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Diversity of the Cave-Dwelling Bat (Chiroptera) in the Ngobaran Coastal Area, Karst of Gunung Sewu

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Abstract. *Bats (Chiroptera) are divided into two suborders (Yinpterochiroptera and Yangochiroptera). More than 50% of species of bats use caves as their roosting sites. Thus, they play a crucial role in the cave ecosystem. For that reason, they also exist as keystone species in the karst area. Gunung Sewu is one of the karst areas in Indonesia that best exemplifies tropical karst. Furthermore, Gunung Sewu is still at risk of habitat loss despite being designated as a Geopark. This study aimed to understand the diversity of bats that live in caves in the karst region of Gunung Sewu, specifically in four caves near Ngobaran Beach between April and June 2020. A harp net and misnet placed at the cave's entrance were used to capture bats for data collection. After they were captured, the bats were identified using Morphometry and the Shannon-Wiener index. Through another index, Margalef index, the bat diversity in the four cave habitats was expressed, with a discovery that there are many different species. Based on the Jaccard similarity index, bats were categorized again using cluster analysis and the unweighted pair-group method using arithmetic averages (UPGMA). A total of nine species across five families were identified. The diversity of existing species variety was also recognized by analyzing the composition of the four cavern inhabitants. The four cave ecosystems' bat diversity was divided into three categories: moderate variety, low similarity, and high species diversity. Except for Cekelan 1 Cave and Gebyog Cave (P=0.015), other variations did not demonstrate a meaningful difference (P0.05). This demonstrates how different each ecosystem is. Therefore, they could be classified as potentially spoiled habitats, demanding additional conservation efforts.*

Keywords: *Bat cave, biospeleology, Chiroptera, diversity, Gunung Sewu*

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INTRODUCTION

Following Rodentia, bats (Chiroptera) are the second most diverse group of mammals. There are at least 1447 distinct species of bats worldwide, and 238 may be found in Indonesia (Vaughan, et al., 2015; Maryanto et al., 2019; IUCN Redlist, 2022). The order of Chiroptera was previously divided into two suborders, namely Megachiroptera and Mi-

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crociroptera. The classification is based on morphological data (Hutcheon & Garland 2004). However, current molecular and evolutionary evidence supports a new classification that groups bats into Yinpterochihroptera and Yangochiroptera (Teeling et al., 2012; Foley et al., 2015). Some bat species use caves as roosting locations. Bats occur in many habitats, including caves (Altringham & Senior, 2005). The cave is among the imperative roosting sites for many bats species due to its physico-chemical parameters (Wijayanti, 2011; Wiantoro, 2012). Each cave and karst ecosystem has a unique set of physical and chemical variables that make up the cave's roosting habitat. This condition depends on the karst region's topography, latitude, and altitude. Karst areas can be found across Indonesia, from the west to the east. Gunung Sewu is one of these as the best exemplifies the tropical karst region and has been designated as a UNESCO World Geopark (Haryono & Day, 2004; Unesco, 2021) with a total area of 3,300 km^2. Despite being a global geopark, the threats keep increasing due to increasing land usage in karst hills, population pressure on high land, excessive use of artificial fertilizers, and expanding large mining Cahyadi et al. (2014). Gunung Sewu Area Coastal regions have been classified as more threatened places. Caves in the Coastal region are threatened habitats because they have narrow areas and unique landscapes and are vulnerable to disturbances that easily damage their habitats.

The diversity of the cave-dwelling bats in the Gunung Sewu karst coastline region and general information on the variety of the fauna is incomplete. These bats have a role in controlling insect populations of agricultural pests and as pollinators (Kunz, 2003; Cleveland et al., 2006; Wanger et al., 2014). Previous studies focused only on the epigean fauna (Ozbek, 2016). This investigation intends to learn more about the variety of bats that live in caves in the Ngobaran Coastal Area, Karst of Gunung Sewu, providing incomplete information in the past so that fitting conservation policies could be created for Gunung Sewu Coastal region in the future.

MATERIALS AND METHODS

Diversity and Richness

This research was conducted between April and June 2020. Field data collection was carried out in four caves, in the Cekelan 1, Cekelan 2, Welutan, and Gebyog caves near Ngobaran Beach (Figure 1)., Meanwhile, the identification and data analysis were conducted in the research laboratory, Biology Study Program, Faculty of Mathematics and Natural Sciences Universitas Negeri Yogyakarta.

