Diversity of cave-dwelling bats in Leang Londrong, Bantimurung-Bulusaraung National Park: An initial field note

N. Nasri, R.I. Maulany and A S Hamzah

Forest Conservation Study Program, Forestry Faculty, Universitas Hasanuddin, Jalan Perintis Kemerdekaan Km. 10, Makassar (South Sulawesi), Indonesia

Email: risma.maulany@unhas.ac.id

Abstract. Leang Londrong is one of the caves in Maros-Pangkep Karst Formation utilized for nature tourism and has become a habitat for bats. Little is known on the bats inhabited the cave. Therefore, this study is aimed to investigate the diversity, abundance, morphometric of cave-dwelling bats in Leang Londrong, Bantimurung-Bulusaraung National Park as well as their distribution of roosting sites and micro-climate conditions between May-June 2021. The bats were trapped and collected by using two-layered mist nets erected in front of cave entrance. With captured-marked-recaptured (CMR) method, bat diversity, abundance, and morphometric, were examined. Direct measurements on roosting sites were employed to determine micro-climate conditions. There were 3 species of Microchiropteran bats found in the site namely Rhinolophus arcuratus, Hipposideros diadema and Myotis sp. Total number of all bats trapped in the net during the observation days was 10 individuals. The largest bat species found living in the cave was Hipposideros diadema (average body length of 101.1 mm; tail of 51.46 mm; ear 24.5 mm; forearm length of 96.12 mm; tibia length of 34.6 mm; hind foot of 14.32 mm; and 63.75 g of weight). Meanwhile, Myotis sp. was known to be the smallest. For micro-climate conditions, the five roosting sites inside the cave had the average temperature of 26.58°C (range: 26.2–27.3) with the humidity in average around 92.88% (range 89.6–93.8%), while the average light intensity was found to be 0 lx in each roost with the noise level recorded in average of 65.08 dB.

1. Introduction

Maros-Pangkep Karst (MPK) is known to be the second largest karst complex in the world after China [1]. Compared to other karst areas, the unique character of MPK karst area is shown by high tower karsts extended over the land [2]. The area is a part of Tonasa Formation with unique ecosystem and known to have 268 caves [3] valued for not only its economical but also for cultural and ecological aspects [4–6]. As many other karst areas, MPK has played important roles in storing and regulating clean drinking water and for other purposes not only to serve Maros and Pangkep Regencies but also Makassar City [7,8]. In water usage, Arsyad et al. [8] have also estimated economic valuation from MPK area where the area has positively contributed around 15 million m$^3$ surplus in water storage per year. In cultural aspects, MPK upholds highly valuables prehistoric evidences with a minimum age of 39,600 years according to uranium dating series which can be seen in 127 sites consisted of 78 caves with cave paintings and others documenting artifacts [6]. In term of ecological roles, karst ecosystem is known to host rich and unique species of flora, fauna, and ecosystem [9,10]. MPK has also become a
home for many endemic and protected species including bats which has not been widely explored [1,11–13].

Karst ecosystems are categorized as non-renewable resources that when it is degraded it cannot be fully recovered [14]. Both karst and caves ecosystems are very susceptible towards changes [15]. Anthropogenic threats are among the highest threats faced by the area in particular quarrying, pollution, groundwater extraction, construction and agricultural activities [16–19]. Cement mining, pollution, and land conversion have negatively impacted and become the major of threats towards the MKP ecosystem [6].

Maros-Pangkep karst complex is spread in three regencies of South Sulawesi Province, Maros, Pangkep, and Barru. The area of MKP in total covers ± 46,200 ha where half of the land is also a part of Bantimurung-Bulusaraung National Park (22,800 ha) [1]. Leang Londrong is one the caves situated in Pangkep Regency with the distance of around 49.6 km from the capital city of South Sulawesi Province, Makassar, or can be reached within 1 hour 15 minutes. ‘Leang’ means cave in Bugisnese-Makassarese language. The site is under the management of Bantimurung-Bulusaraung National Park and is known as one of the seven wonders of nature tourism spots in the area. The cave is now utilized for nature tourism and has become a habitat for bats [3]. However, little is known on the bat species inhabited the cave. Therefore, this study is aimed to the diversity, abundance, morphometrics of cave-dwelling bats, distribution of roosting sites and their micro-climate conditions in Leang Londrong, Bantimurung-Bulusaraung National Park.

