000; Phillips, 1980; Bates and Harrison, 1997). Most caves, which are dark, serve as roost sites for many species of bats and it can be said that bats are the only group of vertebrates that have successfully exploited such caves as permanent roost for mating, hibernation and rearing young (Kunz, 1982). Large numbers of species are reported to be cave dwelling. In temperate countries, caves provide ideal roost for hibernating bats, as often the cave environment is very stable. This stability in the micro habitat of caves is favored for raising the young. Often, not only the resident bats use caves with stable microclimate, but also for some migrating bats that may roost in smaller satellite caves (Brosset, 1962; Van der Merwe, 1975).

Towards the later part of the 20th century, research carried out on the ecology and biology of Sri Lanka bats (Yapa, 1992; Yapa et al., 2002; Digana et al., 2000; Digana et al., 2001). These studies only yielded 20 species of bat from the 30 species which are deemed to exist in Sri Lanka. Further, quantitative information on the population dynamics of different species of bats or their distribution in different geo-climatic zones, which are prime requirements for identifying species which are threatened and need to be conserved, hence the inclusion in the red data book of the International Union for Conservation Nature (IUCN). The current publication by the MOE (2012)

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on the status of threatened taxa of Sri Lanka, states that all families and 23 species of bats (76.6 %) from the 30 species recorded from Sri Lanka are in dire straits. As, five species are Critically Endangered, five species are Endangered, two species are Data Deficient and three species are Near Threatened and eight species are Vulnerable. This further adds gravity to the notion that bat research in Sri Lanka is still in a neonate stage. To fill this void, the authors initiated a systematic study on the chiropteran fauna of Sri Lanka. Here with the authors present the results of one such study conducted at the Pilikuttuwa rajamaha viharaya, an ancient meditation monastery complex in the Gampaha district.

MATERIALS AND METHODS

Study area

The Pilikuttuwa ancient cave temple is located, 7 km southwest of the municipality of Gampaha in the Gampaha district, Western province, Sri Lanka (Figure 1). The area comes under the lowland wet zone of the country. The study area lies under the intersection of N 07^0 03' 45.1'' – 07^0 04' 15.0'' and E 079^0 56' 24.8'' – 080^0 03' 05.3''. The study site was an ancient mediation monastery with 99 caves and over 200 rock ledges/ vertical and horizontal crevices, narrow fissures and spherical crevices chambers in rock cliffs. The temple complex encompasses a large area of secondary forest. Altitude of the study area ranged from 30–100m. Small to large granite boulders and small Rocky Mountains were scattered in the study site.

Survey methods

This study was carried out from February 2011 to April 2012. A total of 20 days (8 hrs per day) was spent on fieldwork, within a period of fourteen months. The Visual Encounter Survey (VES) method was utilized to sample the chiropteran diversity. All possible microhabitats which likely refuges for bats were examined at the study site. Survey was conducted during daylight hours with the aid of head lamps and torches. All the chiropteran fauna encountered at the site were captured using hand nets for species level identification. Key measurements and photographs were taken, the captured specimens were released back to the site of capture, without damaging the specimens. All the bat roosting sites were categorized into three groups. Those are Caves: used by ancient people with some architectural modifications (Figure 2-D); Rock crevices: naturally occurring, large to small rock cracks/crevices (Figure 2-J); Rock-ledges: Overhanging rocks on other rocks (Figure 2-R).

Photographs of bats and their roosting sites were taken using an Olympus C-740 Ultra Zoom Digital Camera. Digital caliper (RD 10) was used to get key measurements of the bats, *viz*., fore arm, head and body, 3rd metacarpal, tail, ear, hind foot, nose leaf structure. A Garmin etrex GPS was used to get the GPS coordinates of all microhabitats which were inhabited by bats. Population dynamic at roost sites were studied applying the Direct Roost Count method and the Photographic count method to keep with the standard methodologies

