BIODIVERSITAS
Volume 26, Number 2, February 2025
Pages: 551-563

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260204

Butterfly diversity along an altitudinal gradient and land uses in East Java, Indonesia

AMIN SETYO LEKSONO[1,♥], BAGYO YANUWIADI[1], NAJMATUL MILLAH[1], SAIFUL ARIF ABDULLAH[2,3]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Ketawanggede, Lowokwaru, Malang 65145, East Java, Indonesia. Tel./fax.: +62-341-575841, ♥email: amin28@ub.ac.id

[2]Adjunct Professor at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Ketawanggede, Lowokwaru, Malang 65145, East Java, Indonesia

[3]Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia. 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia

Manuscript received: 1 December 2024. Revision accepted: 3 February 2025.

Abstract. *Leksono AS, Yanuwiadi B, Millah N, Abdullah SA. 2025. Butterfly diversity along an altitudinal gradient and land uses in East Java, Indonesia. Biodiversitas 26: 551-563.* Butterflies are a group of insects that are vulnerable to disturbances due to changes in land use. Land-use changes due to human activities can have negative impacts on insects, including butterflies. This study aims to analyze butterfly diversity at different elevations and land uses in Lumajang, East Java, Indonesia. Butterfly diversity was surveyed using an active visual survey method by adopting Pollard Walk transect. The samplings were made for three months (August to October 2022) in seven sites along an altitudinal gradient. The characteristics of butterfly assemblages in East Java were analyzed in terms of the number of individuals, the species richness, and Shannon's diversity index. A total of 3099 individual butterflies belong to 123 species and six families were observed in seven locations. The abundance of butterflies varied among study sites. The highest species richness and diversity were found in Ranu Bedali, representing forest/plantation areas in lower altitudes, while the lowest was found in Kandangtepus representing an area dominated by arable land. The abundance, species richness, and diversity across elevation and land use differ significantly between locations. In general temperature, light intensity and forests or plantations had positives effect on butterfly abundance, richness, diversity and composition, while humidity, altitude, shrubs or grasses, and agriculture land had negative influences on those butterfly parameters.

Keywords: Climate, elevation, land use mapping, Lepidoptera, visual survey

INTRODUCTION

In the last two decades, butterflies have received significant attention from scientists and general public due to their ecological importance. As members of the insect class, butterflies act as essential indicators of healthy ecosystems (Durairaj and Sinha 2015). Approximately 21,000 butterfly species have been identified globally, with about 80 percent in tropical regions (Stork 2018). Butterflies have a vital role in maintaining ecosystem balance, environmental indicators, and pollinators (Durairaj and Sinha 2015; Syaripuddin et al. 2015; Sharma et al. 2020; Choudhary and Chishty 2020; Millah et al. 2023). However, its current status shows that butterfly biodiversity faces severe threats on a global scale (Warren et al. 2021). There have been several investigations that showed Lepidoptera might disappear quickly, with estimation about 40% of those species possibly going extinct in the next few years (Sánchez-Bayo and Wyckhuys 2019; Theng et al. 2020; Wagner et al. 2021; Chowdhury 2023). Given this alarming threat, butterflies should be prioritized in conservation efforts (Habel et al. 2019). In this regard, study on butterfly species distribution is needed for its protection and conservation.

Studies have revealed that the distribution of butterfly is affected by abiotic factors like altitude and land use (Wagner et al. 2013; Aguirre-Gutierrez et al. 2017; Gallou et al. 2017). Altitude may affect environmental factors such as temperature, humidity, precipitation and vegetation which influence the distribution of butterfly (Wagner et al. 2013; Gallou et al. 2017). Furthermore, changes in natural land use to modified habitats, such as agriculture, small-farm, settlement and urban areas that lead to habitat loss and fragmentation may affect insect richness to decline including butterfly (Picanço et al. 2017; Tzortzakaki et al. 2019; Vasconcelos et al. 2019). Practices that intensely manage vegetation could destroy important habitats, including places for egg-laying and food sources for larvae, which led to less diversity and stability in butterfly populations (Bubová et al. 2015). In addition, changes in land use could have long-term effects on butterfly diversity (Wagner et al. 2013).

Generally, understanding the effect of altitude and land use changes are important for butterfly conservation. In addition, understanding the effect of the relationship between altitude and land use change is also important and has been shown by several studies for example by Gallou et al. (2017) and Wagner et al. (2021). However, more in-depth studies on how altitude and land use changes shape butterfly composition are rare. Furthermore, the distribution of butterfly diversity and species richness along altitudinal gradients remains unexplored in Indonesia because most studies focus on distribution in a few habitats (Azizah et al. 2021; Millah et al. 2023). Java, the most densely populated island in the country, faced significant anthropogenic pressures, including those in mountainous areas (Leksono et al. 2017). Rapid conversion of land functions, especially forests, to cultivated land and settlements has become a serious threat to the balance of the ecosystem and has severely impacted environmental degradation (Abdullah et al. 2022). For instance, several high-altitude areas on Java, with residential areas exceeding 1500 m influenced the diversity of dragonflies and grasshoppers (Leksono et al. 2017, et al. 2020). In this study, variations in land use were analyzed from differences in vegetation cover, settlements, arable land and transportation areas. This study aims to analyze butterfly diversity at different elevations and land uses in Lumajang, East Java, Indonesia. By combining ecological and anthropogenic perspectives, the results were expected to provide valuable insights into the factors influencing butterfly diversity and their implications for biodiversity conservation in tropical areas.

MATERIALS AND METHODS

Study sites

This study was conducted in Lumajang, East Java, Indonesia, from August to October 2022. Lumajang represents an area with diverse altitudes and land uses ranging from the coast to the conservation area of Mount Bromo Tengger Semeru National Park, with a peak reaching an altitude of 3,676 m. The temperature ranges from 20°C to 35°C, and monthly rainfall is 13 to 271 mm. Lumajang is located in a region that has two seasons. The dry season lasts six months, from May to October, and the rainy season lasts from November to April.

This study was located in seven research locations in Lumajang including Pandanarum (PA) 30 m asl (8°15'15.67"S 113°10'46.54"E), City Park (CP) 55 m asl (8°08'07.72"S 113°13'27.13"E), Ranu Bedali (RB) 200 m asl (7°57'09.47"S 113°16'07.47"E), Kandangtepus (KT) 1121 m asl (8°01'48.18"S 113°03'01.10"E), Ireng-ireng (IR) 1132 m asl (8°02'58.93"S 113°01'40.34" E), Danyangan 1352 m asl (8°00'48.76"S 113°01'30.32"E), Argosari m asl (AS) 1807 m asl (7°59'02.92"S 113°01'02.94"E) (Figure 1). The seven study sites were selected based on different land use and altitudes. The selected study sites reflect the areas with the presence of vegetation (forest, plantation, shrub) and human activities (agriculture, park, settlement). Three sites were located in low land (≤500 m asl/above sea level). Those consisted of agriculture land, City Park and area adjacent to lake. City Park (CP) was selected as one of the locations, even though it supports few vegetation cover. Previous studies showed that city parks have an important role as butterfly habitats in urban areas (Leksono et al. 2016; Azizah et al. 2021; Lin et al. 2024). Four sites were located in highland (>1000 m asl). Those consisted of two agriculture lands and two area adjacent to primary forests. Detailed characteristics of study sites was presented in Table 1.

The sampling procedures

At each location, observations were made on three transects of 600 m. Transect was determined based on the existing pathway tracts. Butterfly observations were carried out using the active visual survey method with the Pollard Walk Transect. A preliminary study was carried out to collect and identify the butterflies. This preliminary study aimed to train the observer for identification in the field. Butterfly collection was done using flying net (frame made of aluminum, 90 cm long stem with a diameter of 2.2 cm, net made of gauze, net diameter 38 cm with a length of 75 cm). The efforts in each study sites were done for times. The specimen of butterflies was transferred to the Laboratory of Animal Diversity and Environmental Technology, Universitas Brawijaya, East Java, Indonesia, for species identification. The identification was conducted based on morphological characters. Furthermore, butterfly species identification was carried out using the Kupunesia butterfly application and several identification books by Wilson (2008) and Peggie (2014).

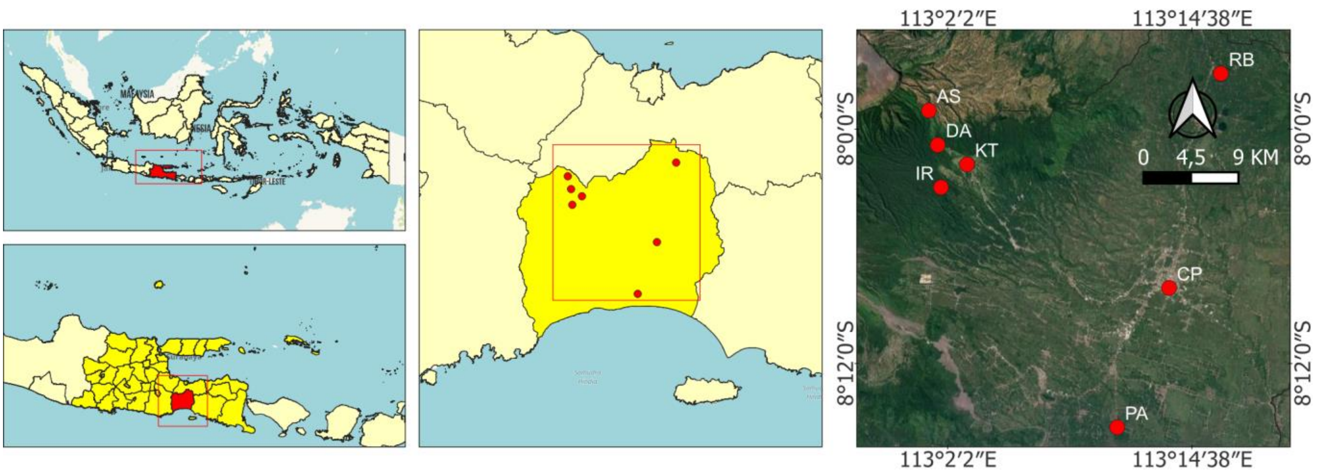

Figure 1. Location of study sites in Lumajang, East Java, Indonesia. Note: PA: Pandanarum; CP: City Park; RB: Ranu Bedali; KT: Kandangtepus; IR: Ireng-ireng; DA: Danyangan; AS: Argosari