2. Material and methods

2.1. Study area

Leang Londrong is situated in Panaikang Village, Minasate’ne District, Pangkep Regency (South Sulawesi) at Maros-Pangkep Karst Formation. The main attractions are karstic cave and river. Geographically, this cave is located between 4° 51′ 43″ S and 119° 38′ 12″ E at the elevation between 1-50 m above sea level (Figure 1). Leang Londrong is a horizontal riverine karst cave with the length of 5.4 km. The cave and its surrounding environment have provided environmental services not only for tourism but also for water utilization. The river had served as the main water sources used not only for agricultural purposes but also for cement industry [6].

2.2. Data Collection and Analysis

The study consisted of 4 (four) phases of data collection: 1) cave exploration; 2) diversity of cave-dwelling bat species; 3) measurement of physical and environmental characteristics of roosting sites; and 4) distribution and abundance of cave-dwelling bats in Leang Londrong. All the data collected were analyzed descriptively by using Microsoft Excel. Any data related with visual mapping were drawn by using Corel Draw software.
2.3. Diversity, abundance, and morphometric of Cave-dwelling bats
In determining the species inhabited Leang Londrong, two layered mist nets were erected in front of the cave entrance. First net of 5x5 m was set 10 m from the cave entrance while the second with the size of 3x3 m net was placed inside with the distance around 25 from the first net. Trapping efforts were carried out for 3 hours starting from 5.00 pm until 8.00 pm in the evening. Any bats trapped in the mist nets will be marked and measured prior to the release. Some measurements towards head to body (HB), tail length (T), ear length (E), length of forearm wing, length of calf (Tib), hind foot (HF) were conducted by using digital calliper. The weight and sex of each individual trapped were also recorded. A pair of male and female of each species will be euthanized and collected for specimen purposes. In addition, for species identification, morphological features were documented through photographing. These photographs were then sent to the Indonesian Research Centre (LIPI) to confirm the species inhabited Leang Londrong for further identification. To estimate the abundance of each bat cave-dwelling species in Leang Londrong, a captured-marked-recaptured (CMR) method was applied. Any individuals trapped in the net were marked and recorded. Any marked individuals from previous capture were also noted.

2.4. Roosting distribution and Micro-climate Conditions
To determine the location of roosting site for each site, the length of the cave was divided into 50 m. The distances from the entrance to the location of bat roosts inside the cave were measured and marked by using laser distance meter Krisbow PRO 100m. Data on each station and roost site were later translated into a map to project the distribution of bat roost sites inside Leang Londrong. In examining micro-climate (temperature, humidity, noise, and light intensity) of roosting habitat inside the cave, manual measurements were utilized to mark each roosting spot inside the cave. Here, then some environmental aspects were monitored. Temperature and humidity of the roosting site inside the cave
was recorded by using a temperature dual laser gun (Krisbow IR 50 T) and Humidity Meter (Krisbow). A sound meter digital (Krisbow 35 TO130 D) was used to detect noise in each roosting site inside the cave. To observe light penetration into the roosting sites, a light meter Krisbow LED 400,000 Lux was used.

3. Result
Leang Londrong is categorized as karstic riverine cave where all the cave system is inundated by river water (Figure 2). To portray the conditions of Leang Londrong, the cave was explored briefly as it could only be accessed by using canoe/small boat. Due to the river conditions, difficulties in access including dark cave, involvement of high cost in renting canoe/small boat, the data collection could not be done simultaneously in particular to conduct repeated data collection for micro-climate conditions of roosting sites.

The cave could only be entered as far as 0.52 km or less than a quarter of the total length from the entrance. There were four roosting spots of cave-dwelling bats found along the cave. The distances of the roosting spots from the cave entrance were accordingly 150 m (R1), 192 m (R2), 180 m, (R3) 375 m and 520 m (R4) (Figure 3).

