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BUTTERFLIES AND MOTHS (ORDER: LEPIDOPTERA) IN PULAU TINGGI, JOHOR, MALAYSIA

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Abstract: Pulau Tinggi is a relatively unexploited island located in the middle arc of the Seribuat Archipelago in Johor, Malaysia. This study is the first to record species of moths and butterflies (Order: Lepidoptera) on the island. Specimens were collected between April and August 2019 through passive sampling methods such as light and baited traps. Active sampling was also done opportunistically using aerial nets. The results showed that Lepidopteran on the island has a high species richness and abundance. A total of 624 individuals from 121 species of Lepidoptera were identified. Out of that, 105 species were butterflies and 16 were moths. The Shannon-Weiner Index (H') value for both butterfly and moth was 4.29. Evenness, measured using Shannon Equitability Index (E_H) was valued at 0.89. Gauging the diversity of fauna in a relatively unexplored island such as Pulau Tinggi is important for properly managing its natural resources. In the near future, activities such as entomotourism may be done in the area to support the local economic ecosystem while ensuring the conservation of the island's biodiversity.

Keywords: Insects, species diversity, richness, abundance, entomotourism, South China Sea, Malaysia.

Introduction

Lepidoptera is among the largest insect orders, with more than 157,000 described species (Regier *et al.*, 2013). Within Peninsular Malaysia (including Singapore and Thailand), about 1,400 species of butterflies are known to occur (Kirton, 2018). The macromoths group possesses at least 5,000 species with common families such as *Limacodidae*, *Sphingidae*, *Saturniidae*, *Lymantriidae*, *Noctuidae and Geometridae* (Choi & Miller, 2013). These numbers show that Lepidoptera is an abundant taxon that can be found in many different ecosystems as herbivores, pollinators and prey (Bonebrake *et al*., 2010; Rivera-Vega *et al*., 2017; Wietzke *et al*., 2018). As phytophagous insects, their presence in an ecosystem is highly reliant on the presence of their host plant. Combined with their high reproductive rates, Lepidopterans are highly sensitive to environmental factors (Fischer & Kirste, 2018). These characteristics allow them to be good indicators for any changes in the environment and ecosystem health (Bonebrake *et al*., 2010; Syaripuddin *et al*., 2015; Ismail *et al*., 2020).

The tropical rainforest of Southeast Asia is a remarkable habitat for a wide array of flora and fauna. Even the islands located on the coast of Peninsular Malaysia are mostly covered with forested areas with important ecological roles. Forested islands offer habitat for several migratory, endemic and endangered species (Choong *et al*., 2017; Rosmidi *et al*., 2017; Mohd-Taib *et al*., 2019). Fortunately, Malaysia is now moving towards mainstreaming biodiversity and increasing conservation efforts in line with the National Policy on Biological Diversity (NPBD 2016-2025) (NRE, 2016). However, global trends show that tropical rainforests (including those on islands) are

threatened by the global economic expansion that is a direct consequence of population growth. The direct implication of deforestation and fragmentation can already be seen in insect species assemblages (Yong *et al.,* 2012; Jain *et al*., 2017). Given the urgency to understand the current state of biodiversity in Malaysia, particularly in the forested islands, inventory studies such as this are crucial. Previous studies on butterflies were done in Pulau Tioman (Quek *et al*., 1999), Pulau Sibu (Azmi & Haris-Hussain, 2019), Pulau Pemanggil, Pulau Tulai and Pulau Sribuat-Sembilang (Liow, 1998), Pulau Perhentian and Pulau Bidong (Rosmidi *et al*., 2017). However, it is important to note that most of these studies only focused on butterfly diversity and abundance.

In the current study, butterflies and moths of Pulau Tinggi were surveyed to document the species composition and obtain the first records of Lepidoptera for this locality. Hopefully, this will help conservation managers, local stakeholders and policymakers make informed decisions regarding the island's natural resources in the future.

Materials and Methods

Study Area

The Seribuat Archipelago is a cluster of 62 islands located on the southeast coast of Peninsular Malaysia. Our island of interest, namely Pulau Tinggi (02° 17′ 06.1″ N, 104° 06′ 55.9″ E) is in the middle arc of the Seribuat Archipelago. For comparison, Pulau Sibu is in the inner arc (Figure 1).

