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Comparative Diversity of Bats in Two Contrasting Habitats in Terengganu

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ABSTRACT

Differentiations in the habitat and resource utilisation lead to segregation and specialisation of niches for bats within the structurally complex tropical rainforest in Malaysia. This research aims to characterise chiropterans' assemblages found in two different habitat types in Tasik Kenyir (dipterocarp forest) and Setiu (oil palm plantation). A total of 48 sampling nights were conducted within two years period from March 2017 to March 2019 which covered four sampling sites in Tasik Kenyir and four sites at Setiu. Two standard four-bank harp traps and 10 mist nets were deployed throughout the study at every site to capture bats at understory levels. This makes a total of 576 sampling efforts for both areas. Song Meter SM2bats and Echo Meter Touch from Wildlife Acoustic were used to record the echolocation of insectivorous bats. The total number of individuals and species observed were used to determine species diversity, richness, and evenness. Paleontological statistic software was used to generate the rank abundance and species accumulation curves. Bray-Curtis similarity index was used to generalise the index that represents the relative abundance of the sampling sites. A total of 835 individuals comprising 31 species from six families were captured at both study areas. Out of 835 individuals, 695 were captured within Tasik Kenyir comprising 27 species from six families (H = 2.381) while 140 individuals were captured in Setiu comprising 20 species from five families (H = 2.40). The diversity of bats in Tasik Kenyir was hypothesised to be higher than in Setiu as the habitat possess a larger undisturbed forest. However, the result showed the opposite in which no significant difference was detected from the diversity index calculated between these two areas. Detailed studies need to be conducted to determine if some areas are used as transient habitats for bats.

Keywords: Dipterocarp forest, fruit bats, insect bats, Kenyir, Malaysia, plantation, Setiu

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INTRODUCTION

Bats are important vertebrate fauna that provides critical ecological services such as pollination and pest control in the tropical rainforest (Kunz *et al*., 2011; Shafie *et al*., 2011; Muhammad *et al*., 2021). They are the second largest order in the class Mammalia after Rodentia in terms of biodiversity (Corbet & Hill, 1992; Jones *et al*., 2002). Bats have a wide distribution across the world due to their flight capability and play important roles in arthropod suppression, seed dispersal, and pollination (Kunz *et al*., 2011). Apart from that, the diverse feeding, roosting habits, social behaviour, and reproductive strategies, also contributes to its broad distribution. Bat species have different preferences in habitat due to variances in morphology and ecology thus some species are more suited to a specific habitat than the others (Kunz *et al*., 2011). For instance, inside the forest compound or the open areas above the canopy (Norberg & Rayner, 1987; Bernard, 2001). A cave ecosystem is known to support colonial species that choose their roosting site based on the ability of the site to hold a large number of individuals (Shazali *et al*., 2017). Being crepuscular and nocturnal, bats have developed, strategised, and evolved in their behaviour to avoid direct competition in the resource utilisation with diurnal birds that are feeding on the wings.

Within 35 years, land conversion to oil palm plantation in Malaysia has increased at a very rapid pace from only 1.5 million hectares to 5.74 million hectares (Kushairi, 2017). In Terengganu alone, almost 3.0% of the land has been

converted to oil palm plantation (Kate *et al.*, 2021; MPOB, 2021). This land conversion indirectly might affect the distribution of chiropteran fauna in this modified habitat as compared to the natural forest habitat in Tasik Kenyir. Other than that, factors such as the forest types and the intensity of the disturbance may influence the difference in the result within these studies (Abdullah *et al*., 1997; Hodgkison *et al*., 2004; Mohd-Azlan *et al*., 2005; Jayaraj *et al*., 2011). This research aims to document and compare the bats' diversity between two contrasting habitats in Tasik Kenyir (dipterocarp forest) and Setiu (plantation area). We hypothesised that the dipterocarp forest harbour higher bat species richness than the oil palm plantation, but the result shows there was no significant difference in species richness between the two habitat types. However, the species abundance between these habitat types was significantly different (Shafie *et al*., 2011).

MATERIALS AND METHODS

Study Site

The study was conducted in two study areas and eight sampling sites (Table 1) within the Kenyir Geopark boundary in Hulu Terengganu and Setiu (Figure 1). Tasik Kenyir was chosen as it represented dipterocarp forest while Setiu areas were mostly covered by oil palm plantations and disturbed forest. Quantum Geographic Information System desktop version 3.20.2 software and Maverick Pro mobile application were used to construct the map, marking the sampling sites within the Tasik Kenyir and Setiu area.

Tasik Kenyir (5°1'53"N, 102°43'43"E) is the largest artificial lake in Southeast Asia to date which covers 260 km^2 of water surface area and contains 340 small islands. The sampling sites within Kenyir Lake boundary are Universiti Malaysia Terengganu (UMT) Kenyir Research Station (STK), Saok Waterfall, Lasir Waterfall, and Tanjung Bewah (Table 1). Universiti Malaysia Terengganu (UMT) Kenyir Research Station is located 64 km from UMT and can be accessed only by road. As for Saok Waterfall, Lasir Waterfall, and Tanjung Bewah, the boat ride is needed to reach the destination. In general, Tasik Kenyir is dominated by Dipterocarpaceae species, hence it is classified as a dipterocarp forest. Tasik Kenyir is also home to 113 floral species and 698 fauna species from class Insecta, herpetofauna, aves and small mammals (Ramlee *et al*., 2020). All sites in Tasik Kenyir were classified as regenerated forests. Universiti Malaysia Terengganu (UMT) Kenyir Research Station is a complex consisting of a research laboratory, interactive biodiversity gallery as well as basic amenities such as housing for staff, dormitories for students and a campsite. Located at 167 m above sea level (asl), this facility is surrounded by a vast area of hill dipterocarp forest with a canopy level higher than 15 m. The sampling site is located 200 m walking distance from the facility. Part of the site was covered with rocky structures as an effect of the dried stream. Deployment of traps and nets was positioned 20 m from the main road and 10 m from the forest-lake edge.