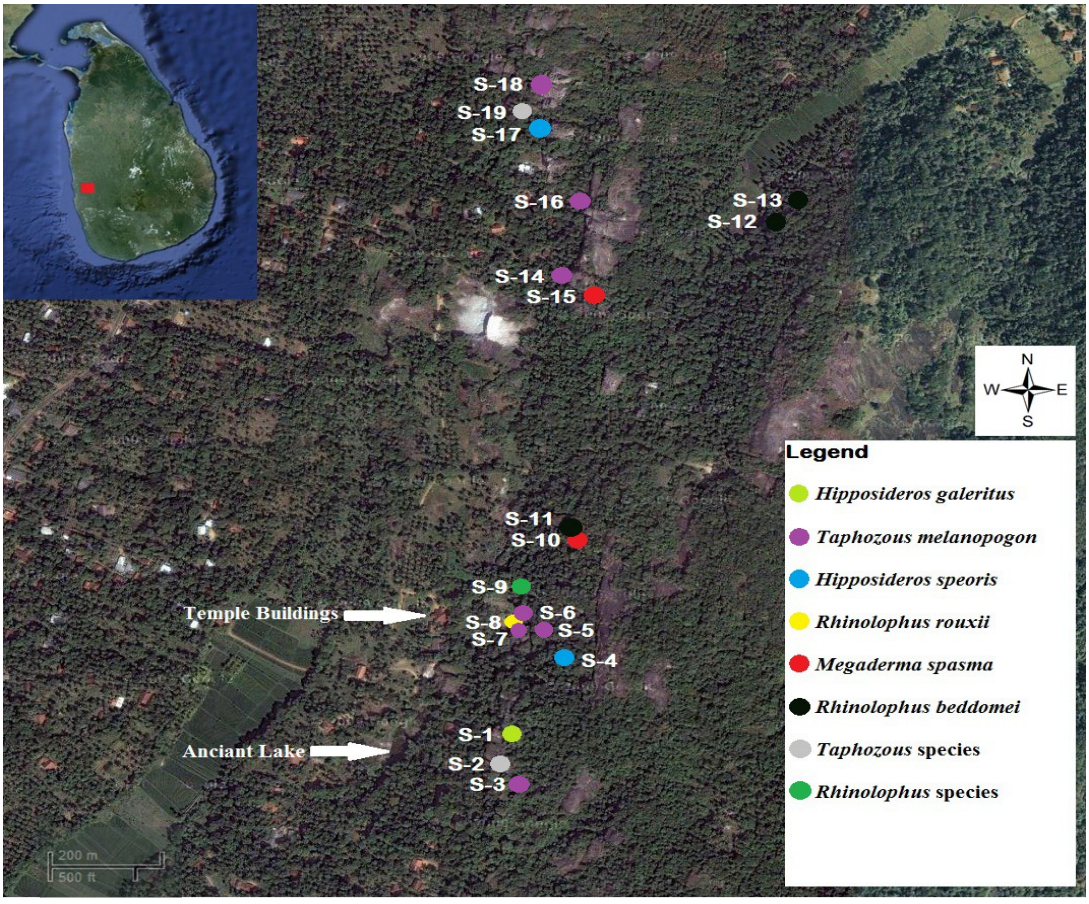

Figure 1. Distribution of bats within the study site.

