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Diversity and Ecological Insights of Fruit Bats in Durian Orchards of Sarawak, Malaysian Borneo

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ABSTRACT

Pteropodid bats are important pollinators for tropical fruits like durian (*Durio zibethinus*), which is very important for both the economy and culture of Southeast Asia. This study aimed to examine the ecological interactions and habitat relationships of pteropodid bats in durian orchards. From August 2021 to November 2022, mist-netting surveys were done at 13 orchards and documented 839 individuals from ten pteropodid species. *Cynopterus brachyotis* was the most common species seen. Floral observations showed that anthesis in *D. zibethinus* started at roughly 16:30 with the opening of flower buds, succeeded by anther dehiscence at 19:00, coinciding with the initiation of feeding activity in pteropodid bats. Pollen analysis verified floral visitation, revealing that 82% of pollen-positive captures were attributed to *C. brachyotis*. Bat captures peaked during the flowering period, especially from September to November. Principal Component Analysis (PCA) and Generalised Linear Mixed Models (GLMMs) were used to look at the habitat, and they showed that the size of the durian orchard (ha) was the sole important factor that affected the number of bats. Other variables, such as orchard age and the quantity of flowering trees, did not exhibit statistical significance. These results show how important durian orchard sites are for bat-mediated pollination services and propose that conservation should be a part of how orchards are managed.

Keywords: Habitat association, mist netting, pollination, pteropodidae

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INTRODUCTION

Old World fruit bats, or pteropodid bats, are necessary for the pollination of several plants, such as durian (*Durio zibethinus*), petai (*Parkia speciosa*), mango (*Mangifera indica*), and kapok (*Ceiba pentandra*) (Aziz et al., 2021; Ramírez-Fráncel et al., 2022; Stewart & Dudash, 2018). In countries like Thailand, Malaysia, Indonesia, Brunei, Vietnam, Myanmar, Cambodia, and Laos, durian is very important to both the economy and culture (Drenth & Guest, 2004). From 2015 to 2017, the world produced almost 2.3 million metric tonnes of durian, which shows how important it is as a staple fruit in Southeast Asia (Altendorf, 2018). Pteropodid bats are the main pollinators in this business, and the orchards are where these bats get their food and shelter (Aziz et al., 2021). Studies in Indonesia showed that pollen analysis can effectively identify the pattern of floral visitation and the functional groupings among the fruit and nectar bats (Bumbut et al., 2016; Maryati et al., 2008; Soegiharto et al., 2010). Different bat species can be better or worse at pollinating, and *Eonycteris spelaea* is known for being quite good at it since it carries a lot of pollen and has particular ways of finding food (Low et al., 2021; Mohammad-Shah et al., 2021). While the bats eat, they move the pollen around. Although *Durio zibethinus* is capable of limited self-pollination, the bat's actions helped the cross-pollination and substantially enhanced genetic diversity, fruit set, fruit size, and overall yield quality (Baqi et al., 2022; Honsho et al., 2007). Habitat loss, poaching, and other human-caused problems are major risks to many bat species, which could hurt natural pollination services (Aziz et al., 2016; Meyer et al., 2016; Mohd-Azlan et al., 2022). The Sarawak Wild Life Protection Ordinance 1998 (WLPO 1998) protects all chiropteran species in the State of Sarawak because of these risks. Anyone who hunts, kills, captures, sells, or says they will sell any species of fruit bat might be fined RM10,000 and sent to jail for up to a year. These species are protected in Sarawak, but not much is known about where they live and how they interact with modified landscapes like durian orchards.

Identifying bat species that inhabit durian orchards can aid the prioritisation of conservation efforts, including the protection of roosting areas, mitigation of disturbances, and development of bat-friendly habitats (Meli et al., 2024). These efforts not only protect bat populations, but they also help keep the ecosystem next to them in balance and full of all kinds of plants and animals. Conserving nearby forests, using fewer pesticides when bats are foraging, and planting more flowering plants to feed bats are all ways to get pollinators to visit all the time (Muchhala & Jarrin, 2002; Oliveira et al., 2020; Ripperger et al., 2015). Studies showed that by having a healthy bat population, durian harvests and quality increase, which benefits farmers, consumers, and local economies (Baqi et al., 2022; Muhammad et al., 2021).