Differed from others, Saok and Lasir are tourist spots as the places have an easy access to waterfall present. Tourists often visit these areas, especially during weekends. These sites also comprised of hill dipterocarp forest with canopy closure more than 15 m high. The sampling was conducted along a 100 m trail between 180 m to 190 m above sea level. Both areas were managed by the Development Authority of Terengganu Tengah.

Tanjung Bewah is located at the south part of Tasik Kenyir. To access Tanjung Bewah, a special research permit was applied from the Department of Wildlife and National Parks (DWNP) before research can be conducted because the area is gazetted as a national park. Elevated 170 m above sea level, Tanjung Bewah sampling sites were adjacent to the limestone hill. There is also a small stream present along the trail. The lake ecosystems are dominated by numerous and unique of flora and fauna yet to be explored.

In Setiu (5°35'46.41"N, 102°44'8.73"E) area, Peladang Agro Resort, Ladang Rakyat Lembah Bidong, Ladang Seri Alam Gong Batu, and Universiti Malaysia Terengganu Setiu Research Station (STU) are the sampling sites (Table 1). UMT Setiu Research Station is located about 59 km from UMT. The sampling in this site was conducted within a plantation around 200 m from the station and less than 100 m from the mangrove forest along Setiu lagoon. This site comprises of Beach Ridges Interspersed with Swales' soil plantation due to

its location adjacent to Setiu wetland (Jamilah *et al.*, 2015). Volant small mammal such as *Cynopterus brachyotis* was recorded as the dominant species within this type of ecosystem. For non-volant small mammal, *Callosciurus notatus* from family Sciuridae also was found common to this site (Khalib *et. al*., 2018).

Ladang Rakyat Lembah Bidong is the second largest oil palm plantation in Setiu next to Ladang Tabung Haji with area of 24.5 km^2. Elevated at only 10 m above sea level and connected to Merang river through ditch, Malayan gharial (*Tomistoma schlegelii*) and Asian water monitor lizard (*Varanus salvator*) are the common reptile encounters in this area. Meanwhile, Ladang Seri Alam possesses a large water body within the oil palm plantation namely Tasik Berombak. However, the common species encountered was very similar to Ladang Rakyat Lembah Bidong except for Malayan gharial.

Although Peladang Agro Setiu is listed as one of the palm oil plantation areas, the location of the site was near the foothill of Gunung Tebu Forest Reserve which is a boundary between dipterocarp forest and oil palm plantation. Gunung Tebu Forest Reserve possesses feature such as small flowing streams and large granite rocks and is surrounded by plantation and resorts (Omar *et al.*, 2019). These forest characteristics made Peladang Agro Setiu a suitable sampling site to study the diversity of animal behaviour at the interconnecting forest type. Selected photographs of the sampling sites are as in Figure 2.

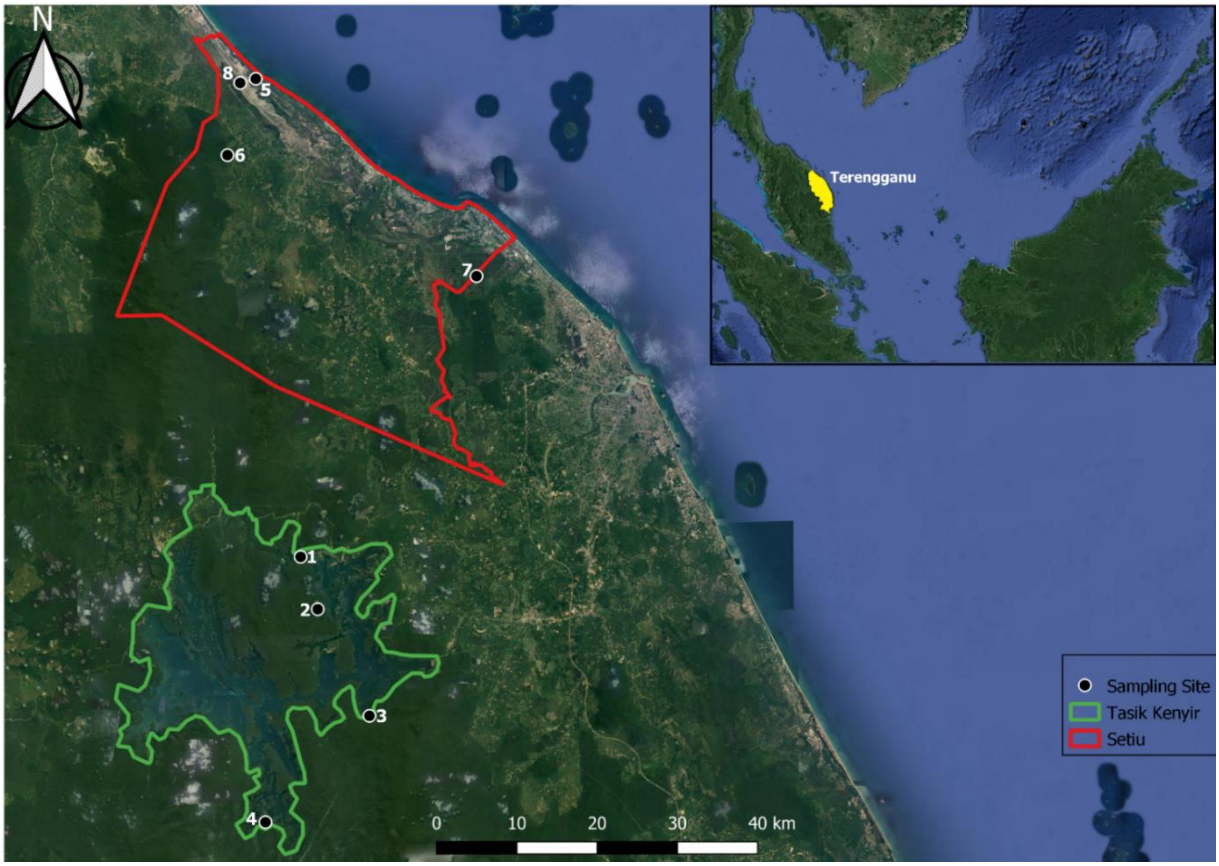

Figure 1. Maps of study areas and sampling sites (Source: Google maps)