Figure 2. Conditions of the entrance and inside of Leang Londrong, Pangkep, Bantimurung-Bulusaraung National Park

Based on the mist net traps installed for 10 observation days, there were three species of Microchiropteran bats found in the site (Figure 4). The cave-dwelling bat species of Leang Londrong were Rhinolophus arcuratus, Hipposideros diadema and Myotis sp. At the beginning of mist net installation from day 1-4, there were no bats caught inside the traps. Only in day 5, some individuals were found. Total number of bats caught in the net was 10 individuals which was consisted of 3 individuals of Rhinolopus arcuratus, 3 individuals of Hipposideros diadema, and 4 individuals of Myotis sp. All marked individuals caught in the mist nets were not found in the other observation days and therefore, a captured-marked-recaptured (CMR) formula can not be deployed (Figure 5).
Figure 3. Roost distribution of cave dwelling bats from the entrance to 0.52 meter inside in Leang Londrong-Pangkep, Bantimurung-Bulusaraung National Park (Modified from Broquisse et al [20])

Figure 4. Diversity of Leang Londrong cave-dwelling bats (a) *Hipposideros diadema*; (b) *Rhinolophus arcuratus*; and (c) *Myotis sp.* in Bantimurung-Bulusaraung National Park
From the morphological measurement, the largest species found was *Hipposideros diadema* with the average body length of 101.1 mm; tail of 51.46 mm; ear 24.5 mm; forearm length of 96.12 mm; tibia length of 34.6 mm; hind foot of 14.32 mm; and 63.75 g of weight. Meanwhile, the size of *Rhinolophus arcuatus* was moderate compared to the other two species with the average body length of 42.35 mm; tail of 17.80 mm; ear 13.97 mm; forearm length of 45.10 mm; tibia length of 17.97 mm; hind foot of 8.33 mm; and 9.75 g of weight. *Myotis sp.* was known to be the smallest. *Myotis sp.* had the average body length of 41.76 mm; tail of 22.06 mm; ear 9.39 mm; forearm length of 37.95 mm; tibia length of 14.61 mm; hind foot of 9.12 mm; and 4.15 g of weight (Table 1).

To examine micro-climate conditions of each roost site inside Leang Londrong, repetitive monitoring and data collection could not be carried out due to difficulties and risks in entering the cave. However, during the first exploration into the cave, it was found that the average temperature of all roost sites was 26.58°C (range: 26.2-27.3) with the humidity in average around 92.88% (range 89.6-93.8%). In term of light intensity, the cave was totally dark with 0 lx in each roost. The noise recorded in average was 65.08 dB (Table 2).
Table 2. Micro-climate conditions of each roost site in Leang Londrong-Pangkep, Bantimurung-Bulusaraung National Park (R=roost site)

| Parameters of microclimate | Roost sites |
|----------------------------|-------------|
|                            | R1  | R2  | R3  | R4  | R5  |
| Temperature (°C)           | Min  | 26.7 | 26.7 | 26.2 | 26.3 | 26.1 |
|                            | Max  | 26.7 | 27.8 | 26.3 | 26.4 | 26.2 |
|                            | Average | 26.7 | 27.3 | 26.3 | 26.4 | 26.2 |
| Noise (dB)                 | Min  | 79.5 | 59.1 | 46.9 | 56  | 70.9 |
|                            | Max  | 81.7 | 76.5 | 50.2 | 58.7 | 71.1 |
|                            | Average | 80.6 | 67.8 | 48.6 | 57.4 | 71  |
| Light intensity (lx)       | Min  | 0    | 0    | 0    | 0    | 0    |
|                            | Max  | 0    | 0    | 0    | 0    | 0    |
|                            | Average | 0    | 0    | 0    | 0    | 0    |
| Humidity (%)               | Average | 95.5 | 89.6 | 93.8 | 91.7 | 93.8 |

4. Discussion

Leang Londrong is under the management of Bantimurung-Bulusaraung National Park in cooperation with the local government of Pangkep Regency. It has become one of nature tourism targets. With the area of 51.57 ha, the tourism activities of Leang Londrong begun to operate since 2006 [21]. It highlights the beauty of natural scenery in the context of karst ecosystem and also the flowing perennial river which constantly coming out from the cave throughout the year as the two main tourism objects. Leang Londrong can be categorized as distrophic cave with constant river [22]. This has made the access into the cave without canoe or small boat becoming impossible. During the study, it could only be entered to around 0.5 km where in total Leang Londrong had 5.9 km in length [21]. Conditions of Leang Londrong as the karstic riverine cave have impeded data collection process in this study and a long-term monitoring of the cave as well as its bats in the future.