Considering the interdependent functions of bats, ecosystems, and agriculture, the presence of pteropodid bats in durian orchards is both ecologically significant and practically essential (Muchhala & Jarrin, 2002; Meli et al., 2024). Protecting these essential pollinators and their ecosystems would ensure the sustainability of an industry that sustains millions of livelihoods while enhancing biodiversity and ecological well-being (Altendorf, 2018; Drenth & Guest, 2004; Kasso & Balakrishnan, 2013).

Ongoing research on bats in Borneo mainly focuses on the diversity, genetics, ecology and conservation (e.g. Habeebur-Rahman et al., 2025; Lok et al., 2021; Mc Arthur et al., 2024; Morni et al., 2025; Yoh et al., 2023). While most of this research focuses on protected and forested areas, very little attention is given to bats in human-modified landscapes. Studies on bats in plantations such as oil palm and in Sarawak have shown that fruit bats dominate the species diversity and abundance. However, no research on bats has been conducted in fruit orchards such as durian, an ecologically important crop for some pteropodids. in Borneo. Therefore, this research is the first in Borneo to (1) document the species of pteropodid bats visiting durian orchards, (2) investigate the floral traits of *D. zibethinus* and its interaction with pteropodid bats, and (3) investigate the influence of habitat heterogeneity on the presence of pteropodid bats in the durian orchards.

MATERIALS AND METHODS

Study Site

This study was conducted in 13 durian orchards located at various sites across Sarawak between August 2021 and November 2022 (Figure 1). At each site, ten mist nets were set for three consecutive nights. The placement of the nets was between tree rows and near flowering durian trees, targeting the bats foraging within the orchard. All mist nets were checked regularly at 15-30 minute intervals after dusk until 2300 hours and resumed the following mornings from 0530 hours. The species identification referred to Phillipps and Phillipps (2018). All bat individuals were released upon morphological measurements and species identification.

Bat Abundance and Conservation Status

For each bat species, the analysis presented the mean number of individuals per night, percentage of species composition, and number of individuals observed through all sampling nights, along with their IUCN conservation status (IUCN, 2025).

Floral Observation and Pollen Analysis

Observations of *D. zibethinus* were conducted at a mixed-fruit orchard in Serian (1°11'54.6"N 110°32'51.2"E, 11 m elevation). To record the process of flower-opening, flowers undergoing anthesis were photographed with a digital camera at two-hour intervals for over 24 hours. The progress of the floral development (from budding to wilting) was categorised into percentage (%) for every two hours. The mean percentage of blooming was plotted to observe the trend.

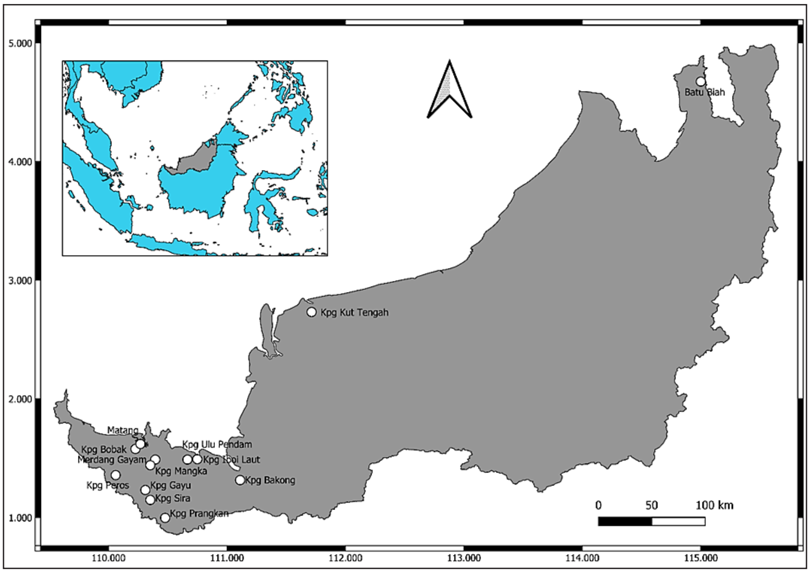

Figure 1. Sampling distribution of pteropodid bats in Sarawak from August 2021 to November 2022