Table 1. Characteristics of study sites in Lumajang, East Java, Indonesia

Locations	Altitude (m asl)	Characteristics
Pandanarum (PA)	30	This area is characterized by artificial ecosystem (agriculture area), controlled vegetation, use of fertilizers and pesticides, and high human activity. The vegetation found in this area consisted of tree species such as *Mangifera indica* (Anacardiaceae), *Carica papaya* (Caricaceae), *Citrus* spp. (Rutaceae), and *Acalypha siamensis* (Euphorbiaceae); and ground cover plant including *Pennisetum purpureum* (Poaceae), *Digitaria ciliaris* (Poaceae), *Ipomea* spp. (Convolvulaceae), and *Oryza sativa* (Poaceae),
City Park (CP)	55	This area is characterized by artificial ecosystems, plants selected based on certain functions (air pollution and ground water absorption) and high human activity. The vegetation found in this area consisted of tree species such as *Filicium decipiens* (Sapindaceae), *Mimusops elengi* (Sapotaceae), *Polyathia longifolia* (Annonaceae), *Pterocarpus indicus* (Fabaceae), *Pseuderanthemum reticulatum* (Acanthaceae); and ground cover plants including *Cupressus papuanus* (Cupressaceae), and *Eupatorium capillifolium* (Asteraceae).
Ranu Bedali (RB)	200	This area is considered as the secondary forest mixed with plantation. Some plants grow naturally, the other are cultivated. There are human activities such as traveling, grazing, and fishing. The vegetation found in this area are consisted of tree species such as *Moringa oleifera* (Moringaceae), *Artocarpus heterophyllus* (Moraceae), *Cercis siliquatrum* (Fabaceae), *Persea americana* (Lauraceae); pole species consisted of *Saccarum officinarum* (Poaceae), *Musa paradisiaca* (Musaceae) and *Musa accuminata* (Musaceae); and ground cover plants including *P. purpureum* (Poaceae), *Mimosa pudica* (Fabaceae), *Tridax procumbens* (Asteraceae), *Hibiscus tiliaceus* (Malvaceae), *Ipomea* sp. (Convolvulaceae), *Antigonon leptopus* (Polygonaceae).
Ireng-ireng (IR)	1121	This area is considered as the primary forest and conservation area where plants grow naturally and minimal human activity. They are very diverse, dominated by trees, so the canopy tends to be more closed when compared to other locations. The vegetation found in this area are consisted of tree species such as *Swietenia mahagoni* (Meliaceae), *Ficus* spp. (Moraceae), *Toona sureni* (Meliaceae), *Albizia chinensis* (Fabaceae), Malvaceae and Urticaceae
Kandangtepus (KT)	1132	This area is characterized by artificial ecosystem (agriculture area), controlled vegetation, and moderate human activity. This area is dominated by bush and grass vegetation, with few scattered trees. The predominant types of shrubs and grasses include *Centella asiatica* (Apiaceae), *Euphatorium odoratum* (Asteraceae) and *Imperata cylindrica* (Poaceae). There are only a few types of trees, these include *P. americana* (Lauraceae), *Casuarina junghuhniana* (Casuarinaceae), and *Albizzia lophanta* (Fabaceae).
Danyangan (DA)	1352	This area is considered as the primary forest and conservation area where plants grow naturally and minimal human activity. They are very diverse, dominated by trees, so the canopy tends to be denser. The vegetation found in this area are consisted of tree species such as Malvaceae, *S. mahagoni* (Meliaceae), *Ficus* spp. (Moraceae), *T. sureni* (Meliaceae), *A. chinensis* (Fabaceae), Urticaceae, Fagaceae and other Moraceae species.
Argosari (AS)	1807	This area is characterized by artificial ecosystem (agriculture area), controlled vegetation, and high human activity. This area is dominated by bush and grass vegetation, with few scattered trees. The predominant types of shrubs and grasses include *Anaphalis longifolia* (Asteraceae), *C. asiatica* (Apiaceae), *Pteris* sp. (Pteridaceae), *E. odoratum* (Asteraceae) and *I. cylindrica* (Poaceae). There are only a few types of trees, these include *C. junghuhniana* (Casuarinaceae), *Vaccinium varingifolium* (Ericaceae), and *A. chinensis* (Fabaceae).

The Pollard Walk transect was visualized in a 5 × 5 × 5 m box in front of the observer by walking constantly along a fixed route (Fang et al. 2023). The number of observers was four people, two persons observed in one location on the same day, so observations at other locations were carried out the next day. At each location, observations were made by two people, one person was tasked with making observations and the other one recorded the results of the observations. At the same time, observations were made at two locations, so it took 4 days to observe all locations. The observers stopped every 10 m distance in transect, and butterflies were spotted, identified, tallied, and recorded. Samplings were carried out two hours per plot, starting from 08.00 to 10.00; 10.30 to 12.30 and 13.30 to 15.30 in the afternoon. The transect order was cycled every week, for example in the first week, the order was 08.00 to 10.00 (transect I); 10.30 to 12.30 (transect II) and 13.30 to 15.30 (transect III), while in the second week the order was 08.00 to 10.00 (transect II); 10.30 to 12.30 (transect III) and 13.30 to 15.30 (transect I), and so forth. The observations were repeated five times every two weeks.

Observations of butterflies included species identification and counting the number of individuals. Environmental factors were measured by measuring air temperature and humidity using a thermo-hygrometer, light intensity using a lux meter, wind speed using an anemometer, and altitude using a Global Positioning System (GPS). Air temperature, humidity, light intensity and wind speed were measured at the base and end points of each transect.

Data analysis

The butterfly species richness, evenness, diversity, and composition were calculated based on the number of individuals. Species richness was analyzed based on the number of species, diversity was analyzed using the Shannon-Wiener index, dominance was analyzed using the Simpson index and rarefaction was analyzed using the Coleman formula, while similarity in butterfly composition between locations were compared with the Bray-Curtis index (Choudhary et al. 2020; Freitas et al. 2021).

The differences in species richness, evenness, and diversity between locations were tested by one-way analysis of variance. Before the normality difference test was carried out, the data were tested using the Kolmogorov-Smirnov test. The test results showed that the data were not normally distributed. Data on the abundance, species richness, and diversity were normally distributed after log transformation, while dominance data were not normally distributed after several methods of transformation. Therefore, the abundance, species richness, and diversity were analyzed using a one-way analysis of variance, while the dominance was analyzed using a Kruskal Wallis non-parametric test. Land use data was analyzed by ArcGIS, using Landsat imagery 8. The analysis was carried out on a circular area with a radius of 0.5 km. Land use analysis was carried out with criteria referring to the Indonesian National Standard. The relationship between butterfly composition and environmental factors was analyzed using Canonical Correspondence Analysis (CCA). Variables explaining most of the variation in the data were used to construct the final model. Rare species (less than ten individuals) were excluded from these analyses, because the rare species distribution was sparse and less representative of habitat preferences (Leksono et al. 2017). The environmental factors were categorical variables. The statistical validity of derived canonical axes was evaluated. All statistical analyses were performed using PAlaeontological Statistics (PAST) ver 4.04.

RESULT AND DISCUSSION

A total of 3099 individual butterflies comprising 123 species and six families were observed in seven locations. The five dominant species were *Eurema hecabe* (24.36%), *Ypthima pandocus* (5.94%), *Leptosia nina* (4.9%), *Junonia iphita* (4.81%), and *Zizula hylax* (4.58%) (Table 1). Several species such as *E. hecabe*, *Graphium sarpedon*, *Mycalesis sudra*, *Neptis hylas*, *Papilio memnon*, *Y. pandocus*, *Catopsilia pomona*, *Graphium agamemnon*, *Zizina otis* have wide distribution, while the others (more than 70%) have narrow distribution (collected in less than 3 locations). A total of 57 species were even found solely on a site. Most were specific in Ranu Bedali, but some were found only in Ireng-ireng and Argosari. The former consisted of *Junonia hedonia*, *Luthrodes pandava*, *Mycalesis horsfieldi*, *Mycalesis janardana*, *Mycalesis perseus*, *Orsotriaena medus*, *Pachliopta adamas*, *Ypthima horsfieldii*, *Ypthima philomela*, whereas the latter consisted of *Cyrestis lutea*, *Ideopsis gaura*, *Notocrypta curvifascia*, *Symbrenthia anna*, *Vagrans egista*, *Ypthima nigricans*, and *Vanessa cardui* (Table 2).

Land use variability surrounding the study sites

Land use analysis showed that Forest or plantation dominated land use in Pandanarum (56.33%), Ranu Bedali (48.52%), Ireng-ireng (99.30%) and Danyangan (85.66%). Those in Kandangtepus and Argosari were dominated by arable land, while City Park was dominated by residential areas (72.74%) (Table 3). Among the land uses, forests or plantations, shrubs or grasses, arable lands, settlements, and traffic areas exist in all locations, while cemeteries, water bodies (lakes or rivers), and recreational areas or parks only exist on some sites.

