Butterfly diversity varies across habitat types in Tangkoko Nature reserve North Sulawesi, Indonesia

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Butterfly diversity varies across habitat types in Tangkoko Nature reserve North Sulawesi, Indonesia

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Abstract

Butterflies (Lepidoptera) are important pollinators. This study aims to analyze the diversity of butterflies in various habitat types in Tangkoko Nature Reserve (TNR) North Sulawesi, Indonesia. Butterflies were sampled in four habitat types (i.e. primary forest, secondary forest, farms and shrubs) along randomly selected transects of 500 m using a sweep net. Sampling was conducted monthly over a three month period. Three families in Superfamily Papilionoidea were found namely Papilionidae, Nymphalidae, and Pieridae with 576 individuals representing 28 species. The highest diversity, as indicated by Shannon-Wiener index (H) was found in the farm (H=2.13), followed by shrubs (H=1.79), and the lowest was in primary forest (H=1.67). Based on Sorensen similarity index (Cn), the composition of butterfly species found in primary forest had a high similarity value with that found in the farm (SI = 0.71), while the lowest was found amongst primary forest and shrub (SI = 0.55). Community similarity analysis indicated that the composition of butterfly species in the primary forest is more similar to species of butterflies in farm, whereas species of butterfly in shrub has much in common with the butterfly species in secondary forest.

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Introduction

Tangkoko Nature Reserve is an important conservation area in Northern Sulawesi, Indonesia (Lee *et al.*, 2001). This reserve protects a broad diversity of flora and fauna, of which many are endemics. Although there has been some investigation into vertebrate fauna little is known about the invertebrates within the region and, the potential of their diversity.

Butterflies have a high conservation value. Apart from their own intrinsic value, butterfly-plant interactions such as pollination and herbivory influence plant community structure. A measure of their diversity is also considered as an effective surrogate for the diversity of invertebrates in any given region (Speight *et al.*, 1999; Hammond and Miller, 1998; Plona, 2002). In the context of ecosystem conservation, butterflies are also very popular to be used as bioindicator of environmental quality changes (Lewis, 2001; Bora and Meitei, 2014).

This is because butterflies are very sensitive to anthropogenic disturbance, relatively easy to collect, and very popular (Addo-Fordjour *et al.*, 2015).

Fragmentation and changes in forest ecosystem that occur due to rapid exploitation are a threat to the existence of butterflies in North Sulawesi. In 1999, a patch of forest which covers an estimated 20 acres with trees with a bole diameter of more than 40 cm was cut down by villagers who live on the outskirt of Tangkoko-Duasudara Nature Reserve (Lee *et al.*, 2001).

This activity resulted in the loss of butterfly host plants. Although some butterflies can move to a new habitat, plants which are specific foods to butterflies have vanished. Several studies have shown that forest disruption has an impact on diversity of butterflies (Akite, 2008; Bobo, 2006).

Research on butterflies distribution and population in North Sulawesi have been conducted for example in Mantehage island by Lamatoa *et al.* (2013), in Bunaken island (Koneri and Saroyo, 2012), at Mount Ambang (Koneri, 2016), in Manembo-nembo (Koneri and Maabuat, 2016), and at Mount Tumpa Forest Park (Tallei *et al.*, 2015), However, the diversity of butterflies in the Tangkoko Nature Reserve (TNR) is unknown. It is difficult to gauge an understanding of the impacts of current forest destruction and hunting in this area without baseline information. Our study aims to investigate butterfly diversity in various habitat types at Tangkoko Nature Reserve (TNR) North Sulawesi, Indonesia. Our findings will serve to inform conservation initiatives in North Sulawesi.

Materials and methods

Study area

This study was conducted for three months from July to September 2010 at Tangkoko nature reserve (TNR) North Sulawesi. North Sulawesi, a province in Indonesia, is located on the

northern peninsula of Sulawesi island. The location is a part of Wallacea region, which is famous with its unique and endemicity of animals and plants (Tallei *et al.*, 2015). Tangkoko nature reserve has an area of about 1250 ha and located at 1109 m above sea level (asl).

This area stretches along the northern coast of Bitung (Figure 1). Observation location was at 30 m to 350 m asl. In addition to sampling inside conservation areas, sampling was also performed outside the nature reserve, at a plantation owned by residents at Batu Putih village. The sampling locations were as follows:

Primary forest

Primary forest refers to pristine forest that retains its original condition and relatively has little or no human disturbance. This forest is characterized by full canopy that only allows a small amout of light to penetrate and is rich in biodiversity.