Table 1. The list of sites and their coordinate for Kenyir and Setiu area

	Kenyir	
Map Point	Site	Coordinate
1.	UMT Kenyir Research Station	5° 8’33.54” N, 102° 45’38.02” E
2.	Saok	5° 5’02.86” N, 102° 46’47.45” E
3.	Lasir	4° 57’53.79” N, 102° 50’16.63” E
4.	Tanjung Bewah	4° 50’45.08” N, 102° 43’15.74” E
	Setiu	
No.	Site	Coordinate
5.	UMT Setiu Research Station	5° 40’38.50” N, 102° 42’36.75” E
6.	Peladang Agro Setiu	5° 35’30.69” N, 102° 40’40.51” E
7.	Ladang Rakyat Lembah Bidong	5° 27’23.28” N, 102° 57’28.74” E
8.	Ladang Seri Alam	5° 40’22.13” N, 102° 41’33.68” E

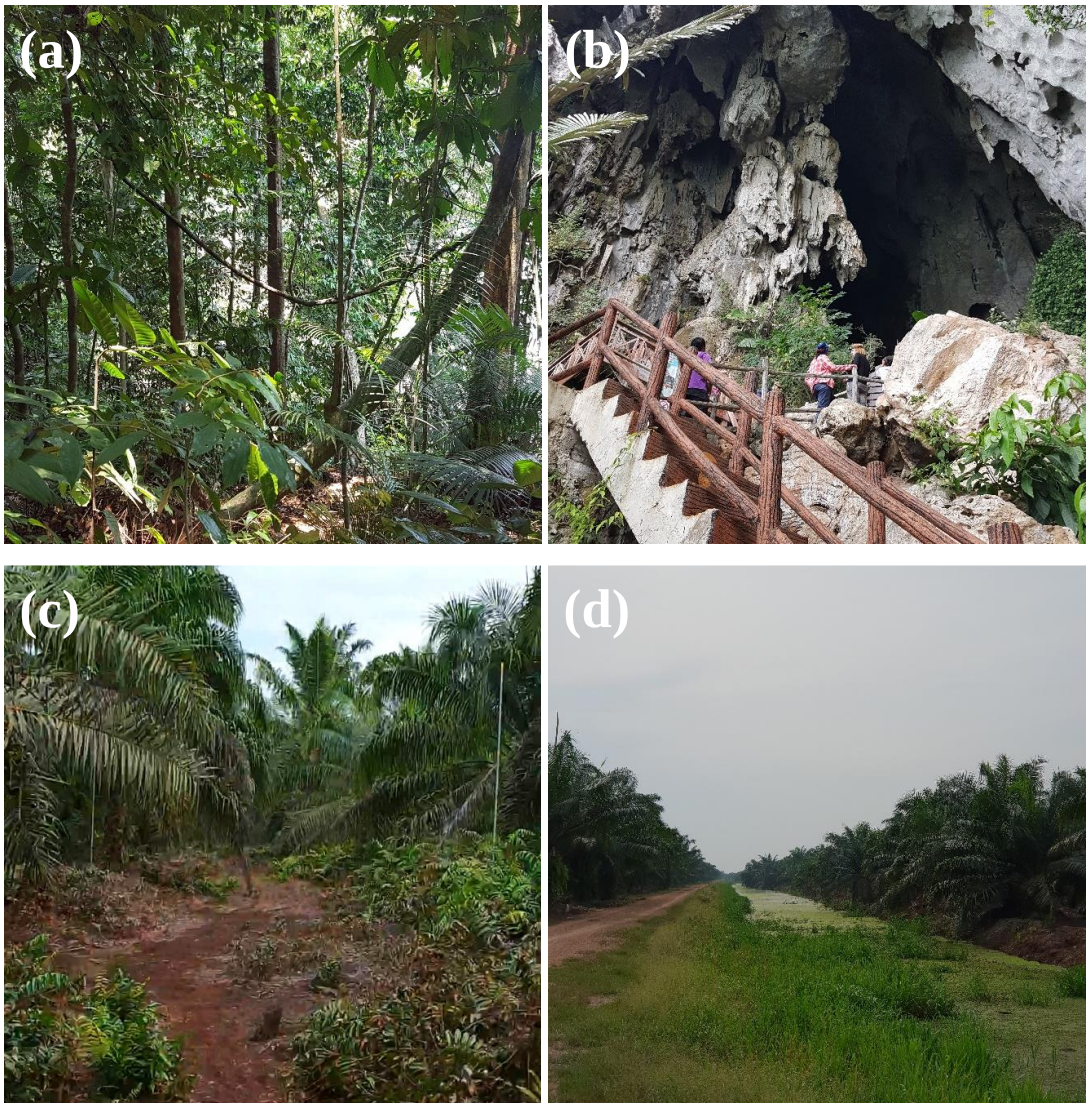

Figure 2. Composite photo of selected sites in Tasik Kenyir and Setiu. (a) Lowland dipterocarp forest structure at UMT Kenyir Research Institute; (b) Limestone and carst formation near sampling site at Tanjung Bewah; (c) Oil palm plantation area in Ladang Seri Alam; and (d) Water body within oil palm plantation in Ladang Rakyat Lembah Bidong

Sampling Method

Eight trapping sessions were conducted from March 2017 to March 2019. Ten mist nets and two harp traps were deployed in both areas and were set up at various locations such as above small streams, at the trails or the narrow pathway which is expected to be the pathway of the bats. Harp traps and mist nets were used to capture bats at the forest floor (5 m) levels as defined by Abdullah and Hall (1997) within the sampling site. The harp traps position was relocated at an interval of two days for a total of six nights at every site to maximise the capture rate. Every position where the harp traps were set up was tagged in coordinate using Garmin GPS 72H model.

Species Identification

The identification of bats species followed Payne and Francis (2007), Francis (2008), and Phillipps and Phillipps (2016). The morphological characteristics of the captured bats were observed and measured. The morphological measurements such as forearm length, ear length, tragus length, tibia length, hindfoot length, tail length, head and body length, total length and the weight of the bats were taken by using vernier calliper and electronic balance, respectively. The species was then cross-referenced with the International Union for Conservation of Nature (IUCN, 2021) Red List of Threatened Species and Wildlife Conservation Act (WCA, 2010) for their conservation status.

