Diversity of butterflies in the tropical wetland of Kayan-Sembakung Delta, North Kalimantan, Indonesia

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Diversity of butterflies in the tropical wetland of Kayan-Sembakung Delta, North Kalimantan, Indonesia

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Abstract. *Harmonis, Rahim A, Hidayat HA, Saud OR, Wilujeng M, Sampe R, Kartika KF, Aminudin, Butar TB. 2022. Diversity of butterflies in the tropical wetland of Kayan-Sembakung Delta, North Kalimantan, Indonesia. Biodiversitas 23: 3303-3312.* Butterflies, which belong to the order Lepidoptera, are considered superior biological indicators to evaluate environmental conditions in various types of habitats due to their high richness in biodiversity, short generation time, good movement, and high sensitivity. Since butterflies produce various benefits for the ecosystem, their conservation currently receives significant attention in order to improve human well-being. However, there is still limited research about butterfly diversity in tropical wetlands, especially in Borneo (Kalimantan) Island. Herein, we identify the diversity of butterflies found in the Kayan-Sembakung Delta, North Kalimantan, which is still unexplored so far. The area was dominated by mangroves, peat swamps, and brackish swamps. The research locations inside the Kayan-Sembakung Delta were divided into 20 groups. The specimen was collected by an aerial insect net and bait traps. The diversity index, taxonomy structure, and domination index were further investigated. The results showed that the highest individuals (69) and species (36) had been found in Pembeliangan. Altogether, we found 608 individuals of 92 species in the areas studied. Among others, the family of Nymphalidae was noted as the most dominant. We stated that the diversity of butterflies was also influenced by the type of habitat, as it could be found at the peat swamp forest where the highest species were found. In the meantime, some unique species have been found in the Kayan-Sembakung Delta, including *Arhopala overdijkinki*, *Hypolycaena thecloides*, *Drupadia johorensis*, *Idea iaconoe*, and *Polyura jalysus*. The results of this study are expected to give more information for future management and conservation of the wetland areas, especially in the Kayan-Sembakung Delta.

Keywords: Butterfly diversity, conservation, Lepidoptera, unique species, wetland

INTRODUCTION

Insects are known as the most diverse group of animals in the world, especially in the terrestrial ecosystem (Łukasik et al. 2017). The total species among insects is predicted to reach 5.5 million species. However, only 1 million species have been successfully identified so far (Stork 2018). According to a previous assessment reported by Mora et al. (2011), the accumulation of biodiversity on the earth exceeds 8.7 million species. Therefore, there is evidence that insects could be one of the most important taxa since they cover more than 60% of global biodiversity. Insects reportedly possess essential interactions with other organisms, especially due to their activities in pollination, in which they are responsible for more than 85% of the flowering plants for achieving their successful reproduction (Divija et al. 2022). With abundant diversity in nature and a short generation time, some insects are sensitive to changes in environmental conditions (Forister et al. 2019). Thus, utilizing insects as bioindicators by observing their composition, adaptation, and species richness could be a great tool to evaluate the degradation of certain ecosystems. Furthermore, this will provide important information for monitoring, managing, and conserving such areas.

Among insects, butterflies are considered the most studied invertebrates for bioindicator agents because of their high richness in diversity, short generation time, good movement, and high sensitivity to environmental disruption (Kwon et al. 2014). In correlation with diversity sampling measurement, their presence is believed to represent all insects (arthropods) in the area studied (Grant et al. 2020). Butterflies are classified in the order Lepidoptera, which is noted to be the second-largest class of insects with a number of 150,000 species up to now (Bibi et al. 2021). They are diurnal fauna, having aesthetic colors and also stunning shapes. Butterflies are considered the second-best pollinators after bees (Thangjam et al. 2018; Koneri et al. 2022). Based on the conservation status, butterflies are also suitable to be umbrella species among arthropods (Pérez-Espona 2021). Since they provide ecosystem services, their conservation nowadays attracts significant attention to improve human well-being (Mukherjee et al. 2015). There has been reported earlier that butterflies are able to be distributed in various habitats, such as forests, gardens, grassland, and metropolitan areas (Basri and Zakaria 2021).

Around 90% of butterfly species live in tropical regions (Suwarno et al. 2018). In Indonesia, it has been estimated that approximately 2500 species are found here, while around 35% of them are endemic (Murwitaningsih and Dharma 2014). Particularly on Borneo Island (Kalimantan), almost 1000 species have been found (Seki et al. 1991).

Kayan-Sembakung Delta is located in North Kalimantan Province, Indonesia. This area is generally dominated by some wetland ecosystems, including mangroves, peat swamps, and brackish swamps. Currently, literature about the identification of butterfly diversities in tropical wetlands is quite limited. The Kayan-Sembakung Delta is still unexplored. Herein, we examined the diversity of butterflies in those areas. The characteristics of each species and its community in correlation with habitat types were also evaluated. Based on our best knowledge, this study will be the first record of the butterfly diversity found in the Kayan-Sembakung Delta. The main results obtained from this study are expected to provide detailed information for better management and butterfly conservation in wetland areas.

