

## Butterfly (Lepidoptera: Papilionoidea) diversity and structure community in Lumajang, East Java, Indonesia

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**Abstract.** Millah N, Leksono AS, Yanuwadi B. 2023. Butterfly (Lepidoptera: Papilionoidea) diversity and structure community in Lumajang, East Java, Indonesia. *Nusantara Bioscience* 15: 118-128. Lumajang is one of the district in East Java, Indonesia with an area of around 1,790.90 km<sup>2</sup> with various ecosystems. Unfortunately, several ecosystems in Lumajang have been degraded, affecting biodiversity, especially butterflies. The aim of this study was to analyze the structure of butterfly communities in Lumajang and analyze the species as bioindicators. The study was conducted in 5 habitats: Village, Agriculture, City Park, Community Forest, and Conservation Forest. The butterfly sampling method in this study was an Active Visual Survey using the Transect Pollard Walk; environmental factors were also measured during the study (temperature, humidity, light intensity, wind velocity, and altitude). The butterfly diversity and the measurement of environmental factors were analyzed for correlation using the Principal Component Analysis (PCA). The results of the study consisted of 124 species. Several were endemic species (*Cyrestis lutea* (Zincken, 1831), *Ypthima nigricans* (Snellen, 1892), *Parantica albata* (Zincken, 1831), *Mycalesis sudra* (Felder, 1867), and *Pachliopta adamas* (Zincken, 1831)), then protected species (*Troides helena* (Linnaeus, 1758), *Troides cuneifera* (Oberthür, 1879), and *Troides amphrysus* (Cramer, 1779)). The Shannon-Wiener diversity index values from highest to lowest are Community Forest (3.52), Conservation Forest (3.32), City Park (2.98), Village (2.79), and Agriculture (2.29). The results can be used as basic data and are expected to support butterfly conservation strategies in Indonesia, especially in Lumajang, East Java, Indonesia.

**Keywords:** Butterfly, community structure, diversity, Lepidoptera, Lumajang

### INTRODUCTION

Butterflies are insects that have many roles in functioning ecological systems. Butterflies also play an important role in a plant's reproductive success because of their role as pollinator agents (Pe'er and Settele 2013). Butterflies and vegetation have a tight correlation because butterflies require vegetation for larval feeding so butterflies can be used as an indicator of the presence of specific plant species (Miller III et al. 2011). Butterflies also serve as bioindicator agents because of their sensitivity to environmental changes (Forister et al. 2010; Ren et al. 2022). Changes in environmental conditions can be observed in the structure of the butterfly community changes, both in terms of abundance and its correlation with the environment (Zografou et al. 2014).

The number of individuals and insect populations is decreasing yearly, and some species are even threatened with extinction globally; one of the endangered insects are the butterfly (Cardoso et al. 2020; Warren et al. 2021). Declining butterfly populations can disrupt ecosystem services, disrupting phylogenetic diversity, functional and ecological networks (Cardoso et al. 2020). The decline in butterfly populations is caused by anthropogenic factors such as pollution (industrial pollution and pesticides), invasive species, climate change, exploitation, and declining hostplant species (Zografou et al. 2014; Cardoso et al. 2020). One of the biggest threats to butterflies is habitat degradation (Basset et al. 2015). Degradation and fragmentation of habitats can affect

butterfly populations because habitat conditions can affect an area's biodiversity (Koneri et al. 2020). Degraded habitats will result in the loss of areas where butterflies seek to feed and reproduce, while fragmented habitats will increase isolated species (Haddad et al. 2015).

Butterfly studies are important because they have many roles in functioning ecological systems, as mentioned before, at the population and ecosystem levels. Furthermore, butterflies can be easily observed and directly identified by their wing patterns; if they cannot be identified directly, they can be caught, tagged, or photographed and released (Ren et al. 2022). The study of butterfly community structure generally describes the diversity of butterflies present in a habitat in terms of abundance and how the butterfly correlates with other organisms (Adey and Loveland 2007). Studying the diversity and structure of the butterfly community worldwide is very popular, especially in Indonesia. Indonesia has a high butterfly population, with over 2,000 butterflies from 17,280 species worldwide (Peggie and Harmonis 2014; Shahrioni et al. 2022). Several studies of butterfly diversity in Indonesia, especially in Java, have been carried out in various habitats, such as forest areas (Widhiono 2015) and urban areas (Leksono et al. 2016; Azizah et al. 2021). In addition, approximately 640 species of butterflies on the island of Java have been recorded, and 46 are endemic species (Peggie and Harmonis 2014; Shahrioni et al. 2022).

Studies on similar topics in Lumajang are still very limited, especially on the communities structure and the diversity of butterflies. Lumajang is one of the districts located in eastern Java. Lumajang has an area of about 1,790.90 km<sup>2</sup> with various ecosystems, such as agricultural areas, forest areas, bushes, residential areas, and other areas, such as lakes, rivers, waterfalls, and wells. Based on topography, Lumajang has a land altitude ranging from 0 to > 2,000 meters above sea level (masl), so it also has coastal and mountain areas (RPJMD of Lumajang District, 2018-2023). Based on this, Lumajang has a high diversity of ecosystems that can affect the high species diversity, including butterflies. Some ecosystems have changed due to land conversion, thus threatening the diversity and existence of butterflies. Data on the diversity of butterflies in Lumajang is limited, so monitoring the butterfly population changes is difficult. Thus, the study aims to analyze the structure of butterfly communities in Lumajang, East Java, as basic data useful for butterflies conservation strategies and to find species with a high sensitivity to environmental changes that have the potential as bioindicator agents for environmental quality.