The sampling sites were located at 150-350 asl with the following transect coordinates: 01° 33'37.50"

S/125°10'09.71"E (transect 1); 01° 32'21.59" S/125°10'07.11"E (transect 2); 01° 33'35.11" S/125°10'13.95"E (transect 3); 01° 33'19.96" S/125°10'00.72"E (transect 4). The mean air temperature was between 27-29°C with relative air humidity in the range of 75-85%.

The vegetation composition consists of *Diospyros minahassae, Canarium littorale, Diospyros cauliflora, Kleinchofia hospital, Garcinia dioidia, Koordersiodendron pinnatun, Palaquium dasyphyllum, Nauclea orientali, Pterospermum diverifolium* and *Talauma candoli*

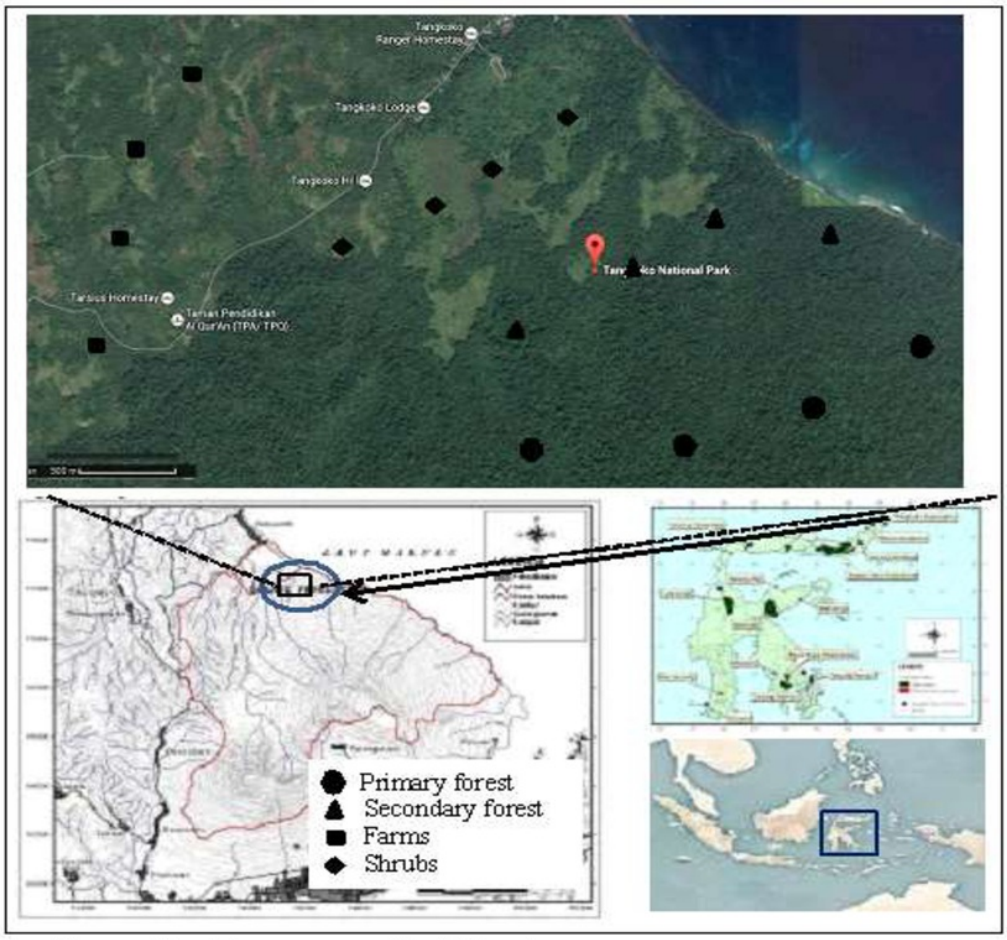

Fig. 1. The map of Tangkoko nature reserve, North Sulawesi.

Secondary forest

Secondary forest is a forest that has recovered naturally or artificially after being cleared for ranching, logging, or agriculture. Secondary forest structure and canopy species composition display a major difference from primary forest. Forest destruction in this location occured about 10-15 years ago.

This habitat is located at 80-180 asl with the following transect coordinates: 01° 34'01.24" S/125°10'03.38"E (transect 1); 01° 33'46.96" S/125°09'50.49"E (transect 2); 01° 34'06.57" S/125°09'56.16"E (transect 3); 01° 33'51.35" S/125°09'49.40"E (transect 4). It had mean air temperature of 28°C-30°C with relative air humidity of 65%-75%.

