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Abundance and diversity of butterfly in the Lombok Forest Park, Indonesia

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Abstract. Ilhamdi ML, Al Idrus A, Santoso D, Hadiprayitno G, Syazali M, Hariyadi I. 2023. Abundance and diversity of butterfly in the Lombok Forest Park, Indonesia. *Biodiversitas* 24: 708-715. The lack of studies on butterflies on Lombok Island has prevented the biology and ecology of this insect group from being widely known. Further, the absence of data on insect communities impacts conservation management, especially that of the Lombok Island Forest Park. Insects can only be effectively managed for conservation by knowing their basic biology and ecology, yet almost nothing about the butterflies on Lombok Island has previously been quantified. This study aims to analyze the abundance and diversity of butterflies in the Forest Park of Lombok Island, Indonesia. The research was carried out from January to July 2022. Further, the samples were collected from three habitat types: waterways, forest middle lanes, and forest edge lanes. Butterfly data collection was carried out on the left and right of each line that became the transect. During this period, 1524 individuals from 42 butterfly species were collected. The most abundant species was *Jamides celeno* (Ra: 7.54%), while the species with the lowest abundance was *Lampides boeticus* (Ra: 0.26). The abundance of other species ranged from 0.45% to 6.95%. The results of the analysis show that the diversity of the butterflies in Lombok Island Forest Park is quite high in each of the habitat types surveyed. The data from this research can be used to design and implement conservation management, especially for butterflies.

Keywords: Abundance, butterfly, diversity, Lombok Forest Park

INTRODUCTION

Based on biodiversity, Lombok is located between the Wallace line and the Weber line. This impacts the fauna, which is relatively different from the oriental fauna in the West and the Australian fauna in the East. Much native fauna is found here, both vertebrates and invertebrates. From the vertebrate group, for example, there is the Rinjani owl, which can be found in the Kerandangan Nature Tourism Park (Sangster et al. 2013; Muttaqin et al. 2020) and *Limnocyttus kadarsani*, whose habitat is in secondary and primary forests (Iskandar et al. 1996; Syazali et al. 2019). Meanwhile, in the invertebrate group, *Pseudagrion pilidorsum declaratum*, for example, is reported to survive in the Suranadi Nature Park (Ilhamdi et al. 2021). As for the butterfly group itself, *Eurema lombokiana* is a butterfly species that can be found in various habitat types, ranging from disturbed to undisturbed habitats (Yukawa et al. 2001). Based on the field studies conducted on Lombok Island, butterflies were recorded in Suranadi Nature Park (Ilhamdi et al. 2018), Sekaroh, Senaru, and Suranadi (Matsumoto et al. 2012).

Lombok Forest Park is a conservation area of 3155 hectares. The environmental carrying capacity of the habitat can support various types of flora and fauna. Various plants from Spermatophyta provide a food source for the herbivorous butterfly fauna in the larval and imago phases (Knerl and Bowers 2013; Soule et al. 2020). Springs

also exist at many points and meet the butterflies' water and mineral needs. On the other hand, butterflies are among the best native pollinators and effectively assist pollination (Duara 2014; Hanula et al. 2016). Thus, without the help of butterflies, the success rate of pollination in flowering plants can potentially be low. The success of pollination itself plays a role in maintaining the regeneration of flowering plants. Further, seeds and fruits produced from pollination are an important source of nutrients for other fauna. Through interactions between the butterfly and its environment, it plays a highly important role in sustaining the ecological process in Lombok Forest Park.

According to the Department of Environment and Forestry, the Lombok Forest Park is the only conservation area whose management is under the authority of the West Nusa Tenggara (WNT) Provincial Government (Rahayu and Hidayah 2018). This raises opportunities as well as challenges while conserving the biological resources in the area. An important factor needed for optimal conservation or conservation efforts is data on the abundance and diversity of the area's biological resources. One of these biological resources is the butterfly. Butterfly conservation is important because they have an important role for humans, either directly or indirectly. From the ecological aspect, the butterfly acts as a balancer of the ecosystem through its herbivorous nature in the caterpillar and adult phases (Knerl and Bowers 2013; Soule et al. 2020). From the tourism aspect, butterflies of various colors can attract

ecotourism (Jensen and Langergaard 2020; Lemelin and Jaramillo-López 2020; Amil et al. 2021). Thus, as one such ecotourism area, Lombok Forest Park has an interest in preserving butterflies.

