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# BATS OF PULAU TINGGI, JOHOR, MALAYSIA

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**Abstract:** A series of bat surveys took place in Pulau Tinggi from July 2019 to September 2019. A total of 242 individuals representing 15 species from six families were captured from a cumulative effort of 462 trap nights. The most caught species for frugivorous bats was *Cynopterus brachyotis* (n = 150) while for insectivorous bats, it was *Hipposideros cervinus* (n = 20). Pulau Tinggi has a high density of bat species per area (1.01 sp/km$^2$) when compared to other tourist islands on Peninsular Malaysia's east coast [e.g., Pulau Tioman (0.13 sp/km$^2$), Pulau Perhentian (0.5 sp/km$^2$) and Pulau Redang (0.4 sp/km$^2$)]. As a result, high levels of disturbance such as tourism and habitat loss may negatively affect the diversity of bat species on the island. Because of time constraints and the study did not cover the entire island, information on the diversity of bats in Pulau Tinggi is still inadequate. Long-term monitoring of bat diversity covering forest areas throughout the island needs to be conducted immediately to identify the number of species, their distribution and ecology. This information is important in formulating a strategic plan for bat conservation in Pulau Tinggi.

Keywords: Bat, Chiroptera, small mammal, Malaysia, Johor, Seribuat Archipelago, South China Sea.

## Introduction

Bats belong to the order Chiroptera, the second-largest group of mammals after Rodentia (Vaughan *et al.*, 2015). It is an important seed disperser, pollinator and insect population controller in ecosystems (Jones *et al*., 2009). Malaysia is one of the biodiversity hotspots for bat species, with 143 species accounting for 10% of the world's total bat species (Senawi & Ahmad, 2021; Simmons & Cirranello, 2022). In Peninsular Malaysia alone, 110 bats have been described and mostly identified based on research conducted on the mainland (Lim *et al.,* 2017). Although many bat surveys have been conducted in Malaysia (Naharuddin *et al.,* 2015; Mohd-Hanif *et al.,* 2015; Shazali *et al.,* 2016; Lim *et al.,* 2017; Mohd-Ridwan *et al.,* 2018; Lim *et al.,* 2019; William-Dee *et al.,* 2019; Senawi *et al.,* 2020; Lok *et al.,* 2021), studies on bat diversity in Peninsular Malaysia's offshore islands are poorly understood and not well documented (Roslan *et al.*, 2016).

Reports on the diversity of Malaysian bats on the islands continue to be limited by effort and funding due to its costly and unpredictable climatic events (Baqi *et al.*, 2021). Previously, offshore island bat diversity surveys, particularly in the South China Sea, took place on Pulau Bidong, Pulau Perhentian (Roslan *et al.*, 2016; Baqi *et al.*, 2021), Pulau Redang (Mohd-Yusof *et al.,* 2019) and Pulau Tioman (Medway, 1966; DWNP, 1995; Csorba *et al.,* 1997; Lim *et al.,* 1999). Pulau Tioman has the most bat species (19 species) while Pulau Bidong has the fewest (three species). According to those surveys, larger islands closer to the mainland had higher

rates of bat diversity than smaller islands with a greater distance from the mainland. The findings support the theory of island biogeography, which states that the richness of a species depends on the size and isolation of the island (MacArthur & Wilson, 2016; Valente *et al.*, 2020). Larger islands have a greater species richness than smaller islands due to abundant resources. However, as the island becomes more geographically isolated from the mainland and smaller, its species richness will decline (MacArthur & Wilson, 2016; Valente *et al.*, 2020).

Habitat loss and human disturbance are major threats island bats face (Jones *et al.,* 2009). The booming tourism industry across Malaysia's islands has put significant pressure on natural resources and land use in the offshore islands. Therefore, extensive scientific surveys and studies must be conducted to determine the impact of development on species diversity, distribution and ecology of island bats. To date, no island bat surveys have occurred on Pulau Tinggi. This survey aims to provide baseline data on bat species in Pulau Tinggi. The results are compared to previous studies conducted on Malaysia's east coast islands. The data gathered is crucial in assisting authorities in developing a strategic plan and policies to improve island bat conservation, particularly in Pulau Tinggi.

