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Lepidoptera diversity in Ndodang Forest, Ngawi, East Java, Indonesia

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Abstract. *Utami S, Nuryatman P, Dewi NK. 2024. Lepidoptera diversity in Ndodang Forest, Ngawi, East Java, Indonesia. Biodiversitas 25: 4772-4780.* The Ndodang Ngawi Forest is characterized by many species of teak (*Tectona grandis*) and rosewood (*Dalbergia latifolia*) trees that grow there, but the richness of its flora and fauna has not been explored and identified. Therefore, this study aimed to analyze the diversity of Lepidoptera in Ndodang Ngawi Forest, East Java, Indonesia, and the physicochemical environmental factors affecting their presence. The experiment was conducted from March to May 2023, where Rhopalocera (butterfly) analysis was carried out using the pollard transect method. This approach periodically monitored the presence of butterfly and the sweep net technique was used as the sampling method. Heterocera (moth) analysis was carried out using a light trap technique determined by the purposive sampling method. A total of three study stations were set, namely the area in forest, edge, and riverbank areas. The results of the Lepidoptera study recorded 8 families, consisting of 37 species and 639 individuals, with Nymphalidae and *Catopsilia pomona* being the most prevalent, while Papilionidae family, *Elymnias hypermnestra* had 2 individuals. In addition to the influence of plant vegetation, the diversity of Lepidoptera species was also affected by environmental physicochemical factors. The air temperature of the Ndodang Forest with an average of 29.3^{O}C, humidity of 65%RH, and light intensity of 3629 lux contributed to the survival of these species. Diversity data were processed using Microsoft Excel, including the Shannon-Wienner diversity, Evenness, and Simpson Dominance indices. Based on the analysis, the values obtained were categorized as medium (1<H'<3), indicating moderate diversity, species evenness was large (E> 0.6), and there were no dominating species (D < 0.5). Lepidoptera diversity in the Ndodang Forest is in the medium category. The evenness index shows the even distribution of the population in the Ndodang Forest area, so that the dominance index is relatively low in this area or there is no dominance of certain types of butterfly species. The diversity of Lepidoptera species is influenced by the presence of vegetation which is a source of food and also environmental physico-chemical factors such as air temperature, light intensity and air humidity. The more and more diverse types of vegetation that provide food sources, the greater the diversity of Lepidoptera.

Keywords: Diversity, Lepidoptera, light trap, Ndodang Forest, Pollard transect

INTRODUCTION

Lepidoptera is classified into invertebrate animals of the Insect Class, Phylum Arthropoda and the second largest order from the Insect Class, accounting for 157,424 species worldwide (Sajjad et al. 2019; Bibi et al. 2022). Approximately 80% of its diversity is found in the tropics (Batool and Hussain 2016), while the remaining 20% thrive in the subtropics. Furthermore, the two Lepidoptera sub-orders are butterfly (Rhopalocera) and moth (Heterocera), consisting of 19,000 and 100,000 species, respectively (Khan and Perveen 2015).

One of the characteristics of Lepidoptera is a variety of wing colors, which are adorned with scales. The Greek origin of the name 'Lepidoptera', is obtained from *lepis* for scales, and the wings are called *ptera*. The two sub-types can be distinguished from several aspects, including based on the shape of their antennae (Basri and Zakaria 2021). Butterflies have antennae that are filiform, club-shaped, hooked (sickle), while moth antennae are smooth and feather-like. The pattern of activity habits shows that butterfly is diurnal, and active during the day when there is sunlight, while moth is active at night (nocturnal). When at rest, butterfly closes its wings upright, possessing a brighter and more diverse body structure (Williams et al. 2018). Meanwhile, the wings of moth are spread flat, with a somber body and epiphyses on the front legs phytophagous (plant-eating insects) (Dar et al. 2021).