To date, data regarding the butterfly community in Lombok Forest Park is only available in one study, which managed to record 16 butterfly species from 4 families (Hapsari 2022). That research was based in the waterway (WW) habitat of the Sesaot area and had limited observation time because the scope was limited to an undergraduate final project report. Sesaot is a part of the Lombok Island Forest Park, so that study's results do not represent the butterfly community in the conservation area. The main factor supporting this statement is that the WW habitat is not the only habitat type of butterflies found in the Lombok Island Forest Park. Ilhamdi et al. (2018) found that butterflies can also be found in the forest edge and middle forest habitats. The different types of habitats impact the differences in composition and population size of each species of the butterfly community in a particular area (Panjaitan et al. 2020; Paul and Sultana 2021; Thakur et al. 2021).

These facts show that the basic data regarding the butterfly community in the Lombok Island Forest Park is still incomplete, which can negatively impact their conservation efforts. Butterfly conservation efforts are important because butterflies are guardians of ecological sustainability due to their herbivorous nature (Knerl and Bowers 2013; Soule et al. 2020). Although they can be detrimental to cultivated plants, which are their source of nutrition as larvae (Bhat et al. 2020), when they are adults, they act as pollinators (Cutter et al. 2022). This causes the butterfly to have a mutually beneficial relationship with its host plant. In addition, butterflies can be bioindicators of

environmental conditions (III et al. 2011; Ismail et al. 2020; Legal et al. 2020; Pacheco et al. 2021). Therefore, this study of butterflies is important and aims to analyze the abundance and diversity of butterfly species in the Lombok Island Forest Park. This study's results can benefit ecotourism, education, and conservation efforts of the biological resources in the Forest Park area of Lombok Island.

MATERIALS AND METHODS

Study area

This study was conducted in Lombok Forest Park, Indonesia, or Taman Hutan Raya (Tahura) Nuraksa (Figure 1). Administratively, the area covers Narmada District-West Lombok and North Batukliang District-Central Lombok. The sampling site comprises three paths that were determined arbitrarily based on the type of habitat. The three routes are the waterway (WW), the forest middle lane (FML), and the forest edge lane (FEL). WW is a watershed with a width of 5-10 m. This line is located from coordinates -8.539747 S, 116.244519 E to -8.533482 S, 116.244727 E. The middle path of the forest is not too dense with trees and banana plantations, and at some points, there are open areas filled with herbaceous plants. This line is located from coordinates -8.518030 S, 116.284426 E to -8.521400 S, 116.286347 E. The FML is a highway on the edge of Lombok Forest Park and is directly adjacent to an urban area. This line is located from coordinates -8.539888 S, 116.245740 E to -8.526410 S, 116.280030 E. The physical and chemical conditions of the three pathways are presented in Table 1.

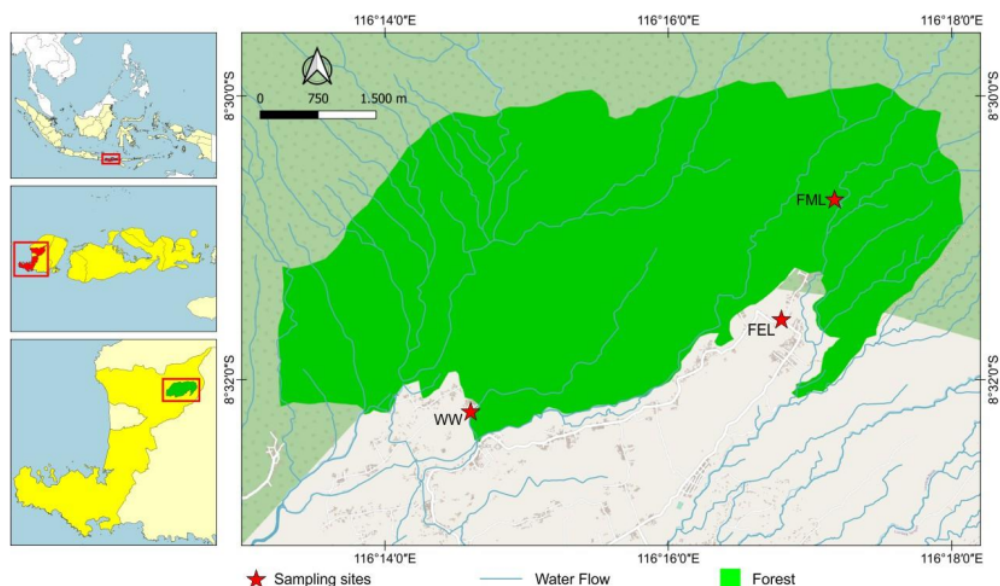


Figure 1. Map of the butterfly research locations in Lombok Forest Park, Indonesia