Pollen grains were collected from pteropodid bats using a hand-picking technique (Low et al., 2021). Pollen adhered to the bats' bodies was carefully removed and transferred into Eppendorf tubes containing FAA (Formalin-Acetic Acid-Alcohol) solution to preserve the samples (Thompson, 2016). The tubes were immediately stored in a polystyrene box with ice packs to prevent drying. After being brought to the lab, the pollen samples were made ready for identification (Baqi et al. 2022). Using a micropipette, pollen grains were moved on glass slides so that they could be seen under a microscope. A Leica DM500 compound microscope with a Leica ICC50 W camera (10X magnification) was used to identify the object. Pollen was identified using comparisons with recognised pollen types collected from the study region.

Habitat Characteristics

The main types of landscapes around the study sites were (1) rubber plantations, (2) oil-palm plantations, (3) mixed-fruit orchards, and (4) places where people live. We recorded the following parameters for each site: (1) the surrounding matrices (n) (forest/oil palm plantation/rubber plantation), (2) the age of the orchard (n), (3) the area of the orchard (hectares), (4) the number of flowering durian trees (n), (5) the number of other flowering trees (n), (6) the total number of durian trees (n), and (7) the distance of the orchards to the forest (m) (Appendix 1). We got this information by measuring things directly in the field, looking at them, and talking to orchard owners. GPS devices were utilised to find the locations of orchards and the distance to the nearest forest edge. Tree counts and species identification were done on site.

This study used Principal Component Analysis (PCA) to find the variables that had the largest effect on the results. PCA simplifies intricate datasets by pinpointing the most significant underlying elements or components that organise species assemblages and environmental traits, hence enhancing data visualisation and interpretation. Utilising the principal components derived from PCA, a Generalised Linear Mixed Model (GLMM) with a Poisson distribution was employed to analyse the impact of habitat heterogeneity factors on the overall abundance of pteropodid bats in durian orchards. We tried 16 different models to cover all the conceivable combinations of the four habitat heterogeneity variables. All analyses were conducted using RStudio (version 2024.9.1.394), with packages such as "readxl", "corrplot", "ggfortify", "gridExtra", "carData", "car", "factoextra", "FactoMineR", "labelling", "farver", "pscl", "boot", "ggplot2", "lme4", "MuMIn", "dplyr" and "performance".

RESULTS

Species Abundance and Composition

A total of 839 individuals of pteropodid bats representing ten species were recorded across 13 durian orchards in Sarawak. This species accounts for approximately 56% of the total pteropodid bat species recorded in Borneo. Among these, three species were nectarivorous: *Eonycteris spelaea*, *Eonycteris major*, and *Macroglossus minimus*, while the remaining seven species were frugivorous, including *Balionycteris maculata*, *Cynopterus brachyotis*, *Cynopterus horsfieldii*, *Cynopterus minutus*, *Dyacopterus spadiceus*, *Penthetor lucasi*, and *Rousettus amplexicaudatus* (Table 1, Figure 2).

Table 1
The checklist of the bat species in durian orchards, Sarawak, Malaysia

Species	Mean ±S.D. (indv./night)	Species Composition(%)	Diet	IUCN 2025
Balionycteris maculata	0.05±0.23	<1	Frugivorous	LC
Cynopterus brachyotis	12.95±3.60	60	Frugivorous	LC
Cynopterus horsfieldii	0.18±0.42	1	Frugivorous	LC
Cynopterus minutus	0.90±0.95	4	Frugivorous	LC
Dyacopterus spadiceus	0.38±0.62	2	Frugivorous	NT
Eonycteris major	0.05±0.23	<1	Nectarivorous	NT
Eonycteris spelaea	2.87±1.69	14	Nectarivorous	LC
Macroglossus minimus	2.13±1.46	10	Nectarivorous	LC
Penthetor lucasi	1.92±1.39	9	Frugivorous	LC
Rousettus amplexicaudatus	0.03±0.16	<1	Frugivorous	LC

Note. *Individual (Indv.); Least Concern (LC); Near Threatened (NT)