## MATERIALS AND METHODS

### Study site

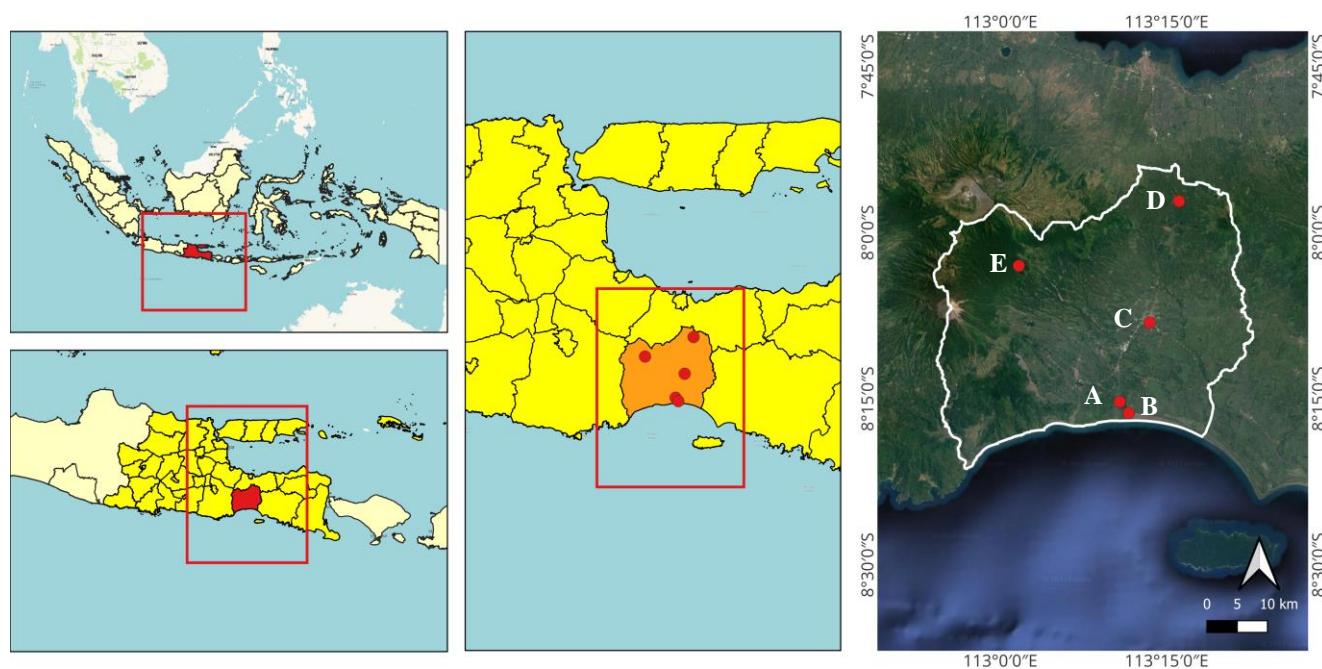
The study was conducted at the end of the dry season, from July to September 2022, in Lumajang, East Java, Indonesia (Figures 1 and 2). The study was conducted in five locations: Village, Agriculture, City Park, Conservation Forest, and Community Forest (Table 1). The

selection of these different study locations is based on the land use of each location so that it can represent several types of ecosystems in Lumajang. There are three transect lines in each location, and each transect has a length of 600 m. Therefore, distances between one transect line and another vary according to the conditions of each location, ranging from 300 to 600 m.

### Sampling procedurs

The butterfly sampling was conducted using the active visual survey method with the Pollard Walk Transect. The Pollard Walk Transect is visualized within the view of 5 m side-by-side and 5 m forward when walking through the transect line by direct observation or with cameras and insect nets (Montgomery et al. 2021). The samplings were conducted from 8:30 AM to 3:30 PM and repeated five times on different days (Ren et al. 2022). Butterfly observations included the identification of species and counting the number of individuals. Identification of butterfly species was based on observing the morphological characters. Furthermore, the butterfly species identification was by the butterfly application Kuponesia and several identification books by Smith and Vane-Wright (2008), Wilson (2008), Rositawati (2017), Baskoro et al. (2018), Fitri (2021), and Iqbal et al. (2021).

Environmental factors were measured by air temperature and humidity measurements using a thermo-hygro-meter, light intensity using a lux meter, wind velocity using an anemometer, and altitude using the Global Positioning System (GPS) at the beginning and the end of each transect line.



**Figure 1.** Map of study site in Lumajang, East Java, Indonesia. Note: A. Village, B. Agriculture, C. City Park, D. Community Forest, E. Conservation Forest

**Table 1.** Description of the conditions of the study site habitat

Habitat	Coordinate	Altitude	Condition
Village	8°15'15.67"S 113°10'46.54"E	28-40 m asl.	Artificial ecosystems, high human activities, controlled vegetation growth, trees, shrubs, and herbs exist. The vegetation found in this area is <i>Mangifera indica</i> L. (Anacardiaceae), <i>Carica papaya</i> L. (Caricaceae), <i>Citrus</i> spp. (Rutaceae), and <i>Acalypha siamensis</i> Oliv. ex Gage (Euphorbiaceae).
Agriculture	8°16'16.48"S 113°11'35.10"E	4-12 m asl.	Artificial ecosystem, controlled vegetation, use of fertilizers and pesticides, and high human activity. The vegetation found in this area are <i>Pennisetum purpureum</i> Schumach. (Poaceae), <i>Digitaria ciliaris</i> (Retz.) Koeler (Poaceae), <i>Ipomea</i> spp. (Convolvulaceae), and <i>Oryza sativa</i> L. (Poaceae).
City Park	8°08'06.72"S 113°13'28.13"E	55-58 m asl.	Artificial ecosystems, plants selected based on certain functions (pollution and water absorption) and high human activity. The vegetation found in this area are Arecaceae, <i>Pterocarpus indicus</i> Willd. (Fabaceae), <i>Eupatorium capillifolium</i> (Lam.) Small (Asteraceae), <i>Pseuderanthemum reticulatum</i> (hort. ex Hook.fil.) Radlk. (Acanthaceae), and <i>Cupressus Papuanus</i> (Cupressaceae).
Community Forest	7°57'09.47"S 113°16'07.47"E	167-280 m asl.	In the secondary forest that local people use, some plants grow naturally and are cultivated; there are human activities (traveling, grazing, and fishing). The vegetation found in this area are <i>Pennisetum purpureum</i> Schumach. (Poaceae), <i>Mimosa pudica</i> L. (Fabaceae), <i>Tridax procumbens</i> L. (Asteraceae), <i>Hibiscus tiliaceus</i> L. (Malvaceae), <i>Ipomea</i> sp. (Convolvulaceae), <i>Antigonon leptopus</i> Hook. & Arn. (Polygonaceae), and Arecaceae.
Conservation Forest	8°02'58.93"S 113°01'40.34"E	1103-1420 m asl.	In the Primary Forest and conservation area, plants grow naturally. They are very diverse, dominated by trees, so the canopy tends to be more closed when compared to other locations, with minimal human activity. The found in this area are Malvaceae, <i>Swietenia mahagoni</i> (L.) Jacq. (Meliaceae), <i>Ficus</i> spp. (Moraceae), <i>Toona sureni</i> (Blume) Merr. (Meliaceae), <i>Albizia chinensis</i> (Osbeck) Merr. (Fabaceae), and Urticaceae.

