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**PJBS**

ISSN 1028-8880

**Pakistan  
Journal of Biological Sciences**

**ANSI***net*

Asian Network for Scientific Information  
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan



## Research Article

# Diversity of Butterflies (Lepidoptera) in Manembo-Nembo Wildlife Reserve, North Sulawesi, Indonesia

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### Abstract

**Background and Objective:** The degradation of a habitat will affect the population of butterflies living in it. This study aims to analyse the diversity of butterflies in the area of Manembo-Nembo Wildlife Reserve, North Sulawesi. **Materials and Methods:** Employing purposive sampling, the study was conducted for five months. The collection of butterflies was done by using the sweeping technique, following the transect line applied randomly along 1000 m to three types of habitat (the primary forest, riverside in the forest and agricultural land). The species diversity was determined by using diversity index (Shannon-Wiener). **Results:** The study identified 4 families, 44 species and 748 individual butterflies. Nymphalidae was a family predominantly found (71.12%), while the species mostly found was *Ideopsis juvena tontoliensis* (10.16%). Abundance (76.50), richness (20.25), diversity (2.66) and species evenness (0.88) were mostly found in riverside habitats in the forest, while the lowest was found in the primary forest. The similarities of butterfly communities in the different types of habitats indicate that the highest similarity index of butterfly communities is in the habitats of the primary forest and riverside in the forest with a value of 80%. **Conclusion:** The highest diversity of butterflies in all types of habitats found in riverside. **Main conclusion:** The high diversity of butterflies in the river is strongly influenced by the presence of vegetation as food and host plants of butterflies and this habitat should be conserved for the survival of the butterfly in a wildlife reserve Manembo-Nembo, North Sulawesi. It is expected that the results of this study could become important data of the diversity of butterflies and effects of changes of habitats on the diversity of butterflies in Manembo-Nembo Wildlife Reserve, North Sulawesi.

**Key words:** Diversity, abundance, richness, butterflies, primary forest, riverside, agricultural land, North Sulawesi

**Received:** February 15, 2016

**Accepted:** March 12, 2016

**Published:** April 15, 2016

**Citation:** Roni Koneri and Pience V. Maabuat, 2016. Diversity of butterflies (Lepidoptera) in Manembo-Nembo Wildlife Reserve, North Sulawesi, Indonesia. Pak. J. Biol. Sci., 19: 202-210.

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**Competing Interest:** The authors have declared that no competing interest exists.

**Data Availability:** All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Butterflies has an important role in the ecosystem, particularly in the pollination process. They can pollinate more than 50 species of agricultural crops having high economic values<sup>1</sup>. Currently, butterflies are facing extinction due to the conversion of land in their habitats<sup>2</sup>. In general, the number of butterflies depends on the management of an area<sup>3</sup>. The diversity of butterflies has a positive correlation with the habitat area and the habitat perimeter; however, it does not have a correlation with the habitat isolation. Other results indicate that the species richness of butterflies increases significantly along with the diversity of plants, while it decreases along with the increase of vegetation closure. The percentage of flowering plant closure does not have a positive correlation with the diversity of butterflies<sup>4</sup>.

Butterflies will leave their habitats because the increasing human activities, particularly in excessive exploitations of natural resources, result in changes of organism compositions in the ecosystem. For example, in Ohio, the USA, the change of habitat and the use of pesticides have reduced the diversity of butterflies<sup>5</sup>. This has been confirmed by Kerr<sup>6</sup>, proposing that ecological factors, changes and modifications of the environment affect the population of butterflies. North Sulawesi is an area with a high level of deforestation, which is more than 67% of productive wet forest within the last two decades for timber and agricultural purposes<sup>7</sup>. Degradation of forest resources occurs because the forest is also exploited to meet the needs of the local community, such as harvesting, shifting/moving cultivation, constructions of roads and tourism. The decrease and change of the ecosystem which occur due to the rapid exploitation is a threat to the existence of butterflies in the ecosystem. The impact of the habitat change in wildlives on the distribution and diversity of butterflies has not been much studied and published. This study aims to analyse the distribution and diversity of butterflies (Lepidoptera) in the area of Manembo-Nembo Wildlife Reserve, North Sulawesi. It is expected that the results of this study could become the database of the diversity of butterflies in North Sulawesi and a base for formulating fauna conservation strategies in the Manembo-Nembo Wildlife Reserve, North Sulawesi.