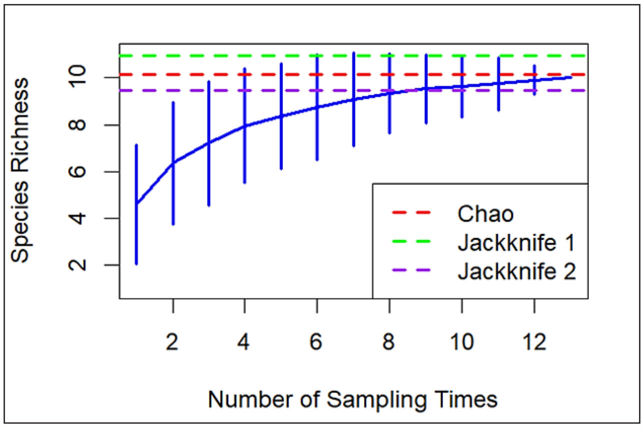

Figure 2. Species accumulation curve of pteropodid bats captured in durian orchards against the number of samplings conducted in Sarawak from August 2021 to November 2022

Anthetic Progression

Observations of *D. zibethinus* floral development revealed that from 1100 hours to 1600 hours, individual buds within each cluster gradually enlarge as they mature. The bracts and sepals begin to loosen, indicating the approach of anthesis. Between 1600 and 1900 hours, petals started to unfold, progressively exposing stamens and pistils as the flower entered full bloom. By approximately 2100 hours, flowers were fully open and emitted a distinctive scent, which is a critical attractant for nocturnal pollinators such as bats and insects. During this phase, the anthers release pollen, facilitating pollination when it contacts the receptive stigma of another flower, consistent with previous studies (Honsho et al., 2004; Thorogood et al., 2022). By 0300 hours the following day, the flowers begin to wilt, and unpollinated flowers abscise and fall from the tree within a day or two, completing their life cycle (Figure 3).

Approximately 26% of the flower buds within a cluster show partial opening by 1100 hours. This proportion increased steadily, with 40-50% opening by early evening. By 1900 hours, approximately 95% of flowers were fully or nearly full bloom. After 0100 hours, the flowers started to show signs of wilting before eventually dropping.

Pollen Analysis

From the ten pteropodid species recorded during sampling, only four species were observed carrying pollen, from which a total of 68 pollen samples were collected. The remaining six species were rarely captured and did not carry detectable pollen. *C. brachyotis* had the highest number of pollen samples (n = 56, 82%), followed by *E. spelaea* (n = 6), *P. lucasi* (n = 5) and *M. minimus* (n = 1). The highest pollen sample count was recorded in August, suggesting this month as the peak flowering season in Sarawak (Figure 4).

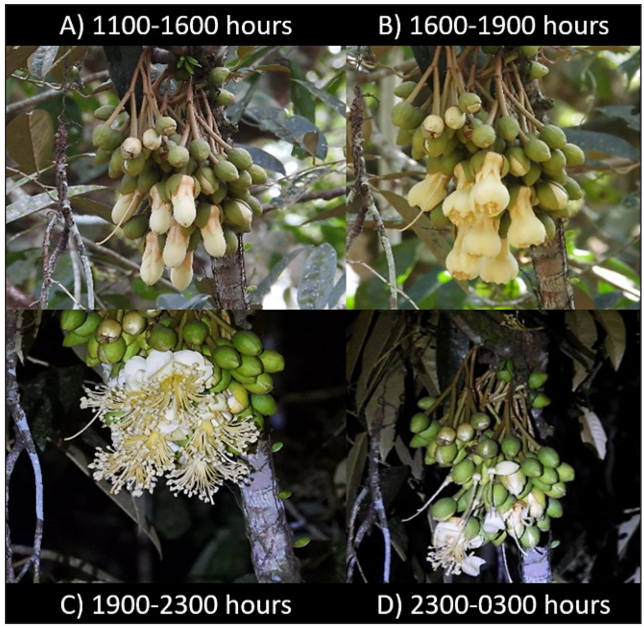

Figure 3. Floral development of *D. zibethinus* from bud initiation to flower abscission with a corresponding timeline