**Figure 2.** Study site in Lumajang, East Java, Indonesia. A. Village, B. Agriculture, C. City Park, D. Community Forest, E. Conservation Forest**Data analysis**

Butterfly data on species and individual numbers are analyzed for diversity values regarding species abundance (n) and taxa richness (S). The diversity index used is the Shannon-Wiener diversity index ( $H' = -\sum p_i \ln p_i$ ) to describe the diversity of butterflies. The Evenness

( $E = H'/\ln S$ ) to determine the pattern of species distribution (Magurran 2004; Ismail et al. 2020). The results of the diversity values are analyzed using the One-Way ANOVA test that aims to analyze different butterfly diversity compositions at each study site. Furthermore, Indval analysis is carried out to measure the percentage of

association for all species found in all habitats through butterflies' consistency and relative abundance. Indval analysis is useful to identify species that could be indicator species in each habitat (Bugno-Pogoda and Durak 2021). All analyses were calculated with the PAST 4.09 software (Hammer et al. 2001).

Individual analysis was also carried out to measure the percentage of associations for all species found in all habitats through their relative consistency and abundance; this analysis is useful for identifying species that could be indicators in a habitat (Bugno-Pogoda and Durak 2021). Individual analysis was calculated using PAST 4.09 (Hammer et al. 2001). Data from measuring environmental factors were analyzed using the Kruskal Wallis test using R studio software (Hollander et al. 1973). The relationship between environmental factors and butterfly diversity correlation analysis using a biplot Principal Component Analysis (PCA) by PAST 4.09 software (Hammer et al. 2001).

## RESULTS AND DISCUSSION

### Community structure of butterfly species

The study of butterflies in Lumajang in several habitats found 2,958 individuals from 124 species and six families (Table 2). The family consists of Hesperidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, and Riodinidae. The family that has the highest number of species and individuals is Nymphalidae, which has 63 species (51.22%) and 1,420 individuals (47.97%), and the smallest were from the Riodinidae family, only 1 species (0.81%) and 1 individual (0.03%) (Table 2). The study recorded several endemic and protected species. The endemic species are *Cyrestis lutea* (Zincken, 1831), *Mycalesis sudra* (Felder, 1867), *Ypthima nigricans* (Snellen, 1892), and *Pachliopta adamas* (Zincken, 1831). Meanwhile, three protected species were recorded from the genus of *Troides*, consisting of *T. helena* (Linnaeus, 1758), *T. cuneifera* (Oberthür, 1879), and *T. amphrysus* (Cramer, 1779) (Table 2 and Figure 6).

### Diversity of butterfly species

Diversity analysis showed that the Community forests have the highest species richness and abundance (1,372 individuals and 72 species). While the lowest number of species is in Agricultural areas (30 species), and the lowest abundance is in City park. (280 individuals). The results of the analysis of the Shannon-Wiener diversity index and Evenness index were the highest in Community forests ( $H' = 3.52$  and  $E = 0.47$ ), and the lowest value was an agricultural area ( $H' = 2.12$  and  $E = 0.30$ ) (table 3). The results of the one-way ANOVA analysis showed that between the five study sites, there were significant differences in terms of species richness ( $F = 23.15$ ,  $p = 0.00005$ ), abundance ( $F = 11.41$ ,  $p = 0.001$ ), Shannon-Wiener diversity index ( $F = 17.18$ ,  $p = 0.0002$ ), and Evenness index ( $F = 5.82$ ,  $p = 0.01$ ) (Figure 3).

### Indicator species analysis (Indval)

The Indval analysis shows the species can be used as an indicator species if the Indval value is close to 100% and

has a significance value of  $p < 0.05$ . The analysis results in Table 2 showed that Agriculture has six species that can be used as indicators. These species have Indval values above 50% and significance values  $p < 0.05$ ; the species consist of *Danaus chrysippus* (Linnaeus, 1758), *Hypolimnas missippus* (Linnaeus, 1764), *Phalanta phalantha* (Drury, 1773), *Graphium agamemnon* (Linnaeus, 1758), *Appias lyncida* (Cramer, 1779), and *Eurema sari* (Horsfield, 1829). In the Village area, six indicator species were found, such as *Borbo cinnara* (Wallace, 1866), *Zizula hylax* (Fabricius, 1775), *Euploea core* (Cramer, 1780), *Papilio memnon* (Linnaeus, 1758), *Papilio polytes* (Linnaeus, 1758), and *Appias olferna* (Swinhoe, 1890). In the City Park, two species could be indicator species, including *Tanaecia pelea* (Fabricius, 1787) and *Delias periboaea* (Godart, 1819). The Community Forest have the highest indicator species among other locations, 22 species have a significance value  $p < 0.05$ , and 12 have a perfect indval value (100%). The species consist of *Chersonnesia rahria* (Westwood, 1857), *Hebomoia glaucippe* (Linnaeus, 1758), *Ideopsis juvena* (Cramer, 1777), *Mycalesis horsfieldii* (Moore, 1892), *Mycalesis janardana* (Moore, 1857), *Orsotriaena medus* (Fabricius, 1775), *Pachliopta adamas* (Zincken, 1831), and *Ypthima horsfieldii* (Moore, 1884). There are 21 species as indicators in Conservation forests, and 11 have an indval value of 100%. These species include *Heliophorus epicles* (Godart, 1823), *Ideopsis gaura* (Horsfield, 1829), *Notocrypta curvifascia* (C. Felder & R. Felder, 1862), *Papilio helenus* (Linnaeus, 1758), *Symbrenthia anna* (Semper, 1888), *Symbrenthia hypselis* (Godart, 1823), *Tanaecia japis* (Godart, 1823), *Troides cuneifera* (Snellen, 1889), *Udara akasa* (Horsfield, 1828), *Vagrans egista* (Cramer, 1780), and *Ypthima nigricans* (Snellen, 1892).