Harp net (Harp trap) and Misnet (9x3 m), set up at the cave's opening, were used to capture bats. The capturing began at 5:00 p.m, lasting until the last bat came out of the cave with 15-minute interval checking. The bats captured were carefully removed from the sharpness and mist nets as soon as possible to prevent stress and damage to the bat's skin and fingers. After that, the captured bats were put in a calico bag. The bats caught were taken in pairs (male-female) to be prepared as specimens. Other individuals were released back after being identified. Ketamine-xylazine (50 mg/kg body weight) was used to render the bats unconscious before they were preserved in a liquid that contained 96% alcohol.

Bats identification was based on the combination of Morphometry and morphology (Payne et al., 2000; Suyanto,2001; Huang et al., 2016; Maryanto et al., 2019). The Shannon-Wiener index and Margalef's measure of species diversity and richness were used to quantify the diversity of bats in each cave (Krebs 1989). Based on the Jaccard similar-

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ity index, bats were categorized using cluster analysis and the unweighted pair-group method using arithmetic averages (UPGMA) (Sneath & Sokal 1973). Based on the Jaccard similarity index, bats were categorized using cluster analysis and the unweighted pair-group method using arithmetic averages (UPGMA) (Sneath & Sokal 1973). Shapiro-Wilk was used to determine the normality of the diversity data between habitats (sig=95%), and Kruskal-Wallis was used to determine whether there were any variations in the diversity between cave habitats (P=0.05). All the analyses were performed using PAST Paleontological Statistics tool, ver. 4.09 (Hammer et al., 2001).

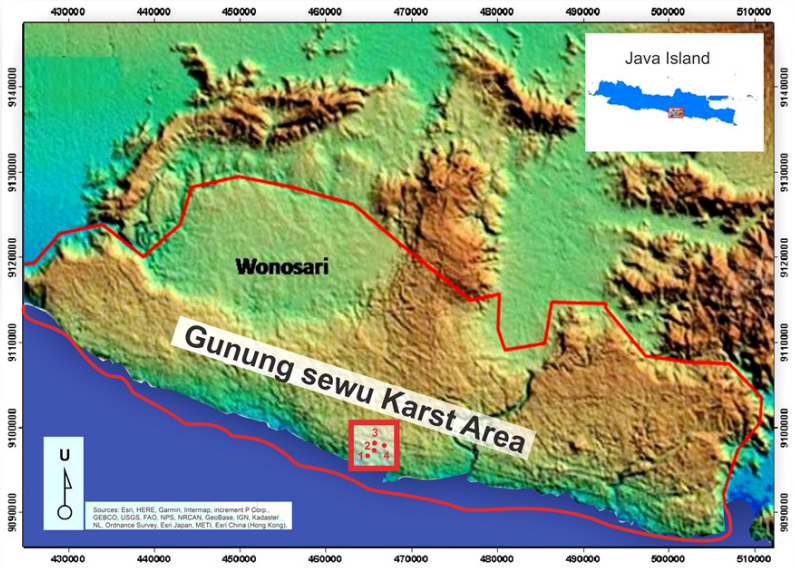

Figure 1. Sampling locations in Gunung Sewu Karst Area, (1. Cekelan 1 cave; 2. Cekelan 2 cave; 3. Welutan cave; 4. Gebyog cave

RESULTS AND DISCUSSION

Diversity and Richness

Based on this study, we recorded nine species from five families distributed in four caves. The nine species are *Nycteris javanica*, *Hipposideros larvatus*, *Hipposideros diadema*, *Rhinolophus pusillus*, *Miniopterus fuliginosus*, *Miniopterus pusillus*, *Miniopterus australis*, *Cynopterus brachyotis*, and *Cynopterus spinx*. Of the nine species, one is endemic and vulnerable (*Nycteris javanica*) (Waldien & Wiantoro, 2021), one is vulnerable (*Miniopterus fuliginousu*) (Garzan et al. 2020), and one has a declining population trend (*Hipposideros diadema*) (Alguilar & Waldien, 2021). *Hipposideros larvatus* was the only species found in the four caves. *N. javanica*, *H. diadema*, and *C. sphinx* were only found in one cave. The results of this study also showed that the species the majority of cave dwellers are insectivorous bats. This condition is related to the condition of the utterly dark cave passages. According to Jones & Teeling (2005) and Teeling et al. (2012), insectivorous bats have good echolocation abilities to inhabit caves. While other species, Frugivor species, do not have this ability, they cannot use caves as a roosting habitat to the fullest. If found in caves, they will generally roost in bright to dim zones. Details of the species found in each cave are presented in Table 1 below.