Data Analysis

The sampling effort was calculated by multiplying the total number of traps by the total number of sampling nights. The capture rate was calculated by dividing the total number of individuals with sampling effort. Venn diagrams was constructed to show species overlap between sites within Tasik Kenyir and Setiu area. Species diversity, richness, and evenness were calculated by using the total number of individual and species caught. Rank abundance curve (RAC) and species accumulation curve (SAC) was constructed by using Paleontological Statistic (PAST) v4.02 software (Hammer *et al*., 2001). Bray-Curtis similarity index was used to generalise the index that represents the relative abundance. To compare and evaluate the statistical significance of bats diversity between Tasik Kenyir and Setiu area, a modified version of t-test (Hutcheson t-test) was used (Hutcheson, 1970). The formula for the Hutcheson t-test is shown in Eq. (1).

$$t = \frac{H_a - H_b}{\sqrt{S^2_{Ha} + S^2_{Hb}}} \qquad \text{Eq. (1)}$$

Where, H = Shannon index, and S^2_H = variance
To use the test, the variance (S^2_H) in Shannon index of both areas needed to be calculated by using Eq. (2);

$$S^2_H = \frac{\sum p.(\ln p)^2 - (\sum p.\ln p)^2}{N} + \frac{S-1}{2N^2} \qquad \text{Eq. (2)}$$

Where, S = total number of species, N = total abundance, p = proportion of each species makes toward the total.

RESULTS

From a total of 835 individuals captured, six families comprising 31 species of bats were identified (Table 2). Eight species were frugivorous bats from the family Pteropodidae while another 23 species were insectivorous bats from five families (Nycteridae, Megadermatidae, Rhinolophidae, Hipposideridae and Vespertilionidae). Twenty-seven species of captured bats were listed as least concern (LC) under the IUCN Red List of Threatened Species. However, four out of 31 species were listed as near threatened (NT) which are *Nycteris tragata, Rhinolophus chiewkweeae, Kerivoula pellucida* and *K. minuta*. All 31 species of bats recorded in this study were classified as not protected based on Wildlife Conservation Act (WCA, 2010).

Table 2. Species checklist and their conservation status

Family	Species	Common name	IUCN (2016)	WCA (2010)
Pteropodidae				
	Cynopterus horsfieldii	Horsfield's fruit bat	LC	NP
	Cynopterus brachyotis	Lesser short-nosed fruit bat	LC	NP
	Penthetor lucasi	Dusky fruit bats	LC	NP
	Balionycteris seimundi	Malayan spotted-winged fruit bat	LC	NP
	Megaerops ecaudatus	Temminck's tailless fruit bat	LC	NP
	Eonycteris spelaea	Lesser dawn bat	LC	NP
	Macroglossus minimus	Lesser long-tongued nectar bat	LC	NP
	Macroglossus sobrinus	Greater long-tongued nectar bat	LC	NP
Megadermatidae				
	Megaderma lyra	Greater false vampire bat	LC	NP
	Megaderma spasma	Lesser false vampire bat	LC	NP
Nycteridae				
	Nycteris tragata	Malayan slit-faced bat	NT	NP
Rhinolophidae				
	Rhinolophus robinsoni	Peninsular horseshoe bat	LC	NP
	Rhinolophus lepidus	Blyth's horseshoe bat	LC	NP
	Rhinolophus chiewkweeae	Chiewkwee's horseshoe bat	NT	NP
	Rhinolophus affinis	Intermediate horseshoe bat	LC	NP
	Rhinolophus luctus	Woolly horseshoe bats	LC	NP
	Rhinolophus pearsonii	Pearson's horseshoe bat	LC	NP
	Rhinolophus stheno	Lesser brown horseshoe bat	LC	NP
Hipposideridae				
	Hipposideros atrox	Lesser bicoloured roundleaf bat	LC	NP
	Hipposideros cervinus	Fawn-coloured roundleaf bat	LC	NP
	Hipposideros bicolor	Temminck bicoloured roundleaf horseshoe bat	LC	NP
	Hipposideros galeritus	Cantor's roundleaf horseshoe bat	LC	NP
	Hipposideros cineraceus	Least roundleaf horseshoe bat	LC	NP
	Hipposideros armiger	Great roundleaf horseshoe bat	LC	NP
	Hipposideros diadema	Diadem roundleaf bat	LC	NP
	Hipposideros larvatus	Large roundleaf horseshoe bat	LC	NP
Vespertilionidae				
	Kerivoula pellucida	Clear-winged woolly bat	NT	NP
	Kerivoula minuta	Least woolly bat	NT	NP
	Miniopterus medius	Medium bent-winged bat	LC	NP
	Murina suilla	Temminck brown tube-nosed bat	LC	NP
	Scotophilus kuhlii	Lesser asiatic yellow house bat	LC	NP

Notes: LC = Least concern, NT = Near threatened, NP = Not protected.

A total of 835 individuals were recorded from both areas by using trapping methods where 695 individuals (83.23%) were captured within Tasik Kenyir and 140 individuals (17.77%) captured in the Setiu area (Table 3). Tasik Kenyir recorded higher number of individuals captured comprising of six families and 27 species while the Setiu area managed to record five families and 20 species, respectively. Within Tasik Kenyir area, Kenyir Research Station recorded the highest number of individuals captured with 317 individuals followed by Tanjung Bewah with 289 individuals, Saok waterfall with 86 individuals, and Lasir waterfall with only three individuals, respectively.