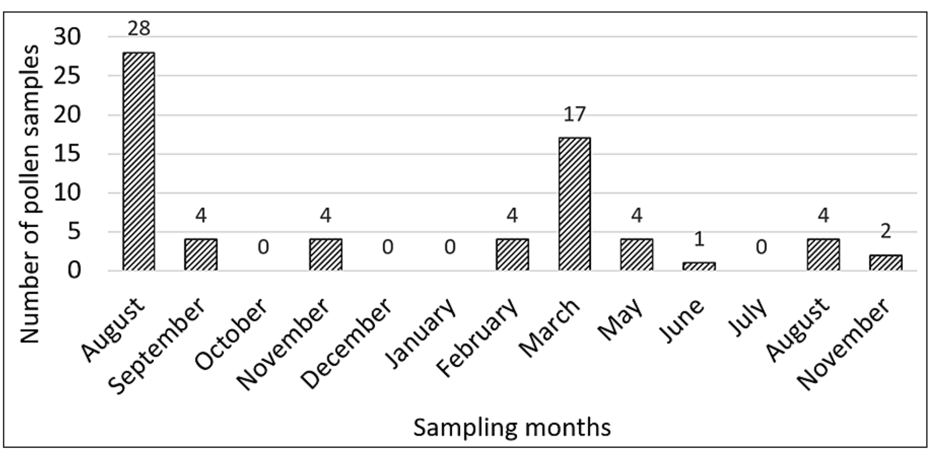

Figure 4. The number of pollen samples collected from August 2021 to November 2022

A linear regression analysis demonstrated a statistically significant positive relationship between the percentage of the flowering progress and the number of pteropodid bats captured, indicating that increased flowering activity is associated with higher bat visitation (Linear regression; $F = 17.41$, $P = 0.02$, $R^2 = 0.61$).

Effect of Habitat Heterogeneity on Bat Species Abundance

Principal component analysis (PCA) was performed to identify the major contributing variables related to habitat heterogeneity. Three principal components accounted for 86% of the total variation. The distance of the orchard to the forest, the number of durian trees and the number of flowering durian trees were negatively correlated with orchard age. Additionally, the orchard area and surrounding matrices showed a negative correlation with the other flowering trees. Based on the PCA results, the variables retained for further analysis were the number of durian trees, other flowering trees, orchard age, and orchard area, as these variables contributed most to the variation in the data and showed strong associations with the principal components that explained the majority of the variance. Specifically, the number of durian trees showed a high loading on PC1 (−0.463), while orchard age (−0.430) and orchard area (−0.420) loaded strongly on PC2. The number of other flowering trees also contributed notably to PC2 (0.341) (Table 2).

A total of 16 Generalised Linear Mixed Models (GLMMs) were run to assess the influence of habitat heterogeneity factors, comprising orchard area (ha), orchard age, number of durian trees, and number of other flowering trees on the abundance of pteropodid bats in durian orchards. The five best-fitting models based on AICc values are summarised in Table 3.

Table 2
Component matrix derived from the result of PCA

Factors	Component Matrix		
	PC1	PC2	PC3
Number of matrices	-0.289	-0.528	-0.272
Area of the orchard (hectare)	-0.347	-0.420	0.388
Age of the orchard	0.137	-0.430	0.623
Number of flowering durian trees	-0.418	0.382	0.370
Number of other flowering trees	0.332	0.341	0.469
Number of durian trees	-0.463	0.296	-0.099
Distance of the orchards to the forest	-0.528	0.107	0.143

Table 3
Results of the GLMM model examine the effect of surrounding habitat heterogeneity factors on the abundance of pteropodid bats in durian orchards

Model	Included Variables	AICc	ΔAiCc	Weight	p-value
2	Area of the orchard	130.42	0	0.46	0.002*
10	Area of the orchard + Number of durian trees	132.54	2.12	0.16	0.999
6	Area of the orchard + Other flowering trees	133.04	2.62	0.12	0.351
5	Other flowering tree	133.77	3.35	0.09	0.050
4	Area of the orchard + age of the orchard	133.91	3.49	0.08	0.999

Note. *Significant value

The best-performing model (Model 2, AICc = 130.42) included only orchard area as a fixed effect and revealed a significant positive association between orchard area and the abundance of pteropodid bats (Weight = 0.46, $p = 0.002$). Other predictors, including orchard age, number of durian trees, and number of other flowering trees, were not statistically significant in any of the top models. Additionally, when the linear predictor for the species-level interaction with orchard area was tested, no significant relationship was found for any of the species ($P>0.05$; Intercept Estimate: 1.98-5.18).