## Materials and Methods

### *Study Site*

The study occurred in Pulau Tinggi (2° 18' N, 104° 07' E), located near Mersing, about 30 km to the southeast of Johor. Pulau Tinggi is located in the district of Mersing in Johor (Figure 1). There are over 19 villages there (Manaf *et al.,* 2011). Pulau Tinggi and other 12 small islands have been listed under East Johor Island Archipelagos (EJIA), where Pulau Tinggi is considered the biggest island among the rest (Azman, 2008). The other 12 islands under EJIA are Pulau Mensirip, Pulau Goal, Pulau Harimau, Pulau Rawa, Pulau Tengah, Pulau Hujong, Pulau Mentigi, Pulau Sibu Hujong, Pulau Sibu, Pulau Besar, Pulau Aur and Pulau Pemanggil.

### *Field Methods, Identification, Processing and Preservation*

Field samplings were done using ground netting, high pole netting, and harp trapping (Mohd-Ridwan *et al.,* 2018). A total of ten mist nets, five high poles and six harp traps were placed throughout several bat flyways, including above

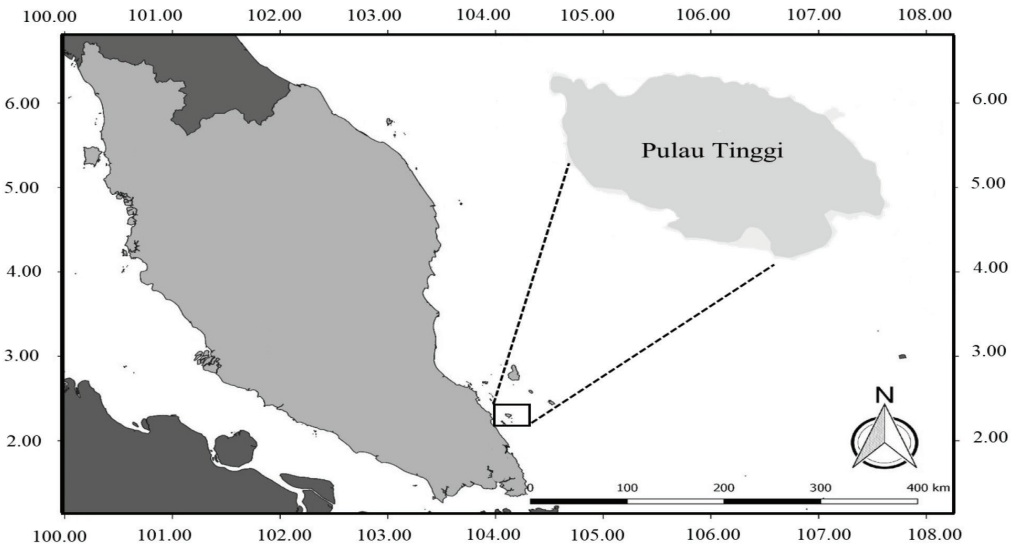


Figure 1: Map showing the location of Pulau Tinggi in Peninsular Malaysia

streams, trails, along narrow paths, in cleared parts of the forest and at the forest edge. The total number of nets and traps multiplied by the number of sampling days was used to evaluate the amount of trapping effort (Mohd-Ridwan *et al.,* 2018). Bats were identified based on Kingston *et al.* (2006) and Francis *et al.* (2008). The morphological measurements of the bats were taken using a digital vernier calliper and weighted using Pesola spring balance (Mohd-Ridwan *et al.,* 2018). Following Kunz (1988), adult bats were determined by examining the epiphyseal-diaphyseal fusion on the third, fourth and fifth metacarpals. To avoid recapture and lessen stress, all trapped bats were kept until all nets were closed (a maximum of 12 hours). Selected voucher specimens were euthanized using chloroform and subjected to skinning procedures. The liver and pectoral muscle were excised and preserved in 75% ethanol. The samples were then deposited at the Universiti Tun Hussein Onn (UTHM) zoological museum.