### Environmental factors

The result of measuring the environmental quality of all habitats varies. For example, the Kruskal Wallis test showed that temperature ( $X^2 = 8,607$ ,  $p = 0,072$ ) and humidity ( $X^2 = 7,067$ ,  $p = 0,132$ ) had no significant differences between habitats. Meanwhile, the wind speed ( $X^2 = 13,987$ ,  $p = 0,017$ ), the intensity of the signal ( $X^2 = 11,433$ ,  $p = 0.022$ ), and the altitude ( $X^2 = 13,5$ ,  $p = 0.009$ ) between habitats have significant differences (Table 4; Figure 4).

### Correlation between butterfly species diversity and environmental factors

The PCA analysis used five variables of environmental parameters and two results of an analysis of butterfly diversity in five habitats. The total variance in the results of the PCA analysis is 77.5%. PC 1 explains 52.8% of the variance, and PC 2 explains 24.7%. The results of the PCA analysis showed that the City park and Agricultural had high temperature, light intensity, and wind velocity characteristics. In contrast, low humidity resulted in low diversity and evenness of butterflies. Conversely, the Community forest was characterized by high diversity and evenness of butterfly populations with moderate temperature and humidity (Figure 4).

**Table 2.** List species each family and Indval value

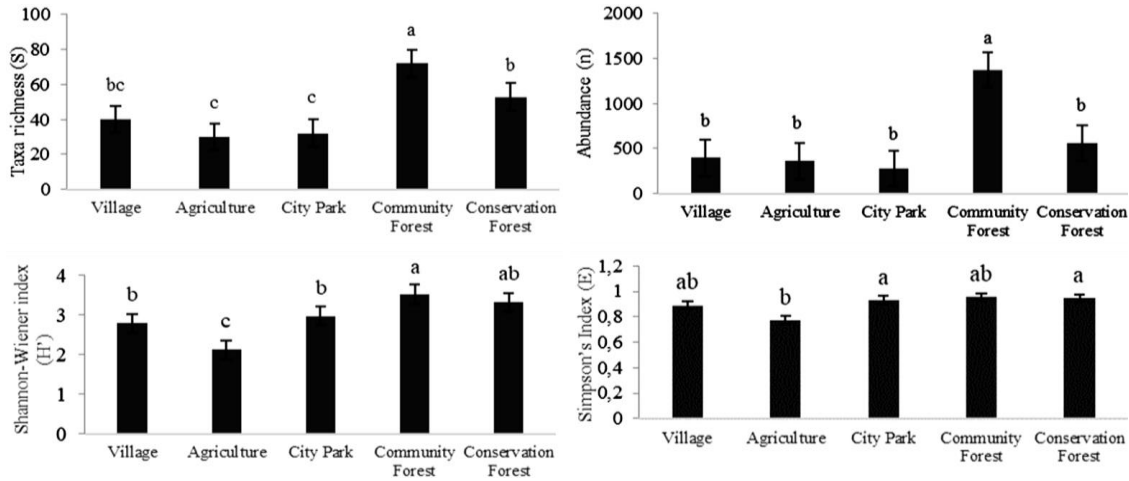
Species	Agriculture		Village		City Park		Community Forest		Conservation Forest	
	Indval (%)	<i>p</i>	Indval (%)	<i>p</i>	Indval (%)	<i>p</i>	Indval (%)	<i>p</i>	Indval (%)	<i>p</i>
<b>Hesperiidae</b>										
<i>Ancistroides</i> sp.	0	1	0	1	0	1	33.33	0.2026	0	1
<i>Borbo</i> sp.	33.33	0.206	0	1	0	1	0	1	0	1
<i>Borobo cinnara</i>	0	1	66.67	0.029	0	1	0	1	0	1
<i>Notocrypta curvifascia</i>	0	1	0	1	0	1	0	1	100	0.0019
<i>Oriens gola</i>	25.64	0.176	35.9	0.084	0	1	2.564	0.731	0	1
<i>Pelopidas</i> sp.	0	1	0	1	8.333	0.520	50	0.053	0	1
<i>Pirdana</i> sp.	0	1	33.33	0.201	0	1	0	1	0	1
<i>Potanthus omaha</i>	40	0.082	0	1	0	1	26.67	0.1553	0	1
<i>Potanthus</i> sp.	0	1	0	1	0	1	0	1	33.33	0.198
<i>Pseudocoladenia dan</i>	0	1	0	1	0	1	50	0.0389	25	0.1534
<i>Suastus gremius</i>	0	1	0	1	33.33	0.203	0	1	0	1
<i>Tagiades ultra</i>	0	1	0	1	0	1	0	1	33.33	0.1975
<i>Telicota augias</i>	0	1	0	1	0	1	33.33	0.1982	0	1
<b>Lycaenidae</b>										
<i>Acytolepis Puspa</i>	0	1	0	1	0	1	33.33	0.2026	0	1
<i>Arhopala centaurus</i>	0	1	6.667	0.741	26.67	0.241	6.667	0.737	6.667	0.7406
<i>Castalius rosimon</i>	0	1	0	1	0	1	33.33	0.1986	0	1
<i>Heliophorus epicles</i>	0	1	0	1	0	1	0	1	100	0.0019
<i>Jamides</i> sp.	0	1	0	1	0	1	50	0.0191	33.33	0.1111
<i>Lampides</i> sp.	0	1	2.778	0.639	0	1	0	1	91.67	0.0035
<i>Leptotes plinius</i>	0	1	12.82	0.272	0	1	61.54	0.0092	0	1
<i>Loxura atymnus</i>	0	1	0	1	0	1	0	1	33.33	0.1948
<i>Luthrodes pandava</i>	4.255	0.489	8.511	0.401	0	1	80.85	0.0103	0	1
<i>Miletus</i> sp.	0	1	0	1	0	1	33.33	0.1982	0	1
<i>Nacaduba</i> sp.	0	1	0	1	16.67	0.377	0	1	16.67	0.3686
<i>Prosotas dubiosa</i>	0	1	0	1	0	1	0	1	33.33	0.1975
<i>Ramelana jangala</i>	0	1	0	1	33.33	0.203	0	1	0	1
<i>Udara akasa</i>	0	1	0	1	0	1	0	1	100	0.0019
<i>Udara</i> sp.	0	1	0	1	0	1	0	1	33.33	0.1948
<i>Zizina otis</i>	0	1	1.333	0.737	7.556	0.421	73.33	0.0087	0	1
<i>Zizula hylax</i>	0.2331	0.880	49.65	0.027	8.159	0.540	25.17	0.1628	0	1
<b>Nymphalidae</b>										
<i>Acraea issoria</i>	0	1	0	1	0	1	0	1	33.33	0.1948
<i>Acraea tepsicore</i>	44.44	0.087	0	1	11.11	0.512	0	1	0	1
<i>Amanthusia pidippus</i>	0	1	33.33	0.201	0	1	0	1	0	1
<i>Ariadne ariadne</i>	0	1	33.33	0.200	0	1	0	1	0	1
<i>Chersonesia rahria</i>	0	1	0	1	0	1	100	0.0022	0	1
<i>Cupha erymanthis</i>	0	1	33.33	0.206	0	1	0	1	0	1
<i>Cyrestis lutea*</i>	0	1	0	1	0	1	0	1	66.67	0.0284
<i>Danaus chrysippus</i>	77.97	0.002	2.26	0.671	0.565	0.833	11.3	0.3663	0	1
<i>Dichorragia nesimachus</i>	0	1	0	1	0	1	0	1	33.33	0.1975
<i>Discophora celinde</i>	0	1	33.33	0.201	0	1	0	1	0	1
<i>Dolescalia bisaltidae</i>	11.11	0.577	18.52	0.370	18.52	0.377	27.78	0.1464	0	1
<i>Elimnias hypermnestera</i>	1.55	0.931	16.28	0.382	26.36	0.173	41.86	0.0399	0	1
<i>Euploea climena</i>	0	1	0	1	0	1	7.692	0.444	88.46	0.0035
<i>Euploea core</i>	0	1	62.5	0.013	0	1	25	0.179	0	1
<i>Euploea corrina</i>	0	1	0	1	100	0.002	0	1	0	1
<i>Euploea eleusina</i>	0	1	33.33	0.206	0	1	0	1	0	1
<i>Euploea eunice</i>	0	1	0	1	0	1	0	1	66.67	0.0284
<i>Euploea mulciber</i>	26.32	0.163	3.509	0.816	0	1	63.16	0.0094	0	1
<i>Euthalia aconthea</i>	0	1	100	0.002	0	1	0	1	0	1
<i>Euthalia malaccana</i>	0	1	0	1	0	1	0	1	33.33	0.1975
<i>Euthalia</i> sp.	0	1	0	1	0	1	33.33	0.2026	0	1
<i>Faunis canens</i>	0	1	0	1	0	1	0	1	66.67	0.0266
<i>Hypolimnas anomala</i>	0	1	0	1	0	1	33.33	0.2026	0	1
<i>Hypolimnas bolina</i>	3.922	0.828	32.35	0.099	44.12	0.037	7.843	0.6675	0	1
<i>Hypolimnas missippus</i>	66.67	0.032	0	1	0	1	0	1	0	1
<i>Ideopsis gaura</i>	0	1	0	1	0	1	0	1	100	0.0019
<i>Ideopsis juventa</i>	0	1	0	1	0	1	100	0.0022	0	1
<i>Ideopsis vulgaris</i>	0	1	0	1	0	1	66.67	0.0291	0	1
<i>Junonia almana</i>	9.677	0.303	1.075	0.789	0	1	58.06	0.0417	0	1
<i>Junonia atlites</i>	6.061	0.545	1.515	0.775	6.061	0.556	45.45	0.05	0	1