During the first 4 days, none of the bats were caught and in total of 10 observation days there were only 10 individuals of three Microchiroptera species found (Hipposideros diadema, Rhinolopus arcuatus, Myotis sp.). No Megachiroptera were seen nearby the entrance cave or trapped in the mist nets. H. diadema, R. arcuatus can be identified to species level, unfortunately one species. Number of species recorded during the study was slightly different with what have been noted by previous study in Leang Londrong. Suyanto & Wiantoro [23] have mentioned only two species inhabited the cave, H. diadema and Miniopterus schreibersii. No record of both R. arcuatus and Myotis sp. were found [23]. This might be related with the nature of the cave. Therefore, there are some possibilities that other species may also occupy this site.

The biggest challenge in studying Leang Londrong and its bats is the difficulty of accessing the cave which cannot be done without proper equipment, sufficient manpower and considerable expense. And therefore, direct measurement of the cave physical characters and direct catching of the bats on each roosting sites inside the cave to confirm species diversity cannot be done. Mist net trap effectiveness was also contributed to number of individuals caught. Using mist net trap to capture bats is considered beneficial as it can provide more comprehensive data on age, sex, reproductive state, including diversity and abundance of bat in the area [24]. In this study, even though the traps were set in two layers with a distance of 25 m apart, due to the nature of the cave, the traps cannot cover all areas of exit/entrance points used by the bats. Some gaps created between the traps and cave walls have made spaces for individuals to escape. Other possible entrance/exit holes inside the cave could exist and the bats used these alternative points to escape. In addition, with the capabilities of Microchiroptera as insectivores
and as most cave dwellers, with their virtuous three-dimensional memory could also enable them to hinder from the trap sites [25].

*Hipposideros diadema* or diadem leaf-nose bat is considered as *Least Concern* (LC) by IUCN though the population showed a decreasing trend [26]. This species mostly lives on caves. In South Sulawesi, *H. diadema* found in Leang Londrong was considered larger than those found in other sites. The majority of body length in others were below 100 mm with the weight between 50-73 g [23,27] while in Leang Londrong the average body length was above 100 mm with the weight above 60 g.

Meanwhile, based on IUCN, *Rhinolopus arcuatus* (Arcuate horseshoe bats) is also classified as *Least Concern* (LC) [28]. The population of the species is reported to be stable but concerns laid on declining habitat with decreasing habitat quality in some areas [28]. Here, *R. arcuatus* was first reported as one species inhabited Leang Londrong. In South Sulawesi, the species has been reported to inhabit Marapettang and Sawi Caves in Maros and Mara Kallang Cave, Pangkep [21,23]. Other has also reported on the existence of the species in Mangolo Nature Park and Rawa Aopa National Park, Southeast Sulawesi [29]. In term of body size, *R. arcuatus* could be considered moderate compared to other two species in Leang Londrong. However, compared to its neighbor populations in Mara Kallang (Pangkep), Marapettang and Sawi (Maros) as well as in the Southeastern part of Sulawesi, the size of *R. arcuatus* in Leang Londrong tended to be smaller in body size [21,23,29].

In the world, Genus *Myotis* have been recorded to have 343 species in total where only 12 species found in Indonesia and 5 species were noted to be existed in Sulawesi [30]. Those were *M. ater*, *M. adversus*, *M. formosus*, *M. horsfieldii*, and *M. muricola*. One of the species was found in Leang Londrong. Unfortunately, it cannot be identified to the species level. This can be due to limited photographs taken in some important morphological key features or errors occurred during the measurements.