### *Data Analysis*

The total number of species caught was used to calculate the species richness. The relative abundance was estimated by the number of individuals per species divided by the number of individuals. The Shannon-Wiener diversity index (*H*') was used to estimate species diversity in Pulau Tinggi, sensitive to changes in the abundance of rare species in a community (Solow, 1993). A diversity t-test was conducted to compare the abundance and composition of bat assemblages between different trapping methods. The Shannon-Wiener index and diversity t-test analysis was calculated using PAST software (Hammer *et al.,* 2001). The phenogram was generated to compare the species richness of bats documented at four east coast islands of Peninsular Malaysia. The cluster analysis comparisons were based on the absence and presence matrix of species documented in all the localities (Tingga *et al.,* 2012). The selected sites include Pulau Perhentian (Tambryn *et al.,* 2005; Roslan *et al.,* 2016), Pulau Bidong (Roslan *et al.,* 2016), Pulau Redang (Mohd-Yusof *et al.,* 2019) and Pulau Tioman (Medway, 1966; DWNP, 1995; Csorba *et al.,* 1997; Lim *et al.,* 1999). A Venn diagram was produced to determine the shared and unique bat species compared to other east coast islands.

## Results

A total of 242 individuals representing 15 species from six families: Emballonuridae, Hipposideridae, Megadermatidae, Pteropodidae, Rhinolophidae and Vespertilionidae were recorded at Pulau Tinggi (Table 1). Pteropodidae has the greatest number of species (five species) on this island, followed by Hipposideridae (four species) and Vespertilionidae (three species), whereas Rhinolophidae, Emballonuridae and Megadermatidae each with one species. A total of 137 individuals representing nine species (220/net-night) were mist-netted, 24 individuals (five species) were captured in harp traps (132/trap-night) and 81 individuals (eleven species) were caught using a high pole (110/net-night). *Cynopterus brachyotis* (62%) was the most captured species in Pulau Tinggi followed by *Eonycteris spelaea* (9.5%). Four species were recorded as singletons: *Hipposideros galeritus*, *Taphozous melanopogon*, *Megaderma spasma* and *Myotis muricola*.

### *Comparison of Trapping Methods*

All three trapping methods were successful in capturing bats (Table 2). The high pole nets recorded the highest number of bat species (11 species), followed by mist nets (nine species) and harp traps (five species). Family Pteropodidae showed the highest overall captured rate for both high poles (trapping effort/nights = 0.64) and mist nets (trapping effort/nights = 0.58). Family Hipposideridae (trapping effort/nights = 0.17) recorded the highest capture rate using harp traps. There was no significant difference in the species and relative abundance of bats captured using mist nets and harp traps ($t = 0.64$, df = 38, $p = 0.52$), mist nets and high poles ($t = 0.61$, df = 154, $p = 0.54$) and between high pole and harp traps ($t = 1.02$, df = 55, $p = 0.30$).

Table 1: Taxonomic list of bats species captured with their average measurements (minimum and maximum ranges) from both study areas