Table 3. Taxonomic diversity and abundance of bats in Tasik Kenyir and Setiu area

Family	Species	Sites							
		Kenyir					Setiu		
		STK	Saok	Lasir	Bewah	Agro	STU	Bidong	LSA
Pteropodidae									
	Cynopterus horsfieldii	5	9	1	0	3	0	0	0
	Cynopterus brachyotis	16	42	1	0	10	1	11	0
	Penthetor lucasi	0	6	0	0	1	0	0	0
	Balionycteris seimundi	2	0	0	1	5	0	0	0
	Megaerops ecaudatus	0	5	0	0	0	0	0	0
	Eonycteris spelaea	0	1	0	4	1	0	0	0
	Macroglossus minimus	0	0	0	0	1	0	0	0
	Macroglossus sobrinus	4	4	0	0	2	0	0	0
Megadermatidae									
	Megaderma lyra	0	0	0	0	2	0	0	0
	Megaderma spasma	1	0	0	4	0	0	0	0
Nycteridae									0
	Nycteris tragata	1	0	0	1	0	0	0	0
Rhinolophidae									
	Rhinolophus robinsoni	1	0	0	10	1	0	0	0
	Rhinolophus lepidus	19	3	0	10	1	0	0	0
	Rhinolophus chiewkweeae	6	0	0	0	0	0	0	0
	Rhinolophus affinis	5	5	0	56	11	0	0	0
	Rhinolophus luctus	1	0	0	1	0	0	0	0
	Rhinolophus pearsonii	0	0	0	4	0	0	0	0
	Rhinolophus stheno	0	0	0	91	3	0	0	0
Hipposideridae									
	Hipposideros atrox	71	0	0	9	10	0	0	0
	Hipposideros cervinus	3	2	1	2	1	0	1	0
	Hipposideros bicolor	157	6	0	50	33	0	0	0
	Hipposideros galeritus	5	0	0	3	0	0	0	0
	Hipposideros cineraceus	14	0	0	12	0	0	1	0
	Hipposideros armiger	0	0	0	0	3	0	0	0
	Hipposideros diadema	3	0	0	4	13	0	0	0
	Hiposideros larvatus	1	0	0	25	6	0	0	0
Vespertilionidae									
	Kerivoula pellucida	1	1	0	1	0	0	0	0
	Kerivoula minuta	1	1	0	0	0	0	0	0
	Miniopterus medius	0	0	0	1	0	0	0	0
	Murina suilla	0	1	0	0	0	0	0	0
	Scotophilus kuhlii	0	0	0	0	19	0	0	0
Number of families		6	4	2	6	5	1	2	0
Number of species		20	13	3	19	19	1	3	0
Number of individual		317	86	3	289	126	1	13	0
Sampling effort/night		72	72	72	72	72	72	72	72
Capture rate		4.40	1.19	0.04	4.01	1.75	0.01	0.18	0
Shannon (*H*')		1.714	1.843	1.099	2.087	2.387	0	0.536	0
Hutcheson t-test (t) Kenyir Vs. Setiu					0.265				

Notes: STK = Station Tasik Kenyir/UMT Kenyir Research Station, STU = UMT Setiu Research Station, LSA = Ladang Seri Alam

In contrast, although STK had a higher number of individuals than Tanjung Bewah but in terms of diversity Tanjung Bewah was higher (*H*'= 2.087). In Setiu area, Peladang Agro Setiu has the highest number of individuals captured (n=126) as well as in terms of diversity (*H*' = 2.387) comprising only three species from two families. Compared to other sites in Setiu such STU which only records one individual and Ladang Rakyat Lembah Bidong (*H*' = 0.536) which records 13 individuals. Meanwhile, no capture was recorded for LSA.

The Venn diagram (Figure 3) shows that only one species that can be found at every site in Tasik Kenyir. Two species from family Pteropodidae family can be found at three sites which are Lasir, STK, and Saok. Tanjung Bewah and STK shared the highest number of species with a total of 13 species. Meanwhile, one species of the bat only can be found at STK.

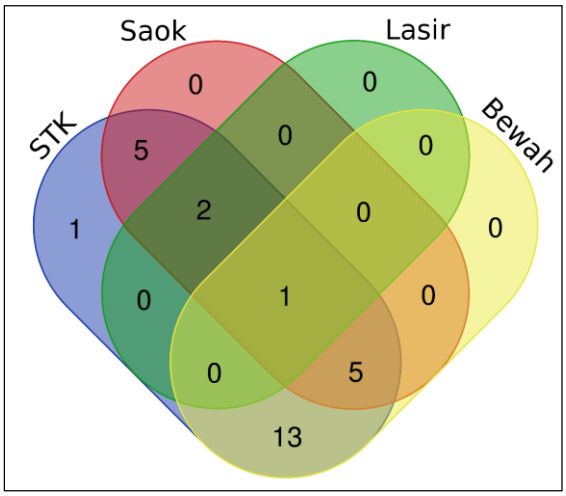

Figure 3. Species overlap between sampling sites in Tasik Kenyir

In Setiu, only three sites can be included in the Venn diagram (Figure 4). From the diagram, all sites shared one species of bat. Peladang Agro and Ladang Rakyat Lembah Bidong also shared one species. There were 17 species from family Pteropodidae, Rhinolophdae, Hipposideridae, Megadermatidae, and Vespertilionidae that unique to only Peladang Agro, Setiu. Meanwhile, only one species was unique to Ladang Rakyat Lembah Bidong.

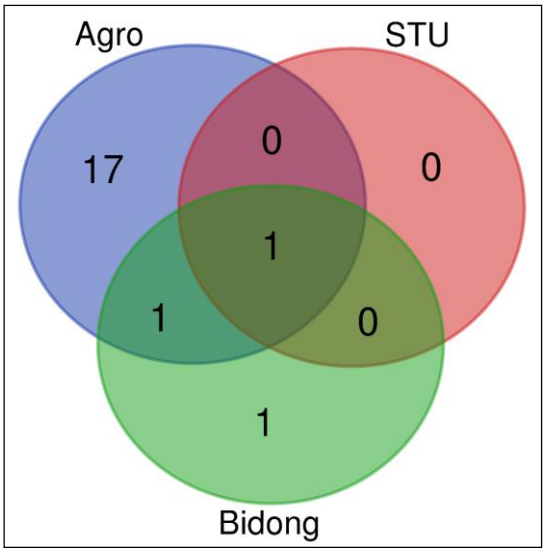

Figure 4. Species overlap between sampling sites in Setiu

From the Venn diagram constructed (Figure 5), as much as 16 species of bats from family Pteropodidae, Rhinolophidae and Hipposideridae can be found in both the Tasik Kenyir dipterocarp forest and Setiu plantation area. Eleven species can only be found in the Tasik Kenyir area while only four species were specific to Setiu area. Based on Bray-Curtis similarities index (Figure 6), four groups were form in between sampling sites based on species richness. Ladang Seri Alam was considered as outgroup due to no captured. Tanjung Bewah, Peladang Agro Setiu, and STK were grouped together in group two while Saok Waterfall and Ladang Rakyat Lembah Bidong were clustered together in group three. Meanwhile, Lasir Waterfall and UMT Setiu Research Station were in group 4.