DISCUSSIONS

Species Composition and Ecological Roles

The current study is the first to report the distribution of pteropids in durian orchards in Sarawak, Malaysia, Borneo. In the study area, *C. brachyotis* was the most abundant species recorded (n = 505, 60%), suggesting that they are adaptable to orchard ecosystems and utilise this habitat for foraging (Campbell et al., 2006; Jayaraj et al., 2012; Karuppudurai & Sripathi, 2018). This is followed by the nectivorous, *E. spelaea* (n=112, 13%) and *M. minimus* (n=83, 10%). The fact that these species are essential pollinators, in particular for durian and other flowering plants near the habitat, suggests that the orchards not only supply sources of food but also play a role in maintaining the ecological niche by providing support for populations of pollinators (Demestihas et al., 2017; Garratt et al., 2023).

This study also recorded a singleton individual of *R. amplexicaudatus.* This species is a high-flying species, therefore the standard mist-netting method is less likely to trap this species. *Rousettus amplexicaudatus* is commonly recorded in krast regions as compared to human-altered areas. Previous studies have documented numerous individuals in orchards (e.g. Heideman & Utzurrum, 2003; Pounsin et al., 2016; Tanalgo et al., 2021). Our study also documented two IUCN RedList Near Threatened species, *D. spadiceus* and *E. major*. This suggests that the durian orchard may function as a sanctuary for these bats, especially in the areas where their populations are fragile due to habitat loss.

Flowering Ecology and Bat Pollination

This study contributed to the ongoing work of looking into the durian flowering ecology in Southeast Asia (Bumrungsri et al., 2009; Honsho et al., 2004; Masri, 1999; Ng et al., 2020). The blooming season in Sarawak is different in different parts of the state. It started in the northern part, moving south and then west across the state. This is influenced by the weather changes such as the temperature, rainfall and soil conditions, affecting the flowering patterns (Rajandran et al., 2024; Suwanseree & Yapwattanaphun, 2017). These alter the fruit's availability of fruit, the harvest time and farmers' profits.

Durio zibethinus's flower started to bloom in the evening and stayed open all night. This coincides with the activity pattern of the pteropodid bats, highlighting the species adaptation to bat-mediated pollination. Previous studies have demonstrated the synergy of the durian-bat pollination (Bumrungsri et al., 2013; Sheherazade et al., 2019; Low et al., 2021).

The detection of pollens on pteropodid bats, mostly on the heads, faces and fur of the bats, showed their important function as pollinators for *D. zibethinus*. These showed that they do effectively interact with the flower reproductive systems while eating, highlighting the significance of head and fur contact in improving pollen transfer efficiency (Ng et al., 2020; Pontes et al., 2024; Sheherazade et al., 2019).

The varying amounts of pollen among species may result from differences in their feeding habits. *Eonycteris spelaea* and *M. minimus* are two examples of nectarivorous species with long tongues that help them get nectar (Phillips & Phillips, 2018). This could help them eat pollen or keep pollen from being externally retained on their fur, which is not the case with other frugivorous species that eat a wide range of foods (Bumrungsri et al., 2013; Stewart & Dudash, 2018). *Cynopterus brachyotis*, which is commonly thought of as a generalist feeder, actually helps with pollination by visiting flowers often. Therefore, pollen should be seen as proof that flowers were visited, not as a way to see how well pollination worked. Similar pollen studies in Indonesia have demonstrated species-specific floral associations and functional grouping among fruit and nectar bats (Maryati et al., 2008; Soegiharto et al., 2010). While certain insects visit durian blossoms, their effectiveness in pollination is inferior to that of pteropodid bats (Fleming et al., 2009).