| No. | Family Species | N | Forearm Mean (range) (mm) | Ear Mean (range) (mm) | Hindfoot Mean (range) (mm) | Tail Mean (range) (mm) |
|---|---|---|---|---|---|---|
| | Pteropodidae | | | | | |
| 1. | *Pteropus hypomelanus* | 12 | 124.17 (116-145) | 25.58 (24-27) | 40.33 (34-45) | NA |
| 2. | *Cynopterus brachyotis* | 150 | 60.29 (52-66) | 16.24 (14-17) | 12.89 (10-15) | 8.78 (8-9) |
| 3. | *Penthetor lucasi* | 7 | 61.86 (57-65) | 15 (11-17) | 14.86 (12-17) | 8 (6-10) |
| 4. | *Eonycteris spelaea* | 23 | 61.22 (55-70) | 16.78 (15-17) | 15 (15-18) | 11.96 (9-14) |
| 5. | *Macroglossus minimus* | 7 | 38.86 (37-42) | 13.43 (11-15) | 11.57 (10-13) | |
| | Rhinolophidae | | | | | |
| 6. | *Rhinolophus stheno* | 4 | 47.25 (43-50) | 17 (15-20) | 11.5 (11-13) | 17.75 (16-20) |
| | Hipposideridae | | | | | |
| 7. | *Hipposideros cervinus* | 20 | 45.55 (45-47) | 14.3 (12-15) | 7.3 (6-9) | 23.5(22-27) |
| 8. | *Hipposideros diadema* | 9 | 82.22 (77-90) | 25 (23-30) | 14.45 (10-16) | 41 (39-49) |
| 9. | *Hipposideros galeritus* | 1 | 50 | 10 | 7 | 30 |
| 10. | *Hipposideros bicolor* | 2 | 44.5 | 16.5 | 5.5 | 28.5 |
| | Megadermatidae | | | | | |
| 11. | *Megaderma spasma* | 1 | 60 | 32 | 14 | NA |
| | Emballonuridae | | | | | |
| 12. | *Taphozous melanopogon* | 1 | 60 | 15 | 12 | 23 |
| | Vespertilionidae | | | | | |
| 13. | *Miniopterus medius* | 2 | 37 (32-42) | 9.5 (7-12) | 8 (7-9) | 30.5(29-32) |
| 14. | *Philetor brachypterus* | 2 | 32.8 (32-33.5) | 11.12 (9.4-12.45) | 6.9 (5-8) | 33.54 (32.08-35.1) |
| 15. | *Myotis muricola* | 1 | 34 | 11 | 7 | 40 |

Table 2: List of species caught at Pulau Tinggi using three different methods including mist nets, harp traps and high-poles

| No. | Family Species | Harp Tarp | Mist Net | High Pole | RA (%) | Total | IUCN (2022) | DWNP (2017) |
|---|---|---|---|---|---|---|---|---|
| | Pteropodidae | | | | | | | |
| 1. | *Pteropus hypomelanus* | - | 12 | - | 5 | 12 | NT | LC |
| 2. | *Cynopterus brachyotis* | - | 94 | 56 | 62 | 150 | LC | LC |
| 3. | *Penthetor lucasi* | - | 3 | 4 | 2.9 | 7 | LC | LC |
| 4. | *Eonycteris spelaea* | - | 17 | 6 | 9.5 | 23 | LC | LC |
| 5. | *Macroglossus minimus* | - | 3 | 4 | 2.9 | 7 | LC | DD |
| | Rhinolophidae | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6. | *Rhinolophus stheno* | - | 2 | 2 | 1.7 | 4 | LC | LC |
| | Hipposideridae | | | | | | | |
| 7. | *Hipposideros cervinus* | 16 | - | 4 | 8.3 | 20 | LC | LC |
| 8. | *Hipposideros diadema* | 5 | 3 | 1 | 3.7 | 9 | LC | LC |
| 9. | *Hipposideros galeritus* | 1 | - | - | 0.4 | 1 | LC | LC |
| 10. | *Hipposideros bicolor* | 1 | - | 1 | 0.8 | 2 | LC | NT |
| | Megademartidae | | | | | | | |
| 11. | *Megaderma spasma* | 1 | - | - | 0.4 | 1 | LC | LC |
| | Emballonuridae | | | | | | | |
| 12. | *Taphozous melanopogon* | - | - | 1 | 0.4 | 1 | LC | LC |
| | Vespertilionidae | | | | | | | |
| 13. | *Miniopterus medius* | - | 2 | - | 0.8 | 2 | LC | DD |
| 14. | *Philetor brachypterus* | - | 1 | 1 | 0.8 | 2 | LC | DD |
| 15. | *Myotis muricola* | - | - | 1 | 0.4 | 1 | LC | LC |
| | No of individuals | 24 | 137 | 81 | | 242 | | |
| | No of species | 5 | 9 | 11 | | 15 | | |
| | Sampling effort | 132 | 220 | 110 | | | | |
| | Capture rate | 0.18 | 0.62 | 0.74 | | | | |
| | Shannon Index (H') | 0.99 | 1.14 | 1.25 | | | | |

Note: RA=Relative Abundance, LC=Least Concern, DD=Data Deficient, NT=Near Threatened

### *Species Diversity Indices*

The number of bat species captured in Pulau Tinggi increased exponentially till the 10th night (Figure 2). Starting from the 11th night, the species accumulation curve hit an asymptote, indicating sampling saturation. Species diversity index (*H'*= 1.47) showed a comparatively high diversity of bat species in Pulau Tinggi (Table 3) in comparison to other east coast islands (e.g., Pulau Perhentian and Pulau Bidong; Roslan *et al.,* 2016).