Large areas of the island consist of primary dipterocarp forest, riparian vegetation and mangroves. The relatively undisturbed forest in the inner part of the island allows for a diverse canopy, a favourable habitat for specialist Lepidopteran species (Ismail *et al*., 2018; Lourido *et al*., 2018). In this research, butterflies and moths of Pulau Tinggi were sampled from Kampung Tanjung Balang and Gunung Semudu from April 2019 to August 2019 for ten

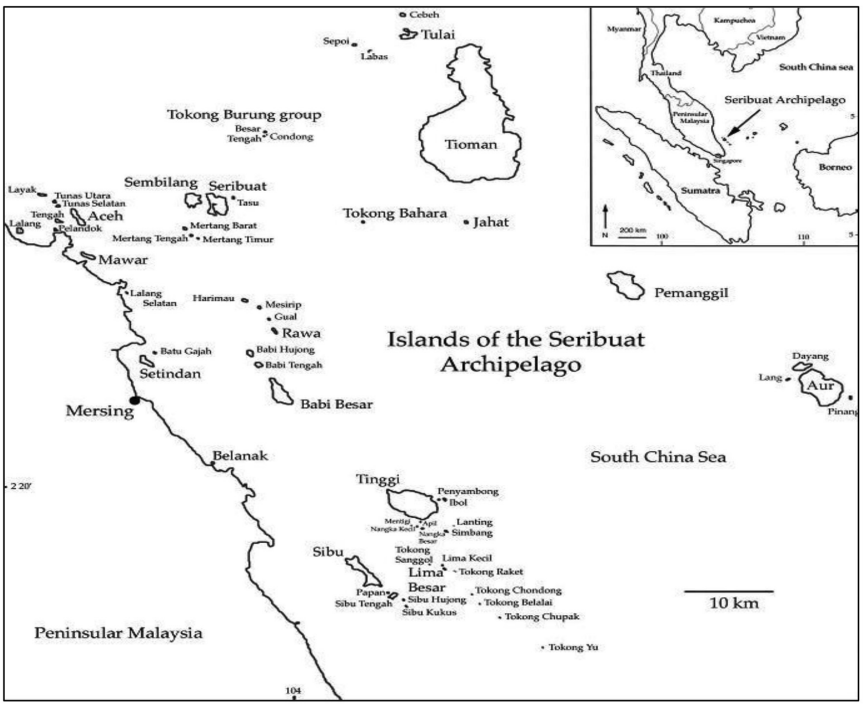

Figure 1: Islands of Seribuat Archipelago in the South China Sea. Pulau Tinggi is located in the middle of the Archipelago

consecutive days each month. The coordinates and habitat types for each sampling trail are specified in Table 1 and Figure 2. The study sites included primary forests, secondary forests and mangrove forests.

Data Sampling

Butterflies and daytime moths were collected through 20 sampling stations along Trails 1, 2 and 3. Each station was fitted with one bait trap adapted and modified from Daily and Ehrlich (1995). The traps were positioned 1.5 m above ground level. A mixture of rotten banana and pineapple was used as bait. While baited traps are effective for frugivorous butterflies such as *Lexias* sp. and *Zeuxidia* sp., this sampling technique will introduce bias against non-nymphalids if not supplemented with manual collection using an aerial net. Each sampling station has a radius of 50 m. Within this radius, active sampling was done by at least two persons daily from 7.00 am to 6.00 pm.

Nocturnal moths were collected using light traps (Nur Atiqah *et al*., 2017). Four sets of light traps were installed throughout the different habitat types as described in Table 1. A 2 x 2 m white fabric attached to a rope was hung vertically and lighted up by a 160-watt mercury bulb. Lepidopterans flutter to the light were collected using a killing jar filled with a tissue soaked with ethyl acetate. Specimens were collected on two occasions at 8.00 pm and 11.00 pm for every sampling day.