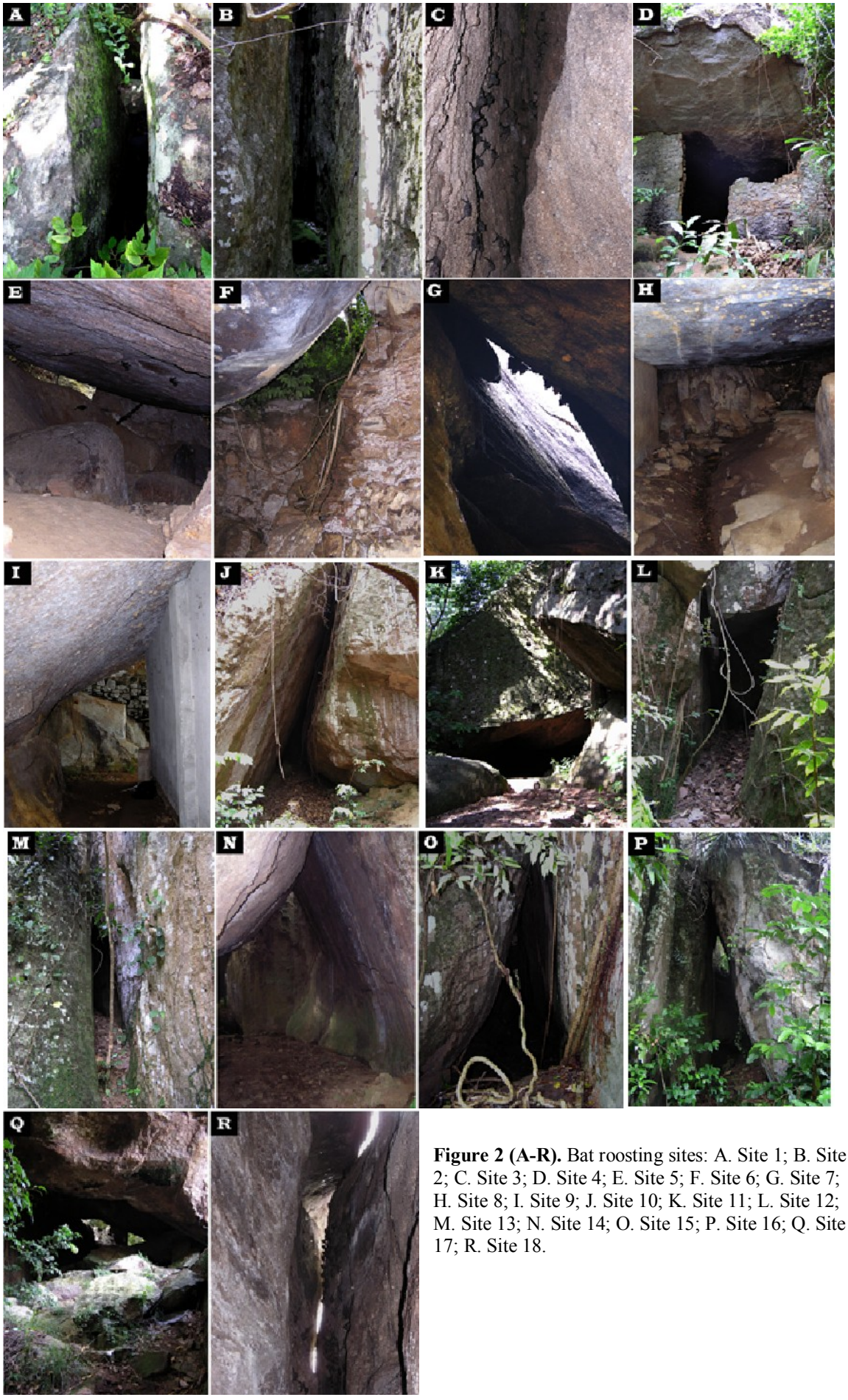

Figure 2 (A-R). Bat roosting sites: A. Site 1; B. Site 2; C. Site 3; D. Site 4; E. Site 5; F. Site 6; G. Site 7; H. Site 8; I. Site 9; J. Site 10; K. Site 11; L. Site 12; M. Site 13; N. Site 14; O. Site 15; P. Site 16; Q. Site 17; R. Site 18.

which has been utilized to get a proper consensus of the population (Thomas et al., 1979; Thomas & Laval, 1988). In direct roost count method, all the individuals at the roosting site are counted, during day light hours using a torch. This has been carried out systematically by subdividing the site (mainly the large caves), counting one section at a time to ensure no area is missed or counted twice. In the photographic count method, photographs were taken of the roosting site, and each photograph as was examined, manually counting each individual in the photograph. Identification of the bat species was done using Phillips (1980) and Bates and Harrison (1997).