The cross-pollination has been consistently shown to enhance fruit development and marketable yield (Honsho, 2007). In this context, pollinator presence, particularly by mobile vertebrate pollinators such as pteropodid bats, plays a functionally essential role in sustaining the optimal yield and durian's fruit quality (Cervancia, 2018). The ecological reliance on cross-pollination reinforces the importance of maintaining bat populations within agricultural landscapes.

Influence of Habitat Heterogeneity

Among the environmental parameters evaluated, only the size of the orchard showed a statistically significant link to the number of pteropodid bats. The positive link between the size of an orchard and the number of bats suggests that connected orchards may provide better foraging possibilities and roosting sites for pteropodid bats. Larger orchards may have more nectar and pollen because they have more flowers, which is in line with research that shows that larger habitats have more bats because there is less competition and better access to resources (Mohd Nokin & Ramli, 2022).

The orchard size may also correlate with the ecological characteristics of pteropodid bats that have large home ranges and can fly around a lot, helping them to keep track of available resources in different places. As an example, Acharya et al. (2015) reported that *E. spelaea* has large home ranges and changes its foraging pattern depending on how many flowers are available (Acharya et al., 2015). During the peak flowering season of the durian flower, the bats do not need to rely much on other flowering plants in the area.

Previous studies have reported that habitat heterogeneity enhances bat activity and diversity by offering multiple resources and microhabitats (Frey-Ehrenbold et al., 2013). Despite this, the impacts of habitat heterogeneity are scale-dependent, differing between local and landscape levels (Mendes et al., 2017). Landscape composition and connectivity are known to influence bat presence and activity (Hale et al., 2012), suggesting that broader spatial factors may be more significant than within-orchard variation for highly mobile fruit bats.

Aziz et al. (2021) have emphasised the essential ecological function of pteropodid bats in pollination and seed dissemination services in both natural and agricultural settings. While most studies have focused on forest landscapes, the study of pteropodid bats in fragmented agricultural settings is still understudied (Ferreira, 2015; Meyer et al., 2016; Struebig et al., 2008). This study highlighted the significance of the orchard area, which supports at least 56% of the Pteropodid bat species identified in Sarawak.

Conservation Strategies

The findings from this study have practical implications for durian orchard management and bat conservation. Since orchard area significantly influences bat species richness and abundance, maintaining larger contiguous orchard plots or integrating smaller orchards into a connected landscape could enhance foraging opportunities. Conservation methods on a landscape scale can make it easier for orchards and natural ecosystems to link (Kay et al., 2018). Setting up habitat corridors can make it easier for bats to migrate around and mix their genes. Adding orchards to larger regional conservation plans can also make them more valuable to the environment (Cleary et al., 2017; Razgour et al., 2014; Ripperger et al., 2014).

The next strategy is to take care of the orchard's ecosystem. Providing native flowering plants and trees such as banana (*Musa acuminata*), domestic jackfruit (*Artocarpus integer*), and rambutan (*Nephelium lappaceum*) in the area will provide a good roosting and foraging site for the bats (Corlett, 2005; Lim et al., 2018).

The other strategy is to reduce pesticide usage. The pesticides can drastically affect the survivability of the bats (Oliveira et al., 2020; Torquetti et al., 2021). The Integrated Pest Management (IPM) needs to be adopted to ensure the negative effects of the pesticides on the bats and their food source can be reduced (Liu et al., 2024). Besides, raising awareness among farmers and local communities in the area on the bat's role in ecology and economic aspects is important in order to shift the negative perception towards bats and foster coexistence (Aziz et al., 2021; Ejotre et al., 2022).

While all bats are protected in Sarawak according to SWLPO (1998), their presence in fruit orchards is sometimes regarded as a pest by local farmers, who are allowed to protect their crops from potential pest species under section 42A of the same Ordinance. Therefore, fruit growers and farmers should be made aware of the role of fruit bats as pollinators for durians, which in turn may increase the yield (Harahap & Yonariza, 2022; Sheherazade et al., 2019). Lastly, it is also important to reduce the hunting pressures and human disturbances at bat roosting locations to make sure the species survives (Frick et al., 2020; Morni et al., 2018).

