

Species Composition of Bat at the Tenghilan Community Forest in Sabah, Malaysia

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ABSTRACT The interior forest ecosystem of Sabah is inhabited by a wide range of bat species, and yet their survivals are threatened by the loss and degradation of the interior forest habitat. The relevant past studies mainly focused onto the bat communities presented at the local permanent forest reserves, which subsequently resulted in the lacking in information on the bat communities at the local state land forests. Therefore, a preliminary bat survey was conducted to determine the bat species that inhabited the Tenghilan Community Forest, Sabah, Malaysia. Three existing forest trails were selected as the sampling areas, and then three sampling points were established along each trail. Mist-net trapping technique was used in sampling the bat individuals, and then ancillary data was recorded through visual observation, at each sampling point. A total of 36 bat individuals belonged to 6 different species and 4 different families were captured and recorded within 6 days of sampling period in this study. The trapped individuals were comprised mainly of the least-concerned ($n = 34$) frugivorous and nectarivorous bat species ($n = 32$). Among the three selected trails, the diversity richness and distribution evenness of bat species at Tongkat Ali Trail were determined to be significantly higher ($H' = 1.351$; $1-D = 0.6979$) than those of both the Liposu Trail and Bambangan Trail ($H' = 0$, $t = -11.315$, $p < 0.001$; $1-D = 0$, $t = 14.317$, $p < 0.001$). In summary, this state land forest serves as an important habitat for the local bat community, even though the existing local bat composition is different from that of an undisturbed forest in Sabah. Further research should be conducted onto the entire area of this state land forest, by using a longer sampling period and more sampling points in future.

KEYWORDS: Bat Community; Composition; Diversity; Habitat Condition; Tenghilan Community Forest

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INTRODUCTION

Sabah of Malaysia Borneo is home to a wide variety of bat species, which have comprised about 40.5 % (100 species) of the Bornean terrestrial mammals (Phillipps & Phillipps, 2018). Then, various bat species are known to inhabit the interior forests of Sabah, especially the Old World frugivorous and insectivorous bats that serve as pollinators, seed dispersers and regulators of insect populations in the local interior forest ecosystem (Kingston *et al.*, 2003; and Kunz *et al.*, 2011). However, these bat species are threatened by habitat disturbance, particularly the worsening of forest degradation and habitat loss at Sabah in recent years (Struebig *et al.*, 2012). Moreover, very limited studies were done on bat community, and then these studies were conducted mainly at permanent forest reserves liked Danum Valley Conservation Area, Maliau Basin Conservation Area, Kabili-Sepilok Forest Reserve, Crocker Range Park, Deramakot Forest Reserve, Imbak Canyon Conversation Area, and Silam Coast Conservation Area (e.g.: Struebig *et al.*, 2012; Pounsinsin *et al.*, 2016; Bansa *et al.*, 2018; Salor & Azhar, 2018; Senawi *et al.*, 2020; Yoh *et al.*, 2020). Species composition of bat at the state land forests, on the other hand, are seldom being examined scientifically by researchers at this moment. The species-rich state land forests are often being converted into small-scale plantations by the local community for generating profits at a regular basis (Latip *et al.*, 2015), which includes the Tenghilan Community Forest at Tuaran, Sabah. This phenomenon can ultimately cause the bat community at this state land forest to be threatened by the anthropogenic habitat disturbance (Struebig *et al.*, 2012). Henceforth, a preliminary assessment was conducted to examine the existing composition of bat species presented at the Tenghilan Community Forest in Sabah, Malaysia Borneo.