In the ecosystem, Lepidoptera plays an important role as pollinating insects by symbiosis with flowering plants. These insects visit flowers in search of nectar, pollen, and other products from plants to fulfill their food sources (Aminah and Syatrawati 2020). The pollination process carried out by butterfly can be used to identify threatened and important species for plants, facilitating the optimization of ecosystem management functions (Zografou et al. 2020; Balmaki et al. 2022). Ecologically, adult Lepidoptera act as pollinating insects on plants, and their larvae are first-level herbivores that eat leaves, enhancing the transfer of radiant energy for plant improvement (Bibi et al. 2022). The larvae are also a food source for other organisms in the ecosystem. In addition, butterfly is often used as a bioindicator to monitor forest biodiversity and ecosystem function due to their sensitivity to environmental fluctuations (Ismail et al. 2020), including climate change, habitat degradation, excessive insecticide use, and nitrogen pollution, making the species vulnerable to extinction (Subedi et al. 2021). Lepidoptera is adaptable to several habitats, such as gardens, forests, grasslands, and metropolitan areas (Basri and Zakaria 2021).

The equatorial position of Indonesia supports stable sunlight and soil fertility, nurturing a diverse range of flora and fauna species, making the country the second mega biodiversity hotspot in the world after Brazil. One of the fauna diversities is Lepidoptera. Previous investigations showed that butterfly diversity in Indonesia was 2,500 species (Harmonis et al. 2022), while moth was 12,000 species (Sutrisno 2020). Based on the size of the body, Moths can be divided into two, namely macro (large) and micro (small). The large type has a wingspan size of >2 cm and is easily recognized due to its size and smaller number than the small moth, which has a wingspan size of <2cm (Sutrisno 2020).

Ndodang Forest, located in Ngawi District, East Java Province, Indonesia, is characterized by several tree species, such as teak (*Tectona grandis* L.f.) and rosewood (*Dalbergia latifolia* Roxb.). Currently, there is limited information on Lepidoptera diversity in Ngawi and Ndodang Forest has not been explored and identified for its rich flora and fauna. This study aimed to analyze species diversity and physicochemical environmental factors affecting the presence of Lepidoptera in the area. Meanwhile, this is the first study regarding the diversity of butterfly and moth in Ndodang Forest. The results obtained are expected to provide valuable information on Lepidoptera and environmental physicochemical factors affecting their presence.

MATERIALS AND METHODS

Study area

Ndodang Forest is included in the working area of the Widodaren Forest Management Unit, covered by the Geneng Forest Management Unit Section, Ngawi Forest Management. The area is in Bangsal Hamlet, Widodaren Village, Gerih Sub-district, Ngawi District, East Java, Indonesia, comprising a Margalit-type soil condition with a 2-3 m depth. The forest is located at an altitude of 130-150 m above sea level with a slope of 6%-15%, an average rainfall of 1200-2100 mm/year, and a soil condition in the medium level of fertility. The dominant plants include teak (*T. grandis*), rosewood (*D. latifolia*), *Johar* (*Senna siamea* (Lam.) H.S.Irwin & Barneby), fresh pacing plants (*Costus speciosus* (J.Koenig) Sm.), turmeric (*Curcuma longa* L.), ginger (*Curcuma zanthorrhiza* Roxb.), bushes (*Buddleja davidii* Franch.), and grasses (Gramineae). The plant families in the riverside areas include Poaceae, Amaranthacea, Fabaceae, Asteraceae, and Loranthaceae.

Procedures

This study was conducted from March to May 2023 and the pollard transect method was used to periodically monitor the presence of butterfly to obtain accurate data (Laref et al. 2022). This method followed a 1,000-meter transect line with 10 imaginary observation sections per station, a width of 10 m, and a length of 100 m in areas representing the forest (Station I) and the forest edge (Station II). In comparison, the length of the transect line in the riverbank area (Station III) is 600 m with an observation section width of 6 m and a length of 60 m, totaling 30 imaginary observation sections. The selection of research station locations was carried out based on 2 types of considerations, namely (i) Location of forest areas (areas on the edge of the forest, areas within the forest, and areas on the banks of rivers). (ii) Types of vegetation in each area. Station I is an area located in the forest with vegetation types of teak trees (*T. grandis*), rosewood trees (*D. latifolia*), *Johar* trees (*S. siamea*), turmeric (*C. longa*), freshwater pacing plants (*C. speciosus*), bushes shrubs (*B. davidii*) and grasses (Gamineae). Station II is an area on the edge of the forest, with the main vegetation types being teak trees (*T. grandis*), turmeric and *Johar* trees (*S. siamea*). Station III is an area on the edge of a river and has more heterogeneous plant species such as plants from the Poacea family, the Asteraceae family, *Johar* trees (*S. siamea*), *Secang* trees (*Caesalpinia sappan* L.), *Putri malu* (*Mimosa pudica* L.), various species of bushes, and various species of herbaceous plants.

