Habitat Characteristics and Population of cave-dwelling bats in Mara Kallang Cave of Maros-Pangkep Karst Area of South Sulawesi

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Habitat Characteristics and Population of cave-dwelling bats in Mara Kallang Cave of Maros-Pangkep Karst Area of South Sulawesi

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Abstract. The cave is one of the important habitats for bats in particular Microchiropterans which provides not only protection but also a shelter for breeding, hibernation, and other events. The characteristics of the cave are crucial for habitat selection. An extensive limestone ecosystem found in the four regencies of South Sulawesi (Indonesia) including Maros-Pangkep karst area has been utilized as the main habitats of cave-dwelling bats. One of the cave inhabited by bats is Mara Kallang Cave. This research aims to examine the physical and environmental characteristics of Mara Kallang Cave. Cave-dwelling bat species diversity and population were also assessed. The direct measurement was carried out to quantify the physical and environmental characteristics of the cave. *Ibutton* data loggers were employed to record data on temperatures and humidity was measured by using thermohygrometer. Several bat individuals were captured and identified by using a mist net trapping method. Roost locations of different bat species inside the cave were also mapped. A number of individuals per species were also recorded by direct counting and re-confirmed with the photographic count. There were 3 species of cave-dwelling bats inhabited Mara Kallang Cave: *Hipposideros cervinus, Rhinolophus cf euryotis* and *Rhinolophus cf arcuatus* roosting in station 4 of the cave with the width of 364.9 m^2. The average temperature of the roosting site was 23.31°C with the average humidity of 98%. From the three species found in the cave, *Rhinolophus cf euryotis* had the largest number of individuals with an average of 386 individuals followed by *Rhinolophus cf arcuatus* with the average individuals of 304. The least colony size was *Hipposideros cervinus* with a total of 188 individuals on average.

1. Introduction

Order Chiroptera is divided into Megachiroptera (large size and frugivore bats) and Microchiroptera (smaller size of bats) [1][2]. The Microchiroptera consists of 834 species from 17 families and 137 genera distributed across tropical to temperate region of the world [2]. However, there are only 112 species known to be classified as Microchiroptera in Indonesia [2] with 50% of the number of inhabit caves [3]. Most of the Microchiropterans are insectivorous. These species of bats have significant contribution to control insect pests and balance the ecological system by depredating nocturnal insects [2]. One of the important habitats for these bats is caves.

The cave is a unique underground channeling ecosystem formed naturally over a million years ago through the dissolution of limestone rock and mostly had an extensive and cavernous underground which

then creates specific micro-climatic conditions [4,5]. Both natural or artificial cave can provide cavities for living creatures (Moseley, 2009). It contains various features which include the occurrence of surfaces, water movement systems, and bulk substrates [4]. These have potentially offered a variety of habitats for mesofauna and/or macrofauna including bats.

Maros-Pangkep area of South Sulawesi Province, Indonesia has an extensive limestone ecosystem area with 40,000 ha. This area has been recorded to consist of 268 caves, yet, only 46 were already identified and visited [6]. From the previous studies conducted by the Indonesian Research Centre (LIPI) in 2007, only 15 species of cave-dwelling bats have been found in several investigated caves [6]. Many studies are required to examine all caves and their living biota in the area. Mara Kallang is one cave located in Maros-Pangkep area that has not been widely explored and studied. This research attempts to provide information on the physical and environmental attributes as well as the diversity of bat species utilized Mara Kallang Cave as a roosting site.

2. Material and Method

2.1. *Study site*

Mara Kallang Cave is located in Maros-Pangkep karst ecosystem area between $04^{0}52'43.4"$ S and $119^{0}46'00.0"$ E. The cave is administratively included in Tompobulu Village, Pangkep Regency, South Sulawesi, Indonesia (Figure 1). The data were collected from September-December 2017. Prior to data collection, the cave was explored to determine maximum access from the entrance to the inside of the cave. In general, there were 4 phases of the research which consisted of 1) cave exploration; 2) measurement of physical and environmental characteristics, 3) diversity of cave-dwelling bat species; and 4) distribution and abundance of cave-dwelling bats in Mara Kallang Cave.