The abundance, species richness, and diversity across elevation and land use

The abundance of butterflies varied among study sites. Average abundance fluctuated along an altitudinal gradient. These decreased from Pandanarum to City Park, then increased in Ranu Bedali. It increased again in Ireng-ireng and then decreased gradually from Ireng-ireng to Argosari. The same trend occurred for species richness and diversity. The most incredible abundance was found in Ranu Bedali (86.93±6.91), while the lowest was in Kandangtepus (4.6±0.75). The highest species richness and diversity were found in Ranu Bedali (richness: 24.33±1.06 and H': 2.83±0.07) (Figures 2 and 3), while the lowest was found in Kandangtepus (richness: 2.8±0.3 and H': 0.87±0.11). The abundance, species richness, and diversity across elevation and land use significantly varied among study sites (Table 4).

Rarefaction result

Results of data interpolation using rarefaction analyses indicated that the expected number of species ranges from 11 to 32. The rarefaction curve slope was steepest for Ranu Bedali (RB), followed by Ireng-ireng (IR), Pandanarum (PA), City Park (CP), Danyangan (DY), Argosari (AS) and Kandangtepus (KT). The results of the analysis estimate the expected number of species for a given minimum sample size (69 individuals), showed the number of species collected at Station RB: 31.7 (32 species), IR: 26.3 (26 species), PA: 22.6 (23 species), CP: 20.9 (21 species), DY: 19.1 (19 species), AS: 13 species, KT: 11 species (Figure 3).

Correlations between butterfly abundance, species richness, species diversity and environmental factors

The data analysis from all study sites showed that the temperature ranged from 21º to 30ºC, humidity from 60% to 73%, wind speed from 0.1 to 3.3 m/s, and light intensity from 2.2 to 309.25 KLux. The temperature had significant positive correlation with butterfly abundance (r: 0.473, $p\leq 0.05$), species richness (r: 0.523, $p\leq 0.01$), and diversity (r: 0.523, $p\leq 0.01$). Humidity had negatively correlation with diversity (r: -0.507, $p\leq 0.01$). Light intensity had significant positive correlation with butterfly abundance (r: 0.420, $p\leq 0.05$).

Table 2. List of all observed species from seven study sites in Lumajang, East Java, Indonesia

Species name	IUCN status	Sites							Total
		PA	CP	RB	KT	IR	DY	AS	
Eurema hecabe (Linnaeus, 1758) (**)	LC	22	2	76	12	76	46	1	235
Ypthima pandocus (Moore, 1857) (***)	NE	0	0	29	22	24	95	14	184
Leptosia nina (Fabricius, 1793) (***)	NE	24	2	125	0	1	0	0	152
Junonia iphita (Cramer, 1782) (***)	NE	0	0	148	0	1	0	0	149
Zizula hylax (Fabricius, 1775) (***)	LC	74	30	38	0	0	0	0	142
Zizina otis (Fabricius, 1787) (*)	LC	3	15	59	8	0	5	0	90
Appias olferna (Swinhoe, 1890) (***)	NE	66	6	11	0	0	0	0	83
Pithecops corvus (Fruhstorfer, 1919) (***)	NE	0	0	53	0	21	0	0	74
Elymnias hypermnestra (Linnaeus, 1763) (***)	NE	10	30	33	0	0	0	0	73
Junonia almanac (Linnaeus, 1758) (***)	LC	46	0	25	0	0	0	1	72
Neptis hylas (Linnaeus, 1758)	NE	6	10	40	0	6	7	1	70
Mycalesis sudra (Felder, 1867)	NE	0	0	18	5	16	28	1	68
Junonia hedonia (Linnaeus, 1764)	NE	2	0	62	0	0	0	0	64
Ypthima baldus Fabricius, 1775	NE	0	0	55	0	6	0	0	61
Eurema sari (Horsfield, 1829)	NE	0	0	1	0	59	0	0	60
Catopsilia pomona (Fabricius, 1775)	NE	9	7	9	10	0	0	23	58
Udara akasa (Horsfield, 1828)	NE	0	0	0	0	44	10	4	58
Junonia atlites (Linnaeus, 1763)	NE	37	4	15	0	0	0	0	56
Vanessa cardui (Linnaeus, 1758)	LC	0	0	0	0	0	0	56	56
Troides cuneifera (Oberthür, 1879)	LC	0	0	0	0	22	25	8	55
Papilio memnon (Linnaeus, 1758)	LC	25	8	11	2	0	3	4	53
Papilio polytes (Linnaeus, 1758)	NE	18	4	29	0	1	0	0	52
Ypthima horsfieldii (Moore, 1884)	NE	0	0	50	0	0	0	0	50
Parantica sp.	NE	0	0	0	0	0	10	37	47
Luthrodes pandava (Horsfield, 1829)	NE	6	0	37	0	0	0	0	43
Troides helena (Linnaeus, 1758)	LD	0	0	23	0	17	0	0	40
Pachliopta adamas (Zincken, 1831)	LC	0	0	38	0	0	0	0	38
Eurema blanda (Boisduval, 1836)	NE	0	0	8	0	27	1	0	36
Graphium agamemnon (Linnaeus, 1758)	NE	7	20	5	0	1	1	0	34
Delias periboea (Godart, 1819)	LC	0	32	0	0	1	0	0	33
Euploea climena (Stoll, 1782)	NE	0	0	3	0	23	7	0	33
Chersonesia rahria (Westwood, 1857)	NE	0	0	30	0	0	0	0	30
Danaus chrysippus (Linnaeus, 1758)	LC	19	1	10	0	0	0	0	30
Ideopsis gaura (Horsfield, 1829)	NE	0	0	0	0	28	0	0	28
Hypolimnas bolina (Linnaeus, 1758)	NE	9	14	4	0	0	0	0	27
Appias epaphia (Cramer, 1779)	LC	0	0	0	0	0	24	0	24
Euploea core (Cramer, 1780)	LC	2	18	3	0	0	0	0	23
Delias aurantiaca (Doherty, 1891)	NE	0	0	0	2	0	3	17	22
Ideopsis juventa (Cramer, 1777)	NE	0	0	20	1	0	0	0	21
Hebomoia glaucippe (Linnaeus, 1758)	NE	0	0	19	0	0	0	1	20
Pseudocoladenia dan (Fabricius, 1787)	NE	0	0	15	0	5	0	0	20
Neptis vikasi (Horsfield, 1829)	NE	0	0	18	0	1	0	0	19
Lampides boeticus (Linnaeus, 1767)	LC	0	0	0	0	0	4	13	17
Graphium sarpedon (Linnaeus, 1758)	LC	0	3	1	0	7	3	2	16
Mycalesis perseus (Fabricius, 1775)	NE	1	0	15	0	0	0	0	16
Orsotriaena medus (Fabricius, 1775)	NE	0	0	16	0	0	0	0	16
Phaedyma columella (Cramer, 1782)	NE	0	11	5	0	0	0	0	16
Appias lyncida (Cramer, 1779)	NE	1	0	14	0	0	0	0	15
Catopsilia scylla (Linnaeus, 1763)	-	1	2	4	0	0	8	0	15
Delias hyparete (Linnaeus, 1758)	NE	3	11	0	0	0	0	0	14
Mycalesis janardana (Moore, 1857)	LC	0	0	14	0	0	0	0	14
Symbrenthia anna (Semper, 1888)	NE	0	0	0	0	14	0	0	14
Ypthima philomela (Linnaeus, 1763)	NE	4	0	10	0	0	0	0	14
Eurema tilaha (Horsfield, 1829)	NE	0	0	6	0	3	4	0	13
Papilio demoleus (Linnaeus, 1758)	NE	3	7	1	0	0	2	0	13
Vagrans egista (Cramer, 1780)	NE	0	0	0	0	13	0	0	13
Doleschalia bisaltide (Cramer, 1777)	NE	2	5	5	0	0	0	0	12
Notocrypta curvifascia (C.Felder & R.Felder, 1862)	NE	0	0	0	0	12	0	0	12
Euploea eunice (Godart, 1819)	NE	0	0	0	2	8	0	1	11
Euploea mulciber (Cramer, 1777)	NE	1	0	10	0	0	0	0	11
Cyrestis lutea (Zincken, 1831)	NE	0	0	0	0	10	0	0	10
Delias belisama (Cramer, 1779)	NE	0	1	8	0	1	0	0	10
Mycalesis horsfieldi (Moore, 1892)	NE	0	0	10	0	0	0	0	10