MATERIALS AND METHODS

Research sites

Field data were collected from 20 different research sites, representing all wetland areas associated with the Kayan-Sembakung Delta. The sites are chosen differently within 3 districts (Bulungan, Tana Tidung, and Nunukan) and 6 watersheds (Kayan, Sekatak, Sesayap, Sembakung, Sebuku, and Pulau Mandul) in the range of 2°59'08.6"-
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representing all wetland areas associated with the Kayan-Sembakung Delta. The sites are chosen differently within 3 districts (Bulungan, Tana Tidung, and Nunukan) and 6 watersheds (Kayan, Sekatak, Sesayap, Sembakung, Sebuku, and Pulau Mandul) in the range of 2°59'08.6"-4°02'45.8" N and 117°01'58.8"-117°44'00.4" E (Figure 1). The elevation ranges from 3 m to 56 m. Detailed information about each code (R1-R20) of the research location combined with its geographical and ecological characteristics is available in Table 1. This study was completely done within 3 months.

Sampling procedure

The sampling activities were conducted from January to February 2020. An aerial insect net and bait traps were utilized to obtain butterfly specimens. Each arbitrary net was placed with a radius up to 500 m. The netting was started from 8 a.m. to 4 p.m., following the active time of butterfly activities (Matsumoto et al. 2015). The required time for the sampling at each site was around 6 hours. The bait traps were placed 5-10 m above the ground, and a total of 10 traps were used during the trapping. The traps were checked at least twice during the day. To attract the butterflies, the fermented pineapple was applied as bait. Considering the conservation purposes, only one specimen per species was collected, while others were released again after being labelled. Specimens were then deposited at the Forest Protection Laboratory, Faculty of Forestry, Mulawarman University in Samarinda, East Kalimantan, Indonesia for further preservation. The laboratory activities included various processes, such as relaxation, fixation, and drying. The identification process followed guidelines and benchmarking images, according to Harmonis (2013).

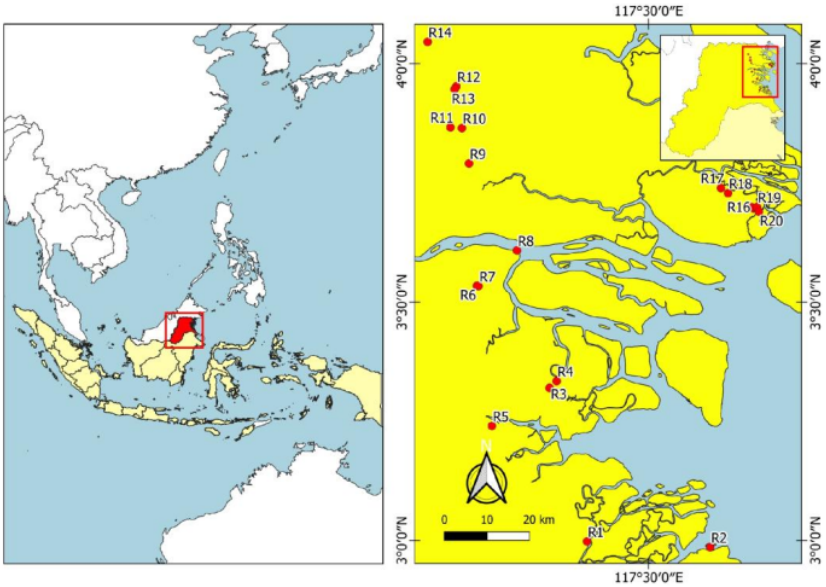

Figure 1. Research location conducted at Kayan-Sembakung Delta, North Kalimantan Province, Indonesia (2°59'08.6"-4°02'45.8" N and 117°01'58.8"-117°44'00.4" E)