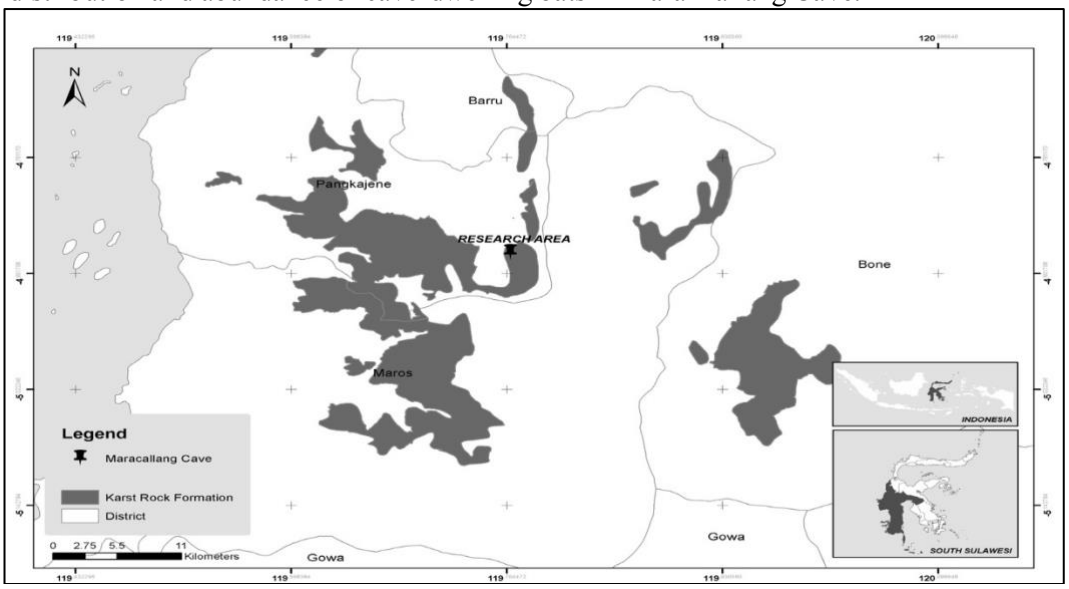

Figure 1. Research Site in Maros-Pangkep Karst Area, South Sulawesi Province, Indonesia

2.2 Data Collection and Analysis

2.2.1 Physical and Environmental Characteristics

In measuring physical and environmental parameters of the cave, observation stations were established by marking the coordinates of each station with a hand-held GPS started from the entrance to the duck of the cave until 10 m after the last roost of bats were seen. Each station was marked 10 m apart. Outside the cave, one observation station was enacted to provide a comparison for the environmental parameters between inside and outside the cave. After stations deployed, the width and the height of the cave

entrance were measured using tape meter. The slope of each station to another was also recorded by using Clinometer. Then, the third measurement of hallway length was done from the entrance to the first station. This method was known as the forward method.
[7]. Here, the first observer conducted the measurement in the first station while the second observer was placed in the second station. The same protocol applied in each station until the last station reached.

To calculate the height of the cave in each station, different equation depending on the slope position and observer were applied [8]. The area of the cave was determined by using piped-cave approach for a cave with pipe channeling. Meanwhile, for the irregular-shaped cave, triangle methods were used for larger size cave and grid methods were applied for smaller size cave [9].

Environmental aspects in each station were monitored. The temperatures of the cave in each station were recorded by using *ibutton* (Model DS1922L, ™Maxim, Dallas, USA) and set to log daily temperature data every hour. On the last day of observation, the *ibuttons* located in each station were withdrawn and the data were taken. Meanwhile, the humidity data was also collected daily by using thermohygrometer at the same time for two times measurement, in the morning (7.00 am) and evening (19.00 pm).