Table 1. Measurements of the physical and chemical conditions of the waterway (WW), forest middle lane (FML) and forest edge lane (FEL)

Physical and chemical conditions	WW	FML	FEL
Temperature (°C)	27.3-27.6	30.6-32.7	29.5-32.5
Height (m asl.)	213-270.4	445.47-474.52	250.78-414.68
Humidity (%)	83-88	69-73	65-83
Light intensity (Cd)	583-4600	1291-3360	380-21700
Canopy (%)	40-70	75-90	10-85

Data collection

Sample collection was carried out in two different seasons (rainy and dry seasons) from January to June 2022 by exploring three sampling sites-WW, FML, and FEL. Then the photos of butterfly samples were taken using the Canon EOS 7D Mark II Kit EF-S18-135 mm IS USM camera. The three lines were used as transects for butterfly sampling, starting from 08.00 to 14.00 local time. The butterfly search area covered the line transect and at least 5 m on the left and right. To obtain representative community data, sample collection was carried out with 24 replications. The time interval between samplings in the field was one week. All the butterflies found were caught using a hand net and wrapped in plastic. Species identification was carried out at the Biology Laboratory of the Faculty of Teacher Training and Education, Mataram University, Indonesia. Species naming was carried out by referring to butterfly identification books (Braby 2004; Orr and Kitching 2010; Wahyuni and Fatahullah 2015).

Data analysis

Data analysis included species abundance and diversity. Abundance was measured using relative abundance. Mathematically, the equation is $Ra = \left(\frac{ni}{n}\right) \times 100\%$, where Ra is the relative abundance, ni is the number of individuals of species i, and n is the number of individuals of all species. The analysis of butterfly species richness was carried out using the Margalef species richness index with the mathematical equation: $RI = S - 1/\ln N$, where RI is the species richness index, S is the number of species and N is the number of individuals of all species. Diversity was also analyzed using the Shannon-Wiener index, whose equation is $H' = -\sum pi \ln pi$, where H' is the index of species diversity and pi is the ratio between the number of individuals of species i and the number of individuals of the entire population (Koneri et al. 2020).

RESULTS AND DISCUSSION

Abundance

The butterflies found in the Lombok Forest Park were from 5 families, namely Papilionidae, Hesperidae, Lycaenidae, Nymphalidae, and Pieridae. The total number of butterfly specimens collected from the field was 1524. Of the total specimens, the highest number was found in the habitat type FEL (887 individuals), followed by FML (319 individuals) and WW (318 individuals). The most abundant family was Nymphalidae, with 744 individuals and a relative

abundance (Ra) of 49.83%. The other families had individual numbers ranging from 68 to 428 individuals and relative abundance (Ra) from 4.55% to 28.67%. The most abundant family was Nymphalidae, with 744 individuals and a relative abundance (Ra) of 49.83% (Table 2). This fact shows that the family thriving the most under the physical, chemical and biological conditions of the Lombok Forest Park is the Nymphalidae family. Similar research results were reported by several researchers who observed other areas on the island of Lombok. In Suranadi Nature Park, the Nymphalidae family has a sizeable proportion of individuals (45%), while other families range from 2% to 25% (Ilhamdi et al. 2018). Similar reports were obtained from the studies in Aik Bukak, West Nusa Tenggara Province (Ashari et al. 2022).