Table 1. Geographical and ecological characteristics of each research site

Site code	Watershed area	Latitude	Longitude	Altitude (m asl.)	Habitat type
R1	Kayan	2°59'52.1" N	117°22'12.5" E	10	Brackish swamp
R2	Kayan	2°59'08.6" N	117°37'49.3" E	9	Mangrove
R3	Sekatak	3°19'11.6" N	117°17'26.6" E	19	Mangrove
R4	Sekatak	3°20'03.1" N	117°18'20.4" E	5	Mangrove
R5	Sekatak	3°14'24.8" N	117°10'08.7" E	12	Mangrove
R6	Sesayap	3°32'03.3" N	117°08'13.9" E	18	Peat swamp
R7	Sesayap	3°32'00.7" N	117°08'26.2" E	18	Peat swamp
R8	Sesayap	3°36'30.1" N	117°13'19.2" E	7	Brackish swamp
R9	Sembakung	3°47'27.2" N	117°07'13.9" E	56	Peat swamp
R10	Sembakung	3°51'54.4" N	117°06'19.9" E	15	Peat swamp
R11	Sembakung	3°52'00.0" N	117°04'53.0" E	26	Peat swamp
R12	Sebuku	3°57'09.7" N	117°05'36.6" E	13	Brackish swamp
R13	Sebuku	3°56'48.9" N	117°05'24.8" E	5	Peat swamp
R14	Sebuku	4°02'45.8" N	117°01'58.8" E	23	Peat swamp
R15	Pulau Mandul	3°41'47.8" N	117°43'19.6" E	15	Peat swamp
R16	Pulau Mandul	3°41'57.4" N	117°43'05.3" E	15	Peat swamp
R17	Pulau Mandul	3°44'21.3" N	117°39'10.9" E	3	Mangrove
R18	Pulau Mandul	3°43'43.3" N	117°40'05.1" E	13	Peat swamp
R19	Pulau Mandul	3°41'58.4" N	117°43'45.0" E	7	Mangrove
R20	Pulau Mandul	3°41'23.3" N	117°44'00.4" E	4	Mangrove

Data analysis

The subject of data analysis was to determine the species diversity, taxonomy structure, and identification of the main species in each type of habitat studied. The diversity of species was calculated using Fisher's Alpha index and Shannon-Wiener index as follows (Magurran 2004):

$$\alpha = \frac{N\,(1-x)}{x}$$

Where, α was the Fisher's Alpha index, S was the total species, and N was the total individuals.

$$H' = -\sum_{i=1}^{n} Pi\ In\ Pi$$

Where, H' was the Shannon-Wiener index, Pi = ni / N, ni was the individual species-i, and N was the total individuals. Values H': 0-1 was classified in the low category, H': 1-3 was medium category, and H'≥3 was high categories in diversity.

Besides species diversity, we also calculated the Simpson evenness index. This index is a measurement of equilibrium values based on the quantity of species in certain community. It was calculated using a mathematical equation as follows:

$$E - \frac{1}{D}$$

$$D = \frac{1}{\Sigma\left(\frac{ni}{N}\right)^2}$$

Where, E was the evenness index; D was the Simpson diversity index; ni was the individual species-i; and N was the total individuals.

The richness of the butterfly species was further estimated by some estimators, namely Chao 1, Chao 2, Jack-Knife 1, and Jack-Knife 2, using BioDiversity Pro® Software. The calculated value was obtained according to the total absolute species found at each research site. The taxonomic structure was determined based on the location of the species level, from genus to family. The analysis focused on the species composition and its family exhibiting the community. The main species types were then obtained by calculating the dominant individual numbers. The calculation of species dominance followed an Equation proposed by Mühlenberg (1989):

$$Di = \frac{ni}{N}\ x\ 100$$

Where, Di was the dominance; ni was the individual species-i; and N was the total individuals. The percentage of dominance, which ranges from 3.2 to 100%, was recognized as the main species, whereas the dominance of less than 3.2% was characterized as the follow-up species (Engelmann 1978).

RESULTS AND DISCUSSION

The diversity of butterfly species

A total of 608 individual butterflies were found during sampling activities at 20 research sites. A total of 92 species were also identified. In general, butterflies were only classified into six families: Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, and Riodinidae. Since all families had been found in the sites, there was evidence that the presence of those species could represent all locations in the Kayan-Sembakung Delta. Furthermore, we summarized the individual species found in the area studied, as appears in Table 2.