2.2. The d*iversity of Cave-dwelling bats*

To record the species of cave-dwelling, two methods were deployed. First, a hand-held net was used in front of the cave entrance to catch individuals. The second mist net trap with the width of 68 cm and length of 37 cm, was installed around 5 m from the cave entrance. The first trapping activities were started in the evening time for two hours (around 18.00 pm) and the second was around 6.00 am in the morning. Once the bat trapped or captured, three individuals of each species were taken as samples. Prior to morphological measurement, each bat was anesthetized by using chloroform and was placed in a cotton bag. Various body length including between head to the body (HB), tail (T), ear (E), forearm wing (FA), calf (Tib), hind foot (HF) were measured by using ribbon meter and body weight (Wt) was scaled. Sex of each bat sampled was also recorded and photographed to assist during the species identification. To confirm on the species being studied, several specimens of the bats were sent to the Indonesian Research Centre (LIPI) for further identification.

2.3. *Distribution and abundance*

Bat counts were carried out with two methods, direct count on roost site and re-confirmed with the photographic count for 7 days. The visual count was conducted by using census technique and to clearly spot individual, counting process began with the use of low-intensity lights and by dividing the observation area (cave wall) into several subplots with a size of 1 m x 1 m. Counting was repeated the next day for seven consecutive days. For photographic count, photographs were taken each day and each photograph was counted three times to obtain the average daily number of bats per species.

3. Results and discussion

3.1. *Characteristics of Mara Kallang Cave*

Mara Kallang Cave is situated administratively in Pangkep Regency about around 50 km from the city center of South Sulawesi Province, Makassar. The cave faced northwest and was located in an open area used to be paddy field. At the back of the cave, moderately dense vegetation can be seen. The cave was 10 km away from the closest village and therefore, it was safe from human disturbances. However, during the data collection, the presence of snakes as the main predator of bat species was often seen at the entrance of the cave. The total length explored from the entrance to the access point was 695.2 m. This study only focuses on measuring the characteristics of the cave in relation to the presence of bats. Therefore, there were 5 observation stations deployed inside the cave with the total length of 50 m from

the cave's entrance to the last station and 1 station was outside the cave with a distance of 8 m from the entrance (Table 1).

Station 1 was located at the entrance of the cave with a narrow entry of 1.9 m length, 1.5 m width, and 3.9 m height. Visibility in this section of the cave is 50%. However, approaching Station 2, the area became narrower with only 0.6 widths and 2 m height and becoming darker. Starting from the cave entrance to Station 3, small water streams were found in the tunnel of the cave. Station 3 had a bit wider area with 2.76 m^2 and the only station that was dry. In Station 1-3, there were no bat roosts found and the area was used as a travelling path for the bats to the outside of the cave. Bat roost sites were located in Station 4 with a distance of 40 m from the entrance which was the widest cave area (364.9 m^2). Here, not only the area was larger but also the cave floor was filled with water of around 30-40 cm depth. While in Station 5 and beyond, there were no bats spotted with narrower cave area (29.15 m^2). In general, the cave shape was like an eye shape began with a narrow entrance for 30 m length followed by a large area in the middle where bats roosting and then narrowed again.