<i>Junonia erigone</i>	0	1	0	1	0	1	33.33	0.1986	0	1
<i>Junonia hedonia</i>	0	1	0.5602	0.611	0	1	98.32	0.0022	0	1
<i>Junonia iphita</i>	0	1	0	1	0	1	99.36	0.0022	0.2123	0.6366
<i>Junonia orithya</i>	40	0.078	0	1	0	1	13.33	0.3716	0	1
<i>Lete confusa</i>	0	1	0	1	0	1	0	1	33.33	0.1948
<i>Lete minerva</i>	0	1	0	1	0	1	33.33	0.199	0	1
<i>Melanitis leda</i>	11.11	0.507	11.11	0.520	0	1	11.11	0.524	0	1
<i>Mycalesis horsfieldi</i>	0	1	0	1	0	1	100	0.002	0	1
<i>Mycalesis janardana</i>	0	1	0	1	0	1	100	0.002	0	1
<i>Mycalesis perseus</i>	0	1	2.083	0.641	0	1	93.75	0.002	0	1
<i>Mycalesis sudra*</i>	0	1	0	1	0	1	52.94	0.019	47.06	0.029
<i>Neptis hylas</i>	0	1	11.11	0.513	10.58	0.535	63.49	0.002	6.349	0.747
<i>Neptis vikasi</i>	0	1	0	1	0	1	63.16	0.029	1.754	0.517
<i>Orsotriaena medus</i>	0	1	0	1	0	1	100	0.002	0	1
<i>Paedhima columella</i>	38.71	0.069	6.452	0.683	35.48	0.075	5.376	0.7	0	1
<i>Phalanta phalantha</i>	66.67	0.028	0	1	0	1	0	1	0	1
<i>Pantoporia hordonia</i>	0	1	0	1	0	1	66.67	0.029	0	1
<i>Parantica albata</i>	0	1	0	1	0	1	0	1	33.33	0.198
<i>Polyura hebe</i>	0	1	33.33	0.2007	0	1	0	1	0	1
<i>Symbrenthia anna</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Symbrenthia hypselis</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Symbrenthia lilaea</i>	0	1	0	1	0	1	0	1	33.33	0.198
<i>Tanaecia japis</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Tanaecia palguna</i>	0	1	0	1	0	1	0	1	33.33	0.198
<i>Tanaecia pelea</i>	0	1	0	1	66.67	0.030	0	1	0	1
<i>Tanaecia sp.</i>	0	1	0	1	0	1	33.33	0.199	0	1
<i>Vagrans egista</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Yoma sabina</i>	0	1	0	1	0	1	66.67	0.029	0	1
<i>Ypthima baldus</i>	0	1	0	1	0	1	89.83	0.006	6.78	0.396
<i>Ypthima horsfieldii</i>	0	1	0	1	0	1	100	0.002	0	1
<i>Ypthima nigricans*</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Ypthima pandocus</i>	0	1	0	1	0	1	52.94	0.023	47.06	0.028
<i>Ypthima philomela</i>	0	1	9.524	0.393	0	1	71.43	0.008	0	1
<b>Papilionidae</b>										
<i>Atrophaneura priapus</i>	0	1	0	1	0	1	0	1	66.67	0.027
<i>Graphium agamemnon</i>	64.91	0.002	8.772	0.611	21.05	0.301	1.462	0.940	0.292	0.981
<i>Graphium doson</i>	0	1	0	1	44.44	0.086	11.11	0.514	0	1
<i>Graphium sarpedon</i>	0	1	0	1	18.18	0.220	3.03	0.737	42.42	0.041
<i>Pacliopta adamas*</i>	0	1	0	1	0	1	100	0.002	0	1
<i>Papilio demoleus</i>	33.33	0.075	14.81	0.468	25.93	0.119	1.852	0.919	0	1
<i>Papilio helenus</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Papilio memnon</i>	0.641	0.978	61.54	0.002	15.38	0.413	21.15	0.272	0	1
<i>Papilio polytes</i>	18.18	0.362	51.52	0.021	8.081	0.740	10.1	0.604	1.01	0.992
<i>Troides amphrysus**</i>	0	1	0	1	0	1	0	1	33.33	0.198
<i>Troides cuneifera**</i>	0	1	0	1	0	1	0	1	100	0.002
<i>Troides helena**</i>	0	1	0	1	0	1	76.67	0.002	23.33	0.165
<b>Pieridae</b>										
<i>Appias albina</i>	33.33	0.206	0	1	0	1	0	1	0	1
<i>Appias olferna</i>	0.5848	0.870	83.33	0.002	3.509	0.647	6.433	0.566	0	1
<i>Appias sp.</i>	0	1	0	1	0	1	66.67	0.029	0	1
<i>Appias lyncida</i>	66.67	0.028	0	1	0	1	0	1	0	1
<i>Catopsilia pomona</i>	5.128	0.826	30.77	0.134	26.92	0.168	23.08	0.229	0	1
<i>Catopsilia scyla</i>	0	1	4.762	0.548	9.524	0.348	38.1	0.071	0	1
<i>Cepora iudith</i>	0	1	0	1	0	1	5.556	0.379	27.78	0.195
<i>Delias belisama</i>	0	1	0	1	3.03	0.517	27.27	0.203	3.03	0.520
<i>Delias hyparete</i>	8.333	0.429	12.5	0.277	45.83	0.121	0	1	0	1
<i>Delias periboea</i>	0	1	0	1	97.22	0.002	0	1	0.926	0.606
<i>Eurema blanda</i>	0	1	0	1	0	1	7.619	0.366	77.14	0.005
<i>Eurema hecabe</i>	1.058	0.97	12.7	0.560	0.3527	0.991	44.44	0.048	40.21	0.064
<i>Eurema sari</i>	71.15	0.007	0	1	0	1	0.160	0.875	28.37	0.130
<i>Eurema sp.</i>	0	1	0	1	33.33	0.204	0	1	0	1
<i>Eurema tilaha</i>	0	1	0	1	0	1	44.44	0.085	22.22	0.136
<i>Hebomoia glaucippe</i>	0	1	0	1	0	1	100	0.002	0	1
<i>Leptosia nina</i>	0.4167	0.905	18.75	0.236	0.8333	0.889	78.12	0.004	0.208	0.977
<i>Pithecopis corvus</i>	0	1	0	1	0	1	70.83	0.015	29.17	0.136
<b>Riodinidae</b>										
<i>Zemeros fleygas</i>	0	1	0	1	0	1	33.33	0.199	0	1