Table 2. List of species with total individuals found in research sites

Species	Family	Total individuals	Research sites
Abisara geza	Riodinidae	1	R14
Allotinus horsfieldi	Lycaenidae	1	R7
Allotinus unicolor	Lycaenidae	1	R14
Amathusia phidippus	Nymphalidae	2	R17 and R18
Anthene lycaenina	Lycaenidae	11	R2, R4 and R5
Appias libythea	Pieridae	1	R10
Appias paulina	Pieridae	1	R2
Arhopala agrata	Lycaenidae	1	R11
Arhopala atosia	Lycaenidae	4	R9
Arhopala avatha	Lycaenidae	1	R11
Arhopala overdijkinki	Lycaenidae	4	R1
Arhopala pseudocentaurus	Lycaenidae	22	R2, R4, R5, R9, R18 and R20
Athyma asura	Nymphalidae	1	R5
Athyma larymna	Nymphalidae	3	R14 and R18
Charaxes bernardus	Nymphalidae	9	R1, R3, R7, R8 and R19
Cigaritis kutu	Lycaenidae	1	R18
Cigaritis syama	Lycaenidae	2	R8
Cirrochroa emalea	Nymphalidae	7	R8, R9, R10, R11 and R14
Coelites epiminthia	Nymphalidae	4	R14
Coelites euptychioides	Nymphalidae	3	R12 and R14
Cupha erymanthis	Nymphalidae	17	R12, R14, R15, R16, R17 and R18
Danaus melanippus	Nymphalidae	31	R1, R2, R4, R5, R8, R15, R16, R18, R19 and R20
Dophla evelina	Nymphalidae	8	R1, R6, R7, R9, R14 and R18
Drupadia johorensis	Lycaenidae	1	R9
Drupadia theda	Lycaenidae	16	R7, R9, R14, R15, R16 and R18
Elymnias nesaea	Nymphalidae	1	R1
Elymnias panthera	Nymphalidae	7	R6, R7, R9 and R14
Euploea crameri	Nymphalidae	16	R7, R15, R16 and R18
Euploea eyndhovii	Nymphalidae	1	R8
Euploea mulciber	Nymphalidae	8	R1, R4, R5, R6 and R7
Eurema andersoni	Pieridae	4	R5 and R14
Eurema blanda	Pieridae	15	R2, R3, R4, R17 and R20
Eurema hecabe	Pieridae	1	R7
Eurema nicevillei	Pieridae	6	R12 and R14
Eurema sari	Pieridae	6	R5, R6, R12 and R18
Euthalia merta	Nymphalidae	1	R7
Faunis kirata	Nymphalidae	21	R6, R7, R9, R11, R14, R16 and R18
Faunis stomphax	Nymphalidae	1	R14
Graphium agamemnon	Papilionidae	13	R1, R4, R6, R7, R9, R12, R14 and R18
Graphium sarpedon	Papilionidae	8	R7, R9, R11, R14 and R18
Hasora badra	Hesperiidae	1	R14
Hasora vitta	Hesperiidae	2	R14
Hyarotis iadera	Hesperiidae	1	R18
Hypolimnas bolina	Nymphalidae	11	R8, R10, R11, R14, R17 and R18
Hypolycaena erylus	Lycaenidae	40	R1, R2, R4, R9, R16, R18 and R20
Hypolycaena thecloides	Lycaenidae	1	R18
Idea leuconoe	Nymphalidae	12	R1, R3, R12, R15, R16 and R18
Jamides aratus	Lycaenidae	8	R10, R12, R13 and R14
Jamides philatus	Lycaenidae	7	R5, R12 and R14
Jamides zebra	Lycaenidae	3	R12
Logania distanti	Lycaenidae	1	R14
Lexias dirtea	Nymphalidae	20	R9, R11 and R12
Lexias pardalis	Nymphalidae	5	R14 and R18
Miletus gopara	Lycaenidae	1	R14
Moduza procris	Nymphalidae	2	R7 and R11
Mycalesis fuscum	Nymphalidae	4	R11 and R18
Mycalesis mineus	Nymphalidae	2	R11
Nacaduba russelli	Lycaenidae	5	R6, R7, R9, R10 and R18
Nacaduba sanaya	Lycaenidae	7	R6, R7, R11 and R14
Nacaduba solta	Lycaenidae	14	R1, R2, R4 and R20
Neptis duryodhana	Nymphalidae	2	R8 and R14
Neptis harita	Nymphalidae	5	R7, R14 and R18
Neptis hylas	Nymphalidae	7	R1, R11 and R16

Neptis leucoporos	Nymphalidae	1	R15
Orsotriaena medus	Nymphalidae	1	R10
Pandita sinope	Nymphalidae	18	R1, R6, R7, R11, R12, R16, R18 and R19
Pantoporia dindinga	Nymphalidae	2	R7
Pantoporia paraka	Nymphalidae	8	R3, R8, R9, R11, R14, R17 and R19
Papilio demoleus	Papilionidae	2	R5
Papilio memnon	Papilionidae	1	R14
Papilio paradoxa	Papilionidae	1	R9
Parantica agleoides	Nymphalidae	20	R1, R6, R7, R12, R15 and R16
Parantica aspasia	Nymphalidae	3	R14 and R15
Parthenos sylvia	Nymphalidae	28	R9, R10, R11, R14, R16 and R18
Polyura jalysus	Nymphalidae	1	R5
Potanthus confucius	Hesperiidae	1	R1
Ritra aurea	Lycaenidae	1	R15
Tajuria ister	Lycaenidae	1	R18
Tagiades japetus	Hesperiidae	1	R18
Tanaecia aruna	Nymphalidae	25	R6, R7, R9, R12, R15 and R16
Tanaecia clathrata	Nymphalidae	10	, R9 and R11
Tanaecia iapis	Nymphalidae	9	R9, R10, R12, R13 and R14
Tanaecia munda	Nymphalidae	24	R6, R7, R9, R11, R12 and R15
Tanaecia pelea	Nymphalidae	3	R7 and R15
Taractrocera ardonia	Hesperiidae	2	R5 and R7
Taxila haquinus	Riodinidae	2	R17
Telicota augias	Hesperiidae	3	R14
Thaumantis klugius	Nymphalidae	4	R14 and R17
Thaumantis noureddin	Nymphalidae	3	R12 and R14
Udara cyma	Lycaenidae	1	R2
Vindula dejone	Nymphalidae	5	R1, R9, R10, R11 and R14
Ypthima pandocus	Nymphalidae	4	R5 and R11