Table 1. Physical and environmental characteristics in five stations of Mara Kallang Cave (Station 1-5=inside the cave; Station 6=outside the cave; *=irregular shape)

Cave Conditions	Mean Value of Parameter measured (±SD; min-max)						
	1	**2**	**3**	**4**	**5**	**Mean Value in Station 1-5**	**Mean Value in Station 6**
Temperature (°C)	22.54 (±3.24; 16.17-25.44)	21.84 (±2.24; 18.98-25.50)	22.94 (±0.42; 22.21-24.34)	23.31 (±0.64; 22.27-25.58)	23.09 (±0.51; 22.41-24.07)	22.74	20.78 (±0.74; 18.58-22.06)
Humidity (%)	3 (±9.09; 8-99)	91 (±9.09; 76-99)	93 (±5.68 85-97)	98 (±1.76 (94-99)	86 (±4.47; 74-99)	92.2	43 ±471 (40-58)
Length (m)	1.9	2.9	1.2	-	5.3	-	-
Width (m)	1.5	0.6	2.3	-	5.5	-	-
Height (m)	3.9	2	3.3	4.79	3.1	-	-
Cave Area (m^2)	2.85	1.74	2.76	364.9*	29.15	-	-
Distance from the entrance (m)	10	20	30	40	50		

The average daily temperatures of the cave taken with *ibuttons* were relatively warmer with 22.74 °C compared with the outside of the cave which was around 20.78°C. In contrast, humidity level inside the cave in average was higher (92.2%) while outside the cave was <50% (Table 1). Among 5 stations established, Station 4 was known to be the warmest with 23.31 °C with the highest humidity level of 98% due to a presence of underground river in the station. Based on the data obtained from the *ibuttons*, daily temperatures inside the cave fluctuated between 16.17°-25.58°C. However, the inside parts of the cave (Station 3-5) were relatively warm with smaller gaps while the outer parts (Station 6 including Station 1-2) were tended to have higher gaps in temperatures.

3.2. *The diversity of Cave-dwelling bats in Mara Kallang Cave*

Based on further identification on samples collected from Mara Kallang Cave, there were three species of cave-dwelling roosting in the area. The three species were *Rhinolophus cf euryotis* (broad-eared horseshoe bat) and *Rhinolophus cf arcuatus* (arcuate horseshoe bat) of Family Rhinolophidae and *Hipposideros cervinus* (fawn leaf-nosed bat) of Family Hipposideridae. All bats were classified as Microchiroptera and insectivorous bats (Figure 2). The two families can be differentiated from the form of the nose, size, and body color.

Figure 2. The species of cave-dwelling bats of Mara Kallang (A) *Rhinolophus cf euryotis;* (B) *Rhinolophus cf arcuatus;* (C) *Hipposideros cervinus* (male); (D) *Hipposideros cervinus* (female)

Table 2. Morphometric Measurement of samples per species of cave-dwelling bats in Mara Kallang Cave, South Sulawesi, Indonesia (HB=head to the body; T=tail (T); E=ear; FA=forearm wing, Tib=calf; HF=hind foot; Wt=weight; SD=standard deviation)

Species	HB (mm)	T (mm)	E (mm)	FA (mm)	Tib (mm)	HF (mm)	Wt (g)
R.cf euryotis	59.3 ±1.53 (58-61)	17.3 ±0.58 (17-18)	19.7 ±2.08 (18-22)	50 ±1 (49-51)	23 ±0 (23)	10 ±0 (10)	11.15 ±0.48 (10.73-11,67)
R.cf arcuatus	59 ±3.61 (55-62)	14.3 ±1.15 (3-15)	13.3 ±2.08 (11-15)	50 ±0.5 (51-52)	23 ±1.53 (20-23)	10 ±0.58 (10-11)	11.15 ±1.15 (12.69-14.95)
H.cervinus (yellowish colour)	41.3 ±1.53 (40-43)	19,7 ±1.53 (18-21)	11,7 ±1.53 (10-13)	40 ±4.16 (35-43)	13.3 ±1.53 (12-15)	6.5 ±0.5 (6-7)	6.0 ±0.04 (6-6.07)
H. cervinus (greyish colour)	42.7 ±2,52 (40-45)	21 ±1 (20-22)	11.3 ±2.31 (10-14	39.3 ±2.08 (37-41)	12 ±1 (11-13)	6.4 ±0.53 (6-7)	4,8 ±0.5 (4.25-5,2)