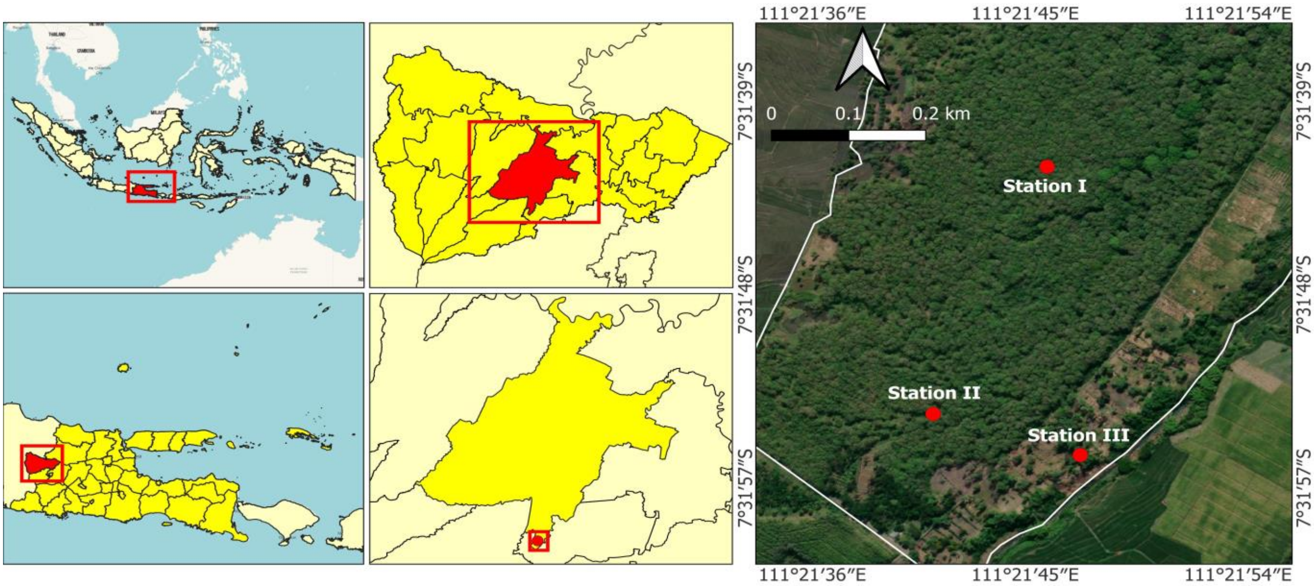

Figure 1. Map of Lepidoptera study site of Ndodang Forest, Gerih Sub-district, Ngawi District, East Java, Indonesia