The most common species overall is *Jamides celeno*. The total number found during the observation was 115 individuals with the highest relative abundance (Ra: 7.55%) (Table 3). Its survival in all types of habitats in Lombok Forest Park is the key to the success of this species. Another interesting fact regarding this species is its relatively small morphometry compared to most butterfly species. Though the availability of food in the habitat directly impacts the abundance of butterfly species (Curtis et al. 2015), the small size of this butterfly allows it to adapt to the availability of feed resources because it does not require large amounts of nutrients. This species also has many different host plants (Cleary and Grill 2004), so it is not difficult to find food sources. During observations, *J. celeno* was often found sucking nectar on various herbaceous plants that were widely available in the Lombok Forest Park area. In addition to these advantages, *J. celeno* also has more strategies to survive. First, *J. celeno* has a mutualistic relationship with ants on the host plant. Second, the larvae can camouflage with the substrate and hide behind the leaves of the host plant (Eastwood et al. 2005), making it difficult for predators to detect them.

Table 3 shows that *Melanitis leda*, *Leptosia nina*, and *Elymnias hypermnestra* are also abundant in Lombok Forest Park. The population size of each species is 106 individuals (Ra: 6.96%), 78 individuals (Ra: 5.12%), and 77 individuals (Ra: 5.05%). *Melanitis leda* and *Elymnias hypermnestra* species have dark brown coloration, can fly quickly, and move at relatively low altitudes. At the time of observation at the Lombok Forest Park, both species were often found flying or perched on leaves or banana stems with a height of 1 m. Their habitat is also protected by a dense canopy, so the environment tends to have low light. Thus, their dark colors camouflage them well, helping them avoid predators such as *Solenopsis invicta*, *Hemidactylus frenatus*, and *Rattus rattus* (Nacua et al. 2020).

Table 2. The abundance of five butterfly families in Lombok Forest Park, Indonesia

Family	Total (ind.)	Abund. (%)
Papilionidae (Kite tail butterflies)	78	5.22
Hesperidae (Skippers)	68	4.55
Lycaenidae (Gossamer-winged butterflies)	206	13.79
Nymphalidae (Brush-footed butterflies)	744	49.83
Pieridae (white and sulfur butterflies)	428	28.67
Total	1524	100

Table 3. The abundance of butterflies in the Lombok Forest Park, Indonesia