Morphometric measurements of cave-dwelling bats inhabited Mara Kallang Cave have shown that Family Rhinolophidae (both *Rhinolophus cf euryotis* and *Rhinolophus cf arcuatus*) had bigger size

compared to Hipposididae with the average height of 59 mm from the head to the body (HB) and the weight of more than 11 g (Table 2). While *Hipposideros cervinus* had two different colours (yellow and grey). The yellowish *Hipposideros cervinus* had smaller body size with the average height of HB of 41.3 mm but a lower weight of 6.0 g in comparison with the greyish one (HB=42.7 mm and weight=4.8 g).

3.3. *Distribution and abundance of cave-dwelling bats*

In Mara Kallang Cave, bat roosts of the three species were located in Station 4. However, each bat species had different patterns of roosting (Figure 3). From the cave entrance to Station 4, the roost of *Hipposideros cervinus* was first spotted forming small colonies between stalactites of the cave. The distance between the colonies of *Hipposideros cervinus* to both *Rhinolophus cf arcuatus* and *Rhinolophus cf euryotis* was 20 m apart. The next roost found living separately was *Rhinolophus cf arcuatus* located in the southern part of Station 4 and utilized the stalactites as their roost. Different from *Hipposideros cervinus,* the individuals of the species were clumped in one part of the cave. Around 5 m from the species to further area of Station 4, *Rhinolophus cf euryotis* placed their roosts. The species had formed one large colony at the top of the clear cave wall (without any cave ornaments).

For population abundance, the results of counting by using two methods were fluctuated for the three species inhabited Mara Kallang Cave (Figure 4). However, the largest individuals found was *Rhinolophus cf euryotis* located in the deepest area of the cave with the average total individuals of 386 (min-max=343-447). This was followed by 304 individuals (min-max=262-345). While the least abundance species in the cave was *Hipposideros cervinus* with 188 individuals.

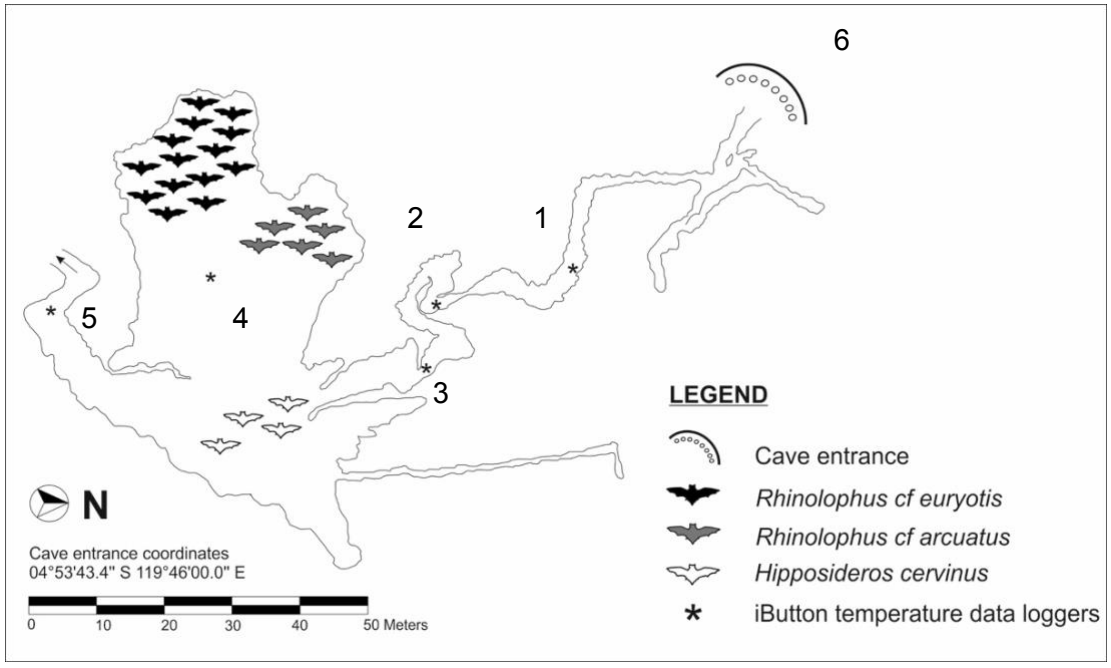

Figure 3. Cave-dwelling bats distribution inside the cave of Mara Kallang, South Sulawesi, Indonesia