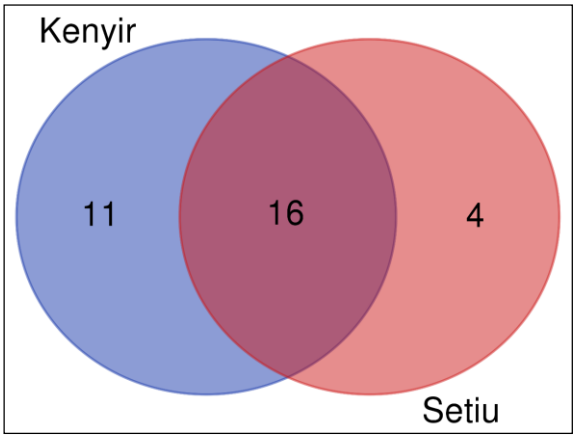

Figure 5. Species overlap between Tasik Kenyir and Setiu

A species accumulation curve was constructed comparing the total number of species in Tasik Kenyir and Setiu area. The graph (Figure 7) shows that both areas have not yet reach asymptote. However, it can be said that Tasik Kenyir almost reaches asymptote level while the Setiu area is still far from reaching the asymptote although the curve for Setiu was steeper. Thus, it has more potential to find more species when given more sampling effort.

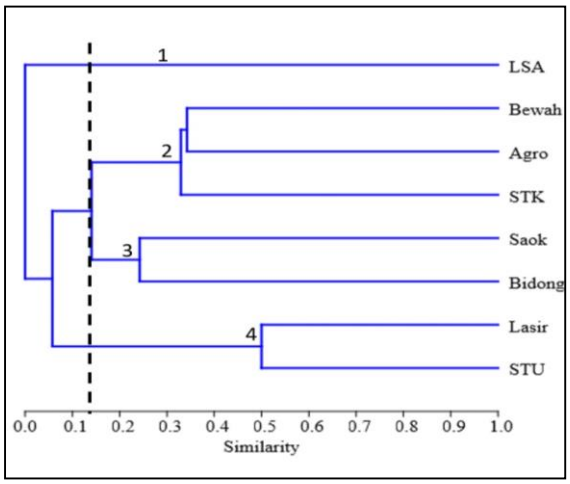

Figure 6. Bray – Curtis similarity index between sampling sites

When comparing Tasik Kenyir and Setiu area, Shannon diversity indexes (Table 4) shows that Setiu area has slightly higher bats diversity compared to Tasik Kenyir differs by only 0.025. However, those differences were not enough to conclude which area appears to have higher diversity as the value of the confidence interval far exceeds 95% ($\alpha = 0.05$). In the meantime, Simpson index shows that both areas were dominated by common species. In terms of species richness also both areas have no significant difference as proven by Menhinick and Margalef index. The data was proven by performing Hutcheson t-test involving Shannon index (Table 5). The result showed that there was no significant difference between these two areas (Figure 8) when p-value ($p = 0.791$) far exceed significant level at 95% ($\alpha = 0.05$). The t-value ($t = 0.265$) also did not exceed critical value (Crit = 1.97). Thus, it can be concluded that we fail to reject the null hypothesis.

Table 4. Diversity indeces comparing Tasik Kenyir and Setiu area

	Kenyir	Setiu	Perm p(eq)
Taxa S	27	20	0.8633
Individuals	695	140	0
Shannon H	2.381	2.406	0.871
Evenness e^H/S	0.4008	0.5547	0.224
Simpson index	0.8529	0.876	0.2551
Menhinick	1.024	1.69	0.4872
Margalef	3.973	3.845	0.8858
Equitability J	0.7226	0.8033	0.173

Table 5. Value obtained from Hutcheson t-test

	Tasik Kenyir	Setiu
Total individual	695	140
Total species	27	20
Shannon index (*H*')	2.381486	2.406477
Variance (S^2_H)	0.00198	0.00693
t-value (t)	0.264752	
Degree of freedom (df)	228	
Critical value (Crit)	1.97047	
P value (p)	0.79144	
CI	0.08899	0.166496

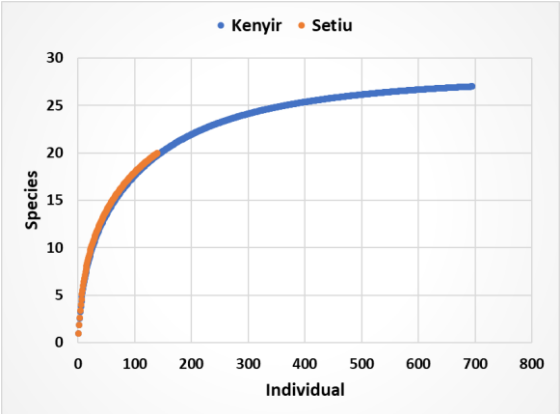

Figure 7. Species accumulation curve comparing Tasik Kenyir and Setiu area

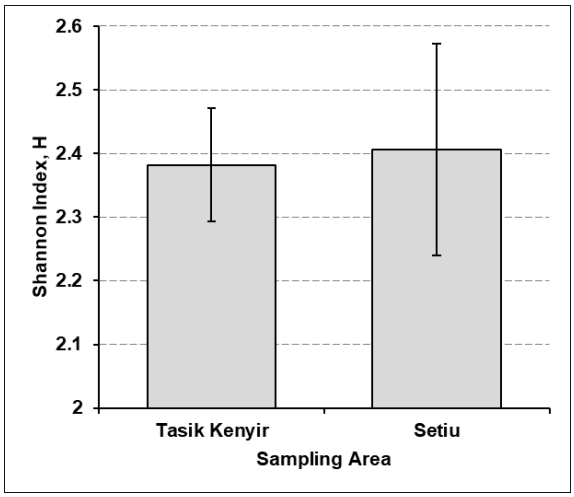

Figure 8. Hutcheson t-test result based on species richness

From the rank abundance curve constructed (Figure 9), in Tasik Kenyir two species from two different families dominated the sample capture which were Hipposideridae (*Hipposideros bicolor*, 30.65%) and Rhinolophidae *(Rhinolophus stheno*, 13.10%) from the total individual thus making these two species the most abundant within the area. Meanwhile, two species were listed as singleton which are *Miniopterus medius* and *Murina suila.*