## MATERIALS AND METHODS

**Sampling site:** This study was conducted from March to July, 2015 in three types of habitats in Manembo-Nembo Wildlife

Reserve: Primary forest, riverside and agricultural land. Manembo-Nembo is located in Wawona village, Tatapan District, South Minahasa, North Sulawesi, Indonesia (Fig. 1).

**Primary forest:** Natural forests which have not been exploited by humans for logging and timber. The vegetations found in the area include cananga (*Cananga odoratum*), nantu (*Palaquium obtusifolium*), champak (*Elmerrillia ovalis*), Bugis wood/mumu (*Koordersiodendron pinantum*), rattan (*Calamus* sp.), palm (*Pinang* sp.), wild betel (*Piper aduncum*), wild banana (*Musa* sp.) and pine (*Casuarina* sp.). Canopy cover or tree canopy ranges from 70-90%. The sampling site is located at an altitude of 312-342 m above the sea level. The temperature ranges from 25.8-27.8 °C with a humidity level of 80-95%.

**Riverside:** The river is located in the forest and the data collection was done on the riverside. The vegetations include *Ficus chelebensis*, *Macaranga minahassae*, *Homalanthus populneus* (Giesel) Pax., *Gmelina arborea* L., *Pandanus* sp., *Lantana camara* L., *Schefflera elliptica*, *Hedychium coronarium* Koenig and *Blechnum capense* L., Schltldl, cananga (*Cananga odoratum*), nantu (*Palaquium obtusifolium*), champak (*Elmerrillia ovalis*), bugis wood/mumu (*Koordersiodendron pinantum*), wild betel (*Piper aduncum*), wild banana (*Musa* sp.), bamboo (*Bambusa* sp.) and calliandra (*Caliandra* sp.). The canopy cover ranger from 40-65%. The sampling site is located at 182-228 m above the sea level. The temperature ranges from 27.2-30.2 °C with a humidity level of 79-87%.

**Agricultural land:** This habitat is directly adjacent to the wildlife sanctuary of Manembo-Nembo. Plantations/ agricultural areas refer to the land/area of the community in which the main crop is cloves (*Eugenia aromaticum*). Other vegetations found include *Arenga pinnata*, *Caliandra* sp., *Imperata cylindrica*, *Bambusa* sp., *Musa* sp., *Lantana camara* and *Eupatorium odoratum*. The canopy cover ranges from 30-60%. The sampling site is located 185-208 m above the sea level. The temperature ranges from 26.6-30.6 °C with a humidity level of 78-88%.

**Sampling method and identification:** The collection of samples was done purposively. Sweeping technique was employed by following the transect line applied randomly to 1000 m. This technique has been used for more than 25 years and is considered effective<sup>8</sup>. The sampling was carried out inside and outside the area of Manembo-Nembo.