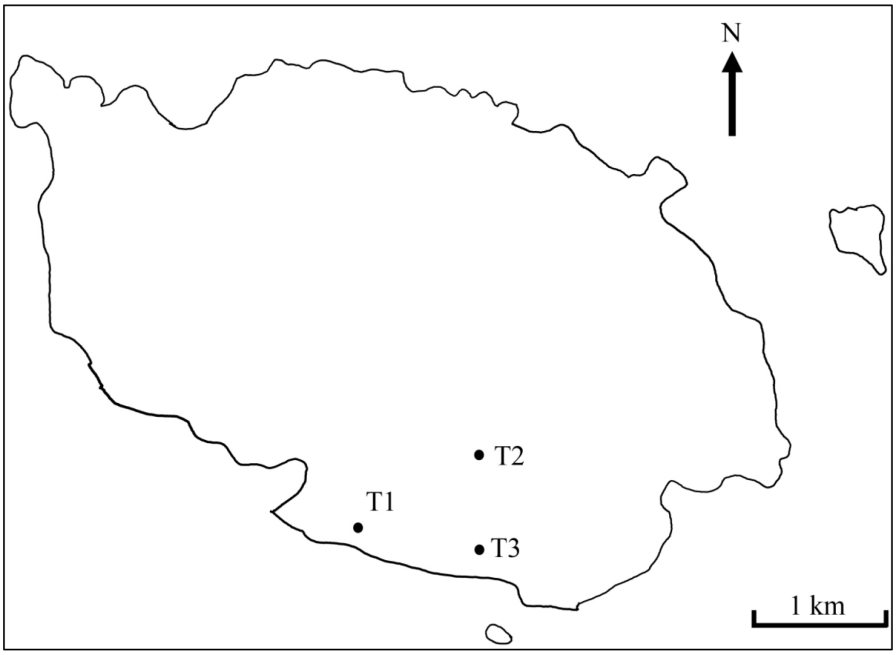

Figure 2: Map of Pulau Tinggi pinpointing sampling Trail 1 (T1), Trail 2 (T2) and Trail 3 (T3)

Table 1: Habitat type and coordinate of sampling trail used in this study

Trail	Habitat Type	Coordinates
T1	Secondary Forest	(02° 17′ 06.1″ N, 104° 06′ 55.9″ E, 4 m)
T2	Primary Forest	(02° 17′ 27.6″ N, 104° 07′ 19.9″ E, 80 m)
T3	Shrub	(02° 17′ 24.5″ N, 104° 07′ 16.3″ E, 53 m)
	Mangrove	(02° 17′ 05.4″ N, 104° 07′ 18.9″ E, 6 m)

All sampled Lepidopterans were temporarily kept in a triangle envelope. The date, time, coordinate, live colouration and other ecological notes were recorded. Specimens were identified in the field whenever possible. All specimens collected were brought to the laboratory, curated and dried in the oven for one week at a temperature between 45°C to 50°C. Corbet and Pendlebury (1992) identified all butterfly specimens using keys. Meanwhile, moth specimens were identified using Holloway (1986, 1993, 1996, 1998).

Data Analysis

For this study, we used biodiversity indices such as species abundance (the whole number of individuals recorded at each site), species richness (total number of species recorded), species diversity (calculated through Shannon-Weiner Index H') and evenness (expressed by Shannon Equitability Index E_H) (Magurran, 2004). The number of species and total abundance were chosen for easy interpretation. Meanwhile, the Shannon-Weiner index was chosen for its insensitivity to rare species and sample sizes (Magurran, 2004). All indices were calculated using Paleontological Statistics Software Package (PAST) (Hammer *et al*., 2001).

Results and Discussion

This study reported a total of 121 species of Lepidoptera with 624 individuals. There were 105 species of butterflies which include the family *Hesperiidae*, *Lycaenidae*, *Nymphalidae*, *Papilionidae*, *Pieridae* and *Riodinidae* (Figure 3). On top of that, 16 moth species were recorded from family Cossidae, Erebidae, Geometridae, Noctuidae and Sphingidae (Figure 4).