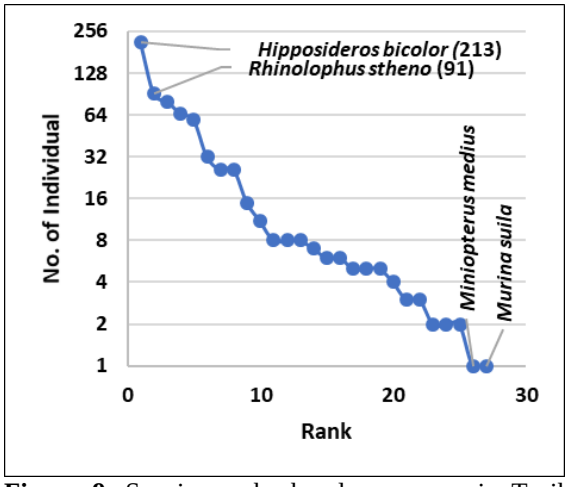

Figure 9. Species rank abundance curve in Tasik Kenyir

Apart from that, in Setiu (Figure 10), the dominant species was the same as Tasik Kenyir, which were *H. bicolor* with a total of 33 individuals (23.57%). However, following *H. bicolor* at second rank was from Pteropodidae family which were *Cynopterus brachyotis* with a total of 22 individuals (15.71%). Unlike Tasik Kenyir, Setiu area recorded six species of bats as a singleton which were from the family Pteropodidae (*Penthetor lucasi*, *Eonycteris spelaea*, *Macroglossus minimus*), Rhinolophidae (*Rhinolophus robinsoni*, *R. lepidus*), and Hipposideridae (*Hipposideros cineraceus*).

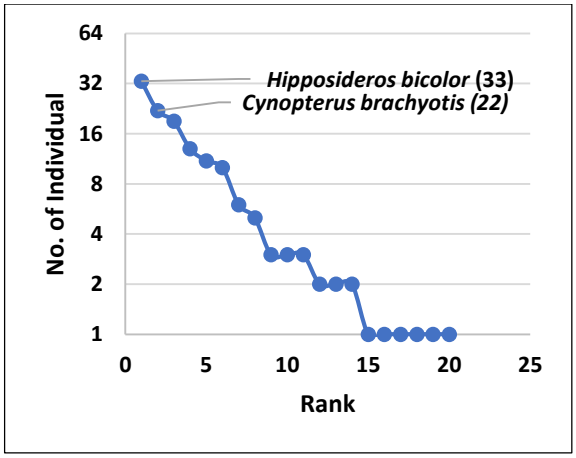

Figure 10. Species rank abundance curve in Setiu

DISCUSSION

In terms of bat species richness, Tasik Kenyir is greater than in Setiu. However, the diversity indices indicate the bat diversity in Kenyir is slightly lower than Setiu. There are many factors that can influence this result such as the microclimate, topography, species abundance, species distribution, type of habitat and food source. Besides, dipterocarp forest contains more niches for more unique species to occupy (Hill & Hill, 2001; Bruhl *et al*., 2003; Podong & Poolsiri, 2013).

Tanjung Bewah, STK and Peladang Agro Setiu have the highest species richness. When compared to other sites, these three sites were in one group with more than 30% similarities although Peladang Agro Setiu were in a different area. This happened because even though Peladang Agro Setiu were classified to be plantation forest (oil palm plantation), the sites were located at the border of Gunung Tebu forest reserve which has dipterocarp forest type, thus some of the bat species roosting inside dipterocarp forest might include the plantation as the transient area in their foraging radius.

Table 6. Result comparison with the previous study in Tasik Kenyir area

	This study	Zakaria *et al*. (2020)	Nor Zalipah *et al*. (2018)	Pounsin *et al*. (2018)	Roslan (2017)	Mazlan *et al*. (2015)
No. of Families	6	4	6	6	9	4
No. of Species	28	15	55	21	42	14
No. of Individual	695	59	Na	170	888	36

Notes: 'Na' indicates data unavailable.

The different scene was observed in Saok Waterfall and Ladang Lembah Bidong which were in the same group with species richness similarities of less than 30%. As for Saok Waterfall, it is one of the tourist attraction spots and receives a lot of disturbance especially during the weekend. Anthropogenic activities and tourism such houseboat trips and waterfall sightseeing may contribute to the disturbances, especially during the night the tourist tend to conduct singing activities which produce very loud noises that can be heard from far away. Low species richness also was the result in Ladang Lembah Bidong although the site was far from forest refuge and human settlement and free from tourists. The disturbance was mostly due to the movement of the plantation workers that often enter the area with heavy machinery equipment such as large tractors and lorry that produce loud noise, thus became the source of the disturbance.

The similarities of species richness between Lasir Waterfall and STU were very high (50%) because the number of species was very low, but the sample captured were common species that can be found in both dipterocarp forest and plantation forest. The reason for the low number of individuals captured at Lasir Waterfall is the same as Saok Waterfall as both of the sites are tourist attraction spots. Different from STU, this site is located very near to the local community settlement.

From the species abundance perspective, both Tasik Kenyir and Setiu area shared one species in common which is *H. bicolor* for the most abundant species although the number was far apart possible due to the abundance or the big boulder and rocky structure present within the area. When comparing between Tasik Kenyir and Setiu areas, Setiu had four more species listed as singleton (*Penthetor lucasi, Eonycteris spelaea, Macroglossus minimus, Rhinolophus robinsoni, R. lepidus* and *Hipposideros cineraceus*).