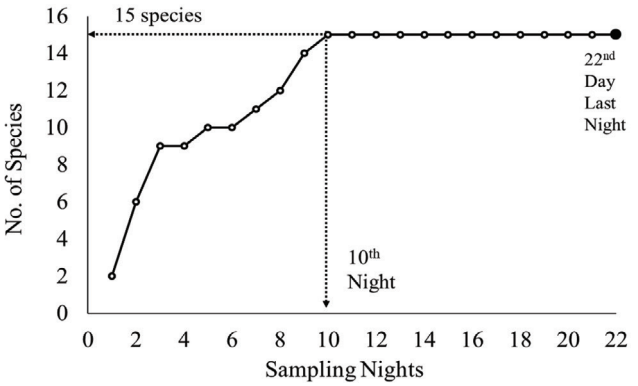


Figure 2: Species cumulative curve of bats captured at Pulau Tinggi

***Comparison with Other Malaysian East Coast Islands***

Our findings are being compared with other east coast islands, Pulau Perhentian, Pulau Bidong Pulau Redang and Pulau Tioman (Table 3). 29 species of bats can be found throughout the east coast islands. Pulau Tioman has the highest number of bats (19 species), followed by Pulau Tinggi (15 species), Pulau Perhentian (nine species), Pulau Redang (eight species) and Pulau Bidong (three species). Three species of bats were distributed throughout east coast islands, namely *Pteropus hypomelanus*, *Cynopterus brachyotis* and *Megaderma spasma* (Figure 2). Eight and nine species are unique to the Pulau Tinggi and Pulau Tioman, respectively (Table 3, Figure 2). The comparisons of four different sites in cluster analysis resulted in two groups (Figure 3). Pulau Perhentian clustered together with Pulau Redang followed Pulau Bidong and Pulau Tioman. Pulau Tinggi is the most distant group to other east coast islands.

Table 3: Taxonomic comparison with other Malaysian east-coast islands

| No. | Family<br>Species | This Study | Pulau Perhentian [a,b] | Pulau Bidong [a] | Pulau Redang [c,d] | Pulau Tioman [e,f,g,h] |
|---|---|---|---|---|---|---|
| | Pteropodidae | | | | | |
| 1. | *Pteropus hypomelanus* | + | + | + | + | + |
| 2. | *Cynopterus brachyotis* | + | + | + | + | + |
| 3. | *Cynopterus horsfieldii* | | | | | +* |
| 4. | *Penthetor lucasi* | + | | | | |
| 5. | *Eonycteris spelaea* | + | + | | + | + |
| 6. | *Macroglossus minimus* | +* | | | | |
| | Rhinolophidae | | | | | |
| 7. | *Rhinolophus affinis* | | + | | + | + |
| 8. | *Rhinolophus lepidus* | | + | | | + |
| 9. | *Rhinolophus luctus* | | | | | +* |
| 10. | *Rhinolophus macrotis* | | | | | +* |
| 11. | *Rhinolophus megaphyllus* | | | | | +* |
| 12. | *Rhinolophus pusillus* | | | | | +* |
| 13. | *Rhinolophus stheno* | + | | | | + |
| 14. | *Rhinolophus borneensis* | | | | | +* |
| | Hipposideridae | | | | | |
| 15. | *Aselliscus stoliczkanus* | | | | | +* |
| 16. | *Hipposideros bicolor* | + | + | | | + |
| 17. | *Hipposideros cervinus* | + | | | | |
| 18. | *Hipposideros cineraceus* | | + | | + | |
| 19. | *Hipposideros diadema* | +* | | | | |
| 20. | *Hipposideros galeritus* | +* | | | | |
| 21. | *Hipposideros larvatus* | | + | | | + |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Megadermatidae | | | | | |
| 22. | *Megaderma spasma* | + | + | + | + | + |
| | Nycteridae | | | | | |
| 23. | *Nycteris tragata* | | | | | +* |
| | Emballonuridae | | | | | |
| 24. | *Emballonura monticola* | | | | + | +* |
| 25. | *Taphozous melanopogon* | + | | | + | |
| | Vespertilionidae | | | | | |
| 26. | *Miniopterus medius* | +* | | | | |
| 27. | *Philetor brachypterus* | +* | | | | |
| 28. | *Myotis muricola* | +* | | | | |
| | Mollosidae | | | | | |
| 29. | *Cheiromeles torquatus* | | | | | +* |
| | No. of family | 6 | 4 | 2 | 4 | 7 |
| | No. of species | 15 | 9 | 3 | 8 | 19 |
| | No. of individuals | 242 | 35 | 84 | Na | Na |
| | Sampling effort | 462 | 80 | 80 | Na | Na |
| | Capture rate | 0.52 | 0.44 | 1.05 | Na | Na |
| | Diversity index (*H'*) | 1.47 | 1.95 | 0.59 | Na | Na |