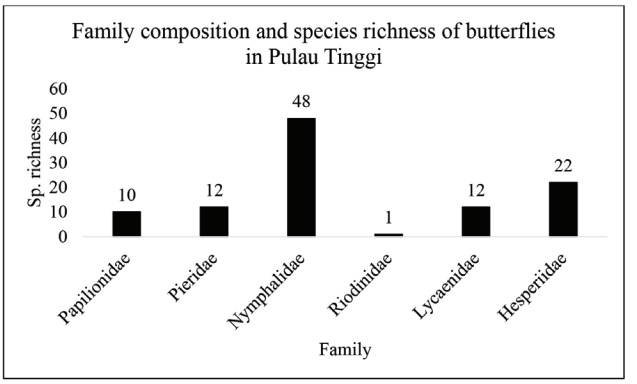

Figure 3: Butterfly family composition and species richness in Pulau Tinggi

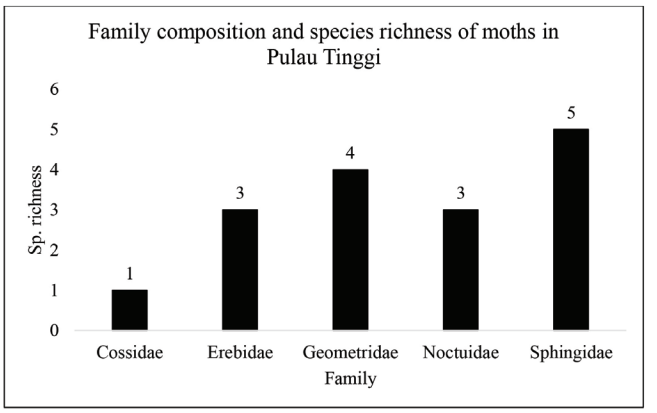

Figure 4: Moth family composition and species richness in Pulau Tinggi

Most of the butterfly species were collected through active sampling using aerial nets. Meanwhile, the majority of the moths were collected from the light traps. The family Nymphalidae is the most abundant species for butterflies with Tanaecia pelea (35 individuals) followed by *Elymnias hypermnestra* (22 individuals). The full list of butterfly species collected is included in Table 2. For moths, the most abundant species is *Darapsa myron* with 15 individuals. The second most abundant moth species recorded was *Asota subsimilis* from the family Cossidae (Table 3).

Table 2: List of butterfly species recorded in Pulau Tinggi

No.	Taxa	No. of Individuals
	(LEPIDOPTERA: RHOPALOCERA)	
	FAMILY: PAPILIONIDAE	
	Subfamily: Papilioninae	
1	*Papilio clytia*	20
2	*Graphium agamemnon*	2
3	*Graphium sarpedon*	4
4	*Pachliopta aristolochiae*	6
5	*Papilio iswara*	1
6	*Papilio memnon*	3
7	*Papilio polytes*	1
8	*Papilio* sp.	1
9	*Trogonoptera brookiana*	1
10	*Troides helena*	5
	FAMILY: PIERIDAE	
	Subfamily: Colianidae	
11	*Catopsilia pyranthe*	12
12	*Catopsilia* sp.	32
13	*Eurema blanda*	4
14	*Eurema brigitta*	6
15	*Eurema hecabe*	4
16	*Eurema sari*	2
17	*Gandaca harina*	6
	Subfamily: Pierinae	
18	*Appias libythea*	6
19	*Cepora iudith*	5
20	*Delias hyparete*	3
21	*Leptosia nina*	18
22	*Saletara panda*	12

	FAMILY: NYMPHALIDAE	
	Subfamily: Apaturinae	
23	*Euripus nyctelius*	1
	Subfamily: Charaxinae	
24	*Polyura hebe*	6
	Subfamily: Danainae	
25	*Danaus melanippus*	9
26	*Ideopsis gaura*	1
27	*Ideopsis similis*	5
28	*Parantica aglea*	2
29	*Parantica agleoides*	4
30	*Parantica aspasia*	1
31	*Parantica melaneus*	1
	Subfamily: Heliconiinae	
32	*Acraea terpsicore*	4
33	*Cirrochroa emalea*	3
34	*Corrochroa orissa*	1
35	*Cirrochroa tyche*	8
36	*Phalanta phalantha*	3
37	*Phalanta alcippe*	2
38	*Vidula dejone*	1
	Subfamily: Limenitidinae	
39	*Athyma* sp.	5
40	*Euthalia aconthea*	1
41	*Lexias dirtea*	2
42	*Neptis hylas*	8
43	*Tanaecia iapis*	16
44	*Tanaecia pelea*	35
	Subfamily: Morphinae	
45	*Amathusia phidippus*	10
46	*Zeuxidia aurelius*	1
47	*Zeuxidia amethystus*	1
48	*Faunis canens*	4

	Subfamily: Nymphalinae	
49	*Doleschallia bisaltide*	2
50	*Hypolimnas anomala*	1
51	*Junonia orithya*	6
52	*Junonia hedonia*	1
53	*Junonia iphita*	1
54	*Junonia almana*	1
	Subfamily: Satyrinae	
55	*Elymnias hypermnestra*	22
56	*Elymnias nesaea*	17
57	*Elymnias panthera*	4
58	*Elymnias penanga*	5
59	*Lethe europa*	1
60	*Melanitis leda*	5
61	*Orsotriaena medus*	20
62	*Mycalesis fusca*	6
63	*Mycalesis orseis*	15
64	*Mycalesis horsfieldii*	3
65	*Mycalesis mineus*	15
66	*Mycalesis perseoides*	10
67	*Mycalesis anapita*	2
68	*Mycalesis visala*	1
69	*Orsotriaena medus*	2
70	*Ypthima baldus*	13
	FAMILY: RIODINIDAE	
	Subfamily: Nemeobiinae	
71	*Zemeros* sp.	2
	FAMILY: LYCAENIDAE	
	Subfamily: Miletinae	
72	*Spalgis epius*	1
	Subfamily: Polyommatinae	
73	*Anthene emolus*	1
74	*Chilades pandava*	1
75	*Zizina otis*	1