When the diversity of bats between Tasik Kenyir dipterocarp forest and Setiu oil palm plantation area was compared, the result shows the opposite of species richness. Statistical analysis suggested, there were no significant differences between these two areas. Although the number of species was higher in Tasik Kenyir, the analysis proves that the Setiu area has similar diversity. When land utilisation occurs, it destroyed the habitat of many unique endemic species. However, the land conversion also creates new habitats for other high adaptable species (McKinney & Lockwood, 1999) such as *Cynopterus brachyotis*. This factor led to a biotic homogenisation where it increases the genetic, taxonomic, or functional similarity allowing a new population to be developed (Lockwood & McKinney, 2001; Olden & Poff, 2003).

Based on the result, 31 species of bats captured were separated into two groups based on morphological cladistic which are frugivorous bat or Megachiroptera and insectivorous bat or Microchiroptera. Of 31 species of bats captured, four out of it were listed as near threatened under the IUCN Red List (*Nycteris tragata, Rhinolophus chiewkweeae, Kerivoula pellucida* and *K. minuta)*. Their population were reduced drastically due to adaptive human anthropology activities such as land clearing for settlement, agriculture, forest fire and illegal logging (World Wildlife Fund - WWF, n.d.). Some of the insect-eating bats such as *Hipposideros cervinus, Rhinolophus stheno,* and *R. lepidus* were common findings in low-land rainforests in Peninsular Malaysia (Kingston *et al*., 2003). These insect-eating bats prey mainly on nocturnal insects especially pests, therefore these bats played a very important role in providing ecological services.

Penthetor lucasi which are a medium size fruit bats and distinguished by dark grey–brown colour, are only found at Saok Waterfall and Peladang Agro. This species roost mainly in the cave and under rock shelters corresponding with the habitat type found within these two sites. *Macroglossus minimus* often inhabits coastal area particularly in mangrove area. Foraging on nectar and pollen from many sources including mangrove and banana flowers, this species made Peladang Agro a suitable habitat. Unlike *M. sobrinus*, this species was found more to inland habitat although they have same preferred diet such wild banana flowers (Payne & Francis, 2007; Francis, 2008; Kingston *et al*., 2009; Phillipps & Phillipps, 2016).

With only two individuals, *Megaderma lyra* were found only at Peladang Agro. This was due to the possibility on abundance of preferred roosting area as this species were commonly found roosting in the temples or unused buildings (Francis, 2008). Species such as *Megaerops ecaudatus, M. minimus, M. lyra, Miniopterus medius*, *Murina suila* and *Scotophilus kuhlii* can be found at one sampling sites, respectively. Distinguished by almost tubular projecting nostril and lack of tail, *M. ecaudatus* primarily inhabit tall forest and sometimes in disturbed forest (Payne & Francis, 2007; Francis, 2008; Kingston *et al*., 2009). Where this species was found, Saok Waterfall was dense with tall trees although this site was one of the main tourist attractions in Tasik Kenyir.

Only found in the Kenyir Research Station area, *Rhinolophus chiewkweeae* is a unique species that are unique to this site and it was also recently recorded at Tasik Kenyir area. Previously this species was recorded only at six localities in west coast of Peninsular Malaysia (Yoshiyuki & Lim, 2005). The first localities report of *R. chiewkweeae* in Tasik Kenyir was recorded by a collaboration of Universiti Malaysia Sarawak and UMT in 2016. The habitat preference of this species was known to be in dipterocarp forests and areas surrounded by big boulders (Yoshiyuki & Lim, 2005; Morni *et al*., 2016).

The result from the Tasik Kenyir area in this study was compared to several previous studies as shown in Table 6. The highest number of the family recorded (9 families) was during Roslan (2017) study, but in term of species, Nor Zalipah *et al*., (2018) recorded the highest number (55 species). Compared to this study, the method used, and the sampling period of both previous studies were very intensive, hence producing great result. For example, Roslan (2017) used canopy mist-netting thus the chances to record canopy dwelling bats were higher compared to this study that only deployed understory mist net. Besides that, better sampling techniques may also increase the probability of discovering new finding such as new locality records of *Chaerephon johorensis* and *Rhinolophus chiewkweeae.* For *R. chiewkweeae*, Tasik Kenyir, Hulu Terengganu was known as the seventh locality reported for this species (Morni *et al*., 2016; Roslan *et al*., 2016). Yoshiyuki and Lim (2005) were the first to describe this species.

Previous study conducted by Mazlan *et al.* (2015) at Tanjung Bewah managed to record only 14 species compared to this study which recorded 19 species. This is due to higher sampling effort conducted during this study. Meanwhile, few species such as *M. minimus, Rousettus amplexicaudatus, R. sedulus, Myotis ridleyi* and *M. siligorensis* were not recorded during this study. Based on the observation in this study, there were *Megaderma* sp. roosting inside Gua Taat in contrast to what was stated during previous study by Mazlan *et al*. (2015).

To obtain more conclusive results, the duration of future studies should be extended in order to cover the distribution for differences in different seasons and to allow more sampling per site until the graph plateau. Other than that, improvement in finance and trained assistants for large sampling efforts are also needed in order to maximise the outcomes of the study. Moreover, modern technology approaches such as adaptation of ultrasonic detectors and high nets that can reach up to 5 m in the subcanopy and canopy nettings are suggested to increase the sampling capacity.

CONCLUSION

The result gained from this study shows that Tasik Kenyir and Setiu areas hold high diversity of bats in terms of species richness and abundance. However, some of the species were categorised as near threatened by IUCN Red List. The difference on habitat type does not

show much effect on bat assemblages especially those sites that were adjacent to highly dense forests such as Peladang Agro Setiu. In contrast, the result also concludes that the area which faced the same problem harbor the same biodiversity result such as Saok Waterfall at Tasik Kenyir and Ladang Rakyat Lembah Bidong at Setiu.

Both sites have high disturbance from human anthropogenic activity either in the tourism industry or agricultural industry. However, when the area was protected by a certain statutory corporation such as Tanjung Bewah, which is within the national park and STK where the areas were restricted to outsiders, species richness and diversity were found to be higher. These areas were suitable for future research due to less disturbance. Providing baseline data to the authorities such Department of Wildlife and National Parks (DWNP) will help them in monitoring the biodiversity of the forest. These actions need to be done quickly so that they can put more effort to plan countermeasures to prevent the loss of Malaysian Biodiversity.

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