It was noticed that *H. erylus* was the most dominant species, with 40 individuals. In second and third place, they were *D. melanippus* and *P. sylvia*, with individuals of 31 and 28, respectively. A presence of *H. erylus* in other places was previously reported by Bohra and Purkayastha (2021), who described that it was one of the species found among 249 species in the urban landscape of Guwahati, Assam, India. The authors described that it was considered a common species in the habitats of forested areas. Among all the species recorded, we observed that *D. melanippus* received the highest frequency since it could be found differently at 10 research sites. Another study reported that the presence of *D. melanippus,* a butterfly species having the English name of white tiger, was available in the mangrove forest ecosystem in Bangladesh (Hossain 2014).

Nymphalidae was noted as the most dominant, with 46 species. It was calculated that the Hesperiidae, Lycaenidae, Papilionidae, Pieridae, and Riodinidae possessed 7, 25, 5, 7, and 2 species, respectively. However, according to the absolute value measured during the field study and its characteristic pattern, only 40-71% of the total species were found in the research location. This percentage was calculated based on the total species found (92 species). The estimated diversity of butterflies found in the Kayan-Sembakung Delta was expected to reach a value in the range of 131-235 species. The calculations from the estimators are shown in Figure 2. Chao 1 predicted the presence of 235 species, whereas Chao 2 estimated 248 species. On the other hand, Jack-Knife 1 estimated around 131 species, whereas Jack-Knife 2 predicted 155 species.

The diversity of butterfly species was also classified according to the location of watershed areas: Kayan, Sekatak, Sesayap, Sembakung, Sebuku, and Pulau Mandul. As can be seen from Table 3, the highest average of trapped butterflies was obtained from Sebuku, with 14.67 species. The following value was obtained from Sembakung (11.33 species). We stated that it might be due to the type of habitat. In this study, we observed that the butterfly diversity found in a peat swamp was considerably higher than in other habitats studied. It was also proved by the simulation from estimators that species diversity decreased when the habitat was near a beach (Figure 2). Specifically, the average number of species found in the swamp peat of Sebuku (R13 and R14) was 19 species, which this value was significantly higher than the average of Sebuku in total. A similar pattern was also observed from the average number of species in the peat swamp of Sembakung (16.3 species). The biodiversity richness of butterfly species found in some peat swamp areas was also reported by several authors. Houlihan et al. (2013) reported that at least 11 species of butterfly in the peat swamp forest in Central Kalimantan were successfully identified. A total of 24 species were found in a peat swamp in Kota Samarahan, Sarawak, Malaysia (Gintoron and Abang 2014). Our previous study revealed that in the peat forest of Kotawaringin, Central Kalimantan, a total of 28 species of butterfly was found (Harmonis and Saud 2017).

All habitat types observed in the tropical wetland of the Kayan-Sembakung Delta contained lower butterfly diversity compared to the habitat of mixed lowland forest, as previously reported (Harmonis 2013). According to the

measurement using Fisher's Alpha and Shannon-Wiener indexes (Table 4), only the peat swamp community had almost equal value to the lowland forest habitat in terms of the diversity aspect. Since climax forest was reported to possess a Fisher's Alpha index with a value of more than 40 (Harmonis 2013), those studied habitat types were still characterized as secondary forests. Our previous work demonstrated that secondary forests in East Kalimantan affected by illegal logging and fire also had low butterfly diversity, with a Fisher's Alpha index of 2.28 to 16.35 (Harmonis and Sutedjo 2021). Besides the diversity index, a similar trend was also recorded in the Shannon-Wiener index, whereas the highest category was still at a moderate level.

The absolute diversity combined with the diversity indices demonstrated that the peat swamp forest was noted as the habitat with the highest level of butterfly diversity. This condition was also observed by the Simpson evenness index, which showed that the peat swamp forest had the highest evenness. The second highest was found in the brackish swamp forest, followed by forest edge and mangrove forest. The low diversity in the brackish swamp and mangrove was related to the limited diversity of plant species to be a host and to provide a feed for butterfly larvae and imago. A forest edge was an open area dominated by shrubs with lots of sunshine. However, only a few species of butterflies live in this area. It is possible that the diversity index at the forest edge received the lowest value. Based on the results obtained from estimators (Table 5), it is necessary for further investigation since butterfly habitat exploration in tropical wetlands is still limited. The biodiversity as well as the presence of unique species, could be great ecological indicators for high conservation value in the future.