Ypthima nigricans (Snellen, 1892)	NE	0	0	0	0	10	0	0	10
Heliophorus epicles (Godart, 1823)	NE	0	0	0	0	9	0	0	9
Jamides celeno (Cramer, 1775)	NE	0	0	0	0	0	9	0	9
Jamides sp.	LC	0	0	5	0	4	0	0	9
Papilio helenus (Linnaeus, 1758)	LC	0	0	0	0	9	0	0	9
Symbrenthia hypselis (Godart, 1823)	LC	0	0	0	0	8	1	0	9
Atrophaneura priapus (Boisduval, 1836)	LC	0	0	0	1	2	5	0	8
Leptotes plinius (Fabricius, 1793)	NE	0	0	8	0	0	0	0	8
Oriens gola (Moore, 1877)	NE	7	0	1	0	0	0	0	8
Poritia erycinoides (Felder, 1865)	NE	0	0	0	0	0	8	0	8
Euthalia monina Fabricius, 1787	NE	0	0	7	0	0	0	0	7
Ideopsis vulgaris (Butler, 1874)	LC	0	0	7	0	0	0	0	7
Pantoporia hordonia (Stoll, 1790)	NE	0	0	7	0	0	0	0	7
Cepora iudith (Fabricius, 1787)	NE	0	0	1	0	5	0	0	6
Euthalia aconthea Cramer, 1779	NE	6	0	0	0	0	0	0	6
Tanaecia japis (Godart, 1823)	NE	0	0	0	0	6	0	0	6
Appias nero (Fabricius, 1793)	NE	0	0	0	0	0	0	5	5
Arhopala centaurus (Fabricius, 1775)	NE	1	2	1	0	1	0	0	5
Castalius rosimon (Fabricius, 1775)	NE	0	0	5	0	0	0	0	5
Faunis canens (Hübner, 1826)	NE	0	0	0	0	5	0	0	5
Lampides sp.	LC	1	0	0	4	0	0	0	5
Lethe confuse (Aurivillius, 1897)	-	0	0	0	0	1	4	0	5
Tanaecia pelea (Fabricius, 1787)	LC	0	5	0	0	0	0	0	5
Borobo cinnara (Wallace, 1866)	NE	4	0	0	0	0	0	0	4
Graphium doson (Felder & Felder, 1864)	NE	0	2	1	0	0	1	0	4
Pelopidas sp.	LC	0	1	3	0	0	0	0	4
Phaedyma sp.	NE	4	0	0	0	0	0	0	4
Pothantus omaha (Edwards, 1863)	NE	0	0	2	0	1	1	0	4
Tagiades ultra (Evans, 1932)	NE	0	0	0	0	2	2	0	4
Acraea issoria (Hübner, 1816)	NE	0	0	0	0	0	2	1	3
Acraea terpsicore (Linnaeus, 1758)	NE	1	1	0	0	0	1	0	3
Miletus symethus (Cramer, 1779)	NE	0	0	3	0	0	0	0	3
Suastus gremius (Fabricius, 1798)	NE	0	3	0	0	0	0	0	3
Acytolepis puspa (Horsfield, 1828)	NE	0	0	2	0	0	0	0	2
Eurema brigitta (Stoll, 1780)	NE	0	0	0	0	0	2	0	2
Eurema simulatrix (Staudinger, 1891)	NE	0	2	0	0	0	0	0	2
Euthalia malaccana (Fruhstorfer, 1899)	LC	0	0	0	0	2	0	0	2
Junonia orithya (Linnaeus, 1758)	LC	0	0	2	0	0	0	0	2
Melanitis leda (Linnaeus, 1758)	LC	1	0	1	0	0	0	0	2
Nacaduba calauria (Felder, 1860)	NE	0	1	0	0	1	0	0	2
Parantica albata (Zincken, 1831)	NT	0	0	0	0	2	0	0	2
Troides amphrysus (Cramer, 1779)	NE	0	0	0	0	2	0	0	2
Yoma sabina (Cramer, 1780)	NE	0	0	2	0	0	0	0	2
Ancistroides sp.	LC	0	0	1	0	0	0	0	1
Ariadne ariadne (Linnaeus, 1763)	NE	1	0	0	0	0	0	0	1
Catopsilia sp.	NE	1	0	0	0	0	0	0	1
Cupha erymanthis (Drury, 1773)	NE	1	0	0	0	0	0	0	1
Dichorragia nesimachus (Boisduval, 1836)	NE	0	0	0	0	1	0	0	1
Euploea eleusina (Cramer, 1777)	NE	1	0	0	0	0	0	0	1
Hypolimnas anomala (Wallace, 1869)	NE	0	0	1	0	0	0	0	1
Junonia erigone (Crammer, 1779)	NE	0	0	1	0	0	0	0	1
Lethe minerva (Fabricius, 1775)	NE	0	0	1	0	0	0	0	1
Loxura atymnus (Cramer, 1782)	NE	0	0	0	0	1	0	0	1
Prosotas dubiosa (Semper, 1879)	NE	0	0	0	0	1	0	0	1
Ramelana jangala (Horsfield, 1829)	NE	0	1	0	0	0	0	0	1
Symbrenthia lilaea (Hewitson, 1864)	NE	0	0	0	0	1	0	0	1
Tanaecia palguna (Moore, 1857)	NE	0	0	0	0	1	0	0	1
Tanaecia sp.	NE	0	0	1	0	0	0	0	1
Telicota augias (Linnaeus, 1763)	NE	0	0	1	0	0	0	0	1
Zemeros flegyas Cramer, 1780	NE	0	0	1	0	0	0	0	1
Total		430	261	1304	69	523	322	190	3099

Note: Study sites consisted of PA: Pandanarum; CP: City Park; RB: Ranu Bedali; KT: Kandangtepus; IR: Ireng-ireng; DA: Danyangan; AS: Argosari; IUCN status consisted of LC: Least Concern; NE: Not Evaluated; NT: Nearly Threatened; E: Endangered; -: Not listed. The star symbol in the bracket following the species name indicated the significant the means among the study sites as follows *: $p \leq 0.05$; **: $p \leq 0.01$; ***: $p \leq 0.001$

Table 3. Land uses (%) variation among seven study sites

Land uses (%)	Sites						
	PA	**CP**	**RB**	**KT**	**IR**	**DY**	**AS**
Forest or plantation	56.33	2.60	48.52	13.60	99.30	85.66	2.64
Shrub	6.88	0.1	2.23	7.78	0.28	12.17	12.77
Arable land	29.41	1.18	0.1	73.45	0.1	1.76	78.06
Settlement	6.77	72.74	5.72	4.19	0.1	0.11	5.84
Traffic area	0.61	15.91	0.69	0.74	0.22	0.31	0.69
Cemetery		0.73	0.36	0.25			
Water body (lake or river)			30.71				
Recreational area or park		6.83	11.67				

Note: Study sites consisted of PA: Pandanarum; CP: City Park; RB: Ranu Bedali; KT: Kandangtepus: IR: Ireng-ireng; DA: Danyangan; AS: Argosari

Table 4. Different means among the abundance, species richness, and diversity across elevation and land use

Parameter	F-value (significant)
Diversity	40.107 (***)
Species richness	47.870 (***)
Abundance	35.211 (***)
	Mann-Whitney U
Dominance	44.000 (**)

Note: The star symbol in the bracket following the species name indicated the significant the means among the study sites as follows *: p< 0.05; **: p≤0.01; ***: p<0.001

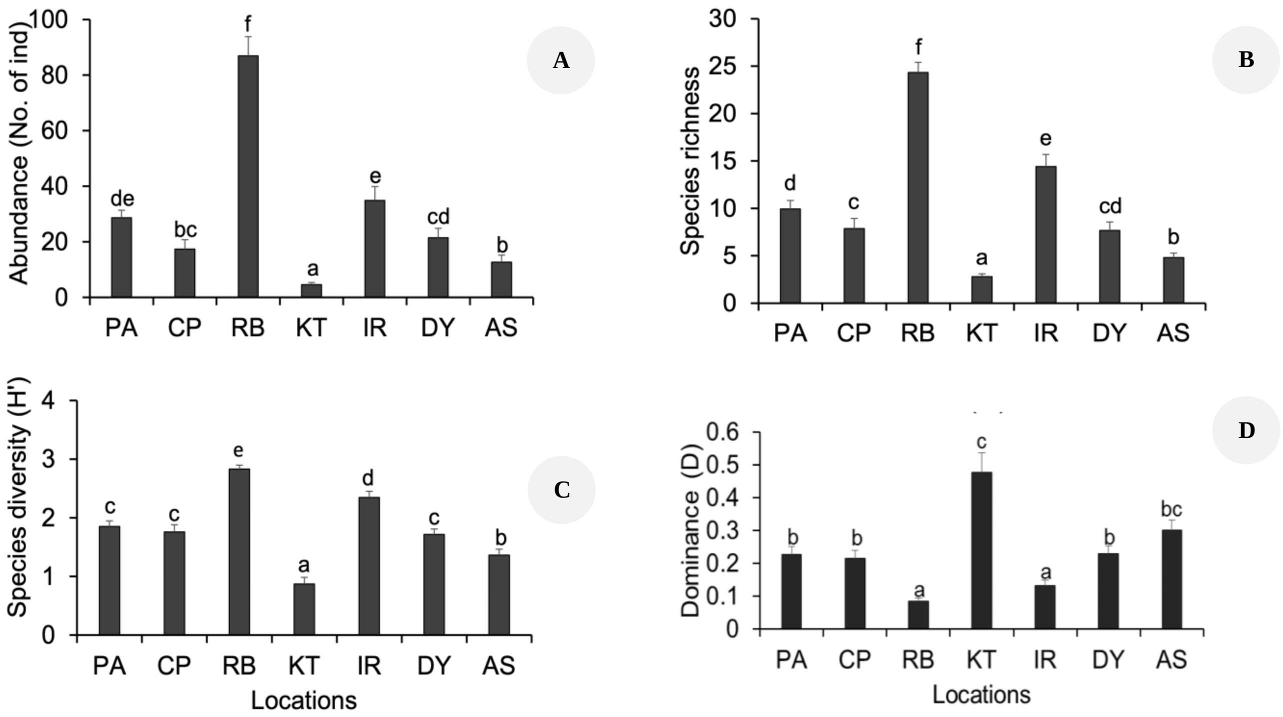

Figure 2. A. The species abundance; B. Richness; C: Diversity; D. Evenness variations (±SE) of butterflies among seven study sites in Lumajang, East Java, Indonesia. Note: PA: Pandanarum; CP: City Park; RB: Ranu Bedali; KT: Kandangtepus; IR: Ireng-ireng; DA: Danyangan; AS: Argosari. The different letters to show statistical significance

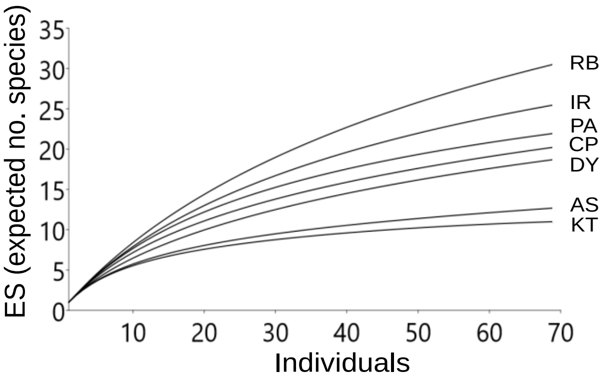

Figure 3. Rarefaction curves. Expected numbers of butterfly species (ES) showed for different sample sizes (n), in terms of the minimum number of individuals recorded from a study site

Altitude had significant positive correlation with butterfly abundance (r: -0.401, p≤0.05), species richness (r: -0.428, p≤0.05) and diversity (r: -0.413, p≤0.05). Three of the five land use factors analyzed showed correlations with abundance, species richness and diversity. Forest or plantation had a significant positive effect on butterfly species richness (r: 0.411, p≤0.05) and diversity (r: 0.505, p≤0.05). Shrubs or grasses had negative significant correlation with butterfly abundance (r: -0.436, P≤0.05), species richness (r: -0.568, p≤0.01) and diversity (r: -0.578, p≤0.01). Arable land also showed negative correlations with abundance (r: -0.503, p≤0.05), species richness (r: -0.614, p≤0.01) and diversity (r: -0.731, p≤0.001) (Table 5).