RESULTS AND DISCUSSION

Of the all caves, rock ledges and crevices that were inspected, 19 were found to support bats, which included eight caves, ten rock crevices and one overhanging rock-ledge (Figure 2). GPS coordinates of all nineteen bat roosts were recorded and mapped (Table 1; Figure 1). A dead specimen, still hanging in its roosting position was found at one site. Thus, the site was disregarded in the analysis. Six species of bats were positively identified, and at least two other species were observed, but only identified upto genus level. Of the total encountered species, two belong to the family Rhinolophidae (*Rhinolophus beddomei* and *Rhinolophus rouxii*). Two to the family Hipposideridae (*Hipposideros galeritus* and *Hipposideros speoris*). And the other two belonged to the family Megadermatidae (*Megaderma spasma*) and family Emballonuridae (*Taphozous melanopogon*) (Figure 3).

Population dynamics and distribution of the bats at the area of study was recorded (Table 2; Figure 4). *Taphozous melanopogon* was the species which most frequently encountered at seven different sites. All other species were encountered with low number of individuals. However, none of the caves supported sympatric roosting sites.

Ratio of occupancy of the 18 micro habitats by different species also varied. Of the total micro habitats 38.9% (7) used by *Taphozous melanopogon.* 16.7% (3) used by *Rhinolophus beddomei,* 11.1% (2) used by *Megaderma spasma* and *Hipposideros speoris* separately, 5.55% (1) used by four species (*Hipposideros galeritus, Rhinolophus rouxii, Taphozous* species and *Rhinolophus* species) separately.

Table 1. GPS coordinates of bat roosting sites.

Roosting Site	GPS Coordinates	
S-1	07^0 03’ 46.7” N	080^0 02’ 54.9” E
S-2	07^0 03’ 45.5” N	079^0 56’ 24.8” E
S-3	07^0 03’ 45.1” N	080^0 02’ 54.2” E
S-4	07^0 03’ 46.7” N	080^0 02’ 55.1” E
S-5	07^0 03’ 49.7” N	080^0 02’ 56.8” E
S-6	07^0 03’ 51.0” N	080^0 02’ 56.2” E
S-7	07^0 03’ 50.6” N	080^0 02’ 55.3” E
S-8	07^0 03’ 50.7” N	080^0 02’ 55.5” E
S-9	07^0 03’ 51.8” N	080^0 02’ 55.8” E
S-10	07^0 03’ 54.0” N	080^0 02’ 57.8” E
S-11	07^0 03’ 54.1” N	080^0 02’ 57.9” E
S-12	07^0 04’ 08.5” N	080^0 03’ 05.0” E
S-13	07^0 04’ 08.7” N	080^0 03’ 05.3” E
S-14	07^0 04’ 05.0” N	080^0 02’ 57.6” E
S-15	07^0 04’ 04.0” N	080^0 02’ 58.7” E
S-16	07^0 04’ 09.2” N	080^0 02’ 58.3” E
S-17	07^0 04’ 12.8 ”N	080^0 02’ 56.6” E
S-18	07^0 04’ 15.0” N	080^0 02’ 56.6” E
S-19	07^0 04’ 13.4” N	080^0 02’ 55.9” E