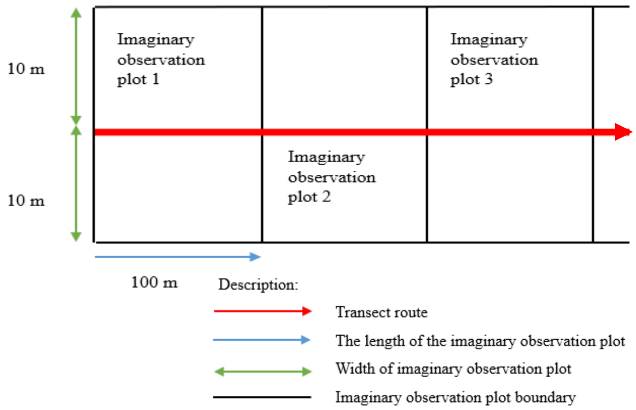

Figure 1. Pollard transect schema

Sampling of butterflies was carried out at active times for pollination between 8.00 a.m-12.00 p.m (Barrios et al. 2016) for 10 days. Heterocera (moth) study was conducted using a light trap technique determined by purposive sampling method. At each station, a single light trap was installed at 17.00 WIB, located at a distance of 1 km from each plot to represent the species (Delabye et al. 2022). These light traps were left at each station from 6.00 p.m. to 6.00 a.m. for 10 days, and samples were taken at 6.00 a.m (Piccini et al. 2023). The light trap model for capturing tent-shaped moth proved to be exceptionally effective for ecological and conservation studies. The model maintained the integrity of the wing morphology of the Lepidoptera order, which was among the most fragile (Lepesqueur et al. 2022). The light trap is designed simply and consists of 4 main systems, namely (i) The roof part as a lamp protector, (ii) A lamp with a power of 150 watt to attract moths, (iii) A funnel with a diameter of 19 cm serves as a passageway for moths to enter the tent, (iv) The cylindrical tent is 60 cm high and 30 cm wide as a moth trap. The tent is made of thin fabric (cotton tulle or voal) and there is a rubber strap at the top of the tent to make sampling easier.

Data analysis

The data analysis method used in this study included the Shannon-Wiener Diversity, Simpson Dominance, and Evenness Indices. Lepidoptera species diversity was calculated using the Shannon-Wiener Diversity Index (H') with the formula:

$$H' = -\Sigma \text{ Pi In} \cdot \text{Pi}$$

$$Pi = \frac{ni}{Ni}$$

Where:
H' : Shannon-Wiener Diversity Index
Pi : Proportion of i-th species
Ni : Total individuals of the population

High, medium, and low diversity is indicated at H>3.0, 1<H<3, and H <1, respectively (Sari et al. 2022).

The level of dominance of Lepidoptera species in a community was calculated using Simpson Dominance Index (D) with the formula:

$$D = \sum(\frac{ni}{N})^2$$

Where:
D : Species Dominance Index
ni : Number of individuals of each species
N : Number of individuals of all species

Criteria for species dominance categories: D<0.5 (close to 0) = no dominating species, D>0.5 (close to 1) = dominating species. The balance of individuals between species in a community was calculated using the Evenness Index (E).

$$E = \frac{H'}{Ln\,(ts)}$$

Where:
H' : Shannon-Wiener Diversity Index
Ln : Natural logarithm
ts : Total species

Criteria: E<0.4 = small population evenness, 0.4>E>0.6 = medium population evenness, E>0.6 = large population evenness.

RESULTS AND DISCUSSION

Community structure of Lepidoptera species diversity

The observation results across the locations of Ndodang Forest a total of 639 individuals were found consisting of 37 species from 9 Lepidoptera families, as shown in Table 1. Generally, Lepidoptera is classified into 9 families, consisting of 4 from the sub-order Heterocera and 5 from Rhopalocera. The 4 families of the sub-order Heterocera include Eribidae, Geometridae, Saturniidae, and Shpingidae, while the 5 families of the Rhopalocera sub-order: Hesperiidae, Lycanidae, Nympahlidae, Papilodae, Pieridae. Furthermore, the family with the most species and individuals was Nymphalidae family, with 12 species and 303 individuals, accounting for 47% of the total number. The least found was Papilionidae family, consisting of 1 species and 2 individuals, constituting 0.2% of the total number, as shown in Figure 2.

Lepidoptera species diversity

Diversity analysis showed that Ndodang Forest riverside area had the highest species richness and abundance, consisting of 254 individuals and 28 species. Meanwhile, the lowest number was in the edge area of Ndodang Forest, with 187 individuals and 26 species. The results of the Shannon-Wiener Diversity, Evenness, and Simpson Indices were the highest in Ndodang Forest riverside area (H' = 2.856, E = 0.857, D = 0.081), and the lowest value was obtained at the edge area (H' = 2.738, E = 0.850, D = 0.064), as shown in Table 2.

Environmental physicochemical factors

The measurement results of environmental physicochemical factors at the three study stations showed relatively consistent variations. On average, during the day, when observing butterflies in Ndodang Forest, the average temperature 29.3°C, average light humidity at 65.25% RH, and average light intensity at 3629 Lux. Meanwhile, when observing moth samples trapped at dawn, the average temperature was around 22.7°C, average light humidity of 81.50% RH, and average light intensity at 1035 Lux. This data is shown in detail in the Tables 3 and 4.