The forest vegetation consists of *Ficus septica, Macaranga tanarius, Morinda citrifolia, Cananga odorata, Pterospermum javanica, Planchoma valida, Ficus varigata, Dracontsomelum dao, Garuga floribunda, Cratev nurlava, Alstonia sumatrana, Pisonia umbellifera, Clerodendrum disvarifolium, Ficus ampelas, Ficus altissima, Pandanus* sp., *Morinda bracteata, Caryota mytis,* and *Piper aduncum*.

Shrub

This habitat is directly adjacent to TNR. It was formerly agricultural land that was abandoned. Altitude of the sampling sites ranged from 50-90 m asl. The coordinates of each transect are as follows 01°34'01.48" S/125°09'30.63"E (transect 1); 01°33'52.56" S/125°09'29.78"E (transect 2); 01° 34'07.96" S/125°09'26.76"E (transect 3); 01° 33'48.69" S/125°09'23.63"E (transect 4). Mean of temperature of this habitat was 29 °C - 31°C with relative air humidity of 45%-65%. Shrub types in this habitat were *Lantana camara, Piper aduncum, Imperata cylindrica, Mimosa* sp., *Kleinhovia hospita, Spatodea campanulata*, and *Eupatrium* sp.

Farm

This habitat was situated outside TNR and previously served as agricultural land managed by the surrounding community and planted with various types of agricultural crops. Sampling was conducted at an altitude of 30-70 meters asl.

The coordinates of each samples are 01° 33'45.53" S/125°08'58.12"E (transect 1); 01° 33'35.52" S/125°08'41.70"E (transect 2); 01° 33'18.55" S/125°07'55.27"E (transect 3); 01° 33'39.47" S/125°08'02.87"E (transect 4). The mean air temperature ranged from 28 °C - 32°C with air humudity of 65%-70%. Vegetation in this area consisted of *Cocos nucifera, Mangifera indica, Arenga pinata, Musa* sp., *Manihot utilisima, Lantana camara* and *Citrus* sp.

Butterfly sampling and identification

Sampling was conducted using a sweep net technique along 500 m transect lines randomly placed in study sites. Four transects were made for each habitat and sampling was conducted monthly over a 3 months period. Sampling was carried out during one day for each transect with each transect occurring between 8.00 am and 3.00 pm (Peggie and Amir, 2006).

The total of 4 sampling days were carried out each month. Only one specimen of each butterlfy species was collected. To prevent the possibility of double counting (more than one), the captured butterflies were marked and released back to the field. Identification of butterflies refers to Tsukada and Nishiyama (1982:1981;1982;1985;1991), Amir *et al.* (2003), Peggie and Amir (2006).

Data analyses

Abundance (n) and species richness (s) were tallied and used to calculate an index of, species diversity (H) and species evenness value (E). Species abundance is the number of individuals per species found at each sampling point. Species richness is calculated based on the number of species present in each habitat type (Michaels and Borneminza, 1999).

Species diversity was calculated using Shannon diversity index (H' = - ΣPi ln Pi) and Shannon evenness was calculated using the formula; E = H'/ln S, where, H' = Shannon diversity index, and Pi = Proportional abundance of the ith species, E = Shannon evenness and S = Total number of species in habitat (species richness) (Magurran 1988).

Sorensen similarity index was used to calculate the similarity index between butterfly community habitats, and the presence and absence of butterflies were used as data (Magguran, 1988).

The index was calculated using Biodiv 97 which is a macros software program in excel (Shahabuddin *et al.*, 2005). Dissmilarity value (1- Sorensen index) was used for cluster analysis (Krebs, 1999; Ludwig and Reynold, 1988).

Cluster analysis in each community was hierarchically arranged in the form of a dendogram. Dendrogram was made using Statistica for Windows 6 (Statsoft, 2001). Grouping was conducted using unweighted pair group method with arithmetic mean (UPGMA) and the Euclidean distance (Lewis, 2001).

Results

A total of 28 species and 576 individuals belonging to Papilionidae, Nymphalidae and Pieridae were found at all sampling sites. The most commonly found was Nymphalidae, while the least was Pieridae (Table 1).

Table 1. Number of Family and butterfly species found in a variety of habitat types at Tangkoko Nature Reserve, North Sulawesi. PF: primary forest; SF: secondary forest; F: Farm; S: shrub.