Species accounts

Six species of bats were identified during the study. The

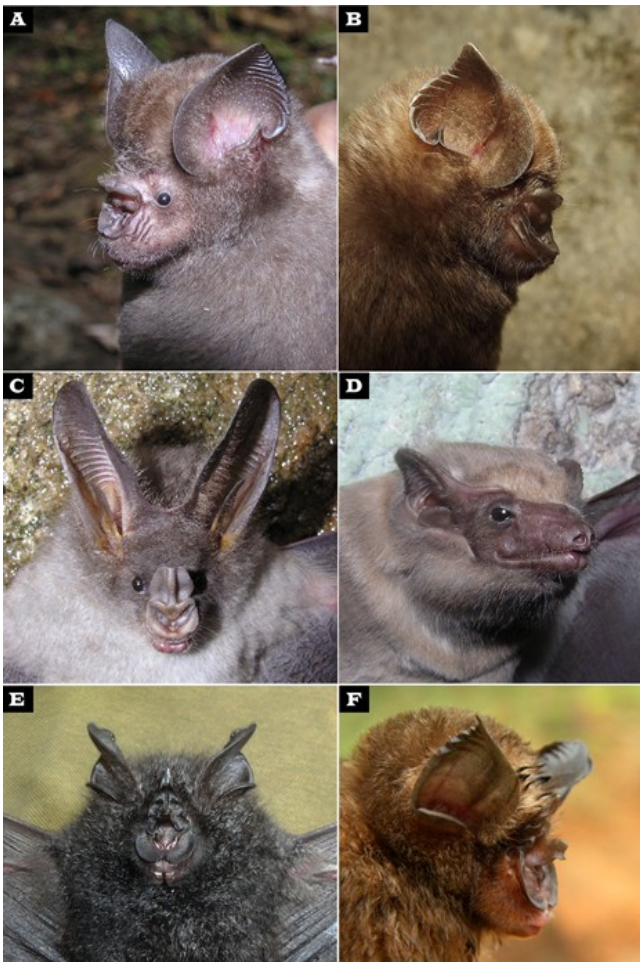

Figure 3. A-F. Bat species recorded from the study: A. *Hipposideros speoris*; B. *Hipposideros galeritus*; C. *Megaderma spasma*; D. *Taphozous melanopogon*; E. *Rhinolophus beddomei*; F. *Rhinolophus rouxii*.

following detailed species accounts are summarized by roosting sites in Table 2.

Emballonuridae

Taphozous melanopogon (Figure 3-D):

This species was recorded from seven roosting sites (Roosting site 3, 5, 6, 7, 14, 16 and 18). This was the most frequently encountered species. Their colony sizes ranged from 5 to 70. Their chatter can clearly be heard around their roosting sites. As the norm for the genus they were found clutching the rock face with their feet and hooked thumbs, with the head held at an angle. When disturbed, they swiftly back up the rock into a fissure. Some flew away to other adjoining roosting sites. They use the same path when entering and exiting the roosting site. When their alarm call was mimicked, they flew close to the source of sound. The specimens observed at roosting site no 7, were somewhat smaller in size than others observed. It could well be a nursery roosting site. Due to restricted space the specimens could not be captured and analyzed. The dead specimen was found from site 19. It was found still clinging on to the rock surface in its natural position (Figure 5). It was dry and well preserved and did not show signs of deterioration. Ants were observed on the carcass.

Table 2. Summary of the day roosting sites with bat species and population.

Roosting Site No.	Species	Micro habitat type	Estimated population size	Remarks
1	*Hipposideros galeritus*	Crevice	3	
2	*Taphozous* species	Crevice	Unknown	Noise & smell only
3	*Taphozous melanopogon*	Crevice	45	
4	*Hipposideros speoris*	Cave	25	
5	*Taphozous melanopogon*	Cave	19	
6	*Taphozous melanopogon*	Overhanging rock-ledge	-	Temporary roosting site for roosting site no 5
7	*Taphozous melanopogon*	Cave	15	Potential nursery
8	*Rhinolophus rouxii*	Cave	1	
9	*Rhinolophus* species	Cave	2	
10	*Megaderma spasma*	Crevice	18	
11	*Rhinolophus beddomei*	Cave	3	
12	*Rhinolophus beddomei*	Crevice	1	
13	*Rhinolophus beddomei*	Crevice	1	
14	*Taphozous melanopogon*	Cave	40	
15	*Megaderma spasma*	Crevice	4	
16	*Taphozous melanopogon*	Crevice	5	
17	*Hipposideros speoris*	Cave	1	
18	*Taphozous melanopogon*	Crevice	70	
19	*Taphozous melanopogon*	Crevice	1	Dead specimen