[a]Roslan *et al.,* 2016, [b]Tambryn *et al.,* 2005, [c]MNS 1990, [d]Mohd-Yusof, [e] Lim *et al.,* 1999, [f]Csorba *et al.,* 1997, [g] Medway 1966, [h]DWNP 1995. *Unique for the respective island

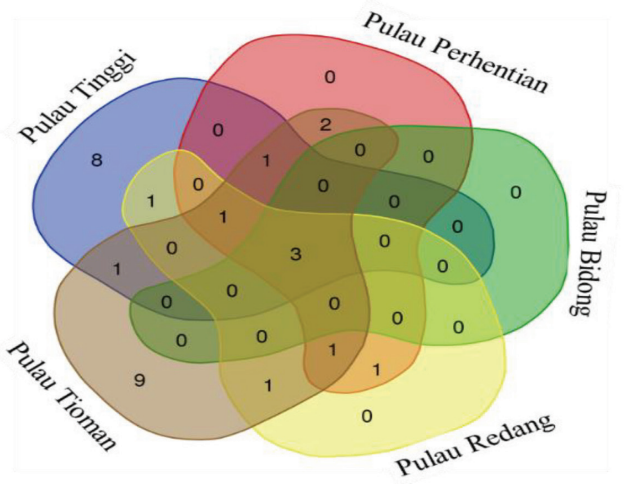


Figure 3: The Venn diagram illustrates the number of shared and unique bat species across east-coast islands

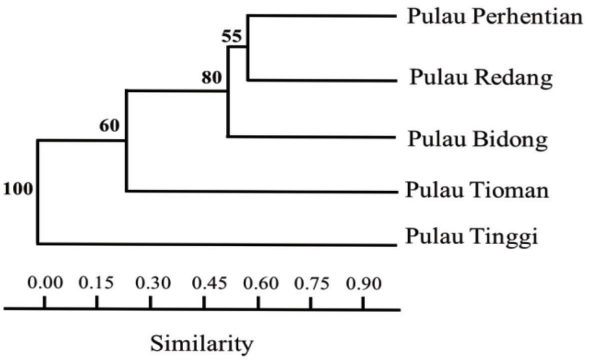


Figure 4: Phenogram of the comparison between Pulau Tinggi with other bats survey records in east-coast islands of Peninsular Malaysia

## Discussion

### *Species Richness and Abundance*

This study contributes 15 species, accounting for approximately 13.6% of the bats in Peninsular Malaysia (Lim *et al.*, 2017). A short-nosed fruit bat, *C. brachyotis* was frequently captured during the study period. Similarly, with high capture rates, this species is found on all east coast islands (e.g., Pulau Perhentian and Pulau Bidong) (Roslan *et al.*, 2016; Baqi *et al.*, 2021). This adaptable species inhabits a wide range of habitats on the mainland and islands (Mohd-Ridwan *et al.*, 2011; 2018). Trap traps may have contributed to the richness and abundance of frugivores bats species on Pulau Tinggi. Most species caught in the harp trap are insectivorous bats from the family Hipposideridae. *Hipposideros cervinus* is the most caught insectivorous species during this survey. In Borneo, this species moves in large groups resulting in high numbers of individuals caught in a single harp trap (Mohd-Ridwan *et al.,* 2018).