The positions of roost site have been marked and mapped along 0.5 km from the entrance. But, to determine the location based on the species, it was difficult as the visibility inside the cave was very poor. Inside the cave, temperatures were quite constant inside the cave with relatively high humidity and starting from the entrance to 150 m (R1) to the last roost found (0.52 km-R5), the situation of the cave was very dark (0 lx). The noise levels were around 65 dB which were generated from the sound of the river flowing. This tranquil situation with damp conditions and stable temperatures are suitable for roosting sites [31,32]. Microclimate conditions chosen as roosting sites in particular sound intensity, distance from the cave entrance, temperature, humidity and light intensity are usually adjusted with the needs of their body conditions [33,34]. However, details are required to portray the conditions of the three species roosting inside the cave.

5. Conclusions
Leang Londrong is one of important caves for *Microchiropteran* bats even though in this study there were only three species recorded *Hipposideros diadema, Rhinolopus arcuatus, Myotis sp*. There are possibilities that this site might uphold more species. Details on species diversity, abundance, roosting site distribution, and also microclimate conditions could not be attained due to the nature of the cave. Therefore, further studies on the cave and its bats need to be carried out in the future with more proper equipment, trained staff, and sufficient budget to further elaborate the site. Complete and comprehensive data on cave and bat species can be later used to properly manage the area for future development of ecotourism activities in Leang Londrong as well as to support the conservation of bats and its habitat protection in Maros-Pangkep Karst area.

References
[1] Achmad A and Hamzah A S 2016 Database Karst Sulawesi Selatan (Karst Database of South Sulawesi Province)
[2] Sunartadirdja M A and Lehmann H 1960 Der tropische karst von Maros und Nord-Bone in SWC Celebes (Sulawesi) *Z. Geomorph. Suppl* 2 49–65
[3] Suhardjono R Y, Marwoto R M, Achmadi A S, Iesaningsih N R, Lupiyaningdyah P, Suyanto S,
Rahmadi C, Wiantoro S, Nugroho H, Wowor D and Kurnianingsih K 2012 Fauna Karst dan Gua Maros (Jakarta: LIPI Press)

[4] Sherwood S and Simek J 2001 Cave Archaeology in the Eastern woodlands. Midcontinental Archaeol.

[5] Pipan T and Culver D C 2013 Forty years of epikarst: what biology have we learned? Midcont. J. Archaeol. 42 215–23

[6] Duli A, Mulyadi Y and Rosmawati 2019 The Mapping Out of Maros-Pangkep Karst Forest as a Cultural Heritage Conservation IOP Conf. Ser. Earth Environ. Sci. 270

[7] Ford D and Williams P D 2013 Karst Hydrogeology and Geomorphology (Chichester: John Wiley & Sons)

[8] Arsyad M, Pawitan H, Sidauruk P and Putri E I K 2014 Analisis ketersediaan air sungai bawah tanah dan pemanfaatan berkelanjutan di Kawasan Karst, Maros Sulawesi Selatan (Analysis of Underground River Water Availability and Its Sustainable Uses at Karst Maros Area in South Sulawesi) J. Mns. dan Lingkung. 21 8–14

[9] Barton H A and Northup D E 2007 Geomicrobiology in cave environments: past, current and future perspectives J. Cave Karst Stud. 69 163–78

[10] Forti P 2015 A Brief for GSDR 2015: The scientific and socio-economic importance of karst and caves and their vulnerability Int. Union Speleol.