METHODOLOGY

Study Site

Tenghilan Community Forest was situated at 6°16'58.00"N and 116°22'4.40"E within the District of Tuaran, Sabah, Malaysia Borneo. This state land forest was hot and humid throughout the year, and then the annual rainfall and mean temperature were 2,700 mm and 28.0°C respectively. Mixed-matrices of rubber plantations and regenerated lowland dipterocarp forest occupied the undulating terrain of this state land forest, hence various species of indigenous and exotic flora and fauna were presented here. Various species and individuals of fruit trees were found in the vicinity of this state land forest, liked the Bambangang (*Mangifera pajang*), Liposu (*Baccaurea lanceolata*), Durian (*Durio* sp.), and Jackfruit (*Artocarpus* sp.). Moreover, several clear streams were discovered within this state land forest. A total of three existing forest trails located within the regenerated lowland dipterocarp forest were selected as the sampling areas of this study, which were the Liposu Trail (302 m), Bambangang Trail (199 m) and Tongkat Ali Trail (129 m). Then, three potential bat flyways were determined and selected as sampling points along each selected trails (Lim & Mojiol, 2019; Yoh *et al.*, 2020). Both the Bambangang Trail and Liposu Trail were established alongside the streams at valley, although a portion of the Liposu Trail was located in the rubber plantation forest. On the contrary, the Tongkat Ali Trail was found along the mountain ridge of this state land forest. Figure 1 displays the locations of the sampling points at the three selected forest trails in Tenghilan Community Forest, Sabah.

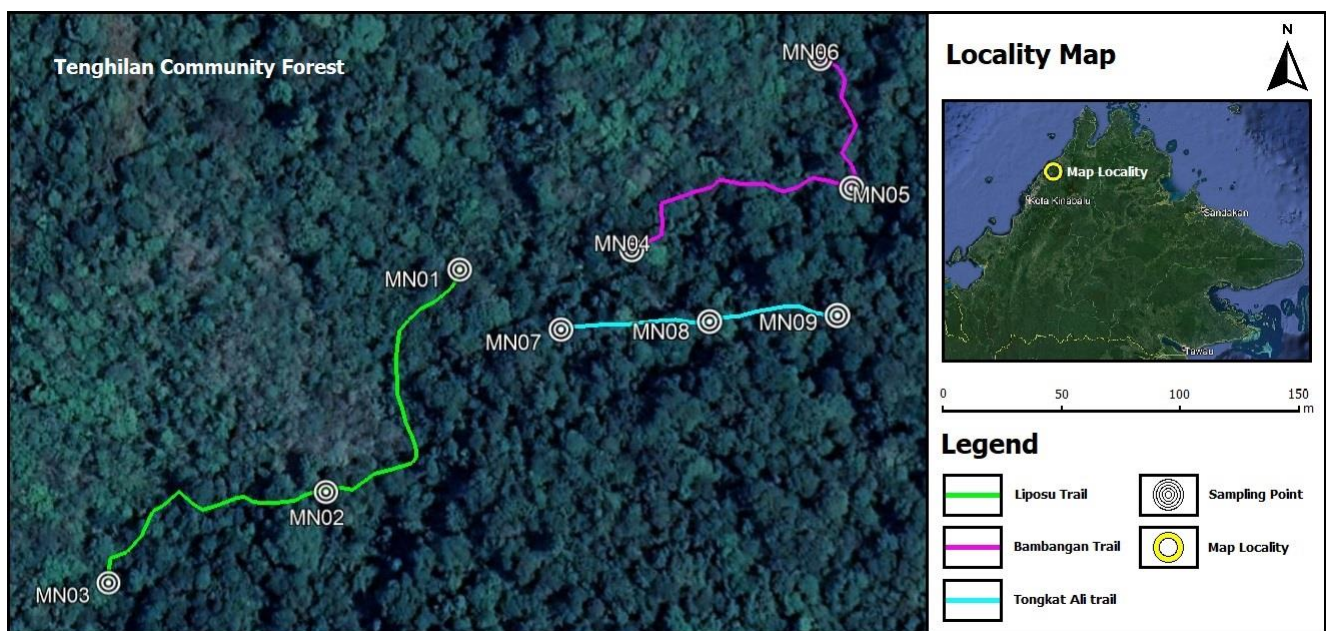


Figure 1. Locations of the sampling points at the three selected forest trails in Tenghilan Community Forest, Sabah.