	Subfamily: Lycaeninae	
76	*Flos anniella*	1
77	*Jamides alecto*	1
78	*Jamides ferrari*	1
79	*Nacaduba angusta*	1
80	*Eooxylides tharis*	1
81	*Nacaduba sanaya*	1
82	*Remelana jangala*	1
	Subfamily: Theclinae	
83	*Arhopala athada*	2
	FAMILY: HESPERIIDAE	
	Subfamily: Coeliadinae	
84	*Burara etelka*	2
	Subfamily: Pyrginae	
85	*Celaenorrhinus ladana*	2
86	*Odina hieroglyphica*	4
87	*Tagiades japetus*	4
88	*Tagiades gana*	2
	Subfamily: Hesperiinae	
89	*Cephrenes trichopepla*	2
90	*Eetion elia*	1
91	*Erionota sybirita*	8
92	*Iambrix salsala*	1
93	*Iambrix stellifer*	1
94	*Notocrypta curvifascia*	1
95	*Notocrypta feisthamelii*	8
96	*Notocrypta paralysos*	1
97	*Oriens gola*	1
98	*Pelopidas* sp.	1
99	*Pithauria marsena*	10
100	*Potanthus ganda*	1
101	*Potanthus omaha*	1
102	*Potanthus serina*	10
103	*Psolos fuligo*	8

104	*Suastus gremius*	8
105	*Taractrocera ardonia*	8

Table 3: List of moth species recorded in Pulau Tinggi

No.	Taxa	No. of Individuals
	(LEPIDOPTERA: HETEROCERA)	
	FAMILY: COSSIDAE	
	Subfamily: Zeuzerinae	
1	*Xyleutes strix*	10
	FAMILY: EREBIDAE	
	Subfamily: Aganainae	
2	*Asota subsimilis*	12
3	*Asota isthmia*	1
	Subfamily: Arctiinae	
4	*Cyana* sp.	3
	FAMILY: GEOMETRIDAE	
	Subfamily: Ennominae	
5	*Plutodes flavescens*	6
	Subfamily: Geometrinae	
6	*Comostola pyrrhogona*	1
7	*Dysphania* sp.	1
8	*Spaniocentra* sp.	8
	FAMILY: NOCTUIDAE	
	Subfamily: Aventiinae	
9	*Metaemene atrigutta*	3
	Subfamily: Calpinae	
10	*Eudocima discrepans*	3
11	*Ommatophora* sp.	3
	FAMILY: SPHINGIDAE	
	Subfamily: Ceratocampina	
12	*Eacles imperialis*	6

	Subfamily: Macroglossinae	
13	*Deilephila elpenor*	3
14	*Darapsa myron*	15
15	*Thereta clotho*	5
	Subfamily: Smerinthinae	
16	*Smerinthus ocellata*	2

Overall, in Pulau Tinggi, butterflies are found in abundance compared to moths. There may be a difference in sampling effort between daytime and nighttime sampling. On a regular sampling day, a massive amount of sampling time was spent using a sweep net to conduct active sampling during the day rather than at night. Nighttime sampling only focused on light trapping.

The high species richness from the family *Nymphalidae* might be due to the use of baited traps as one of the sampling methods. Baited traps are known to exclusively attract fruit-feeding butterflies such as nymphalids (Awg Abdul Rahman *et al*., 2018; Mohamed *et al*., 2019). For comparison, a study done in Pulau Bidong and Pulau Perhentian Besar in Terengganu gathered 26 species of butterflies from 117 individuals, with 19 species recorded in Pulau Perhentian Besar and 10 species recorded in Pulau Bidong (Rosmidi *et al*., 2017). Both studies recorded Nymphalidae as the family with the highest species richness. The difference in species richness of butterflies in both studies is pretty remarkable (105 butterfly species in Pulau Tinggi, 26 butterfly species in Pulau Bidong and Pulau Perhentian Besar combined), proving that Pulau Tinggi holds a comparatively high number of butterfly species.