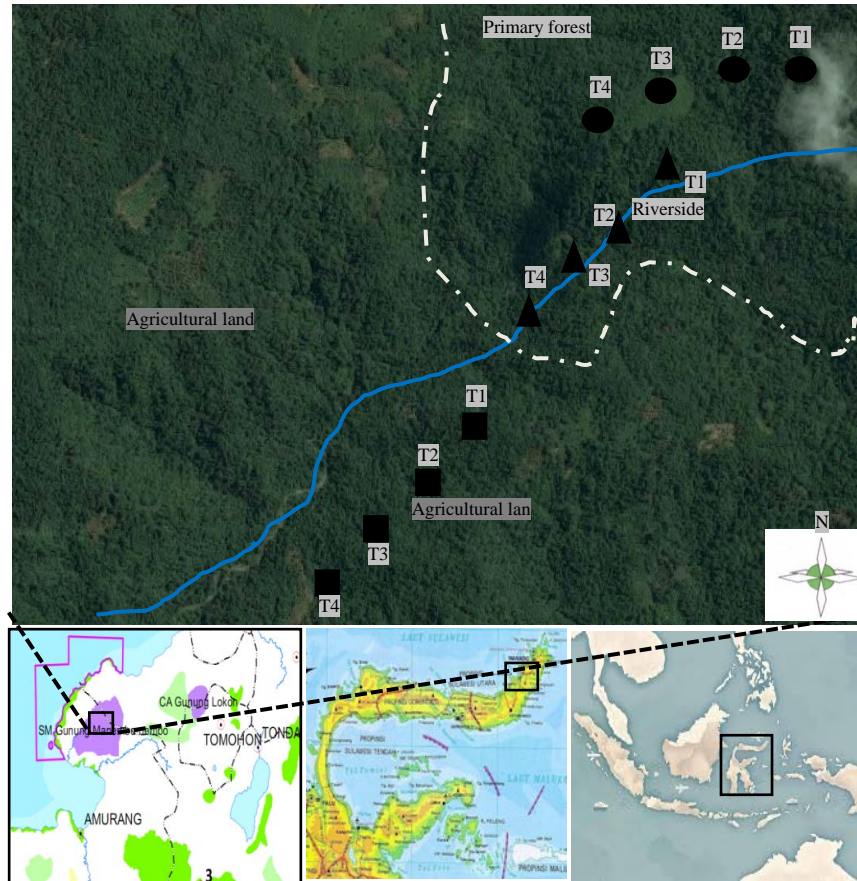


Fig. 1: Research site Manembo-Nembo Wildlife Reserve, North Sulawesi (T: Transect)

The habitat sampling includes forest, secondary forest and riverbanks in the forest.

In each of the habitats, four transects with a length of 1000 m were created. The collection was done four times in each transect. There were 16 transects. The samples were taken every month. The sampling was done from 8:00 to 15:00 (Indonesian Central Time)<sup>9</sup>. One butterfly specimen was collected for one species. If a similar specimen was found, the butterfly was released. To avoid double calculation, butterflies which had been caught were marked/labelled and then released. The identification and classification process used an identification book<sup>9-16</sup>.

**Data analysis:** The richness of the species is based on the number of species present at the study site<sup>17</sup>. The species diversity was determined using Shannon-Wiener index, with the following formula:

$$\text{Species diversity index (H')} = -\sum_{i=1}^s (P_i) (\ln P_i)$$

Description:

$P_i$  = Proportion of each species

$\ln$  = Natural logarithm (natural number)

To determine the level of species evenness, Shannon evenness index was used Magurran<sup>18</sup>, as follows:

Species evenness index (E):

$$E = H/\ln(S)$$

S = No. of species

The statistical analysis employed Statistica ver. 6, one-way Anova and Tukey's test at the level of 95%; they were used to determine the differences in species richness, the abundance of species, the value of species diversity and evenness of butterfly species on each island and landscape type<sup>19,20</sup>.

## RESULTS

**Composition of butterfly species:** The butterfly species identified in the study is 44 species and 748 individuals which

Table 1: The number of butterfly families and species found in the three habitats