Family	Species	Habitat Type						N	Ra	
		WW		FML		FEL				
		Ni	Ra	Ni	Ra	Ni	Ra			
Papilionidae	<i>Papilio memnon</i>	15	4.72	1	0.31	9	1.01	25	1.64	
	<i>Papilio polytes</i>	7	2.2	1	0.31	2	0.22	10	0.65	
	<i>Graphium agamemnon</i>	16	5.03	1	0.31	11	1.24	28	1.84	
	<i>Graphium doson</i>	2	0.63	1	0.31	5	0.56	8	0.52	
Hesperiidae	<i>Graphium sarpedon</i>	2	0.61	1	0.31	4	0.45	7	0.45	
	<i>Erionota torus</i>	8	2.52	4	1.25	8	0.9	20	1.31	
	<i>Udaspes folus</i>	16	5.03	1	0.31	10	1.13	27	1.77	
	<i>Pseudo coladeniadan</i>	6	1.89	4	1.25	11	1.24	21	1.38	
Lycaenidae	<i>Jamides celeno</i>	15	4.72	16	5.02	84	9.47	115	7.54	
	<i>Doleschallia bisaltide</i>	2	0.63	31	9.72	54	6.09	87	5.71	
Nymphalidae	<i>Lampides boeticus</i>	2	0.63	0	0	2	0.22	4	0.26	
	<i>Elymnias hypermnestra</i>	4	1.26	24	7.52	49	5.52	77	5.05	
	<i>Euploea eunice</i>	4	1.26	2	0.63	25	2.82	31	2.03	
	<i>Euploea climena</i>	6	1.89	4	1.25	34	3.83	44	2.89	
	<i>Junonia iphita</i>	10	3.14	28	8.78	31	3.49	69	4.53	
	<i>Junonia hedonia</i>	6	1.89	25	7.84	28	3.16	59	3.87	
	<i>Melanitis leda</i>	10	3.14	47	14.73	49	5.52	106	6.95	
	<i>Mycalesis horsfieldii</i>	6	1.89	16	5.02	37	4.17	59	3.87	
	<i>Tagiades gana</i>	2	0.63	13	4.08	29	3.27	44	2.89	
	<i>Tanaecia pelea</i>	5	1.57	5	1.57	12	1.35	22	1.44	
	<i>Neptis hylas</i>	9	2.83	12	3.76	20	2.25	41	2.69	
	<i>Parantica pseudomelanosis</i>	3	0.94	8	2.51	15	1.69	26	1.7	
	<i>Ideopsis juvena</i>	5	1.57	4	1.25	12	1.35	21	1.38	
	<i>Danaus chrysippus</i>	5	1.57	1	0.31	16	1.8	22	1.44	
	<i>Junonia erigone</i>	5	1.57	7	2.19	20	2.25	32	2.09	
	<i>Pantoporia hordonia</i>	3	0.94	2	0.63	15	1.69	20	1.31	
	<i>Elymnias casiphone</i>	3	0.94	5	1.57	9	1.01	17	1.12	
	<i>Hypolimnas bolina</i>	3	0.94	2	0.63	11	1.24	16	1.03	
	<i>Tirumala hamata</i>	6	1.89	2	0.63	10	1.13	18	1.18	
	<i>Ypthima baldus</i>	7	2.2	5	1.57	8	0.9	20	1.31	
Pieridae	<i>Catopsilia pomona</i>	21	6.6	3	0.94	31	3.49	55	3.61	
	<i>Delias belisama</i>	7	2.2	0	0	6	0.68	13	0.85	
	<i>Eurema hecabe</i>	14	4.4	1	0.31	21	2.37	36	2.36	
	<i>Eurema blanda</i>	11	3.46	1	0.31	45	5.07	57	3.74	
	<i>Leptosia nina</i>	24	7.55	11	3.45	43	4.85	78	5.13	
	<i>Cepora iudith</i>	9	2.83	6	1.88	22	2.48	37	2.43	
	<i>Lebadea martha</i>	3	0.94	3	0.94	18	2.03	24	1.57	
	<i>Parnara ganga</i>	4	1.26	10	3.13	17	1.92	31	2.03	
	<i>Euploea midamus</i>	6	1.89	3	0.94	15	1.69	24	1.57	
	<i>Euploea tulliolus</i>	8	2.52	3	0.94	11	1.24	22	1.44	
	<i>Euploea mulciber</i>	8	2.52	3	0.94	14	1.58	25	1.64	
	<i>Polyura hebe</i>	10	3.15	2	0.63	14	1.58	26	1.71	
	Total		318		319		887		1524	