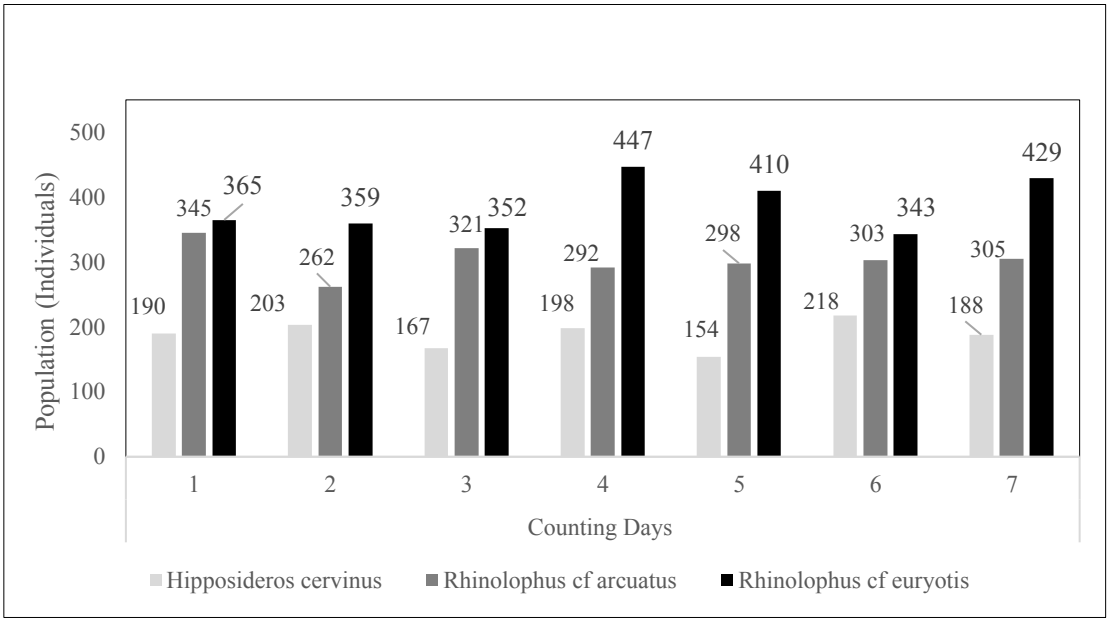

Figure 4. Relative abundances of three species (*Hipposideros cervinus, Rhinolophus cf arcuatus,* and *Rhinolophus cf euryotis* in Mara Kallang Cave, South Sulawesi

The location of Mara Kallang Cave is quite far from human settlement in the open area of previously utilized for paddy field and therefore, it is only received minimum contact with a human. This situation benefits the bats living in the unexposed cave where no human activities in the area. Moreover, the absence of a barrier in front of the cave has made easier for bats to enter and leave the cave. This was also important aspects in the selection of roost site. Based on bat trapping and sample's identification, Mara Kallang Cave inhabited by the three species of cave-dwelling bats, *Rhinolophus cf euryotis* (broad-eared horseshoe bat), *Rhinolophus cf arcuatus* (arcuate horseshoe bat), and *Hipposideros cervinus* (fawn leaf-nosed bat).