Family/Species	Primary forest		Agricultural land		Riverside		Total	
	Σ	(%)	Σ	(%)	Σ	(%)	Σ	(%)
<b>Hesperiidae</b>								
<i>Chaospes plateni plateni</i>	0.00	0.00	0.00	0.00	1.00	0.13	1.00	0.13
<b>Nymphalidae</b>								
<i>Ideopsis juvena tontoliensis</i>	3.00	0.40	69.00	9.22	4.00	0.53	76.00	10.16
<i>Junonia hedonia intermedia</i>	1.00	0.13	40.00	5.35	29.00	3.88	70.00	9.36
<i>Faunis menado</i>	44.00	5.88	0.00	0.00	23.00	3.07	67.00	8.96
<i>Idea blanchardii</i>	14.00	1.87	10.00	1.34	39.00	5.21	63.00	8.42
<i>Parthenos shylva salentia</i>	8.00	1.07	15.00	2.01	22.00	2.94	45.00	6.02
<i>Ideopsis vitrea oenopsis</i>	5.00	0.67	24.00	3.21	9.00	1.20	38.00	5.08
<i>Orosotriaena jopas jopas</i>	0.00	0.00	31.00	4.14	0.00	0.00	31.00	4.14
<i>Euploea eupator</i>	14.00	1.87	5.00	0.67	7.00	0.94	26.00	3.48
<i>Lohara dexamenus</i>	11.00	1.47	2.00	0.27	10.00	1.34	23.00	3.07
<i>Danaus genutia leucoglene</i>	0.00	0.00	19.00	2.54	0.00	0.00	19.00	2.54
<i>Cyrestis strigata</i>	0.00	0.00	0.00	0.00	13.00	1.74	13.00	1.74
<i>Lasippa neriphus tawayana</i>	3.00	0.40	1.00	0.13	7.00	0.94	11.00	1.47
<i>Vindura celebensis</i>	2.00	0.27	1.00	0.13	4.00	0.53	7.00	0.94
<i>Euploea algea horsfieldi</i>	1.00	0.13	2.00	0.27	3.00	0.40	6.00	0.80
<i>Hypolimnas bolina</i>	1.00	0.13	4.00	0.53	1.00	0.13	6.00	0.80
<i>Euploea leucostictos westwodii</i>	2.00	0.27	0.00	0.00	2.00	0.27	4.00	0.53
<i>Nymphalidae</i> sp., 4	2.00	0.27	0.00	0.00	2.00	0.27	4.00	0.53
<i>Medusa lymire</i>	1.00	0.13	0.00	0.00	2.00	0.27	3.00	0.40
<i>Melanitis phyrria hylecoetes</i>	0.00	0.00	3.00	0.40	0.00	0.00	3.00	0.40
<i>Lexias aetes aetes</i>	0.00	0.00	0.00	0.00	3.00	0.40	3.00	0.40
<i>Nymphalidae</i> sp., 1	0.00	0.00	0.00	0.00	3.00	0.40	3.00	0.40
<i>Elymnias mimalon</i>	1.00	0.13	0.00	0.00	1.00	0.13	2.00	0.27
<i>Nymphalidae</i> sp., 2	0.00	0.00	0.00	0.00	2.00	0.27	2.00	0.27
<i>Parantica cleona luciplena</i>	1.00	0.13	1.00	0.13	0.00	0.00	2.00	0.27
<i>Euploea phaenareta celebensis</i>	0.00	0.00	0.00	0.00	1.00	0.13	1.00	0.13
<i>Hypolimnas missippus</i>	0.00	0.00	1.00	0.13	0.00	0.00	1.00	0.13
<i>Medusa libnites</i>	1.00	0.13	0.00	0.00	0.00	0.00	1.00	0.13
<i>Melanitis leda obsolete</i>	1.00	0.13	0.00	0.00	0.00	0.00	1.00	0.13
<i>Nymphalidae</i> sp., 3	0.00	0.00	0.00	0.00	1.00	0.13	1.00	0.13
<b>Papilionidae</b>								
<i>Papilio gigon</i>	9.00	1.20	15.00	2.01	18.00	2.41	42.00	5.61
<i>Papilio sataspes</i>	4.00	0.53	6.00	0.80	15.00	2.01	25.00	3.34
<i>Papilio ascalaphus</i>	5.00	0.67	4.00	0.53	15.00	2.01	24.00	3.21
<i>Graphium androcles</i>	4.00	0.53	0.00	0.00	12.00	1.60	16.00	2.14
<i>Graphium milon</i>	1.00	0.13	1.00	0.13	6.00	0.80	8.00	1.07
<i>Papilio blumei</i>	1.00	0.13	3.00	0.40	3.00	0.40	7.00	0.94
<i>Pachliopta polyphonthes</i>	0.00	0.00	1.00	0.13	0.00	0.00	1.00	0.13
<i>Troides helena</i>	0.00	0.00	0.00	0.00	1.00	0.13	1.00	0.13
<b>Pieridae</b>								
<i>Eurema tomina</i>	8.00	1.07	9.00	1.20	9.00	1.20	26.00	3.48
<i>Pareronia tritaea</i>	1.00	0.13	6.00	0.80	16.00	2.14	23.00	3.07
<i>Hebomia glaucippe celebensis</i>	2.00	0.27	5.00	0.67	12.00	1.60	19.00	2.54
<i>Catopsilia scylla asema</i>	0.00	0.00	12.00	1.60	0.00	0.00	12.00	1.60
<i>Appias zarinda</i>	1.00	0.13	0.00	0.00	8.00	1.07	9.00	1.20
<i>Catopsilia pamona flava</i>	0.00	0.00	0.00	0.00	2.00	0.27	2.00	0.27
Grand total	152.00	20.32	290.00	38.77	306.00	40.91	748.00	100.00