Additionally, the flowering season was happening during the sampling period, resulting in a surge of Lepidoptera species diversity. A similar finding was discovered in a study on butterfly diversity in Endau Rompin National Park where flowering season gathers many butterfly species (Norradihah *et al*., 2018). Rajah Brooke Birdwing (*Trogonoptera brookiana*) and the Black-Tipped Archduke (*Lexias dirtea*) were observed at the waterfall area of Gunung Semudu. This is expected as *T. brookiana* are known to exhibit puddling behaviour (Phon *et al*., 2017). It is also important to note that *T. brookiana* are known widely as an iconic species in Malaysia. *Lexias dirtea* on the other hand, is known to be attracted to rotting and fallen fruit that can be found surrounding the area (Benjamin *et al*., 2021). Cherry trees surround the resort area and the secondary forest is covered with *Melastoma* species. The flourishing vegetation in this unexploited area supports a diverse insect fauna, including Lepidoptera.

Diversity Indices

The Shannon-Weiner Index (H') value for this particular sample (including butterflies and moths) is 4.29. For evenness, Shannon Equitability Index (E_H) observed a value of 0.8956. For comparison, a similar inventory study on Lepidoptera in R.E.A.C.H BioD Centre in Cameron Highland recorded 48 moth species and 11 butterfly species, with H' values of 3.22 for moth and 2.15 for butterflies (Zamari Aris *et al*., 2017). Based on these findings, Pulau Tinggi has a relatively diverse butterfly and moth assemblage.

When compared with a study done in Pulau Sibu (Azmi & Haris-Hussain, 2019) (Table 4), Pulau Tinggi only shared two similar Lepidoptera species which are Swallowtail butterfly (*Papilio polytes*) and Great Mormon (*Papilio memnon*). This shows that there is so much more to explore in the archipelago in terms of lepidopteran diversity. Looking at further comparison between Pulau Tinggi and Johor mainland,

we discovered 10 shared species between Pulau Tinggi and Gunung Ledang (Ismail *et al*., 2018) which are *Hypolimnas* sp.*, Euploea* sp.*, Amathuxidia amythaon, Gangara thyrsis, Tagiades litigiosus, Jamides ferrari, Mycalesis maianeas, Ypthima pandocus, Cirrochroa malaya* and *Eurema hecabe*. On the other hand, there were six shared species between Pulau Tinggi and Tanjung Piai (Maryati *et al*., 2019): *Amathusia ochraceofusca, Hypolimnas* sp.*, Polyura athamas, Delias hyparete, Parantica agleoides* and *Euploea* sp.

Entomotourism is an effective tool to increase public awareness of insects and nature. The bright colour and attractive morphology of butterflies have a high chance of sighting (Norradihah *et al*., 2018). Several butterfly farms around the country, including Kuala Lumpur, Penang, Sabah and the Cameron Highlands. With proper planning from various stakeholders, Pulau Tinggi may just be the next tourist attraction for entomotourism. The high species richness and abundance of butterflies can be transformed into a potential tourism product in Pulau Tinggi (Norradihah *et al*., 2018; Saikim *et al*., 2020). In turn, this will help increase tourists' awareness of the contribution of wildlife in maintaining the food web and providing ecosystem services (Le *et al*., 2021).

Conclusion

This study has shown that Pulau Tinggi is rich in butterfly and moth species. This was proven through the Shannon-Weiner Index (H) value of 4.29. For evenness, Shannon Equitability Index observed a value of 0.8956. While this may be the first record of butterflies and moths on the island, consistent monitoring and future study is necessary to monitor the health of the island's ecosystem. Future work may involve studying the lepidopteran diversity on the remaining islands of the Seribuat Archipelago. More new species are expected to be found here in Pulau Tinggi and the other islands with further research.

Table 4: Sharing species between Pulau Tinggi, Gunung Ledang (Ismail *et al*., 2018), Tanjung Piai (Maryati *et al*., 2019) and Pulau Sibu (Azmi & Haris-Hussain, 2019)

Pulau Tinggi	Gunung Ledang	Tanjung Piai	Pulau Sibu
Amathusia ochraceofusca		/	
Hypolimnas sp.	/	/	
Polyura athamas		/	
Delias hyparete		/	
Parantica agleoides		/	
Euploea sp.	/	/	
Amathuxidia amythaon	/		
Gangara thyrsis	/		
Tagiades litigiosus	/		
Jamides ferrari	/		
Mycalesis maianeas	/		
Ypthima pandocus	/		
Cirrochroa malaya	/		
Eurema hecabe	/		
Papilio memnon			/
Papilio polytes			/

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