The aspect of the cave entrance in Mara Kallang Cave was to the northwest which limits the effect of sun exposure toward the inside of the cave and in turn, would affect the temperature of the cave. Bats tend to occupy roost site with specific requirements particularly for cave species where suitable micro-climatic conditions become important parameters [10,11] A study conducted by [11] on brown-long eared bat (*Plecotus auritus)* reveals that there were 13% of bats occupying roost with north-west orientation while the majority chose to face north-south (39%), east-west (33%), and northeast-southwest (15%).

Another unique feature of Mara Kallang cave were that the access to the inside of the cave was quite difficult. This would secure the cave from predators and human activities. The cave has also a unique shape where a long passage connected to a large hall (Station 4) where the bat species occurred inside the cave. A long passage of the cave is required for the bat species to do the maneuver while traveling out and to the roost site inside the cave [12]. Deep roost may provide the bat species quite area to be used for detecting objects during flying by using echolocation system in dark places [13].

Many studies have confirmed that in selecting a particular cave for roosting, bats would determine the choice according to the need of their body conditions [12]. Numerous of cave-dwelling bats inhabits caves with damp conditions, stable temperature, minimum noise disturbances [14] distances from water sources and foraging areas. This was also the case of Mara Kallang Cave, where the three bat species were situated their roost sites in the largest area of the cave (Station 4). Station 4 was located around 40 m from the cave entrance with an abundance of water sources both in the cave floor and from the cave wall. The large area of Station 4 could provide security from human disturbances as it was located

further from the entrance with difficult access. It could also enable the bats to have sufficient space to move freely inside the area, rest, and to reproduce [15].

In general, the daily air temperatures inside the cave were also warmer (22.74°C) with minimum fluctuation compared to the outside of the cave (20.78°C) with more extreme changes between the times of the day (18.58°-22.06°C). In contrast, the humidity inside the cave was higher (>90%) due to the existence of water sources needed by the bats than the outside. However, inside the cave, the differences occurred between stations. The warmest part was in Station 4 where the bats can be found (23.31°C). The station was also the most humid area among the five stations due to the existence of water (98%). The three species of bats placed their colonies differently in the cave wall of Station 4. The fawn leaf-nosed bat (*Hipposideros cervinus*) was the first species encountered in Station 4 followed by *Rhinolopus cf arcuatus* and *Rhinolopus cf euryotis*. The distribution of the three species might be largely affected by temperature and humidity where bats preferred lower temperature with higher humidity (Maryanto & Mahardatunkamsi, 1991). For tropical caves, normal conditions of temperature inhabited by bats was between 20-30ºC [1].

Mara Kallang Cave can be considered suitable for cave-dwelling bats with a relatively stable temperature between 21.84º-23.31ºC. However, compared to other cave inhabited by bats in Indonesia, the temperature range of Mara Kallang was lower. There is also a variation of cave micro-climatic conditions within a species over a different habitat. For example, in Bratus Cave of West Borneo, between December 2014 to January 2015, *Hipposideros cervinus* had roosted in the area with a higher temperature between 26-27 ºC and humidity of 94% [16]. This finding was in line with the species found roosting in Queensland, Australia [17]. In Bandung Cave, Central Java, a Family of Hipposideridae, *Hipposideros bicolor,* had even higher temperatures of 30.2ºC and more lower humidity with 76.86% during a study between January to June 2012 [18]. Another study of *Hipposideros larvatus* roosting in Putih Cave, West Java had found that the temperature of the cave was between 26.5º-28.1 ºC in February 2015. Meanwhile, for the family of Rhinolophidae, *Rhinolophus affinis* was found roosting in Buni Ayu Cave, West Java with the temperature of 25.7^0C and humidity of 84.48% [19].