Mist Net Survey

Mist net survey was conducted at the 9 established sampling points for 6 days, from 8/9/2020 to 10/9/2020 and 10/10/2020 to 12/10/2020. A mist net was posited 3 m wide and 2 m aboveground level at each sampling point and in perpendicular to the trail. Throughout these 6 days, each mist net was left opened from 6.00 p.m. to 6.00 a.m. (12 hours), and then checked once per day at 6.00 a.m., which was varied from the other bat studies conducted in Sabah (e.g.: Pounsinsin *et al.*, 2016; Salor & Azhar, 2018; Senawi *et al.*, 2020). Actually, the sampling technique applied in this study resembled that of a bird survey, because the established mist nets were used in surveying the local bird community during daytime (6.00 a.m. to 6.00 p.m.) throughout the given sampling period (Lim & Mojiol, 2019). The number of individual and species of bats captured by the mist nets were recorded and identified

respectively, before they were released back to the study site. Species of the detected bat individuals were verified by referring to their respective physical appearances (e.g.: wing span, nose shape, head shape, body size, ear shape, and fur colour), using the field guide of Phillipps and Phillipps (2018). After that, the species traits (IUCN Red List Status, endemism, feeding guild, and foraging layer) for each recorded bat species were determined, based on the relevant secondary data (e.g.: Phillipps & Phillipps, 2018; Salor & Azhar, 2018; Senawi *et al.*, 2020; Yoh *et al.*, 2020; IUCN, 2021).

Data Analysis

Chi-Squared test was employed to determine the main composition of bat species that inhabited the Tenghilan Community Forest. Furthermore, Shannon's (H') and Simpson's (D) Diversity Indices were estimated, and then Diversity t-test was applied to examine the significance differences in the diversity richness and distribution evenness of bat species between the given three trails in this state land forest. These statistical analyses were conducted by using the statistical software PAST ver. 3.25 (Hammer *et al.*, 2001), at 95.0 % confidence interval level ($p=0.05$).

RESULTS

A total of 36 bat individuals belonged to 6 different species and 3 families were captured by using mist nets across Tenghilan Community Forest in this study. The bat family with the highest number of recorded species was determined to be the Pteropodidae (Fruit Bat) family (4 species), including the *Macroglossus minimus* (Dagger-toothed Long-nosed Fruit Bat), *Cynopterus brachyotis* (Lesser Dog-faced Fruit Bat), *Eonycteris spelaea* (Dawn Bat), and *Balionycteris maculata* (Spotted-winged Fruit Bat). After that, only one bat species was recorded for both the Rhinolophidae (Horseshoe Bat) family and Megadermatidae (False Vampire) family in this study, which were the *Rhinolophus trifolius* (Trefoil Horseshoe Bat) and *Megaderma spasma* (Lesser False Vampire) respectively. Next, all six recorded bat species were determined to be non-endemic to Sabah and Borneo, and also the given species mainly foraged at the understory layer of this state land forest. Nevertheless, a majority of these bat species were classified as "Least-concerned" species, except for the near-threatened *R. trifolius*. Moreover, two species were determined to be frugivorous species (*C. brachyotis* and *B. maculata*), while another two bat species were nectarivorous species (*M. minimus* and *E. spelaea*). Finally, the *M. spasma* and *R. trifolius* were confirmed as the sole carnivorous and insectivorous species respectively, which were successfully being recorded in this research. Table 1 shows the list of bat species that are detected at Tenghilan Community Forest in this study.

Table 1. A list of bat species that are detected at Tenghilan Community Forest in this study.

Family	Scientific Name	Common Name	*IUCN Red List Status	Feeding Guild
Megadermatidae	<i>Megaderma spasma</i>	Lesser False Vampire	LC	Carnivore
Pteropodidae	<i>Balionycteris maculata</i>	Spotted-winged Fruit Bat	LC	Frugivore
	<i>Cynopterus brachyotis</i>	Lesser Dog-faced Fruit Bat	LC	Frugivore
	<i>Eonycteris spelaea</i>	Dawn Bat	LC	Nectarivore
	<i>Macroglossus minimus</i>	Dagger-toothed Long-nosed Fruit Bat	LC	Nectarivore
Rhinolophidae	<i>Rhinolophus trifolius</i>	Trefoil Horseshoe Bat	NT	Insectivore

*Note: LC = Least Concern, and; NT = Near-threatened.