belong to 4 families: Papilionidae, Nymphalidae, Pieridae and Hesperidae. The biggest was from the family of Nymphalidae, which was 29 species. The lowest was from the family of Hesperidae, which was 1 species (Table 1). Based in the type of habitat, habitat with the largest number of species was riverside in the forest (35 species); the next is the

primary forest (29 species), while only 26 species were found in the agricultural land. The species mostly found during the study was *Ideopsis juvena tontoliensis* (76 individuals or 10.16%). The next species is *Junonia hedonia intermedia*, which consists of 187 individuals (11,05%) (Table 1).

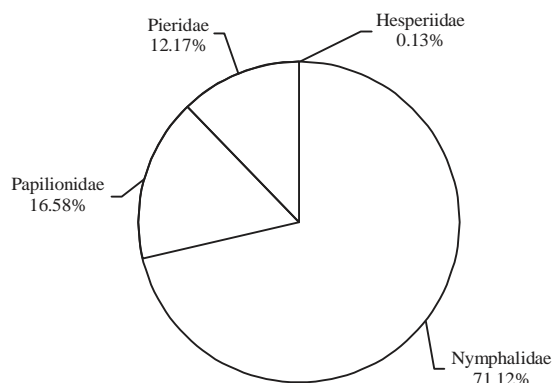


Fig. 2: Abundance of butterfly families in Manembo-Nembo wildlife reserve

The composition of butterfly species found in the 3 types of habitat varied. Some species were found in the three habitats and there are species only found in one habitat. *Medusa libnites* and *Melanitis leda* obsolete were only found in the primary forest, not in other habitats (Table 1).

The family whose species and individuals were mostly found is Nymphalidae, which consists of 29 species and 532 individuals. The next is Papilionidae, consisting of 8 species and 124 individuals. Hesperidae is a family with the lowest number of species and individuals found, which was one species and one individual (Table 1 and Fig. 2).

**Community structure of butterflies:** Community structure refers to the presence of butterflies in the context of space, which includes the value of species abundance (N), species richness (S), species diversity (H) and species Evenness (E). Abundance (N = 76.50), richness (S = 20.25), diversity (H = 2.66) and evenness of butterfly species (E = 0.88) were identified in the Wildlife of Manembo-Nembo. The highest value was identified in the riverside habitat in the forest, followed by agricultural land (N = 72.50, S = 15.50, H = 2.29 and E = 0.84), while the lowest was from the primary forest (N = 38.00, S = 13.50, H = 2.13 and E = 0.82) (Fig. 3a-d).