The results of morphological measurement of bat samples from Mara Kallang Cave have shown that there were differences of the bat size (HB) of the three species. *Hipposideros cervinus* in Mara Kallang were bigger (average of 42 mm) compared to the one found in Bratus Cave, West Borneo (average of 39.9 mm) [16]. Meanwhile, in Liang Cave, North Sumatera, *Hipposideros cervinus* had longer ears (16.40-21.00 mm) compared to similar species found in Mara Kallang (10-14 mm). The weight of *Hipposideros cervinus* in Mara Kallang (4.25-6.07 g) was almost similar to the one roosting in Togendra Cave, Maros (4.1-6.5 g) [6].

Based on the size measured, *Rhinolophus cf euryotis* roosting in Mara Kallang Cave, had a similar length of tail (17-18 mm) compared to the one found in Southeast Sulawesi (16,2-21,6 mm) [19]. However, for the length of an arm, the *Rhinolopus* sp. in Mara Kallang had similar with length (49-51 mm) with the species from Papua New Guinea (48-51 mm).

The species of *Rhinolophus cf arcuatus* in Mara Kallang cave had a smaller hind leg with 20-23 in comparison with the one in Marapettang, Maros (22-24 mm) [6]. In Southeast Sulawesi, Jenis *Rhinolophus arcuatus* had between 6.4-12.1 mm [20], while in Mara Kallang was between 10-11 mm.

A number of bat species living in Mara Kallang Cave was similar to other caves in Indonesia. In Gombong Karst Area of Central Java, five caves were inhabited by mostly three bat species that were different from one cave to another [12]. Meanwhile, in Alas Purwo National Park, [21] discovered three species of cave-dwelling bats roosting in three different caves. It was suggested by [22] that the majority of a cave in Indonesia was inhabited by 1-6 bat species.

Out of the three species roosting in Mara Kallang, *Rhinolophus cf euryotis* had the highest number of individuals with an average of 386 individuals followed by *Rhinolophus cf arcuatus* for 304 individuals. While *Hipposideros cervinus* had only 188 individuals. Even though the calculations were generated from two methods, however, dark conditions and sensitive behavior of the bats during the study could make the data becoming inaccurate. The presence of predators several time in front of the cave entrance could trigger the fluctuation of the bats during the counting.

Bats of Family Rhinolophidae and Hipposideridae are mostly found to inhabit similar caves [12,22,]. [23]The two family of bats hunt for insects as their main diets. The surrounding areas (farmland and forest vegetation) provide different types of insects required by the species [24]. However, intraspecific and interspecific competition is limited as the bats had their own niches. They not only consume different types of insects but also different stages of insect development adjusted with each bat development stage [12,24].

4. Conclusion

Based on the findings of this study, there were three species of insectivorous bats (*Rhinolophus cf euryotis, Rhinolophus cf arcuatus,* and *Hipposideros cervinus*) utilized Mara Kallang Cave in Maros-Pangkep Karst Area, South Sulawesi. The cave had a free-barriers entrance with difficult access to the inside of the cave. Moreover, an eye shape cave with 40 m long passage to the main hall had benefitted the bats to access in and out of the cave. Large main hall situated in the middle of the cave has provided a suitable warm (23.31°C) and damp conditions (98%) for bats. The area was also close to the water sources. Both physical and environmental characteristics of Mara Kallang Cave had supported the existence of the bat species as a roosting site. *Rhinolophus cf euryotis* had the highest number with 386 individuals. According to these findings, it is suggested that Mara Kallang Cave has a significant contribution to the protection of cave-dwelling bats and therefore, it needs to be protected and conserved. Further research is required to better understand the requirements for species-specific towards the physical and environmental habitat characteristics to design an appropriate conservation strategies of cave-dwelling bats. Many caves in Maros-Pangkep Karst Area have not been discovered and further studies in a relationship with the use of caves as the important habitat of bat species are still urgently needed. Most studies in this area are still partially conducted by different stakeholders. Therefore, it is essential to conduct a comprehensive and integrated exploration to the area to map the use of caves by bats in the area and to fill many knowledge gaps in order to support the conservation of bats in Indonesia.

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