Among these six recorded bat species, *E. spelaea* was detected most frequently in this study ($n = 14$ or 38.9 %), and followed by *C. brachyotis* ($n = 12$ or 33.3 %), *B. maculata* ($n = 5$ or 13.9 %), both the *M.*

spasma and *R. trifoliatus* (n = 2 or 5.56 %), and lastly *M. minimus* (n = 1 or 2.78 %; $X^2_{10} = 40.18$, $p < 0.001$). Moreover, the trapped bat individuals were comprised mainly of the least-concerned (n = 34 or 94.4 %) frugivorous and nectarivorous (n = 32 or 88.9 %) species. However, only one species was detected travelling through the Liposu Trail (*M. minimus*: n = 1) and Bambang Trail (*C. brachyotis*: n = 2) in this research. Additionally, *M. minimus* was detected only at Liposu Trail, while the *C. brachyotis* was observed once at both the Bambang Trail and Tongkat Ali Trail. Moving on, *E. spelaea* was verified as the most frequently-detected species at Tongkat Ali Trail (n = 14 or 42.4 %), and then followed by *C. brachyotis* (n = 10 or 30.3 %), *C. maculata* (n = 5 or 15.1 %), and finally both the *R. trifoliatus* and *M. spasma* (n = 2 or 6.06 %). The distribution evenness and diversity richness of bat species presented at Tongkat Ali Trail ($H' = 1.351$; $1-D = 0.6979$) were determined to be significantly higher compared to those at Liposu Trail and Bambang Trail ($H' = 0$, $t = -11.315$, $p < 0.001$; $1-D = 0$, $t = 14.317$, $p < 0.001$) in this research. Table 2 reveals the number of individuals recorded for each of the six bat species at the three different trails in Tenghilan Community Forest, Sabah.

Table 2. Number of individuals recorded for each bat species detected at the three different trails in Tenghilan Community Forest, Sabah.

Species	Number of Individual (n)			
	Liposu Trail	Bambang Trail	Tongkat Ali Trail	Total
<i>Megaderma spasma</i> (Lesser False Vampire)	0	0	2	2
<i>Balionycteris maculata</i> (Spotted-winged Fruit Bat)	0	0	5	5
<i>Cynopterus brachyotis</i> (Lesser Dog-faced Fruit Bat)	0	2	10	12
<i>Eonycteris spelaea</i> (Dawn Bat)	0	0	14	14
<i>Macroglossus minimus</i> (Dagger-toothed Long-nosed Fruit Bat)	1	0	0	1
<i>Rhinolophus trifoliatus</i> (Trefoil Horseshoe Bat)	0	0	2	2

DISCUSSIONS

The abundance and diversity of bat species detected at Tenghilan Community Forest in this study was generally higher (36 individuals and 6 species) than those reported by Salor and Azhar (2018) at the Ulu Senagang Substation of Crocker Range Park (11 individuals and 5 species). However, the bat communities presented at the Inobong, Mahua and Malungung Substations of Crocker Range Park (260 individuals and 31 species), and also at the Silam Coast Conservation Area (91 individuals and 9 species), were verified by past studies (Pounsinsin et al., 2016; Yoh et al., 2020) as more abundant and diverse, when compared to those recorded in this study. This difference in bat composition can be resulted from the variations in the sampling duration, number of sampling point, vegetation type, and present habitat condition of the respective study sites (Struebig et al., 2012). This study and the other mentioned past studies conducted bat surveys at human-modified habitats that were different in vegetation type and condition. The abundance and diversity of food and roosting site for the bat community are dictated by the vegetation composition, and then both the availabilities of food and roosting site at the least-disturbed forest are higher than those at the highly-disturbed forest, which ultimately shaped the species composition of bat at a given habitat (Senawi et al., 2020; Yoh et al., 2020). This phenomenon can explain the differences in abundance and diversity of bat between the Tenghilan Community Forest and the other human-modified habitats presented in Sabah.