The results of the statistic analysis indicate that the richness (ANOVA:  $F_{2,9} = 9.26$ ,  $p = 0.001 < 0.05$ ) and the diversity of butterfly species (ANOVA:  $F_{2,9} = 5.28$ ,  $p = 0.034 < 0.05$ ) are different between the habitats. The species abundance (ANOVA:  $F_{2,9} = 2.93$ ,  $p = 0.104 > 0.05$ ) and the index of species evenness (ANOVA:  $F_{2,9} = 0.96$ ,  $p = 0.42 > 0.05$ ) do not show significant difference between the habitats (Fig. 3a-d).

## DISCUSSION

The number of species found in Manembo-Nembo Wildlife is about 2.75% of all species of butterflies found in Indonesia (1600 species) and 7.89% of the butterfly species found on the Island of Sulawesi (557 species)<sup>21</sup>. This result is higher than the number of butterfly species found on the Island of Manado Tua, North Sulawesi, which has 29 species<sup>22</sup>.

The number of butterfly species found in this study is larger than that in the research of Subahar and Yuliana<sup>23</sup>, which identified 26 butterfly species which belong to 5 families. The findings of Sharma and Joshi<sup>24</sup> related to the diversity of butterflies in Dholbaha Dam (Distt. Hoshiarpur) in Punjab Shivalik, India identified 42 species. Some studies reported larger numbers of identified species, such as the study in Lembah Anai Nature Reserve which found 60 species<sup>25</sup>, study in Ton Nga-Chang Nature Reserve, India which identified 147 species<sup>26</sup>, study in North Borneo which found 66 species<sup>8</sup>, study in Slamet Mountain, Central Java, which identified 105 species<sup>27</sup> and study in West Himalaya, India which found 75 species<sup>28</sup>.

Species which can be found in almost all locations is polifag. The polifag nature allows the species to thrive in a variety of habitats. Polifag butterfly larvae survive better in a condition where the host plants have low diversity. The appearance of some butterflies is found to be low; the butterflies could only be found in one study site. Butterfly species with a low frequency of appearance and limited distribution are sensitive to habitat factors. The damages of habitat result in fragmentation and extinction of plants which act as the source of nectar and hosts for specialist butterflies. The polifag butterflies can breed on various plant species. Polifag butterfly larvae survive better in a condition where the host plants have low diversity<sup>29</sup>. The high presence of butterfly species is supported by the availability of plants as the source nectar/food<sup>30</sup>.

Some butterflies were found to have a low frequency of appearance and can only be found in one habitat type. The butterflies are sensitive to habitat factors/disturbance<sup>31</sup>. The damages of habitat cause the fragmentation and extinction of plants as the source of nectar and the host of specialist butterflies<sup>32</sup>.

Nymphalidae is a family which has the highest abundance found in the study site. This is due to their ability to adapt to various environmental conditions, so that the species can be found in all sites. This finding is different from Baltazar<sup>33</sup> study in the Philippines which found the families