Butterfly assemblages

When the abundance of the butterfly pooled in each location, their compositions were grouped into three clusters. The first was composed of butterflies in Ireng-ireng and Danyangan. Both compositions had 34.6% similarity. The second was those in Kandangtepus and Argosari. Both compositions had 23.9% similarity. The third was those in Pandanarum, City Park and Ranu Bedali. Those three compositions had 23.1% similarity. The comparison results show apparent similarities in the composition of butterflies in Kandangtepus and Argosari, as well as Ireng-ireng and Danyangan with similarities in the composition of land uses (Figure 4).

Results of Canonical Correspondence Analysis (CCA) demonstrated that environmental variables were significant in explaining the variance in species abundance pattern. The sum of the first two canonical eigenvalues was 1.285. The first axis explained 30.72% of the species-environment relations, while the second axis explained 25.03%. Elevation, forest, traffic and light intensity significantly explain community composition variation. On CCA ordination, the component species were clustered into three groups (Figure 5). Group 1 consisted of 34 species, such as *E. hecabe, L. nina, Z. hylax, A. olferna, P. corvus, E. hypermnestra, J. almanac, N. hylas, E. sari, U. akasa, J. atlites, P. memnon, P. polytes, Y. horsfieldii, L. pandava, T. helena, E. blanda, G. agamemnon, D. periboea, E. climena, D. chrysippus, I. gaura, H. bolina, I. juventa, P. dan, D. hyparete, S. anna, Y. philomela, V. egista, D. bisaltide, N. curvifascia, E. eunice, C. lutea, Y. nigricans*. Group 2 consisted of 14 species, i.e. *Z. otis, C. pomona, V. cardui, T. cuneifera, Parantica* sp., *A. epaphia, E. core, D. aurantiaca, L. boeticus, P. columella, A. lyncida, C. scylla, P. demoleus, E. mulciber*. Group 3 consisted of 16 species, i.e. *Y. pandocus, J. iphita, M. sudra, J. hedonia, Y. baldus, P. adamas, C. rahria, H. glaucippe, N. vikasi, G. sarpedon, M. perseus, O. medus, M. janardana, E. tilaha, D. belisama*, and *M. horsfieldi*.

Correlation analysis showed that butterfly assemblages in group 1 and group 3 had many similar correlations with environmental factors, including temperature, altitude, forests/plantations, shrubs/grasses, and crop land. Group 1 had a positive correlation with temperature (r: 0.468, p≤0.001), light intensity (r: 0.165, p≤0.05), and forests/plantations (r: 0.280, p≤0.01). Group 1 had a negative correlation with humidity (r: 0 0.277, p≤0.01), altitude (r: 0 0.508, p≤0.001), shrubs/grasses (r: 0 0.563, p≤0.001), and arable land (r: 0 0.509, p≤0.001). The correlation of group 1 with wind speed, settlement and traffic area was not significant. Group 2 had positive correlation with light intensity (r: 0.233, P≤0.01), altitude (r: 0.420, p≤0.05), shrubs/grasses (r: 0.257, p≤0.01). Group 2 correlation with temperature, humidity, wind speed, forests/plantations, arable land settlement and traffic area was not significant. Group 3 had positive correlation with temperature (r: 0.256, p≤0.01) and forests/plantations (r: 0.221, p≤0.05). Group 3 has a negative correlation with wind speed (r: 0 0.200, P≤0.05), altitude (r: 0 0.213, p≤0.05), shrubs/grasses (r: 0 0.183, p≤0.01), arable land (r: 0 0.327, p≤0.001), settlements (r: 0 0.245, p≤0.01) and traffic area (r: 0 0.253, p≤0.01). The correlation of group 3 with humidity and light intensity was not significant (Table 6).

Table 5. Pearson correlation (r values) between environmental variables and butterfly abundance, species richness, and species diversity

Parameter	TE	H	W	L	A	F/P	S/G	C	S	TA
Individual	0.473 (*)	-0.257 (ns)	-0.089 (ns)	0.420 (*)	-0.401 (*)	0.309 (ns)	-0.436 (*)	-0.503 (*)	-0.163 (ns)	-0.179 (ns)
Species richness	0.523 (**)	-0.362 (ns)	-0.056 (ns)	0.247 (ns)	-0.428 (*)	0.411 (*)	-0.568 (**)	-0.614 (**)	-0.134 (ns)	-0.143 (ns)
Diversity	0.523 (**)	-0.507 (**)	0.020 (ns)	0.251 (ns)	-0.413 (*)	0.505 (*)	-0.578 (**)	-0.731 (***)	-0.047 (ns)	-0.050 (ns)

Note: TE: Temperature; H: Humidity; W: Wind speed; L: Light Intensity; A: Altitude; F/P: Forests or Plantations; S/G: Shrubs or Grasses; C: Arable lands; S: Settlements; TA: Traffic Area (ns: Not Significant; *: p< 0.05; **: p≤0.01; ***: p<0.001)

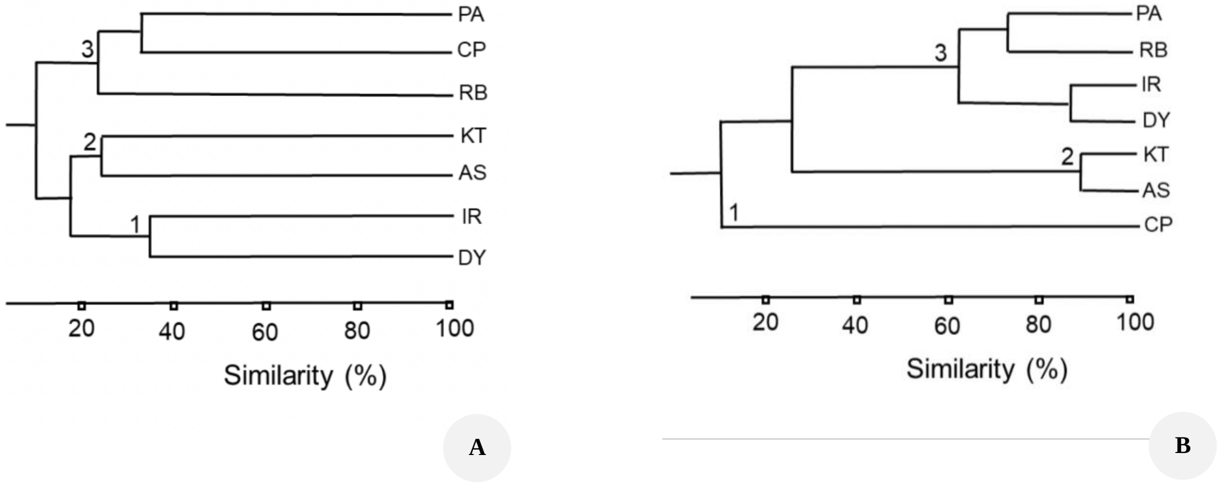

Figure 4. The results of cluster analysis of the Bray-Curtis similarity of butterfly composition among the locations (A) and land uses (B). Note: The butterfly species composition among the locations were clustered into three groups. Group 1 consisted of butterfly assemblages in Ireng-Ireng and Danyangan. Group 2 consisted of those in Kandangtepus and Argosari, while Group 3 consisted of those in Pandanarum, City Park and Ranu Bedali. Meanwhile, those among the land uses were grouped into three clusters. Group 1 consisted of butterfly assemblages in City Park and Ranu Bedali. Group 2 consisted of those in Pandanarum and Kandangtepus, while Group 3 consisted of those in Ireng-Ireng, Danyangan and Argosari