The bat community at Tenghilan Community Forest was comprised mainly of the nectarivorous and frugivorous species (32 individuals or 88.9 %; and 4 species or 66.7 %). The given bat species are dominant at the human-modified lowland forests with high abundances of fruit trees, whereas the carnivorous and insectivorous species rarely visit the given habitats (Pounsing *et al.*, 2016; Salor & Azhar, 2018). The least-disturbed lowland and montane forests, on the other hand, remain visited by a wide range of bat species varied in feeding guilds, because of the presences of high abundance and variation of food at the given habitats, regardless of these habitats are situated near or afar from the human-modified habitats (Senawi *et al.*, 2020; Yoh *et al.*, 2020). This emphasizes that different bat species with different feeding guilds are evenly distributed across a natural forest, and then human disturbance can result in the bat species with certain feeding guild become dominant at a particular habitat, in response to the change in resource availabilities at the given habitat, in Sabah.

Both the *E. spelaea* and *C. brachyotis* are frugivorous species, therefore abundant at a forest habitat with high fruit availability (Phillipps & Phillipps, 2018). However, landscape modification by human can trigger the loss of roosting sites and food sources for the bat community (Salor & Azhar, 2018). Therefore, these fruit bat species may prefer in visiting the Tongkat Ali Trail in this state land forest, for both the Liposu Trail and Bambang Trail were heavily impacted by the local human activities (e.g.: agriculture and plantation, timber harvesting, and cabin construction). Moreover, the *E. spelaea* and *M. minimus* visit fruit orchards for nectar-feeding regularly (Acharya *et al.*, 2015), and then this phenomenon can explain the presences of these two nectarivorous species at Tenghilan Community Forest, which is rich in fruit tree abundance and diversity. Nevertheless, *M. minimus* is known to live alone or in a small group (Phillipps & Phillipps, 2018). Since the abundance of fruit tree at the Liposu Trail was higher than those of the Bambang Trail and Tongkat Ali Trail, hence its sole detection at the Liposu Trail in this study could be resulted from the given matter. Additionally, *M. spasma* and *E. spelaea* are cave-roosting species (Phillipps & Phillipps, 2018), thus their detections at Tongkat Ali Trail may indicate the presence of a cave that serves as their roosting site, at the upper ridge of this trail. Likewise, *R. trifoliatus* and *B. maculata* mainly avoid visiting the disturbed habitats (Phillipps & Phillipps, 2018), and then this phenomenon could explain the detections of the given two bat species only at the Tongkat Ali Trail with minimal human disturbance, in this study.

In summary, different bat compositions were obtained for the forest trails examined in this study, and then the Tongkat Ali Trail was verified with the highest bat distribution evenness and diversity richness in Tenghilan Community Forest. This is because the presences of food sources and roosting sites, and also the anthropogenic disturbance, can impact the presence-or-absence, and subsequently the species composition, diversity richness and distribution evenness of bat presented at a particular forest (Struebig *et al.*, 2012; Acharya *et al.*, 2015; Salor & Azhar, 2018). Furthermore, the H' -value (1.351) and $1-D$ -value (0.6979) of the Tongkat Ali Trail indicated low diversity, but high distribution evenness of bat species, presented across the given trail (Magurran, 2004; Lim & Mojiol, 2019). Henceforth, the Tongkat Ali Trail is regarded as critical to the survival of the local bat community.

CONCLUSION

Various species of bat can be found in the Tenghilan Community Forest, especially at the Tongkat Ali Trail, which is situated entirely in the local regenerated lowland dipterocarp forest. The local bat community is comprised mainly of the least-concerned frugivorous and nectarivorous species, and then their abundances are closely related with the presences of roosting site, food source and human disturbance. Therefore, further conservation effort is required to conserve and prevent these species from being extinct locally in future. However, this study has examined only a part of the Tenghilan Community Forest, and also only for a short period of time. Because of that, further study should be

conducted onto this matter for the entire area of this state land forest and under a longer sampling period, to ensure that a much holistic understanding on the influences of presences of food source, human disturbance and roosting site to the local bat community can be validated in future.

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