The *Leptosia nina* species has a bright color, but its morphometry is small, so it does not need much feed to meet its nutritional needs. In addition, this species was found in various flowering plants that are abundantly available in the area. Even with limited host plant availability, the larvae of *Leptosia nina* can adapt well (Agarwala et al. 2014). Its good habituation to habitat disturbance by humans is also advantageous because Lombok Forest Park is an ecotourism area that cannot be separated from tourist activities. The morphology of the four species with the highest abundance and several other species are presented in Figure 2.

Species diversity

A total of 42 butterfly species from 5 families were found in the Lombok Forest Park. The number of species

found in this study is higher than the previous studies (Hapsari et al. 2022), which only recorded 16 species from 4 families. This indicates there are more species than previously reported (with a difference of 26 species), and the family taxon is also more numerous. The family found in this study that was not reported in the previous studies is the Hesperidae family. This family was found because the locations observed in this study have more diverse habitat types. In the previous study, the search for butterflies was only carried out on WW, while in this study, exploration was carried out on three types of habitats with the addition of FEL and FML. Each habitat type has different physical and chemical conditions (Table 1).

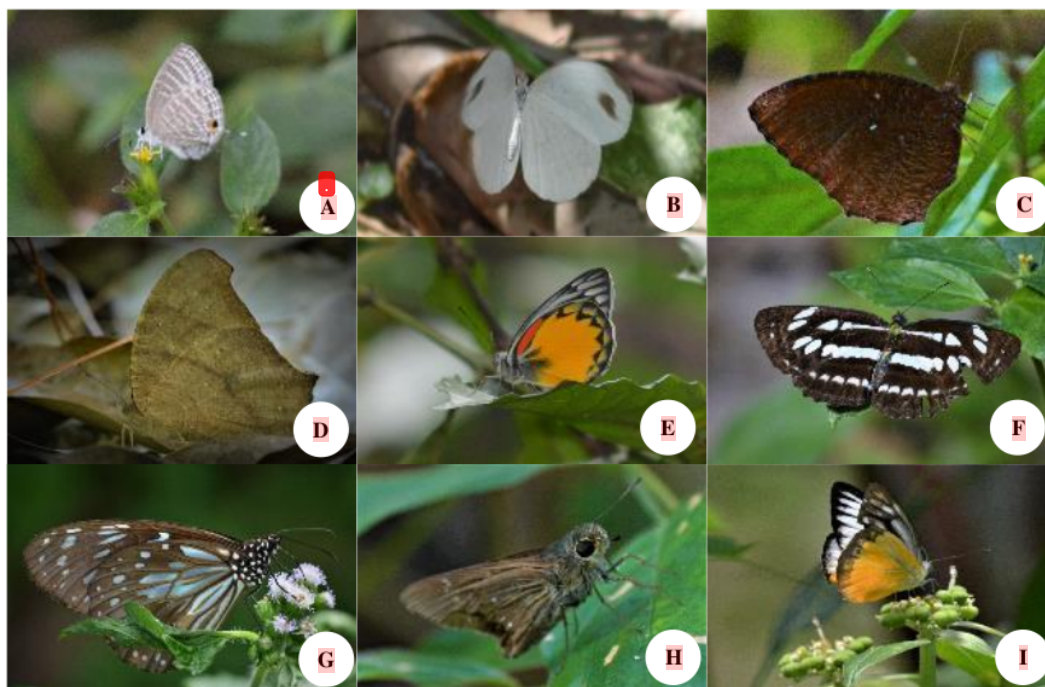


Figure 2. The four most predominant butterfly species: A. *Jamides celeno*; B. *Leptosia nina*; C. *Elymnias hypermestra*; D. *Melanitis leda*; and the other species are E. *Delias belisama*; F. *Pantoporia hordonia*; G. *Tirumala hamata*; H. *Parnara ganga*; and I. *Cepora iudith*

The habitat type is directly proportional to the number of butterfly species that can be found in an area because each species has an ecological niche; Hence, the distribution pattern due to environmental factors is different (Jemal and Getu 2018; Arya et al. 2020; Rija 2022). This impacts diversity in each type of habitat, which is evidenced by a study conducted by a university in Nigeria on Mount Slamet, Indonesia and Talaud Island, Indonesia (Widhiono 2015; Koneri et al. 2019; Efenakpo et al. 2021).

The family that has the most species is the Nymphalidae family (19 species), followed by Pieridae (12 species), Papilionidae (5 species), and the least Hesperidae and Lycaenidae (each 3 species) (Figure 2A). Several studies have also reported the same findings in Talaud Island, Sangihe and North Minahasa (Koneri and Nangoy 2019; Koneri et al. 2019; Koneri et al. 2020). The factors that cause the Nymphalidae to have a higher number of species are their high abundance and survival. In Lombok Forest Park, this is evidenced by its distribution in all habitat types and the abundance of individuals (Table 2). In several places in the world, this family is represented by more species than any other family (Koneri et al. 2019). In addition, the species that are members of this taxon are generally cosmopolitan. Nymphalidae uses of many suitable plants, including Asteraceae, Annonaceae,

Fabaceae, and Poaceae for natural food sources (Peggie and Amir 2006). Nymphalidae can also be easily found in all seasons because of their generality. Some species are not dependent on flower nectar and can use rotten fruit and animal urine as a source of nutrition (Sarma et al. 2013).

Related to the habitat type, all the species were found in all the habitat types, except in the FML habitat type, where two species were not found i.e., *Lampides boeticus* from the family Lycaenidae and *Delias belisama* from the family Pieridae. Thus, the total number of species in this habitat type is 41 (Figure 3). This shows that the two species are not compatible with the environmental conditions in FEL. Based on the physical and chemical conditions of each habitat type, the condition that is unfavorable to the two species is a high canopy (covering), which reaches 90% or more. Each species of butterfly prefers certain conditions in a habitat. Many physical or chemical factors may limit a species, thus affecting its abundance there. For example, the higher a habitat is located, the lower the number of species that can survive there (Jemal and Getu 2018). Another example is the results of a study conducted in North Minahasa, Sulawesi Island (Koneri et al. 2020). Only seven species were found in all the habitat types, while the other species were only found in certain habitat types. For example, the *Euploea eupator* is only found in one habitat type, the Kuwil City Forest.