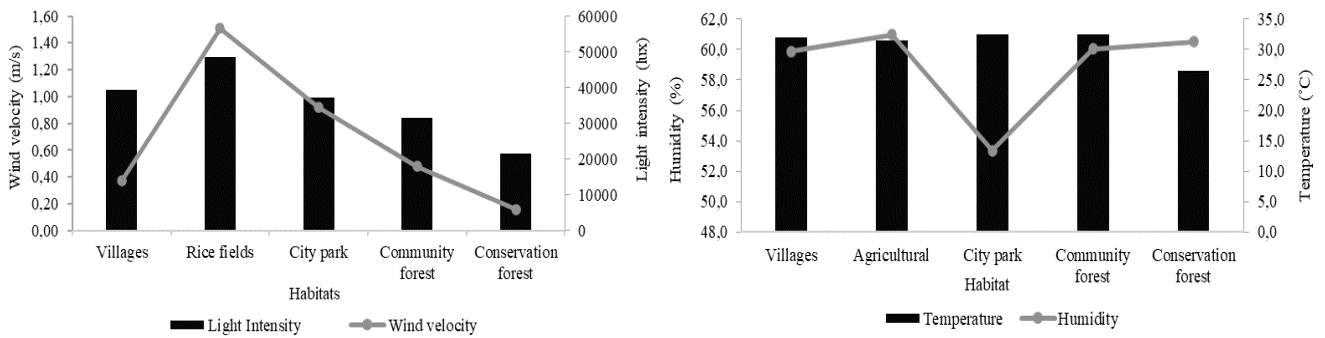
Note: The mark \*: Endemic species, \*\*: Protected species