The year-round availability of fruits and the long fruiting season may be important factors in sustaining a frugivorous bat population in the tropics (Fleming, 1988). In Pulau Tinggi, our study site is surrounded by locally-owned fruit orchards and small-scale banana plantations (*Musa sapientum*). Among the crops grown by the villagers are durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*), guava (*Psidium quajava*), jackfruit (*Artocarpus heterophyllus*) and mango (*Mangifera indica*). Frugivore bats like *P. hypomelanus*, *C. brachyotis*, *E. spelaea*, *P. lucasi* and *M. mininus* are likely to affect forest regeneration and plant dispersal across the island. At night, large groups of *P. hypomelanus* visited durian flowers and fig trees. *Pteropus hypomelanus* is an important seed disperser and pollinator, particularly for durians (Aziz *et al.*, 2017).

### *Species Checklist*

Species composition of bats in Pulau Tinggi (15 species) seems to be comparatively lower than Pulau Tioman (19 species) but relatively higher to other east coast offshore islands of Peninsular Malaysia such as Pulau Perhentian (nine species), Pulau Redang (eight species) and Pulau Bidong (three species). Size of an island and its distance to the mainland influence the diversity of organisms (Valente *et al.,* 2020). The size of Pulau Tioman is ten times bigger (136 $km^2$, 32 km to the mainland) than Pulau Tinggi (14.85 $km^2$, 20 km to the mainland). Even though the species richness of bats at Pulau Tioman is higher than Pulau Tinggi, the rate of bats per area is considered lower (0.13 sp/$km^2$) than Pulau Tinggi (1.01 sp/$km^2$). Meanwhile, Pulau Perhentian (15.35$km^2$, 19 km to the mainland), Pulau Redang (19.09 $km^2$, 25km to the mainland) and Pulau Tinggi are considerably

similar in terms of size and their distance to the mainland. However, the richness and the rate of bats per area for Pulau Perhentian (0.5 sp/km$^2$) and Pulau Redang (0.4 sp/km$^2$) are less than Pulau Tinggi. The level of anthropogenic activity also affects the diversity of insular bats (Wiles & Brooke 2010). This is evident on well-known tourist islands such as Pulau Perhentian, Pulau Redang and Pulau Tioman, where many forested areas have been converted into chalet and resort buildings (Weng, 2009).

According to the IUCN (2022), 14 species of Pulau Tinggi were classified as Least Concern, with only one species classified as Near Threatened. However, some species are included in several conservation categories at the national level (DWNP, 2017). Four bat species are globally classified as Least Concern (IUCN, 2022) and at the national level, they are listed as Data Deficient and Near Threatened (DWNP, 2017). Bats are experiencing more serious threats nationally, and local conservation actions are urgently required. The main threat to the bat community on Pulau Tinggi is habitat loss due to deforestation. Some forest areas on Pulau Tinggi have been developed into settlements, chalets, and resorts. However, compared to other tourist islands, the rate of land use is still low because development is concentrated in coastal areas. Most of the forested areas on Pulau Tinggi are still intact and unaffected by human activity.

## Conclusion

This study successfully provided a checklist of bats in Pulau Tinggi. A total of 15 species from five families were successfully recorded during the seven-week study on the island. Given the short study period and the fact that it does not cover the entire island region, information on the bat community in Pulau Tinggi is still incomplete. Long-term monitoring of unexplored forest areas on Pulau Tinggi is required to determine the number of species, distribution and ecology of bats on the island. Furthermore, this information contributes to a better understanding of how bats react to changes in the island's landscape. The research findings can also be adapted to the tourism module and used for awareness programs and conservation activities in Pulau Tinggi.

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