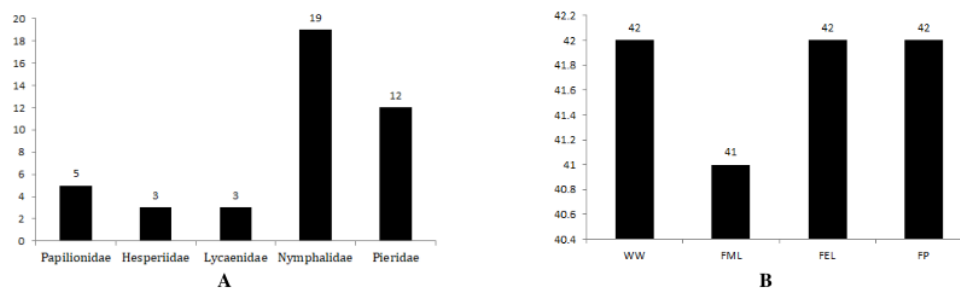


Figure 3. Species composition of (A) each butterfly family and (B) habitat type in Lombok Forest Park, Indonesia

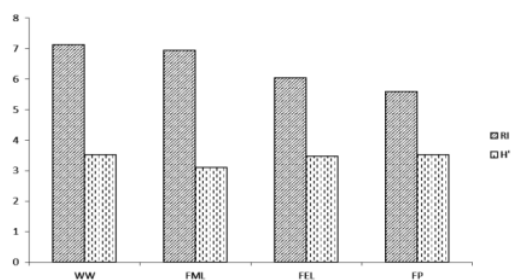


Figure 4. Diversity of butterflies

The difference in the number of species directly impacts the differences in the butterfly species diversity index. The results of the analysis using the Shannon-Wiener index show that the butterfly species diversity index in Lombok Forest Park is 3.52. This index is higher than the index found in Suranadi Nature Park (Ilhamdi et al. 2018). The diversity of butterflies in Lombok Forest Park is also higher than in some areas of Wallacea. Koneri et al. (2017) reported that the butterflies in Tangkoko Nature Reserve, North Sulawesi, are of 28 species with H' ranging from 1.67 to 2.13. Two factors that are directly proportional to diversity are the richness and evenness of species that are components of the butterfly community. This can be observed from the diversity of butterflies in each habitat type (Figure 4). H' in the habitat types WW and FML is higher than H' in FEL, where the species richness of the two habitat types is greater than in FEL. Empirically, the role of the number of species (S) and species evenness (E) factors is proven from the results of field studies. When S: 20.25 and E: 0.88, then H' is 2.66; when S: 15.50 and E: 0.84, then H' is 2.29; when S: 13.50 and E: 0.82, then H' is 2.13 (Koneri and Maabuat 2016).

Based on S and H' index values of (Figure 4), the diversity of butterflies in Lombok Forest Park is quite high. This is an encouraging fact because high diversity indicates a stable ecological system, and there will be more food chain models and an increase in the complexity of food webs. The extinction of populations will impact the food chain but have an insignificant negative effect on the food web so that the process of energy flow and material cycles can run normally. However, many species are not found in

this area, even though they can survive in locations not too far from the area. Some of these species are the *Troides helena*, *Tagiades gana*, and *Tanaecia pelea*, which were found in Suranadi Nature Tourism Park (Ilhamdi et al. 2018). Nine species from 10 species were found in Sekaroh, Senaru, Pusuk and Suranadi (Matsumoto et al. 2012). This needs to be noted and can be used as evaluation material by area managers. Has the conservation management system implemented so far been effective or ineffective? At least an improvement in the management system can be observed based on the findings of recent studies, including the results of research on the abundance and diversity of this butterfly.

In conclusion, the butterflies in Lombok Forest Park are of five families and 42 species. The most abundant butterfly is *Jamides celeno*, and the population size found during the observation was 115 individuals, with a relative abundance of 7.55%. Other species have relative abundances ranging from 0.26 (*Lampides boeticus*) to 6.85 (*Melanitis leda*). In terms of the richness index and species diversity index, the diversity of butterflies in Lombok Forest Park is quite high. This also applies to each type of butterfly habitat in the area. This data can be utilized by management and related agencies to design and implement better conservation management. To add to the area's attractions, some butterflies that have potential as tourist objects can be bred in greenhouses. This, of course, can attract greater tourist visits, both local and foreign tourists. From the educational aspect, teachers and lecturers can use it as learning material, especially biodiversity and ecology.

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