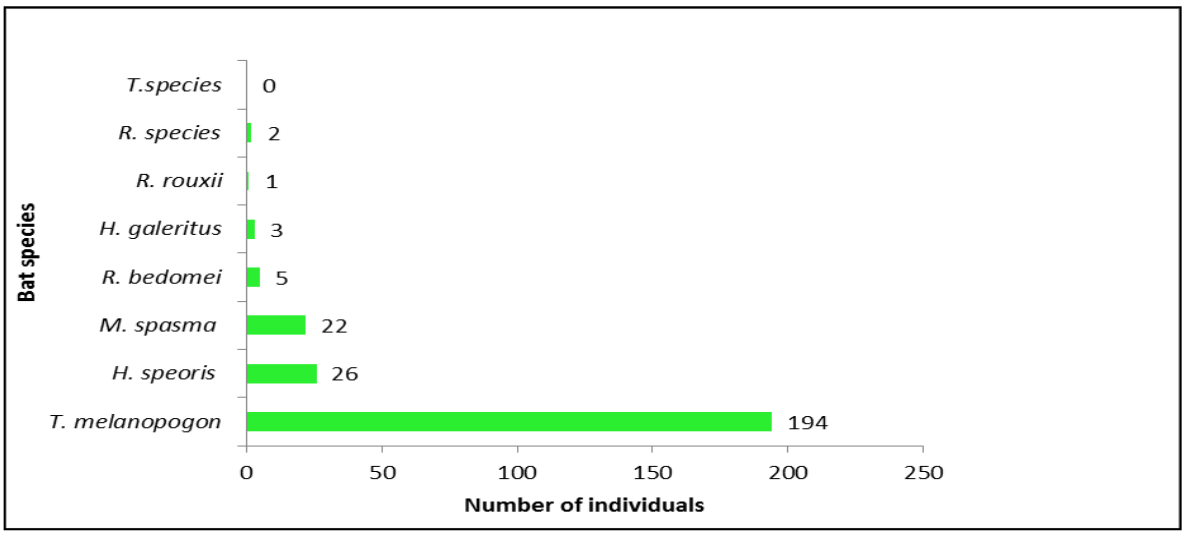

Figure 4. Population dynamics of bats found at the study site

Figure 5. Dead bat specimen.

***Taphozous* species:**

Day roosting site 2, there was no access to the crevice. But by the chattering and by the different curious musty unpleasant smell, it could be identified as a *Taphozous* species.

Hipposideridae

Hipposideros galeritus (Figure 3-B):

Roosting Site 1 was occupied by this species. There were three individuals roosting in this medium sized rock crevice. Opening of this crevice was located on the rock face of a huge boulder. The crevice was accessible due to the vines and creepers that were hanging down the rock face. Inside of this crevice was dark. They were observed hanging from one leg and constantly cleaning and grooming themselves.

Hipposideros speoris (Figure 3-A):

This species was recorded from roosting site 4 and 17. A small colony of 25 bats was recorded from roosting site 4, with the animals hanging of the roof. Further one specimen was recorded from site 17; however, a large amount of guano was recorded from the site. As the norm for the genus the bats were observed, constantly twitching their ears and nose. When the colony was disturbed they start to flying in circles and move to the adjoining cave, which is connected by a small tunnel. When disturbed at the second site, the colony flew out of the roosting site.

Rhinolophidae

Rhinolophus beddomei (Figure 3-E):

Roosting Site 11, 12 and 13 were occupied by this species. Site 11 used by three individuals, roosting in close proximity to one another. Further, site 12 and 13 used by two individuals (one from each). This species was found occupying open places of over hanging rock ledges, where they are exposed to day light. They were found roosting, hanging by one foot with their wings wrapped around them.

Rhinolophus rouxii (Figure 3-F):

In roosting site 8, a single bat was seen hanging in the dark zone of this cave.

***Rhinolophus* species:**

Two individuals were recorded from roosting site 9. They were very alert, hence restricting capturing or securing a good photograph for identification. They were found occupying a small cave with sufficient day light.

Megadermatidae

Megaderma spasma (Figure 3-C):

This species was recorded from roosting site 10 and 15. A colony of 18 bats was observed in site 10, when the colony was disturbed, they moved further up the fissure. Further, four bats were recorded from site 15, they were hanging in a cluster. When the site was disturbed, they started to call, using squeaks. When they were flying they did not fly great distances, but alighted within close proximity to where they initially took to flight. Both roosting sites were crevices were damp inside. Remains of beetles and larger insects were scattered on the floor of the crevice.