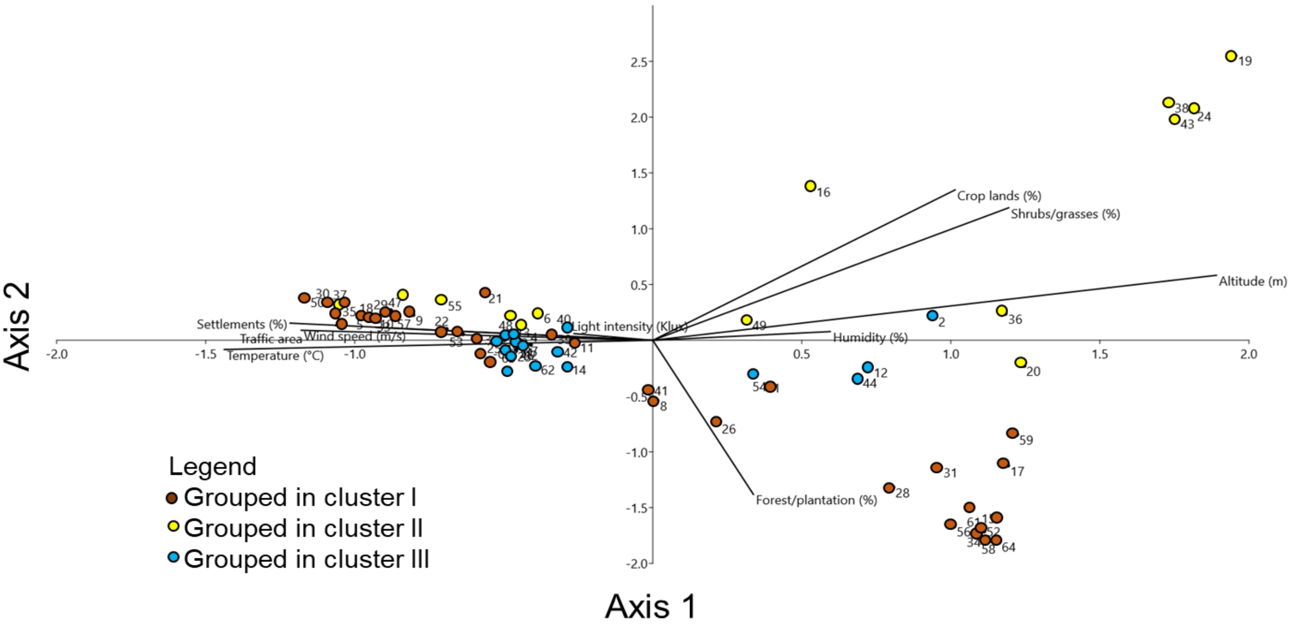

Figure 5. Ordination of family compositions responding to environmental factors: arrows represent the degree of environmental variable. The numbers of species were grouped by k-means clustering. It consisted of three groups. Small colored circles in the figure represent species name as follows 1. *Eurema hecabe*; 2. *Ypthima pandocus*; 3. *Leptosia nina*; 4. *Junonia iphita*; 5. *Zizula hylax*; 6. *Zizina otis*; 7. *Appias olferna*; 8. *Pithecops corvus*; 9. *Elymnias hypermnestra*; 10. *Junonia almanac*; 11. *Neptis hylas*; 12. *Mycalesis sudra*; 13. *Junonia hedonia*; 14. *Ypthima baldus*; 15. *Eurema sari*; 16. *Catopsilia pomona*; 17. *Udara akasa*; 18. *Junonia atlites*; 19. *Vanessa cardui*; 20. *Troides cuneifera*; 21. *Papilio memnon*; 22. *Papilio polytes*; 23. *Ypthima horsfieldii*; 24. *Parantica* sp.; 25. *Luthrodes pandava*; 26. *Troides helena*; 27. *Pachliopta adamas*; 28. *Eurema blanda*; 29. *Graphium agamemnon*; 30. *Delias periboea*; 31. *Euploea climena*; 32. *Chersonesia rahria*; 33. *Danaus chrysippus*; 34. *Ideopsis gaura*; 35. *Hypolimnas bolina*; 36. *Appias epaphia*; 37. *Euploea core*; 38. *Delias aurantiaca*; 39. *Ideopsis juventa*; 40. *Hebomoia glaucippe*; 41. *Pseudocoladenia dan*; 42. *Neptis vikasi*; 43. *Lampides boeticus*; 44. *Graphium sarpedon*; 45. *Mycalesis perseus*; 46. *Orsotriaena medus*; 47. *Phaedyma columella*; 48. *Appias lyncida*; 49. *Catopsilia scylla*; 50. *Delias hyparete*; 51. *Mycalesis janardana*; 52. *Symbrenthia anna*; 53. *Ypthima philomela*; 54. *Eurema tilaha*; 55. *Papilio demoleus*; 56. *Vagrans egista*; 57. *Doleschalia bisaltide*; 58. *Notocrypta curvifascia*; 59. *Euploea eunice*; 60. *Euploea mulciber*; 61. *Cyrestis lutea*; 62. *Delias belisama*; 63. *Mycalesis horsfieldi*; 64. *Ypthima nigricans*

Table 6. Pearson correlation (r values) between environmental variables and butterfly assemblage abundance

Parameter	TE	H	W	L	A	F/P	S/G	C	S	TA
Group 1	0.468 (***)	-0.277 (**)	-0.014 (ns)	0.165 (*)	-0.508 (***)	0.280 (**)	-0.563 (***)	-0.509 (***)	-0.006 (ns)	-0.1007 (ns)
Group 2	0.103 (ns)	-0.157 (ns)	-0.041 (ns)	0.233 (**)	0.420 (*)	0.144 (ns)	0.257 (**)	0.124 (ns)	-0.070 (ns)	-0.080 (ns)
Group 3	0.256 (**)	-0.026 (ns)	-0.200 (*)	0.107 (ns)	-0.213 (*)	0.221 (*)	-0.183 (**)	-0.327 (***)	-0.245 (**)	-0.253 (**)

Note: TE: Temperature; H: Humidity; W: Wind speed; L: Light intensity; A: Altitude; F/P: Forests or Plantations; S/G: Shrubs or Grasses; C: Arable lands; S: Settlements; TA: Traffic Area (Ns: Not Significant, *: $p<0.05$, **: $p\leq0.01$, ***: $p\leq0.001$)

Discussion

This study recorded 3,099 individual butterflies from 123 species across six families. The five dominant species were *E. hecabe, Y. pandocus, L. nina, J. iphita,* and *Z. hylax,* all showing different distribution patterns. Some, such as *E. hecabe, G. sarpedon, M. sudra, N. hylas, P. memnon, Y. pandocus, C. pomona, G. agamemnon, and Z. otis,* were widely distributed along the slopes of Lumajang. Conversely, species consisting of *V. cardui, Y. horsfieldii, P. adamas, C. rahria,* and *I. gaura* showed narrow distributions. For instance, *V. cardui* was found exclusively in Argosari, *Y. horsfieldii, P. adamas,* and *C. rahria* were restricted to Ranu Bedali, and *I. gaura* was abundant only in Ireng-ireng.

A study in Nepal reported that *E. hecabe* and *N. hylas* were classified as having a fairly wide distribution and found in all sacred forest locations in the Sacred Forests of Kathmandu valley (Shrestha et al. 2018). In Malaysia, an investigation also found that *E. hecabe and Y. pandocus* were present across altitudinal gradients in Gunung Ledang National Park, Johor (Ismail et al. 2018). *Vanessa cardui* was known as a migratory species, going between Europe and Africa every year (Talavera and Vila 2016). In Indonesia, this species was observed as pollinator of cucumber plant. The Malaysian Five-Ringed Butterfly, *Y. horsfieldii*, often lived in vegetated places and used host plants such as *Axonopus compressus* (Sujitha et al. 2019) and *Ottochloa nodosa* (Kwatrina 2018), which were usually near oil palm plantations and residential areas. *Pachliopta adamas* utilizes *Aristolochia acuminata* as the main food plant. *Chersonesia rahria* lived in areas like coffee plantations, rubber plantations, and open lands (Yusup et al. 2023). *Ideopsis gaura* was another species found in different altitude in Gunung Ledang National Park, Johor, with most found at 1200 m (Ismail et al. 2018).

The changes in how many species were found could be influenced by factors such as sampling efforts, the methods, and the general richness of species in each region. While using the same methods and sampling efforts, differences in species richness between the areas were still discovered. Abiotic factors, including land use, climate, and altitude, also made a difference. The highest diversity and species richness were found in Ranu Bedali, at an altitude of 200 m. Butterfly species richness and diversity were affected by land use like forests, plantations, and lakes. The species richness and diversity in Ranu Bedali was due to two things. First, land use analysis showed that forests and plantations were linked with species richness and diversity. This place had more natural land use than other lowland areas, like Pandanarum and City Park.

Previous studies found high species richness and diversity in natural areas (Botham et al. 2015; Sharma et al. 2020). Meanwhile, in agricultural areas, organic and traditional system practices in agroecosystems play a complementary role in protecting protected areas and encouraging the conservation of biodiversity and ecosystem services. Therefore, new afforestation measures to protect biodiversity-rich areas in agricultural landscapes are needed to support further management (Pe'er et al. 2016). Second, community forests, plantations, and riparian areas along lakes could help butterfly species richness. The results of this study are consistent with previous studies that stated that the presence of riparian supports butterfly richness and diversity (An and Choi 2021). Watershed habitats were suitable for butterflies because they provided resources, no matter the weather.

During the dry season, the river zone gets water from lakes to help plants survive. Gardens also helped butterflies when food in forests was limited. This situation could make butterfly move to human-made habitats, like plantations. Watersheds and wetlands also gave good habitats due to several food sources (An and Choi 2021; Sharma and Goswami 2021; Subedi et al. 2021). Shrubs, grasslands, and farmland were linked to fewer butterfly, species richness, and diversity. In this research, areas with agricultural land (Kandangtepus and Argosari) and shrubs or grasslands (Pandanarum, Kandangtepus, Danyangan, and Argosari) had fewer species richness and diversity. The shrub or grasslands were often situated near agricultural land, hence those were affected by farming. Intensive grazing and mowing activities could threaten butterfly diversity (Luppi et al. 2018; Karacetin et al. 2022; Rakosy et al. 2022). Moreover, dry seasons also may affect the availability of annual plants, which can explain the changes. This research was conducted toward the end of the dry season when the availability of larval host plants was significantly reduced. Land use could have both positive and negative effects on butterfly diversity. More traditionally managed or organic land use, are reported to preserve high biodiversity including those conservation concern species (Sharma et al. 2020).