[11] Achmad A 2011 Rahasia ekosistem hutan bukit kapur (Surabaya)

[12] Maulany R I, Wolor F S, Nasri N and Achmad A 2019 Habitat Characteristics and Population of cave-dwelling bats in Mara Kallang Cave of Maros-Pangkep Karst Area of South Sulawesi IOP Conf. Series: Earth and Environmental Science 270

[13] Ruslan R K, Maulany R I, Nasri N and Ngakan P O 2021 Potential and regeneration of tree species used as roosting habitat by Sulawesi fruit bats Acerodon celebensis in Jenetaesa, Maros Regency IOP Conf. Series: Earth and Environmental Science 807

[14] Gunn J, Harwick P and Wood P . 2000 The invertebrate community of th Peak-Speedwell cave system, Derbyshire, England: pressures and considerations for conservation management Aquat. Conserv. Mar. Freshw. Ecosyst. 10 353–69

[15] Telbisz T and Mari L 2020 The significance of karst areas in European national parks and geoparks Open Geosci. 12 117–32

[16] Baker A and Genty D 1998 Environmental pressures on conserving cave speleothems: effects of changing surface land use and increased cave tourism J. Environ. Manage. 58 165–76

[17] Arfib B, de Marsily G and Ganoulis J 2000 Pollution by seawater intrusion into a karst system: New research in the case of the Almyros source (Heraklio, Crete, Greece) Acta Carsol 29 15–31

[18] Calò F and Parise M 2006 Evaluating the human disturbance to karst environments in Southern Italy Acta Carsologica 35 47–56

[19] Parise M and Pascali V 2003 Surface and subsurface environmental degradation in the karst of Apulia (Southern Italy) Environ. Geol. 44 247–56

[20] Brouquisse F, Lasca M and Rigal D 1992 Sulawesi: Résultats spéléologiques 37–82

[21] Hayati N 2019 Pengelolaan Ekowisata Leang Londrong Berbasis Desa Di Kabupaten Pangkep Sulawesi Selatan (Management of Leang Londong Ecotourism Based on Village in Pangkep District, South Sulawesi) ANR Conference Series 02 p 578

[22] Gnaspini P E and Trajano E J 2000 Guano Communities in Tropical Caves in Wilkens, H., D.C. Culver, W.F. Humphreys (Eds) vol 30 (Amsterdam: Elsevier)

[23] Suyanto A and Wiantoro S 2012 Kelelawar (Bats) Fauna karst dan Gua Maros (Jakarta: LIPI Press)

[24] Erkert H G 1982 Ecological aspect of bat activity in Kunz, T.H. (Ed). Ecology of Bats (New York: Plenum Press)

[25] Neuweller G and Möhres F P 1967 Die role des ortsgedächtnissesbei der orientierung der grossblatt-fledermaus Megaderma lyra Z.Vergl. Physiol. 57 147–71

[26] Aguilar J and Waldien D L 2021 Hipposideros Diadema. The IUCN Red List of Threatened
Species: e.T10128A22095445.

[27] Ansharullah S A 2021 *Populasi kelelawar Genus Hipposideros dan ancaman terhadap keberadaannya di Gua Togenra, Desa Madello, Kecamatan Balusu, Kabupaten Barru (Bat Population Study of Genus Hipposideros and their threats in Togenra Cave, Madello Village, Balusu District, Barru)* (Universitas Hasanuddin)

[28] Rosell-Ambal G, Tabaranza B and Wright D 2008 *Rhinolophus arcuratus IUCN Red List Threat. Species* 2008

[29] Wiantoro S, Hitch A T, Engilis I E, Gunawan H and Engilis A 2016 Bats (Chiroptera) recorded in the lowland of Southeast Sulawesi, Indonesia with notes on taxonomic status and significant range extensions *Mammalia* 81 385–400

[30] Hill J E and Rozendaal F G 1989 Records of bats (Microchiptera) from Wallacea *Zool. Med. Leiden* 63 97–122

[31] Altringham J D 1996 *Bats: Biology and Behaviour* (New York: Oxford University Press)

[32] Zahn A and Hager I 2005 A cave dwelling colony of Myotis daubentonii in Bavaria, Germany *Mamm. Biol.* 70 242–65

[33] Nam S C, Kang J H, Lim J D, Choi D W and Kim T H 2009 Study on hibernating caves and food source of Copper-winged Bat (Myotis formosus), for multiplication and preservation *J. Korean Nat. 2* 129–36

[34] Wijayanti F and Maryanto I 2017 Diversity and pattern of nest preference of bat species at bat-dwelling caves in Gombong Karst, Central Java, Indonesia *Biodiversitas* 18 864–74