Threats

In roosting site no. 3, a common palm civet (*Paradoxurus hermaphoditus*) was recorded resting during the day. This species is an opportunistic feeder and is known to feed on species of bats (Figure 6). Domestic Dogs (*Canis familiaris*) and Cats (*Felis cattus*) were observed in the study site. They are the potential domestic predators of bats at the site.

Figure 6. *Paradoxurus hermaphoditus*, a potential predator of bats.

As the study site is an ancient monastery, pilgrims frequent the area. It was observed that some pilgrim disturb the roosting sites by venturing inside, flashing torches and shouting. This site is also very popular among film crews, for shooting clips.

Pilikuttuwa Rajamaha Viharaya was built nearly 2400 years ago. It was a monastic meditation complex with 99 caves spread over 200 acres. Its' history in Buddhist tradition is evitable at every step including its structures and flora around it (Stranger times, 2012).

According to the Bates and Harrison (1997) only *Megaderma spasma* was recorded from Pilikuttuwa. However, the present study, recorded *Taphozous melanopogon, Hipposideros galeritus, Hipposideros speoris, Rhinolophus beddomei* and *Rhinolophus rouxii* in additional to *Megaderma spasma*. With the one exception (*Megaderma spasma*), all other sightings are new site records from Pilikuthuwa cave complex.

Taphozous melanopogon is sometimes found in caves. However, it prefers light zone areas near entrances (Mackinnon et al., 1996). This species uses visual aid for orientation during day light hours, which is evident by their comparatively large eyes (Phillips, 1980). The present study, confirms the notion by Mackinnon et al. (1996) and Phillips (1980) on habitat preference of *Taphozous melanopogon*. It was the most commonly found species of bat in the study site. It can be due to the availability of light penetrating caves at the study site. *Hipposideros galeritus* was found roosting in a dark rock crevice with a small opening. It similar to other recorded of site fidelity of roosting sites of this bat, e.g culverts, small rock caves or over-hanging rock ledges in some secluded jungle, old house and artificial caves or rooms which are dark and small in size (Bates and Harrison, 1997).

Rhinolophus beddomei prefer to roost in hollow trees, small caves or overhanging rock ledge indark secluded retreats, dungeons, old barracks, houses, tunnels and deserted wells (Phillips, 1980; Bates and Harrison, 1997). All three records of *Rhinolophus beddomei* in the present study come from highly secluded places with forest cover. In this study, only one individual of *Rhinolophus rouxii* was found in a small and dark rock cave. But generally it lives in colonies, sometimes consisting of very large numbers (Phillips, 1980). This bat is a forest species which like to hunt in glades, along paths in forest and around bushes (Bates and Harrison, 1997). According to the Phillips (1980) this bat may also be found singly or in small parties. In the early part of the 20th century this species was very plentiful in Sri Lanka.

Megaderma spasma is not partial to a particular type of roosting site; it uses various types of sites. Most of the time, it tend to use abandoned man-made structures. But its natural preferred roosting sites would appear to be caves (Bates and Harrison, 1997; Phillips, 1980). Two damp rock crevices were used by *Megaderma spasma* in the present study, representing its natural preference in roosting sites. Inside of both crevices were wet and entrances of the crevices are well covered by natural surroundings.

According to the MOE (2012), National conservation status of *Taphozous melanopogon, Hipposideros galeritus, Megaderma spasma* and *Rhinolophus beddomei* documented as Vulnerable. *Hipposideros speoris* and *Rhinolophus rouxii* stated as Least Concerned. So, Pilikuttuwa ancient cave temple harbors four of the eight Vulnerable bat species in Sri Lanka.

CONCLUSION

The present study clearly shows the importance of this study site, as an in-situ conservation site for the bats. Due to this site being a monastery the bats are not hunted for their meat, as it was evident in other parts of the country where research is being carried out. This study only focused on recording the diversity of chiropteran fauna found roosting in the caves in the site. However, further studies could yield many more species of bats that inhabit this ancient monastery, as the monastery is surrounded by secondary forest, as such many more species that prefer to roost in hollows in tree and among dried up leaves could well be recorded from this site.