Furthermore, human activities like traditional agriculture could maintain open habitats (permanent agricultural land or extensive grasslands) and promote environmental heterogeneity, which provided favorable conditions for butterfly (Botham et al. 2015; Horák and Šafářová 2015; Jew et al. 2015; Bartonova et al. 2016; Uchida et al. 2016). The positive effects resulted from the availability of essential resources that butterfly needed. In contrast, the other human activities simultaneously had detrimental effects on their diversity. Land conversion, such as transformation of forests or shrubland into agricultural land and urban development, has negatively affected butterfly diversity.

This research attributed the low species richness and diversity in the lowlands to urbanization and agricultural land use. While the total impacts of residential areas and traffic on butterfly species were not significant, CCA analysis showed certain groups that responded negatively to both factors. These species included *Y. pandocus, J. iphita, M. sudra, J. hedonia, Y. baldus, P. adamas, C. rahria, H. glaucippe, N. vikasi,* and *G. sarpedon,* which were absent in agricultural (Pandanarum) and urban (City Park) areas. The results aligned with previous investigations that highlighted the negative effect of urbanization and agricultural land on butterfly diversity in lowland areas. This negative correlation was clear because the conversion of grassland into cultivated agricultural land resulted in habitat destruction for butterflies (Konvicka et al. 2021).

The application of insecticides in agricultural land may disadvantage butterfly species in nearby areas (Braak et al. 2018). In the French Alps, research showed a negative relationship between human activity and butterfly richness between altitude of 200 and 500 m, where the area with more human activity took up most of the land. Both urbanization and agricultural land use had a strong negative effect on butterfly richness and diversity (Gallou et al. 2017). These findings were similar to other research that studied how human disturbance affected butterfly diversity along urban gradients. These investigations found that areas with fewer species were strongly linked to higher urbanization (Lizee et al. 2016), mainly because urban development and modern agriculture (Habel et al. 2016; Thomas 2016) caused habitat loss.

The next factor that affected butterfly species was climate and altitude. This research found that temperature, humidity, light intensity, and altitude all linked with butterfly abundance, species richness, and diversity. Temperature was positively related to abundance, richness, and diversity, while light intensity was only linked to abundance. Humidity was negatively related to diversity, and altitude had a negative link with abundance, richness, and diversity. Climate affected butterfly both directly and indirectly. For example, temperature was positively related to butterfly species richness, meaning species numbers tended to decrease at higher altitude (Mtui et al. 2022). However, climate could affect plants, which were important for butterflies. In this research, microclimate factors were examined because such factors, mainly rainfall were not measured. Previous studies have shown that butterfly species richness and abundance were strongly linked to temperature, and the strength of the relationship changes with the seasons (Gupta et al. 2019; Lourenço et al. 2020).

Lourenço et al. (2020) highlighted the role of season and temperature affected the distribution of butterfly over time. Butterfly abundance increased during the rainy season and with higher temperature in all areas. Our findings matched the hypothesis that butterfly species changed along altitude gradients. Butterfly richness and abundance decreased with altitude, and species composition changed, consistent with earlier investigations in other places (Carneiro et al. 2014). Gallou et al. (2017) found that butterfly richness along altitude gradients first went up from 200 to 500 m, reached its highest at 700 m with 150 species, then dropped sharply above 1900 m. This research showed a similar pattern, with high species richness and diversity at mid-altitudes. Species richness was highest at mid-altitude and went up with plot size, as Wagner et al. (2021) found. Both climate and habitat characteristics played important roles in butterfly distribution, with human activities having a negative effect in lowlands and climate playing a strong role at higher altitude (Gallou et al. 2017).

In conclusion, the abundance of butterflies varied among study sites. The highest species richness and diversity were found in Ranu Bedali, representing forest/plantation area in lower altitude, while the lowest was found in Kandangtepus representing an area dominated by arable land in highland. The abundance, species richness, and diversity across elevation and land use differ significantly between locations. In general temperature, light intensity and forests or plantations had positives effect on butterfly abundance, richness, diversity and composition, while humidity, altitude, shrubs or grasses, and agriculture land had negative influences on those butterfly parameters. This study has limitations in determining the location of the study and the sampling time is only in the dry season. To identify the key determining factors, further research is recommended to investigate the impact of habitats with water bodies on butterfly species richness and diversity.

ACKNOWLEDGEMENTS

The authors thank the Rector and Head of the Research and Community Empowerment Institute, Universitas Brawijaya, East Java, Indonesia. This study was partially funded by the Research and Community Service Institute Universitas Brawijaya through the Professor Grant Scheme. The authors declare that there is no conflict of interest with other parties.

REFERENCES

Abdullah SA, Leksono AS, Hong SG. 2022. Conserving Biocultural Landscapes in Malaysia and Indonesia for Sustainable Development. Springer, Singapore. DOI: 10.1007/978-981-16-7243-9.

Aguirre-Gutiérrez J, WallisDeVries MF, Marshall L, van't Zelfde M, Villalobos-Arámbula AR, Boekelo B, Bartholomeus H, Franzén M, Biesmeijer JC. 2017. Butterflies show different functional and species diversity in relationship to vegetation structure and land use. Glob Ecol Biogeogr 26 (10): 1126-1137. DOI: 10.1111/geb.12622.

An JS, Choi SW. 2021. Butterflies as an indicator group of riparian ecosystem assessment. J Asia-Pac Entomol 24 (1): 195-200. DOI: 10.1016/j.aspen.2020.12.017.

Azizah A, Mustafa I, Gama Z, Leksono A. 2021. The diversity and abundance of butterfly [Lepidoptera] in several urban green spaces of Malang city. IOP Conf Ser Earth Environ Sci 741: 012057. DOI: 10.1088/1755-1315/741/1/012057.

Bartonova A, Benes J, Fric ZF, Chobot K, Konvicka M. 2016. How universal are reserve design rules? A test using butterflies and their life history traits. Ecography 39 (5): 456-464. DOI: 10.1111/ecog.01642.

Botham MS, Fernandez-Ploquin EC, Brereton T. 2015. Lepidoptera communities across an agricultural gradient: How important are habitat area and habitat diversity in supporting high diversity. J Insect Conserv 19: 403-420. DOI: 10.1007/s10841-015-9760-y.

Braak N, Neve R, Jones AK, Gibbs M, Breuker CJ. 2018. The effects of insecticides on butterflies-A review. Environ Pollut 242: 507-518. DOI: 10.1016/j.envpol.2018.06.100.

Bubová T, Vrabec V, Kulma M, Nowicki P. 2015. Land management impacts on European butterflies of conservation concern: A review. J Insect Conserv 19: 805-821. DOI: 10.1007/s10841-015-9819-9.

Carneiro E, Mielke OHH, Casagrande MM, Fiedler K. 2014. Community structure of skipper butterflies (Lepidoptera, Hesperiidae) along elevational gradients in Brazilian Atlantic forest reflects vegetation type rather than altitude. Plos One 9 (10): e108207. DOI: 10.1371/journal.pone.0108207.

Choudhary NL, Chishty N, Parveen R, Sharma P. 2020. Abundance and diversity gradient of butterflies from urban to rural habitats In Udaipur District, Rajasthan, India. Environ Ecol 38: 893-901.

Choudhary NL, Chishty N. 2020. Effect of habitat loss and anthropogenic activities on butterflies survival: A review. Intl J Entomol Res 5 (4): 94-98. DOI: 10.1111/j.1365-2028.2008.00923.x.

Chowdhury S. 2023. Threatened species could be more vulnerable to climate change in tropical countries. Sci Total Environ 858: 159989. DOI: 10.1016/j.scitotenv.2022.159989.

Durairaj P, Sinha B. 2015. Review of butterflies (Lepidoptera: Rhopalocera) from Arunachal Pradesh: Conservation status and importance of research in protected areas. In: Proceedings of National Conference on Zoology for Future Education and Research 2015. India, 23-24 January 2014.

Fang SQ, Li YP, Pan Y, Wang CY, Peng MC, Hu SJ. 2023. Butterfly diversity in a rapidly developing urban area: A case study on a university campus. Diversity 16 (1): 4. DOI: 10.3390/d16010004.

Freitas AV, Santos JP, Rosa AH, Iserhard CA, Richter A, Siewert RR, Gueratto PE, Carreira JYO, Lourenço GM. 2021. Sampling methods for butterflies (Lepidoptera). In: Santos JC, Fernandes GW (eds). Measuring Arthropod Biodiversity: A Handbook of Sampling Methods. Springer, Cham. DOI: 10.1007/978-3-030-53226-0_5.

Gallou A, Baillet Y, Ficetola GF, Després L. 2017. Elevational gradient and human effects on butterfly species richness in the French Alps. Ecol Evol 7 (11): 3672-3681. DOI: 10.1002/ece3.2803.

Gupta H, Tiwari C, Diwakar S. 2019. Butterfly diversity and effect of temperature and humidity gradients on butterfly assemblages in a sub-tropical urban landscape. Trop Ecol 60: 150-158. DOI: 10.1007/s42965-019-00019-y.

Habel JC, Gossner MM, Schmitt T. 2019. What makes a species a priority for nature conservation? Anim Conserv 23: 28-35. DOI: 10.1111/acv.12512.

Habel JC, Segerer A, Ulrich W, Torchyk O, Weisser WW, Schmitt T. 2016. Butterfly community shifts over two centuries. Conserv Biol 30 (4): 754-762. DOI: 10.1111/cobi.12656.

Horák J, Šafářová L. 2015. Effect of reintroduced manual mowing on biodiversity in abandoned fen meadows. Biologia 70: 113-120. DOI: 10.1515/biologia-2015-0009.