**Table 3.** Butterfly diversity indices for each habitat

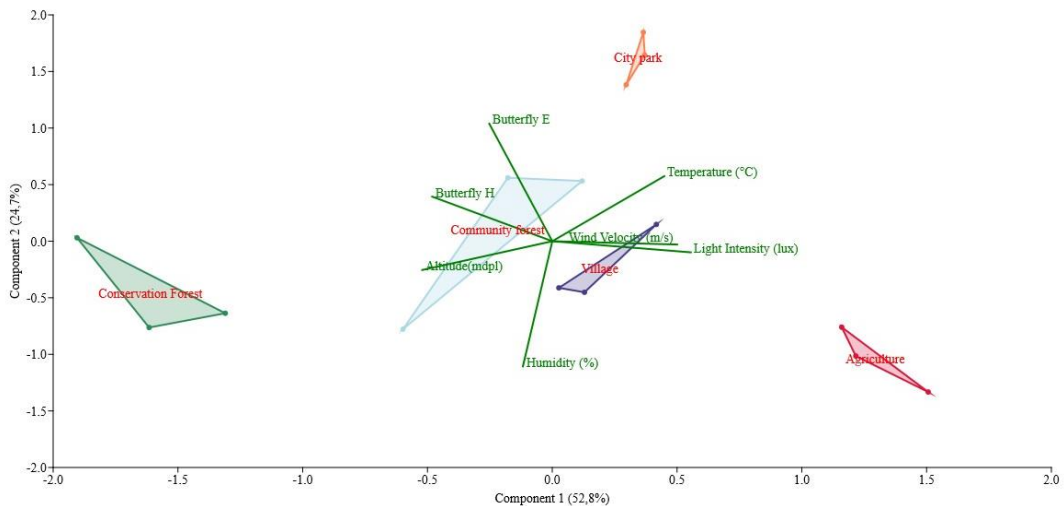
Diversity indices	Village	Agriculture	City Park	Community Forest	Conservation Forest
Taxa richness (S)	40	30	32	72	53
Abundance (n)	397	360	280	1372	559
Shannon-Wiener (H')	2.79	2.12	2.98	3.51	3.32
Evenness (E)	0.41	0.30	0.62	0.47	0.52



**Figure 3.** Butterfly diversity indices across habitats. Note: The same letter in the same diversity indices is significantly different according to Tukey's test at the 95% confidence level



**Figure 4.** Environmental factor values



**Figure 5.** PCA biplot of the correlation between species diversity and environmental factors. H: Diversity index, E: Evenness Index

**Table 4.** The calculation of environmental factors with the Kruskal Wallis test

	T	H	WV	LI	ALT
chi-square	8.607	7.067	13.987	11.433	13.5
df	4	4	4	4	4
p-value	0.072	0.132	0.017	0.022	0.009

Note: Environmental factors. T: Temperature, H: Humidity, WV: Wind Velocity, LI: Light Intensity, ALT: Altitude

## Discussion

The number of species of butterflies found in Lumajang is higher compared to similar studies in other areas of Java, Indonesia, such as Ledokombo Hillocks Jember (34 species) (Mubarok et al. 2023), Mount Muria Kudus, Central Java (40 species) (Sukma et al. 2021), Selorejo Waterfall Area, Ponorogo, East Java (26 species) (Zulaikha and Susanto 2021), Sumber Clangap and Waduk Selorejo, East Java (22 species) (Ashari et al. 2019), Baluran National Park, East Java (63 species) (Leo et al. 2016), green spaces in Malang and Pasuruhan, East Java (67 species) (Leksono et al. 2016), Mount Slamet, Central Java (99 species) (Widhiono 2015), Pasirlangu Village, Puncak Cisarua, Bandung, West Java (45 species) (Septianella et al. 2015). Suaka Elang (Raptory Sanctuary) Mount Halimun Salak National Park in West Java (40 species) (Murwitaningsih and Dharma 2014). The difference in the number of species of butterflies obtained is due to the difference in the study site, period (season) of study, and other environmental factors. The differences in the location of the study range from the area, altitude, type of habitat, and vegetation at each location. Periods or seasons of every study area also differ; this study was carried out in the rainy season near the raining-times, while other studies were those carried out when the rainy season shifts (Mubarok et al. 2023); seasonal differences affect the butterfly microhabitat (Koneri et al. 2020). Another environmental factor that influences the number of species of butterflies is the environmental disturbance caused by anthropogenic factors; the study conducted by Basri and Zakaria (2021) mentioned that environmental disruption could affect the number of species of butterflies significantly.

The butterfly species composition in each family in Lumajang is also different; in this study, the Nymphalidae family has the highest number of species and individuals among other families. Another study found that the Nymphalidae family is more dominant in urban areas (Azizah et al. 2021) and other forest areas (Widhiono 2015; Rusaman 2016). That is because the Nymphalidae family is a family type in which many species are polyphagous, so they can survive even if the main host plant is unavailable. In addition, the imago population of the Nymphalidae family is not only dependent on the availability of nectar from flowering plants (its source of nutrition) but also be found in rotting plants, fruits, and animals' urine. Host plants of the Nymphalidae family dominate the site of the study, consisting of *M. indica* (Anacardiaceae), *P. indicus* (Fabaceae), *E. capillifolium* (Asteraceae), *Ficus* spp. (Moraceae), and Malvaceae (Table 1). This result is

consistent with other studies that mention the host plants of the family Nymphalidae are Fabaceae, Annonaceae, Asteraceae, Verbenaceae, Moraceae, Rubiaceae, Malvaceae, and Anacardiaceae (Koneri et al. 2022). In addition, the Nymphalidae family has a broad distribution and the highest number of species than other families (Koneri et al. 2022). Meanwhile, the Riodinidae family found only one species and one individual, *Zemeros flegyas* (Cramer, 1780), in the Community Forest area. That is due to the narrow distribution of species in the family Riodinidae. The family is most common in the Neotropical region, which accounts for about 95% of the total species found only in the region (Siewert et al. 2014). About 40 species are found in Indonesia (Rusman et al. 2016).