All of these conservation strategies can be implemented to encourage environmentally friendly farming. The orchard owners can protect the pollinator populations, keep the ecosystem in balance, and make sure more consistent durian production over time.

CONCLUSION

This study showed that the durian orchards are not only beneficial for the economy, but also can serve as an important habitat for a wide range of bat species, including important pollinators, seed dispersers and species of conservation interest. The ecological relationship between the bats and the durian orchard is mutually beneficial, and their protection, therefore, should be prioritised in future conservation planning.

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SUPPLEMENTARY DATA

Table S1
List of habitat heterogeneity factors of 13 durian orchards in Sarawak (Acronyms for sites are given below the table)

Factors	Sites												
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**
Number of surrounding matrices (n)	2	1	2	1	1	1	1	2	1	1	1	2	1
Age of the orchard (years)	53	86	57	40	66	48	44	50	15	33	30	27	32
Area of the orchard (hectare)	3.22	0.79	1	0.7	1.12	0.75	1	1.26	0.72	0.26	0.94	0.59	0.32
Number of durian trees (n)	10	7	10	5	5	7	5	10	20	5	5	10	7
Number of flowering durian trees (n)	4	3	0	0	1	2	1	1	7	1	1	1	0
Number of other flowering trees (n)	2	3	3	3	4	3	3	2	3	4	3	2	2
Distance of the orchard to the nearest forest (m)	345	83	79	66	60	147	84	162	310	75	84	83	148

Note. S1, Kampung Ulu; S2, Kampung Peros; S3, Kampung Sira; S4, Kampung Bobak; S5, Kampung Gayu; S6, Merdang Gayam; S7, Kampung Prangkan; S8, Kampung Iboi Laut; S9, Matang; S10, Kampung Mangka; S11, Kampung Kut Tengah; S12, Kampung Bakong; S13, Batu Biah

Table S2
Number of pteropodid bat species captured from 13 sampling sites in durian orchards between August 2021 and November 2022 in Sarawak (Acronyms for sites are given below the table)

Species	**Sites**													**Relative abundance**	**IUCN 2025**
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**		
Balionycteris maculata	0	0	0	1	0	0	1	0	0	0	0	0	0	0.24	LC
Cynopterus brachyotis	218	16	17	12	1	46	22	82	30	26	10	2	23	60	LC
Cynopterus horsfieldi	0	0	0	0	0	6	0	0	0	0	1	0	0	0.83	LC
Cynopterus minutus	0	0	2	0	0	0	5	10	9	3	3	2	1	4.17	LC
Dyacopterus spadiceus	1	0	0	5	0	3	0	0	0	0	0	4	2	1.79	NT
Eonycteris major	0	0	1	0	0	0	1	0	0	0	0	0	0	0.24	LC
Eonycteris spelaea	0	2	16	0	7	0	11	0	13	34	0	27	2	13.35	LC
Macroglossus minimus	1	2	1	0	1	9	1	46	0	0	11	3	8	9.77	LC
Penthetor lucasi	0	11	30	4	12	7	0	0	2	0	0	9	0	8.94	LC
Rousettus amplexicaudatus	0	0	0	0	0	0	1	0	0	0	0	0	0	0.12	LC
Number of Individuals	220	31	67	22	21	71	42	138	54	63	25	47	36		
Number of species	3	4	6	4	4	5	7	3	4	3	4	6	5		
Shannon-Wiener Index	0.058	1.06	1.28	1.12	0.98	1.11	1.30	0.87	1.09	0.84	1.11	1.29	1.041		
Simpson Index	0.018	0.60	0.68	0.62	0.56	0.55	0.64	0.53	0.60	0.54	0.63	0.62	0.54		
Species evenness	0.35	0.72	0.60	0.76	0.66	0.61	0.52	0.79	0.74	0.77	0.76	0.60	0.57		

Note. S1, Kampung Ulu; S2, Kampung Peros; S3, Kampung Sira; S4, Kampung Bobak; S5, Kampung Gayu; S6, Merdang Gayam; S7, Kampung Prangkan; S8, Kampung Iboi Laut; S9, Matang; S10, Kampung Mangka; S11, Kampung Kut Tengah; S12, Kampung Bakong; S13, Batu Biah