No	Family/Species	PF	%	SF	%	F	%	S	%	∑	%
I	Nymphalidae										
1	*Ideopsis juventa tontoliensis*	2.00	0.35	13.00	2.26	41.00	7.12	70.00	12.15	126.00	21.88
2	*Ideopsis vitrea oenopsis*	19.00	3.30	19.00	3.30	16.00	2.78	12.00	2.08	66.00	11.46
3	*Idea blanchardii*	4.00	0.69	33.00	5.73	19.00	3.30	9.00	1.56	65.00	11.28
4	*Euploea algea horsfieldi*	11.00	1.91	27.00	4.69	2.00	0.35	7.00	1.22	47.00	8.16
5	*Melanitis leda obsoleta*	13.00	2.26	5.00	0.87	15.00	2.60	3.00	0.52	36.00	6.25
6	*Neptis ida*	1.00	0.17	0.00	0.00	10.00	1.74	0.00	0.00	11.00	1.91
7	*Euploea phaenareta celebica*	3.00	0.52	6.00	1.04	0.00	0.00	0.00	0.00	9.00	1.56
8	*Junonia hedonia intermedia*	0.00	0.00	6.00	1.04	0.00	0.00	2.00	0.35	8.00	1.39
9	*Lohara dexamenus*	2.00	0.35	1.00	0.17	5.00	0.87	0.00	0.00	8.00	1.39
10	*Parthenos shylva salentia*	1.00	0.17	0.00	0.00	6.00	1.04	0.00	0.00	7.00	1.22
11	*Cyrestis strigata*	0.00	0.00	1.00	0.17	4.00	0.69	0.00	0.00	5.00	0.87
12	*Meduza libnites*	4.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.69
13	*Vindura celebensis*	4.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.69
14	*Amanthusa phiddipus*	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.35	2.00	0.35
15	*Hypolimnas bolina*	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.35	2.00	0.35
16	*Euploea eupator*	0.00	0.00	0.00	0.00	1.00	0.17	0.00	0.00	1.00	0.17
17	*Euploea leucostictos westwoodi*	0.00	0.00	1.00	0.17	0.00	0.00	0.00	0.00	1.00	0.17
II	Papilionidae										
18	*Papilio jordani*	0.00	0.00	0.00	0.00	17.00	2.95	3.00	0.52	20.00	3.47
19	*Troides helena*	1.00	0.17	2.00	0.35	6.00	1.04	8.00	1.39	17.00	2.95
20	*Troides hypolitus*	1.00	0.17	2.00	0.35	14.00	2.43	0.00	0.00	17.00	2.95
21	*Papilio gigon*	4.00	0.69	10.00	1.74	0.00	0.00	2.00	0.35	16.00	2.78
22	*Graphium agamemnon*	0.00	0.00	2.00	0.35	0.00	0.00	1.00	0.17	3.00	0.52
23	*Graphium androcles*	0.00	0.00	0.00	0.00	1.00	0.17	0.00	0.00	1.00	0.17
24	*Papilio blumei*	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.17
III	Pieridae										
25	*Hebomia glaucippe celebensis*	0.00	0.00	4.00	0.69	19.00	3.30	19.00	3.30	42.00	7.29
26	*Pareronia tritaea*	2.00	0.35	6.00	1.04	16.00	2.78	6.00	1.04	30.00	5.21
27	*Catopsilia pamona flava*	10.00	1.74	0.00	0.00	2.00	0.35	7.00	1.22	19.00	3.30
28	*Appias zarinda*	0.00	0.00	0.00	0.00	0.00	0.00	8.00	1.39	8.00	1.39
Total		83	14.41	138.00	23.96	194.00	33.68	161.00	27.95	576.00	100.00

Habitat with the most abundant species was farm, followed by shrub, and the least was primary forest. The most abundant species found in the four habitat types were *Ideopsis juventa tontoliensis* and *I. vitrea oenopsis* (Figure 2A-B).

Species that had the least number of individuals were *Euploea eupator*, *E. leucostictos westwoodi*, *Graphium androcles* and *Papilio blumei* with one individual respectively (0,17%) (Table 1; Figure 2C-F).

Abundance, species richness, diversity, and evenness of butterfly species in farms were higher than in the primary forest, secondary forest and shrubs.