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Table 1. Bat species which were recorded in four caves at the coast of Ngobaran, Gunung Sewu Karst Area

Family	Species	Kons Status (IUCN)	Cave Habitat				N
			Cekelan 1	Cekelan 2	Welutan	Gebyog	
Nycteridae	*N. javanica*	VU	36	-	-	-	36
Hipposideridae	*H. larvatus*	LC	43	57	72	34	206
	H. diadema	LC	42	-	38	-	80
Rhinolophidae	*R. pusillus*	LC	-	-	-	45	45
Miniopteridae	*M. fuliginosus*	VU	56	50	67	-	173
	M. pusillus	LC	-	33	-	-	33
	M. autralis	LC	-	64	96	-	160
Pteropodiae	*C. brachyotis*	LC	-	-	32	26	58
	C. spinx	LC	-	-	-	36	36

This study result shows that an average of 4 -5 bat species occupy each cave. This result differs from a similar study on a karst cave in Tuban, Ngerong cave, occupied by nine bat species (Prakarsa, 2013). This composition of bat species is also fewer than bat species composition found in karst caves on Menoreh, which is occupied by six species on average (Prakarsa, 2013). Moreover, considering the length of the cave passage in this study, it is longer than in the two karst areas. This result is also different from Brunnet & Mendellin (2001), which state that there is a positive correlation between the length of the cave passage and the number of species in it.

All the studied caves generally had a low diversity index, which falls between 1 and 2 (Table 2). The five levels of Shannon-Wiener are extremely low (1), low (1-2), moderate (2-3) and high (3-4) and very high (>4). (Odum, 1994; Maharadatunkamsi, et al., 2015). Welutan Cave has the highest level of bat diversity compared to the others, indicated by the Shannon-Wiener diversity index value of 1.54, while Cekelan 1 Cave has the lowest diversity (H' = 1.02). However, vulnerable species in these areas, as evidenced by the low diversity and numerous species with VU status from the IUCN. The existence of vulnerable species with low levels of biodiversity should receive special attention because they will be vulnerable to extinction locally if they face threats and pressures on the habitat.

Table 2. Shannon-Wiener Diversity Index and species richness (Margalef) of each cave

Cave Habitat	H'	S
Cekelan 1	1.02	0.62
Cekelan 2	1.31	0.68
Welutan	1.54	0.85
Gebyog	1.33	0.65

There are disparities in the richness of existing species, as evidenced by the species of the four caverns' residents. Except for Cekelan 1 Cave and Gebyog Cave (P=0.15), this difference did not demonstrate a meaningful difference (P0.05). Table 3 displays significance values between habitats.

Table 3. Significance values between cave habitats based on bat diversity

Cave Habitat	Cekelan 1	Cekelan 2	Welutan
Cekelan 1			
Cekelan 2	0.094		
Welutan	0.072	0.193	
Gebyog	0.015*	0.266	0.194

According to the Jaccard similarity measure, Cekelan 2 Cave and Welutan had the two habitats' highest level of similarity, at 50%, while the other three were less similar. A similarity of less than 50% falls under the low category (Odum 1994). Table 4 below shows how closely related all environments are.

Table 4. Jaccard similarity between cave habitats

	Cekelan 1	Cekelan 2	Welutan	Gebyog
Cekelan 1	1			
Cekelan 2	0.4	1		
Welutan	0.333333	0.5	1	
Gobyog	0.166667	0.142857	0.285714	1

The dendrogram produced by cluster analysis based on the Jaccard similarity index using the UPGMA (unweighted pair-group technique using arithmetic averages) approach (Sneath & Sokal 1973) method illustrates the similarities between the four caves (Figure 2). After forming a distinct group, Welutan, which later joined with Cekelan 1 Cave at a similarity of 33%, and Cekelan 1 at a similarity of 17%.