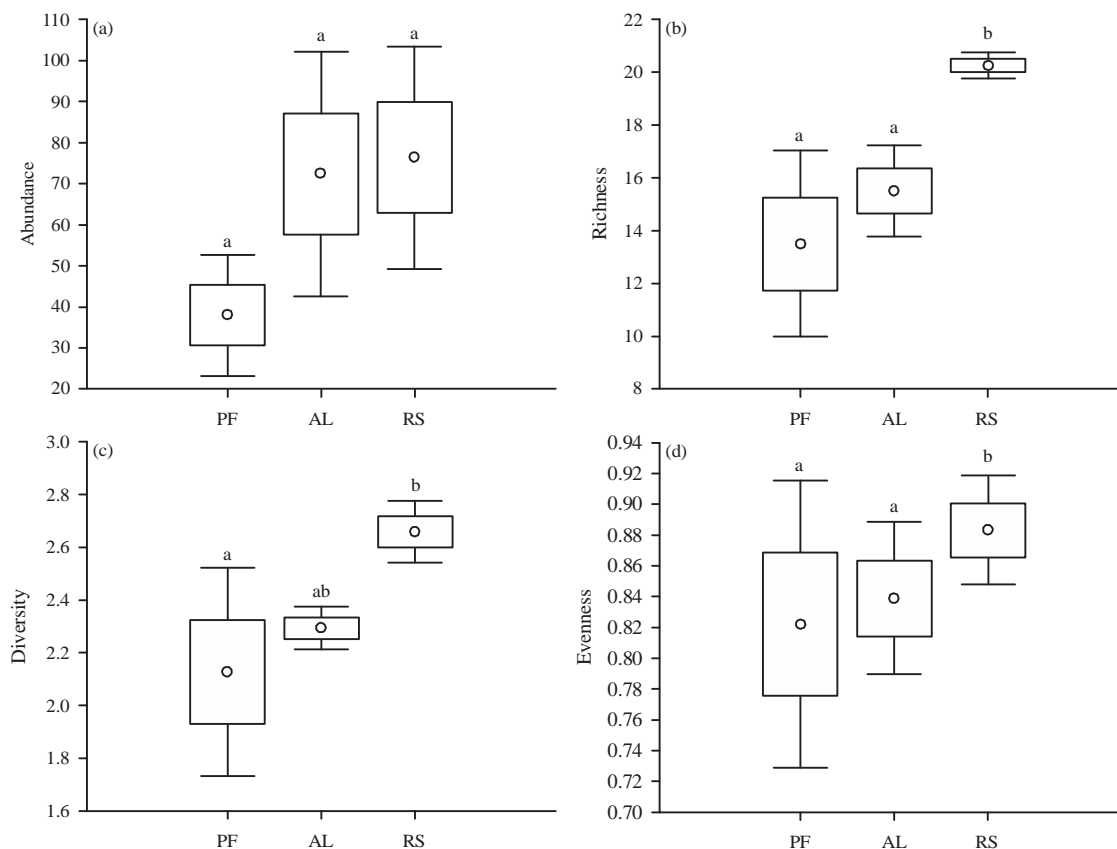


Fig. 3(a-d): Community structure of butterflies in three habitats (PF: Primary forest, AL: Agricultural land, RS: Riverside, (○) : Mean, (□) :  $\pm$  SE, (I) :  $\pm$  SD. The same letter in the same picture does not differ significantly according to Tukey's test at 95% confidence level

of Lycaenidae (33.84%) and Nymphalidae (26.69%) to be dominant, while Papilionidae was only 6.32%.

Nymphalidae has been reported to be dominant in some locations, such as Ujung Kulon National Park<sup>34</sup>, in Ton Nga-Chang Nature Reserve, Songkhla Province, South Thailand<sup>26</sup>; in Sanctuary Aralam Nature Reserve, South India<sup>35</sup>; in TNGH-S<sup>15</sup>, in the forest of Slamet Mountain, Central Java<sup>8</sup>, in Itapua National Park, Brazil<sup>36</sup>, in the protected forest of West Himalaya, India<sup>37</sup> and in Minyambou, Arfak Mountains Nature Researve, Manokwari, West Papua<sup>38</sup>.

Nymphalidae is a butterfly family with the largest members and distributions compared to other families<sup>25</sup>. Nymphalidae was found in a large number because in the study site there are plants supporting its life, both as a source of food and shelters. The food source of Nymphalidae includes Annonaceae, Leguminosae and Compositae<sup>9</sup>. The difference of the dominant family was found in some areas because the distribution of butterflies is influenced by the distribution of host plants and ecology<sup>15,38</sup>.

Hesperiidae is a butterfly family with the fewest identified individuals, because this family tends to be monofag. Tiple *et al.*<sup>39</sup> proposed that Hesperidae has a monofag nature. Limited host plants and the monofag nature of Hesperidae result in the family's low imago phase; thus, the imago of Hesperidae found was also few in number.