Fig. 2. Photographs of butterflies (A-F). A. *Ideopsis juventa tontoliensis,* B. *I. vitrea oenopsis,* C. *Euploea eupator,* D. *E. leucostictos westwoodi,* E. *Papilio blumei,* F. *Graphium androcles.*

Abundance and species diversity were significantly different between habitat types (Anova: $F_{3;12} = 5.84$ $p < 0.05$ and Anova: $F_{3;12} = 3.89$; $p < 0.05$), whereas species richness and evenness showed no significant differences (Anova: $F_{3;12} = 0.20$; $p > 0.05$ and Anova: $F_{3;12} = 1.04$; $p > 0.05$ (Figure 3).

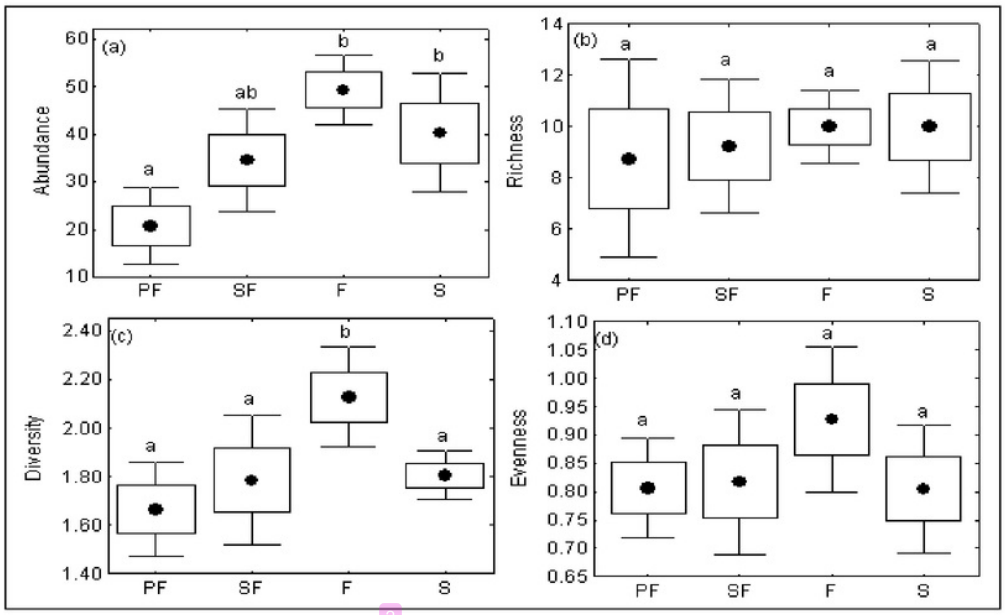

Fig. 3. The influence of habitat types on (a) abundance, (b) richness (c) diversityand (d) evenness at Tangkoko Nature Reserve North Sulawesi. (PF: primary forest, SF: secondary forest, F: farm land, S: shrubs. The same letter in the same picture did not differ significantly according to Tukey's test at 95% confidence level.

Composition of butterfly species found in four habitat types was less varied. There were species found in all four habitat types, as well as species found only in one habitat, but not in the other three habitats. Of the 28 species collected, seven were found in four habitat types and eight were only found in one habitat type (Table 1).

The highest similarity index of butterfly species was in primary forest and farms (Cn =0.71). The lowest similarity index was shrub and primary forest (Cn = 0.55). Primary forests are in a group with farms, while shrubs are with secondary forest (Figure 4). This means that 71% of species found in primary forest are similar to those found in farms. On the contrary, the species found in primary forest are very much different from those found in the shrub.

Discussion

The number of butterfly species found in this study only amounted to 0.16% of all the species that exist in the world (17.500 species) and 1.75% of the butterfly species that were reported in Indonesia (1.600 species). Nymphalidae is a family that had the highest abundance found in the study sites. Potentially this is due to its ability to adapt to environmental conditions so that the species of this family can be found in any study sites. Another factor could be also because Nymphalidae is a family of butterfly that is the largest and most wide spread members compared to other families.