Table 1. Diversity of Lepidoptera found in the study site

Sub-order	Family	Species	Station			Total species
			I	II	III	
Heterocera	Erebiidae	*Creatonotos gangis* (Linnaeus, 1763)	1	1	1	3
		Creatonotos transiens (Walker, 1855)	2	1	2	5
		Mocis frugalis (Fabricius, 1775)	3	4	1	8
		Raparna transversa (Moore, 1882)	3	-	-	3
	Geometridae	*Idaea biselata* (Hufnagel, 1767)	-	2	1	3
		Macaria abydata (Guenée, 1858)	1	2	2	5
		Scopula immutata (Linnaeus, 1758)	3	2	-	5
	Saturniidae	*Antheraea paphia* (Linnaeus, 1758)	2	1	2	5
	Sphingidae	*Theretra oldenlandiae* (Fabricius, 1775)	3	1	-	4
Rhopalocera	Hesperiidae	*Ancistroides folus* (Butler, 1874)	4	3	2	9
		Erionota thrax (Linnaeus, 1767)	-	-	9	9
		Potanthus omaha (Edwards, 1863)	5	4	7	16
		Suastus gremius (Fabricius, 1798)	6	10	-	16
		Tagiades japetus (Stoll, 1781)	5	6	-	11
	Lycaenidae	*Anthene emolus* (Godart, 1823)	2	-	4	6
		Castalius rosimon (Fabricius, 1775)	9	-	7	16
		Luthrodes (*Chilades*) *pandava* (Horsfield, 1829)	4	-	8	12
		Zizina otis (Fabricius, 1787)	-	-	7	7
	Nymphalidae	*Acraea terpsicore* (Linnaeus, 1758)	-	-	5	5
		Athyma perius (Linnaeus, 1758)	7	4	4	15
		Cupha erymanthis (Drury, 1773)	-	3	7	10
		Hypolimnas bolina (Linnaeus, 1758)	4	6	6	16
		Junonia almana (Linnaeus, 1758)	-	-	45	45
		Junonia atlites (Linnaeus, 1763)	14	19	17	50
		Junonia hedonia (Linnaeus, 1764)	13	10	-	23
		Lethe europa (Fabricius, 1775)	-	1	4	5
		Melanitis leda (Linnaeus, 1758)	19	15	-	34
		Mycalesis visala (Moore, 1857)	16	18	20	54
		Phalanta phalantha (Drury, 1773)	-	-	38	38
		Tanaecia pelea (Fabricius, 1787)	-	-	8	8
	Papilionidae	*Elymnias hypermnestra* (Linnaeus, 1763)	-	2	-	2
	Pieridae	*Appias libythea* (Fabricius, 1775)	-	-	4	4
		Catopsilia pomona (Fabricius, 1775)	7	30	23	60
		Delias hyparete (Linnaeus, 1758)	11	7	5	23
		Delias pasithoe (Linnaeus, 1758)	5	5	-	10
		Eurema hecabe (Linnaeus, 1758)	23	20	14	58
		Leptosia nina (Fabricius, 1793)	21	10	6	37
Total			193	187	259	639

Table 2. Diversity, Dominance, and Evenness Indexes in each habitat

Habitat type	Total individual	Total species	Shannon-Wiener		Evenness		Simpson	
			H'	Category	E	Category	D	Category
In Forest	193	26	2.747	Medium	0.843	Large population	0.065	Low
Forest Edge	187	26	2.738	Medium	0.850	Large population	0.064	Low
Riverbank	254	28	2.856	Medium	0.857	Large population	0.081	Low

Table 3. Environmental physicochemical factors of Lepidoptera (butterfly)

Environmental physicochemical factors	Station I	Station II	Station III	Average	Standard deviation
Temperature (°C)	26.5-31	27-31	28-31	29.3	0.507
Air humidity (%RH)	62.5-82.5	55-75	50-67.5	65.25	4.75
Light intensity (Lux)	1992-5617	2131-4185	2825-7409	3629	1028.891

Table 4. Environmental physicochemical factors of Lepidoptera (moth)

Environmental physicochemical factors	Station I	Station II	Station III	Average	Standard deviation
Temperature (°C)	20-24	20-24	20-24	22.7	0.057
Air humidity (%RH)	75-87.5	75-87.5	75-87.5	81.5	1.089
Light intensity (Lux)	565-996	421-937	984-2084	1035	484.278