Taxonomic structure

The high complexity of the butterfly family has been shown in forested habitats, especially peat swamp forests and mangrove forests, which potentially become the ideal habitat. Due to the pattern of its distribution, it demonstrated that the complexity in the wetland forest was also lower than that of the lowland forest (Harmonis 2013). Normally, all families of butterflies are easily found in each habitat of the lowland forest, from shrub to climax forest. The pattern observed from Figure 3 was a decline in the total of Hesperiidae from peat swamp forest to brackish swamp forest and mangrove forest. The percentage of Hesperiidae decreased in line with a decrease in the number of species. Nevertheless, this family was not found in forest edge habitats. An absence of Riodinidae was observed in the habitats of forest edge and brackish swamp forest. The distribution and composition of the butterfly family could become essential data for its future conservation. Thus, it will provide validation to understanding a butterfly community in the wetland of the Kayan-Sembakung Delta.

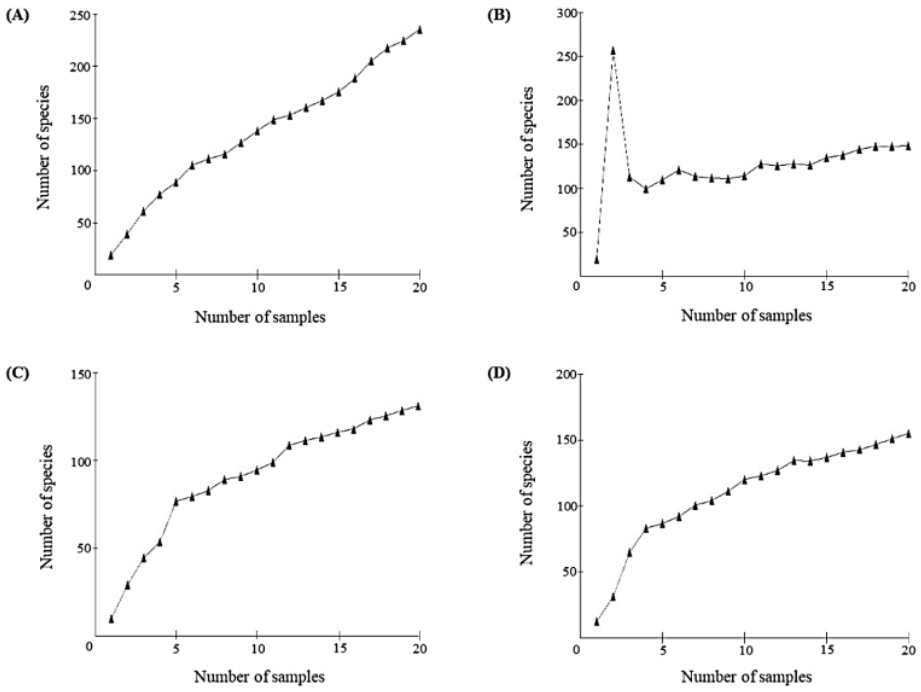

Figure 2. Predicted species number of butterflies calculated from various estimators: Chao 1 (A); Chao 2 (B); Jack-Knife 1 (C); and Jack-Knife 2 (D)

Table 3. Total individuals and species of butterfly based on watershed area

Watershed area	Habitat type	Number of sites	Total individuals	Species	
				Total	Average
Kayan	Brackish swamp and mangrove	2	69	20	10.00
Sekatak	Mangrove	3	75	19	6.33
Sesayap	Peat swamp and brackish swamp	3	106	31	10.33
Sembakung	Peat swamp	3	111	34	11.33
Sebuku	Peat swamp and brackish swamp	3	112	44	14.67
Pulau Mandul	Peat swamp, brackish swamp, and mangrove	6	135	41	6.83

Table 4. Diversity and evenness index of butterfly species based on various habitat types

Habitat type	Total individuals	Total species	Fisher's alpha	Shannon-Wiener		Simpson evenness
				H'	Category	
Peat swamp forest	350	75	29.28	1.66	Medium	35.14
Brackish swamp forest	73	28	16.61	1.31	Medium	19.91
Mangrove forest	142	28	10.44	1.12	Medium	8.88
Forest edge	43	13	6.33	1.00	Medium	10.15

Table 5. Estimation of species richness based on each habitat type

Habitat type	Estimation of total species				Sampling results (%)	Average (%)
	Chao 1	Chao 2	Jack-Knife 1	Jack-Knife 2		
Peat swamp forest	139	133	110	131	56-68	59
Brackish swamp forest	78	81	43	50	35-65	48
Mangrove forest	60	119	45	57	24-62	45
Forest edge	30	18	19	21	43-72	61
Total	235	148	131	155	40-71	58