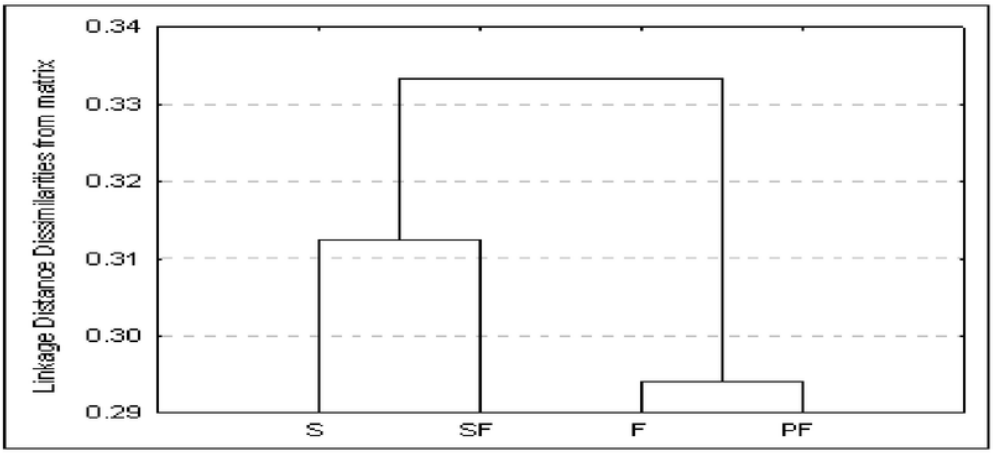

Fig. 4. Dendogram about butterfly community similarity among habitats in Nature Reserve Tangkoko (SM: shrubs, F: Farm, SF: Secondary forest, and PF: Primary forest).

This result is in contrast to research of Baltazar (1991) in the Philippines who found Lycaenidae (33.84%) and Nymphalidae (26.69%) as dominant family and only found 6.32% Papilionidae family. Nymphalidae existence in large numbers is also influenced by vegetation as their food source and nesting site. Nymphalidae feeds on plants belong to family Annonaceae, Leguminoceae, and Asteraceae. Members of the Nymphalidae were always dominant in the tropical region because most of the species are polyphagous in nature, consequently helping them to live in all the habitats (Bora and Meitei, 2014).

Fewer butterfly species were collected in this study in comparison to other similar studies conducted across Indonesia. Amir *et al.* (1993), collected 56 species of butterflies in Bantimurung South Sulawesi. Other research showed that 46 species were found in Tanjung Puting National Park Kalimantan, 60 species found at Lembah Anai Nature Reserve West Sumatera, and 131 species in National Park Kerinci Seblat (Rizal, 2007). This difference is due to the diversity of vegetation as butterfly host plants. Other factors that affect the species richness of butterflies in a habitat are temperature, humidity, rainfall, light, predators and parasites.

Dominant species were *Ideopsis juventa tontoliensis* and *I. vitrea oenopsis*. The likely reason for their dominance is because they are polyphagous, utilising a diversity of plants. This property causes the species to thrive in all types of habitat. Butterfly species with low frequency and limited distribution are sensitive to habitat disturbances. Habitat destruction leads to loss of vegetation as a source of nectar and host for specialist butterflies.

Highest abundance of butterfly species was found in farms and significantly different from that found in primary forest, while the diversity of butterflies in farms was significantly different from other habitats. This is potentially due to differences in food plant and the host plant in every type of habitat as sources of food and shelter for laying eggs.

Farms are located on the edge habitat of forest vegetation and many have flowering plants, such as Rutaceae, Anonanceae, Fabaceae, and Asteraceae. This causes high butterfly diversity compared to other locations. The presence of vegetation also serves as a source of food and shelter for butterflies. *Lantana camara* (Asteraceae) is frequently visited by butterflies in farms and shrubs because of its color, scent, and nectar (Fetwel, 2001).

High diversity of vegetation will lead to a high diversity of other organisms. As with the butterfly, both polyphagus and oligophagus, because food sources are available in one habitat, the butterflies do not need to find sources of food from elsewhere. So besides feeling quite safe as a place to live, the presence of the host on the site and also the availability of adequate food, as well as the intensity of light that supports the needs of the butterfly life, can lead to a high diversity of butterflies in the farm (Amir and Kahono, 2003).

Results of this study are supported by other studies which reported that the diversity of butterfly species increases markedly if there is a diversity of plants, and decreases with increasing vegetation cover. Research on differences of butterflies on six types of landscapes, namely: less disturbed forest, very disturbed forests, farms, primary forest, secondary forest, and shrub showed that the diversity and abundance of butterflies was highest in the farms and the lowest was in primary forest (Lien and Yuan, 2003).

Highest species evenness was also found in the farm. High evenness value of the habitat means that no butterfly species are dominant. The smaller the evenness value of species the more uneven spread of the species which results in dominance by certain species of butterflies.

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