Ismail N, Mohamed M, Khim PC, Tokiman L. 2018. Spatial distribution of butterfly (Lepidoptera: Papilionoidea) along altitudinal gradients at Gunung Ledang National Park, Johor, Malaysia. AIP Conf Proc 2002 (1): 020047. DOI: 10.1063/1.5050143.

Jew EKK, Loos J, Dougill AJ, Sallu SM, Benton TG. 2015. Butterfly communities in miombo woodland: Biodiversity declines with increasing woodland utilisation. Biol Conserv 192: 436-444. DOI: 10.1016/j.biocon.2015.10.022.

Karacetin E, Durmuş M, Yılmaz K, Lise Y. 2022. Effects of grazing and mowing on butterfly diversity, a case study from the east of Turkey. In: Ambarli D, Aleksanyan A, Venn S, Li FY, Wu J (eds). Asian Grassland Conference. Turkey, 19-21 April 2022. DOI: 10.21570/BUL-202201-3.

Konvicka M, Kuras T, Liparova J, Slezak V, Horázná D, Klečka J, Kleckova I. 2021. Low winter precipitation, but not warm autumns and springs, threatens mountain butterflies in middle-high mountains. PeerJ 9: e12021. DOI: 10.7717/peerj.12021.

Leksono AS, Feriwibisono B, Arifianto T, Pratama AF. 2017. The abundance and diversity of Odonata along an altitudinal gradient in East Java, Indonesia. Entomol Res 47 (4): 248-255. DOI: 10.1111/1748-5967.12216.

Leksono AS, Nisa ARK, Kurniawan L, Normalitasari NA. 2016. Diversity and composition of butterfly visitors of green spaces in Malang and Pasuruhan, East Java, Indonesia. Ecol Environ Conserv 22: 1165-1169.

Leksono AS, Yanuwiadi B, Afandhi A, Farhan M, Zairina A. 2020. The abundance and diversity of grasshopper communities in relation to elevation and land use in Malang, Indonesia. Biodiversitas 21 (12): 5614-5620. DOI: 10.13057/biodiv/d211206.

Lin Y, Huang S, Fang W, Huang Y, Gao C, Huang Y, Fu W. 2024. Impact of urban landscape patterns on butterfly diversity in Fuzhou City parks. Sci Total Environ 957: 177165. DOI: 10.1016/j.scitotenv.2024.177165.

Lizee MH, Tatoni T, Deschamps-Cottin M. 2016. Nested patterns in urban butterfly species assemblages: Respective roles of plot management, park layout and landscape features. Urban Ecosyst 19: 205-224. DOI: 10.1007/s11252-015-0501-5.

Lourenço GM, Luna P, Guevara R, Dáttilo W, Freitas AVL, Ribeiro SP. 2020. Temporal shifts in butterfly diversity: Responses to natural and anthropic forest transitions. J Insect Conserv 24 (2): 353-363. DOI: 10.1007/s10841-019-00207-0.

Luppi M, Dondina O, Orioli, V, Bani L. 2018. Local and landscape drivers of butterfly richness and abundance in a human-dominated area. Agric Ecosys Environ 254: 138-148. DOI: 10.1016/j.agee.2017.11.020.

Millah N, Leksono AS, Yanuwiadi B. 2023. Butterfly (Lepidoptera: Papilionoidae) diversity and structure community in Lumajang, East Java, Indonesia. Nusantara Biosci 15 (1): 118-128. DOI: 10.13057/nusbiosci/n150115.

Mtui DT, Ogutu JO, Okick RE, Newmark WD. 2022. Elevational distribution of montane Afrotropical butterflies is influenced by seasonality and habitat structure. Plos One 17 (7): e0270769. DOI: 10.1371/journal.pone.0270769.

Pe'er G, Zinngrebe Y, Hauck J, Schindler S, Dittrich A, Zingg S, Tscharntke T, Oppermann R, Sutcliffe LME, Sirami C, Schmidt J, Hoyer C, Schleyer C, Lakner S. 2016. Adding some green to the greening: Improving the EU's ecological focus areas for biodiversity and farmers. Conserv Lett 10: 517-530. DOI: 10.1111/conl.12333.

Peggie D. 2014. Mengenal Kupu-Kupu. Pandu Aksara Publishing, Jakarta. [Indonesian]

Picanço A, Rigal F, Matthews TJ, Cardoso P, Borges PA. 2017. Impact of land use change on flowers-visiting insect communities on an oceanic island. Insect Conserv Divers 10 (3): 211-223. DOI: 10.1111/icad.12216.

Rakosy D, Motivans E, Ştefan V, Nowak A, Świerszcz S, Feldmann R, Kuhn E, Geppert C, Venkataraman N, Sobieraj-Betlińska A, Grossmann A, Rojek W, Pochrząst K, Cielniak M, Gathof AK, Baumann K, Knight TM. 2022. Intensive grazing alters the diversity, composition and structure of plant-pollinator interaction networks in Central European grasslands. Plos One 17 (3): e0263576. DOI: 10.1371/journal.pone.0263576.

Sánchez-Bayo F, Wyckhuys KAG. 2019. Worldwide decline of the entomofauna: A review of its drivers. Biol Conserv 232: 8-27. DOI: 10.1016/j.biocon.2019.01.020.

Sharma K, Acharya BK, Sharma G, Valente D, Pasimeni MR, Petrosillo I, Selvan T. 2020. Land use effect on butterfly alpha and beta diversity in the Eastern Himalaya India. Ecol Indic 110: 105605. DOI: 10.1016/j.ecolind.2019.105605.

Sharma N, Goswami P. 2021. Species richness and diversity of butterflies (Insecta: Lepidoptera) of Ganga Lake, Itanagar Wildlife Sanctuary, Arunachal Pradesh, India. Rec Zool Surv India 121(2): 231-240. DOI: 10.26515/rzsi/v121/i2/2021/152867.

Shrestha BR, Sharma M, Magar KT, Gaudel P, Gurung MB, Oli B. 2018. Diversity and status of butterflies at different sacred forests of Kathmandu valley, Nepal. J Entomol Zool Stud 6 (3): 1348-1356. DOI: 10.1002/ece3.7177.

Stork NE. 2018. How many species of insects and other terrestrial arthropods are there on Earth? Ann Rev Entomol 63 (1): 31-45. DOI: 10.1146/annurev-ento-020117-043348.
Subedi B, Stewart AB, Neupane B, Ghimire S, Adhikari H. 2021. Butterfly species diversity and their floral preferences in the Rupa Wetland of Nepal. Ecol Evol 11 (5): 2086-2099. DOI: 10.1002/ece3.7177.
Sujitha PC, Prasad G, Sadasivan K. 2019. Butterflies of the *Myristica* swamp forests of Shendurney Wildlife Sanctuary in the Southern Western Ghats, Kerala, India. J Threat Taxa 11 (3): 13320-13333. DOI: 10.11609/jott.4399.11.3.13320-13333.
Syaripuddin K, Sing KW, Wilson JJ. 2015. Comparison of butterflies, bats and beetles as bioindicators based on four key criteria and DNA barcodes. Trop Conserv Sci 8 (1): 138-149. DOI: 10.1177/194008291500800112.
Talavera G, Vila R. 2016. Discovery of mass migration and breeding of the paintedlady butterfly *Vanessa cardui* in the Sub-Sahara: the Europe–Africa migration revisited. Biol J Linn Soc 2016: 1-12. DOI:10.1111/bij.12873.
Theng M, Jusoh WF, Jain A, Huertas B, Tan DJX, Tan HZ, Kristensen NP, Meier R, Chisholm RA. 2020. A comprehensive assessment of diversity loss in a well-documented tropical insect fauna: Almost half of Singapore's butterfly species extirpated in 160 years. Biol Conserv 242: 108401. DOI: 10.1016/j.biocon.2019.108401.
Thomas JA. 2016. Butterfly communities under threat. Sci 353 (6296): 216-218. DOI: 10.1126/science.aaf8838.
Tzortzakaki O, Kati V, Panitsa M, Tzanatos E, Giokas S. 2019. Butterfly diversity along the urbanization gradient in a densely-built Mediterranean city: Land cover is more decisive than resources in structuring communities. Landsc Urban Plan 183: 79-87. DOI: 10.1016/j.landurbplan.2018.11.007.
Uchida K, Hiraiwa MK, Ushimaru A. 2016. Plant and herbivorous insect diversity loss are greater than null model expectations due to land-use changes in agro-ecosystems. Biol Conserv 201: 270-276. DOI: 10.1016/j.biocon.2016.07.017.
Vasconcelos RN, Cambui ECB, Mariano-Neto E, da Rocha PLB, Cardoso MZ. 2019. The role of *Eucalyptus* planted forests for fruit-feeding butterflies' conservation in fragmented areas of the Brazilian Atlantic forest. For Ecol Manag 432*:* 115-120. DOI: 10.1016/j.foreco.2018.09.017.
Wagner DL, Grames EM, Forister ML, Berenbaum MR, Stopak D. 2021. Insect decline in the Anthropocene: Death by a thousand cuts. Proc Natl Acad Sci 118 (2): e2023989118. DOI: 10.1073/pnas.2023989118.
Wagner KD, Krauss J, Steffan-Dewenter I. 2013 Butterfly diversity and historical land cover change along an altitudinal gradient. J Insect Conserv 17: 1039-1046. DOI: 10.1007/s10841-013-9587-3.
Warren MS, Maes D, van Swaay CA, Goffartd P, Van Dycke H, Bournf NAD, Wynhoffc I, Hoaref D, Ellisf S. 2021. The decline of butterflies in Europe: Problems, significance, and possible solutions. Proc Natl Acad Sci 118 (2): e2002551117. DOI: 10.1073/pnas.2002551117.
Wilson M. 2008. 101 Butterflies of Indonesias Low Lands. Yellow Dot Publishing, Jakarta, Indonesia. [Indonesian]