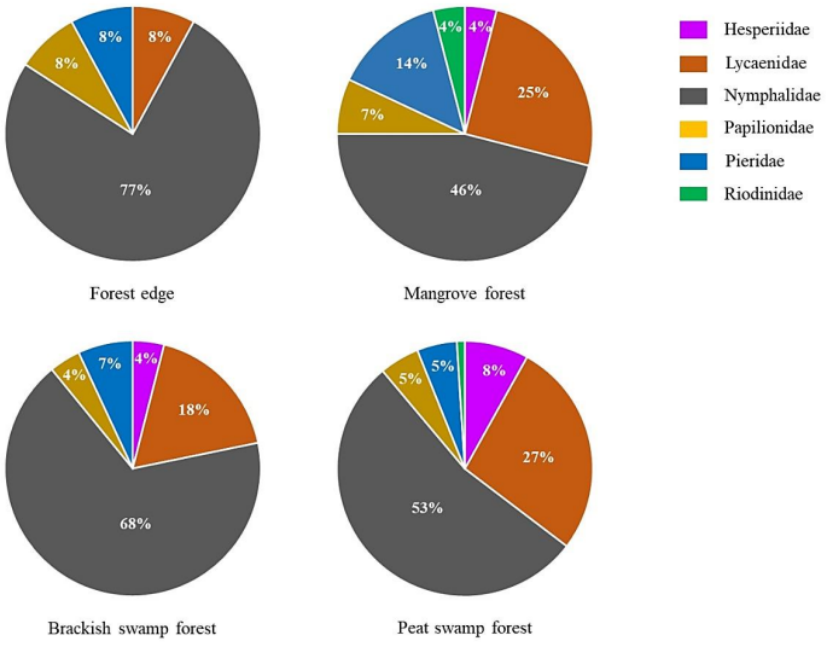

Figure 3. Percentage of families based on their presence based on various habitat types

Distribution of main species

The main species criteria were analyzed according to Engelmann (1978). We found that there were 28 main species that represented each type of habitat in the Kayan-Sembakung Delta. The peat swamp forest, brackish swamp forest, and mangrove forest were represented by 8, 9, and 6 species, respectively. A total of 9 species were found in the forest edge habitat. The summarized distribution of the main species in each habitat can be seen from Table 6. The species identified in this wetland ecosystem did not significantly differ from butterflies found in the terrestrial ecosystem (Harmonis 2013). However, there were notable differences in terms of their communities. The butterfly species as biological indicators in the mixed lowland forest were not commonly dominant species even at the same succession level. An appropriate indicator was often found at the forest edge at the same level as the habitat of a shrub community. This phenomenon indicated that the wetland habitats had a specific pattern of butterfly community that differed from other habitat types. Therefore, it is possible that the wetland habitats possess some unique species. However, the presence of *L. dirtea* also indicated that the forested habitats were recovered after being disturbed due to illegal logging activities. *L. dirtea* is considered one of the native species found in Southeast Asia forests (Choi et al. 2021). Those areas were required to be preserved in order to maintain the natural succession, which could be a suitable habitat for the butterfly communities.

Unique species in the tropical wetland

Results obtained from a literature review on the butterfly species commonly found in the various habitats in Borneo Island demonstrated that there were 5 species known as unique species in the wetland ecosystem (Matsumoto et al. 2015). As shown in Table 7, *A. overdijkinki* and *P. jalysus* were only recorded in the forest edge habitat, while *D. johorensis* and *H. thecloides* were in the peat swamp forest. Furthermore, *I. leuconoe* was found in all habitat types. Among those species, *A. overdijkinki* was reported as a very rare fauna due to its fast-flying and cryptic habits (Ismail et al. 2018). The appearance of all unique species can be seen in Figure 4.

Table 7. List of some unique butterfly species found in the tropical wetland of Kayan-Sembakung Delta

Spesies	Family	Habitat type
A. overdijkinki	Lycaenidae	Mangrove (edge)
D. johorensis	Lycaenidae	Peat swamp forest
H. thecloides	Lycaenidae	Peat swamp forest
I. leuconoe	Nymphalidae	Peat swamp forest, brackish swamp forest, and mangrove
P. jalysus	Nymphalidae	Mangrove (edge)