The highest abundance, richness, diversity and evenness of species found on riverside in the forest is strongly influenced by vegetation as the food source and host plants for the butterflies. The vegetation is the host of several butterfly species larvae. According to Sharma and Joshi<sup>24</sup>, the structural complexity of habitat and the diversity of vegetation have a correlation with the diversity of insect species. The high abundance of particular species in each habitat is affected by sunlight and the habitat conditions.

Butterfly habitats which are humid and have many flower vegetations as well as water ways are preferred by butterflies. The more sunlight enters the habitat, the higher the butterfly activities. Flowering plants found on the



riverside include Asteraceae, Mimosaceae, Caesalpiniaceae, Fabaceae, Musaceae, Achantaceae and Euphorbiaceae. These plants are the source of food and host plants for butterflies. *Junonia hedonia* butterflies (Nymphalidae) stay on Acanthaceae and Malvaceae<sup>9</sup>.

Other factors can also influence the diversity of butterflies on the riverside in the forest, because the tree canopy is not too tight/densed (40-70%). This allows sunlight to enter the area on the riverbanks. Hamer *et al.*<sup>8</sup> proposed that in the primary forest habitat, the diversity of butterflies is higher, particularly on the area where the canopy is open and that the tree canopy which is good for butterflies is less than 60%. Rocks on the riverbanks will be places for butterflies to sunbath. Butterflies need water and mineral; they drink from flooded ground.

The temperature of the habitat on the riverside ranges from 27.2-30.2°C, the temperature range needed by butterflies. Butterflies are poikilotherm, whose body temperature is affected by the environment temperature<sup>40,41</sup>. Generally, butterflies need a body temperature of 28-40°C<sup>42</sup>, 25-41°C<sup>43</sup> to do their activities. Butterflies will bask before flying to obtain an optimal body temperature<sup>44,45</sup>. Thermoregulation is an important part of adult butterflies, particularly for butterfly species living in open habitats<sup>43</sup>.

Hirota and Obara<sup>44</sup> reported their research conducted in a farm at Tokyo University. They found that the mating process of *Pieris rapae* reaches its peak at the temperature between 24-29°C. Butterflies can be found in open areas because sunlight is not blocked by trees. Light is needed by butterflies because they belong to cold-blooded animals. Light provides thermal energy for butterflies, so that their body temperature can increase and their body metabolism becomes faster. The increase of their body temperature will also accelerate the development of the butterfly larvae.

Type evenness index (E) can be used as an indicator of the dominance of each butterfly type in a community. The higher species evenness was found on the riverside, then agricultural land and in the primary forest. This suggests that on the riverside, there is no butterfly species dominating. According to Rahayuningsih *et al.*<sup>45</sup>, the high type evenness index in an area indicates that the habitat in the area is more stable compared to habitats with low evenness. The lowest butterfly species evenness was found in the primary forest. This shows that there are some butterfly species dominating in the number of individuals per species. This can be found on the butterfly species of *Faunis menado* predominantly found in the primary forest. Efendi<sup>46</sup> view, the higher the value of

butterfly species evenness, the distribution of butterflies is even and the dominance of particular butterfly species is not found.

## CONCLUSION

There are 44 species of butterfly that consist of 4 families in order Lepidoptera recorded in Manembo-Nembo Wildlife Reserve, North Sulawesi, Indonesia during the study period. Family Nymphalidae is the most number of species than other families. Data analysis result showed that the diversity, abundance, richness and species evenness index of riverside habitats is higher than agricultural and primary forest. The riverside environment in the forest plays an important role in conserving butterfly abundance.

## ACKNOWLEDGMENTS

The researchers would like to express their gratitude to the Rector of Sam Ratulangi University, Manado, North Sulawesi, who has approved the funding for this study through the scheme of Advanced Research, Sam Ratulangi University, fiscal year 2015. Also, they would like to thank the Head of Natural Resources Conservation Centre (BKSDA) of North Sulawesi and staffs for giving permission and providing facilities during the implementation of the study.

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