Three species of the *Troides* genus found are protected species; these species consist of *T. helena*, *T. cuneifera*, and *T. amphrysus* (Peggie 2011). These species are protected by law Regulation of the Ministry of Environment and Forests of the Republic of Indonesia No. P.20/MENLHK/SETJEN/KUM.1/6/2018. In addition to being protected by law, three of these species listed in Appendix II have status in Cites and are Least Concern in IUCN (Böhm et al. 2018). Meanwhile, *T. helena* is Moderately Depleted (MD) in the Green Status IUCN (Sultana and Chowdhury 2021). In addition, several endemic species were found in this study, consisting of *C. lutea*, *M. sudra*, *Y. nigricans*, and *Y. horsfieldii* are endemic species of Java-Bali and *Parantiaca albata* (Zincken, 1831) and *P. adamas* are endemic species of Java. In addition, *P. adamas* previously belonged to *P. aristolochiae*, and then separation was proposed (Page and Tradeway 1995; Peggie et al. 2021).

The evenness, diversity, abundance, and taxa richness of butterflies in each habitat in Lumajang is different (Figure 3). The differences are because butterflies' activity, growth, reproduction, and even distribution depend on environmental factors (Jacquier et al. 2020; Koneri et al. 2022). The Community Forest was the habitat with the most butterfly species than other study sites. The Community Forest is a secondary forest with complex vegetation because it utilizes land by combining forestry and agriculture. Vegetations found in this habitat include *P. purpureum* (Poaceae), *M. pudica* (Fabaceae), *T. procumbens* (Asteraceae), and Arecaceae. Butterflies use these plants as larval host plants. The Community Forest also found flowering plants such as *H. tiliaceus* (Malvaceae), *Ipomea* sp. (Convolvulaceae), and *A. leptopus* (Polygonaceae), which make good habitats for butterflies to find nectar. Although the variation and heterogeneity, Conservation Forest have the second-highest number of species after Community Forest 30 species (24% from all study sites) are found there. The dominant families of vegetation in Conservation Forest are Malvaceae, Meliaceae, Moraceae, Fabaceae, and Urticaceae. This vegetation becomes a host plant for the butterfly species found. For example, plants from the Moraceae family are hosts of *Euploea* spp., and plants from the Fabaceae family are hosts of *Eurema* spp. (Rahman et al. 1985; Iqbal et al. 2021).



**Figure 6.** Photos of endemic and protected species. A. *Parantica albata*, B. *Pachliopta adamas*, C. *Cyrestis lutea*, D. *Troides cuneifera*

Furthermore, the presence of butterflies is closely related to the presence of vegetation. Different species of butterflies have adapted to feed on specific plant types, and the presence of these plants is necessary for their survival and reproduction. Therefore, vegetation diversity greatly affects butterfly diversity (Muto-Fujita et al. 2017; Okamura et al. 2019). Some studies show that more butterflies are found in habitats with complex structures and vegetation diversity (Han et al. 2021; Koneri et al. 2022).

In addition, the existence of butterflies also depends on environmental factors. The measurement of environmental factors in each habitat aims to determine the influence and relationship between environmental factors and butterfly diversity. The results of the PCA analysis show that environmental factors greatly influence the diversity and evenness of butterfly species. For example, biplot on PCA analysis shows that temperature is averse to altitude and humidity, which shows that temperature negatively correlates with altitude and humidity. In addition, the index of diversity and evenness of butterflies, as opposed to light intensity and wind velocity, shows a negative correlation (Figure 4). Light intensity that is too low or too high can also affect the presence of butterflies (Liao et al. 2017). Based on these findings, this study's results indicate that butterflies prefer habitats with optimal temperature and humidity, such as Community Forest. Furthermore, butterflies are poikilotherm organisms, so environmental temperature greatly influences their body temperature (Muhelni and Anwar 2020; Comay et al. 2021). Temperature can also affect butterfly activity; for example, high temperatures can cause the volume of secretions in

flowering plants to decrease, resulting in a lack of food intake (Ramesh et al. 2012; Koneri et al. 2022).

Each butterfly species has a different tolerance level, either to host plants or to their environmental conditions. Based on indval analysis, some species in Conservation Forest inhabit forest areas. These species include *Troides* spp., *H. epicles*, *Symbrenthia* spp. and *Euthalia malaccana* (Fruhstorfer, 1899), and *Dichorragia nesimachus* (Boisduval, 1836) (Saha and Das 2012; Mehra et al. 2018; Bhowmik and Chowdhury 2021; Peggie et al. 2021). The result showed that butterflies could be bioindicators either in terms of the diversity of environmental characteristics (abundance and vegetation diversity) or sensitivity to environmental conditions (temperature, humidity, light intensity, wind speed, as well as the presence of pollutants) (Ghazanfar et al. 2016; Comay et al. 2021). This is consistent with some studies showing that several species tolerant to all conditions can be found in all habitat types. On the contrary, some found only in forest habitats tend to have lower tolerance (Forister et al. 2010; Ren et al. 2022).

This study concludes that butterflies' existence depends on their habitat conditions. This study shows a significant difference in the diversity of butterflies at each site. The Community Forest has the highest value of diversity among the other habitats (72 species and 1,372 individuals). This is because this habitat has complex vegetation and optimal environmental conditions for butterfly existence. Meanwhile, Conservation Forest have the second highest diversity rating after Community Forest, and 30 species (24% of the 124 species found) are inhabited only in this habitat. The results also show that some species that can be

considered indicator species in Conservation Forest habitats are native species of forest inhabitants. These species include *Troides* spp., *H. epicles*, *Symbrenthia* spp., and *E. malaccana*. The study also recorded protected species (*T. Helena*, *T. cuneifera*, and *T. amphrysus*) and endemic species (*C. lutea*, *M. sudra*, *Y. nigricans*, *Y. horsfieldii*, *P. albata*, and *P. adamas*). Research on similar things in Lumajang is still limited, so the results of this research can be used as basic data to support the conservation efforts of butterflies in Indonesia, especially in Lumajang, East Java, Indonesia.

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