Table 6. Dominance value and distribution of main species in each habitat types

Species	Family	Dominance value				Common habitat type
		1*	2**	3***	4****	
A. lycaenina	Lycaenidae	0.0	0.0	7.8	0.0	Mangrove
A. pseudocentaurus	Lycaenidae	0.6	0.0	14.1	0.0	Mangrove
C. bernardus	Nymphalidae	1.4	2.7	1.4	0.0	Mangrove
C. erymanthis	Nymphalidae	4.0	1.4	1.4	0.0	Peat and mangrove
D. melanippus	Nymphalidae	2.0	11.0	11.3	0.0	Brackish, mangrove, and mangrove
D. theda	Lycaenidae	4.6	0.0	0.0	0.0	Peat
E. crameri	Nymphalidae	4.6	0.0	0.0	0.0	Peat
E. mulciber	Nymphalidae	1.1	0.0	1.4	4.7	Forest edge
E. blanda	Pieridae	0.0	0.0	10.6	0.0	Mangrove and mangrove
E. nicevillei	Pieridae	0.3	6.8	0.0	0.0	Brackish
F. kirata	Nymphalidae	6.0	0.0	0.0	0.0	Peat
G. sarpedon	Papilionidae	1.7	0.0	0.0	4.7	Forest edge
H. bolina	Nymphalidae	0.6	1.4	0.7	16.3	Mangrove and forest edge
H. erylus	Lycaenidae	0.9	2.7	24.7	0.0	Mangrove
J. aratus	Lycaenidae	0.9	2.7	0.0	7.0	Forest edge
J. philatus	Lycaenidae	0.3	6.8	0.7	0.0	Brackish
J. zebra	Lycaenidae	0.0	4.1	0.0	0.0	Brackish
L. dirtea	Nymphalidae	2.9	13.7	0.0	0.0	Brackish
N. solta	Lycaenidae	0.0	5.5	7.0	0.0	Brackish and mangrove
N. hylas	Nymphalidae	0.3	0.0	0.0	14.0	Forest edge
P. sinope	Nymphalidae	3.1	8.2	0.7	0.0	Brackish and mangrove
P. agleoides	Nymphalidae	4.3	1.4	0.0	9.3	Peat and forest edge
P. sylvia	Nymphalidae	5.4	0.0	0.0	20.9	Peat and forest edge
T. aruna	Nymphalidae	6.9	1.4	0.0	0.0	Peat
T. iapis	Nymphalidae	1.1	5.5	0.0	2.3	Brackish
T. munda	Nymphalidae	6.0	4.1	0.0	0.0	Peat and brackish
V. dejone	Nymphalidae	0.6	0.0	0.0	7.0	Forest edge
Y. pandocus	Nymphalidae	0.0	0.0	0.7	7.0	Forest edge

Note: * Peat swamp forest; ** Brackish swamp forest; *** Mangrove forest; **** Forest edge

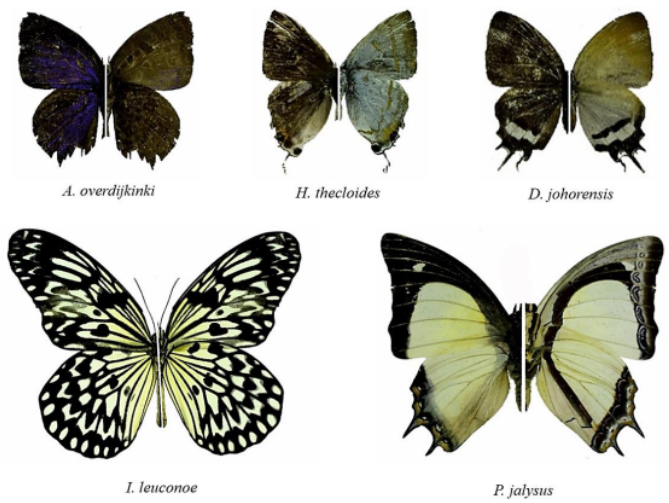

Figure 4. Appearance of some unique butterfly species found in the tropical wetland of Kayan-Sembakung Delta, North Kalimantan, Indonesia

The wetland ecosystem not only has unique butterfly communities but also unique butterfly species. This could emphasize the importance of maintaining the remaining types of ecosystems through a protective measure to preserve their existence. It could be further expected that after forest succession being complete, the climax forest with high biodiversity could be achieved. This condition will improve the ecological aspect, and the endemic species will obtain a proper habitat.

Finally, butterfly diversity found in all habitats of the tropical wetland of the Kayan-Sembakung Delta in North Kalimantan, Indonesia, has been successfully identified. Although the biodiversity in the wetland ecosystem was lower than that of the lowland forest, the uniqueness of the community species was found. Therefore, it could clearly show that the uniqueness of wetland habitats might not be found in other types of habitats. More interestingly, they had a special characteristic in both their community pattern and their main species. Based on the observation of indicators found in the research sites, especially in the forested areas, each habitat was in the process of succession into a climax forest. Moreover, concerning the uniqueness of the tropical wetlands and their ecological function, it would be appropriate that those areas receive significant priority for conservation. Then, concerning the possibility of threat, it will be necessary to create an integrated protection concept, starting from the legal aspect to field monitoring, involving the government and all stakeholders. Since estimators predicted that the butterfly biodiversity found in this study only reached 40–70%, it will provide an opportunity to find other species in the research sites or in other areas near the Kayan-Sembakung Delta.

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