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REFERENCES

Bates, P.J.J. and Harrison, D.L. 1997. Bats of the Indian Subcontinent. Harrison Zoological Museum Publication.

Brosset, A. 1962. The bats of central and western India. J. Bombay Nat. Hist. Soc. 59: 707-746.

Digana, P.M.C.B., Yapa, W.B., Randeniya, P.V. and Ratnasooriya, W.D. 2000. Roost selection of Sri Lankan bats. Proceeding of the 1st Annual Session, University of Colombo, Sri Lanka, p 39.

Digana, P.M.C.B., Yapa, W.B., Randeniya, P.V. and Ratnasooriya, W.D. 2001. Present status of Sri Lankan bats. Proceedings of IOB 21st Annual Session. p 21.

Fenton, B. 1984. Echolocation: Implication for ecology and evolution of bats. The Quaterly Review of Biology. 59: 33-53.

Hutson, A.M., Mickleburgh, S.P. and Racey, P.A. (compilers) 2001. Microchiropteran Bats: Global Status Survey and Action Plan. IUCN/SSC Chiroptera Specialist Group, IUCN, Gland, Switzerland and Cambridge, UK.

Koopman, K.F. 1993. Order Chiroptera. Pp. 137-241. In Mammal Species of the World. (eds Wilson, D. E. and Reeder, D. M.), Smithsonian Institution Press, Washington.

Kunz, T.H. (eds) 1982. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington.

Mackinnon, K., Hatta, G., Halima, H. and Mangalik, A. 1996. The Ecology of Kalimantan. Oxford University Press, Singapore.

MOE. 2012. The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna and Flora. Ministry of Environment, Colombo, Sri Lanka.

Mickleburgh, S.P., Hutson, A.M. and Racey, P.A. (compilers) 1992. Old World fruit bats. An action plan for their conservation. International Union for Conservation of Nature and Natural Resources, Chiroptera Specialist Group (IUCN/SSC). Gland, Switzerland.

Mickleburgh, S.P., Hutson, A.M. and Racey, P.A. 2002. A review of the global conservation status of bats. Oryx. 36(1): 18-34.

Phillip, W.W.A. 1980. Manual of the mammals of Sri Lanka. Part 1, 2nd revised edition, Wildlife and nature protection society of Sri Lanka, Colombo.

Srinivasulu, C. and Srinivasulu, B. 2001. Bats of the Indian subcontinent. Current Science, 80(11): 1378 -1380.

Stranger times (2012). Pilikutuwa – A monastic cave complex of ancient Lanka. www.damithah.wordpress.com. Cited 07 Feb 2013.

Thomas, D.W., Fenton, M.B. and Barclay, R.M.R. 1979. Social behavior of the little brown bat, *Myotis lucifugus* Mating behavior. Behav. Ecol. Sociobiol., 6: 129–136.

Thomas, D.W. and Laval, R.K. 1988. Survey and Census Methods. Pp. 77–89. In Ecological and Behavioral Methods for the Study of Bats. (eds Kunz, T. H.). Smithsonian Institution Press, Washington D. C.

Usman, K. 1998. Role of light and temperature in the roosting ecology of tropical microchiropteran bats. Proceedings Animal Sciences, 97 (6), Springer Link website, www.link.springer.com, Cited 10 Feb 2013.

Van der Merwe, M. 1975. Preliminary study on the Annual Movements of the Natal Clinging Bat. S. Afri. J. Sci. 71: 237-241.

Yapa, W.B. 1992. Ecological and ethological studies of cave dwelling bats in Sri Lanka. M.Phil Thesis, University of Colombo. Sri Lanka.

Yapa, W.B., Randeniya, P.V. and Ratnasooriya, W.D. 2002. Ecology and Biology of Bats in Sri Lanka. A survey on the distribution of bats in Sri Lanka. Final Report. National Science Foundation, Sri Lanka.