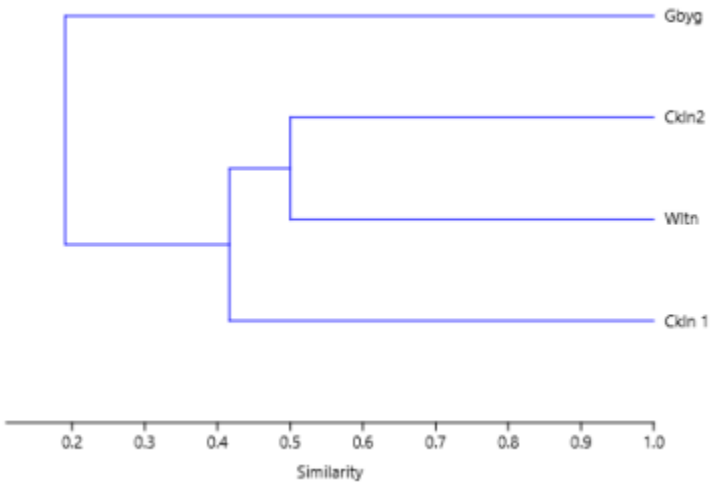

Figure 2. Dendrogram of bat habitat disribution grouping based on the Jaccard similarity index

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In a habitat not entirely usable by bats, only some parts can be used. This condition is influenced by three main factors: access, biotic, and abiotic factors. Alternatively, this cave habitat provides the carrying capacity for the existence of bats (Wiantoro, 2012). This part of the habitat is called a niche (Chase & Leibold, 2003; Pocheville, 2015). Furthermore, according to Wijayanti et al. (2011) and Prakarsa et al. (2021), the influential abiotic factors are the physicochemical conditions of the cave habitat, especially air ammonia levels, oxygen levels, air temperature, and air humidity. This condition makes bats must be able to adapt in order to survive. One of these adaptations is a physiological adaptation by increasing the number of erythrocytes and hemoglobin. These conditions allow bats to be able to meet the oxygen needs in their bodies. On the other hand, flying activity also affects the hemoglobin profile in bats (Saimina et al., 2019).

The four caves with low similarity, low diversity, and medium species richness show the uniqueness of each habitat. Therefore, from a conservation point of view, the four cave habitats and their environmental quality are preserved. So that the sustainability of the habitat will ensure the existence of the species of its inhabitants. On the other hand, it is necessary to increase efforts to reduce the level of habitat disturbance by humans and encourage the use of sustainable environmental services. According to Tanalgoa et al. (2018), cave habitats currently rated as least vulnerable are highly likely to become vulnerable under improper management or if accessibility improves.

Future Perspective

Until now, few countries have legislation or regulations to protect and conserve cave environments, which are generally weak and poorly enforced (Van Beynen, 2011; Prakarsa et al., 2021). For instance, the law for animal protection is usually established to regulate species level only and override the broader context of the ecosystem (Prakarsa et al. 2021). In addition, the misconception on how to describe the ecosystem hampers effective regulation, such as the definition of karst area as a terrain rather than an ecosystem. Therefore, cave and karst conservation needs more attention and prioritization in the future. However, a baseline study on species diversity and its habitats were urgently required to develop a proper and effective conservation strategy.

CONCLUSION

Based on this study, nine species of cave-dwelling bats were found in The Ngobaran Coastal Area, Karst of Gunung Sewu. The majority of bats found are insectivorous. Of these nine species, two species are classified as Vulnerable (VU) by the IUCN. The four cave habitats studied had low diversity and moderate species richness. This result shows the uniqueness of each habitat. So that it is categorized as a vulnerable habitat, and further conservation efforts are needed. They are bearing in mind that conserving habitat means preserving all species in that habitat.

AUTHOR CONTRIBUTION

T.B.P.P., R.A.P. and Y.F.R. supervised all the process, field study, and wrote the manuscript. A.D.D helped supervise the project and support the writing.

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CONFLICT OF INTEREST

There is no conflict of interest during the research work.

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