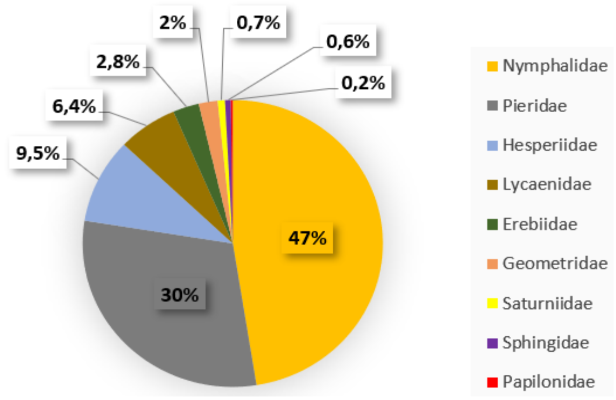

Figure 2. Percentage of Lepidoptera family in Ndodang Forest, Ngawi, Indonesia

Discussion

Lepidoptera species diversity

Nymphalidae family was the highest number and dominated in the study site due to its adaptability to various environmental conditions, a vast array of subfamilies, and tendency to be polyphagous (Koneri and Nangoy 2019). Furthermore, a total of 12 species were identified in the study area, among others: *Acraea terpsicore*, *Athyma perius*, *Cupha erymanthis*, *Hypolimnas bolina*, *Junonia almana, J. atlites*, *J. hedonia*, *Lethe europa*, *Melanitis leda*, *Mycalesis visala*, *Phalanta phalantha*, *Tanaecia pelea*. These findings are in line with previous investigations (Bibi et al. 2022). Nymphalidae is renowned as the largest family globally. Nymphalidae consists of 16 subfamilies with a total of 7000 species (Suhaimi et al. 2017). The presence of suitable vegetation, particularly an abundance of host plants, plays a crucial role in supporting their thriving population. Nymphalidae family is also known as a polyphagous insect capable of surviving in almost all habitats (Wang et al. 2017), including the tundra biome (Leung and Reid 2013; McFarland 2024), due to its inclination to use multiple food sources. Therefore, butterfly searches for other sources when the main food source is not available (Koneri and Nangoy 2019), which contributes to the abundance of Nymphalidae species in the study site.

Papilionidae was the least identified family at the study site, consisting of *Elymnias hypermnestra* as the only identified species (Figure 3). This phenomenon was attributed to the larval host plants of Papilionidae family, which were nectar-producing. Furthermore, the family is very selective in nectarine plants, showing a preference for flowers with abundant nectar and sweet aroma due to the high concentration of sugar in the nectar (Nacua et al. 2020). Community forests overgrown with flowering plants such as the Malvaceae, Convolvulaceae, and Polygonaceae families can be a good habitat for butterfly to find nectar necessary for their larval nourishment (Millah et al. 2023). Based on observations at the study site, Ndodang Forest was predominantly dominated by woody plants, with only a few flowering plants. Butterfly abundance has been associated with sufficient availability of host plants, indicating a strong relationship with the plant vegetation (Muto-Fujita et al. 2017; Mairawita et al. 2023). Papilionidae family also tends to have the ability to fly fast and agile in tree crowns, contributing to their lower numbers in the study site. These findings are in line with previous investigations (Mustari and Gunadarma 2019; Khew 2024).

The most common species found were *Catopsilia pomona* and *Eurema hecabe*, consisting of 60 and 58 individuals, respectively (Figure 3). *C. pomona* belonging to Pieridae family was observed in groups flying with fast movements around *S. siamea* trees found in the three stations of Ndodang Forest. This species was recorded mostly in forest edge areas covered with *S. siamea* trees. Butterfly species of Pieridae family were often found sucking nectar on plants of the Rosaceae, Residaceae, Rhamnaceae, Fabaceae, Brassiceae, and Tropaeloceae families (Frahtia et al. 2022). The abundance of species from Pieridae family correlated with their host plants from Fabaceae family (Frahtia et al. 2022). The availability of host plants such as johar trees in various sites contributed to the even distribution of these species within Ndodang Forest.

One of the Rhopalocera sub-order species commonly found in Ndodang Forest was *E. hecabe* with 58 individuals, often found hiding behind the leaves, grasses, or bushes. The genus *Eurema* can be found in various habitats due to its polyphagous nature, allowing breeding in several areas (Koneri et al. 2022). Furthermore, the host plants comprise the Fabaceae, Astraceae, Euphorbiaceae, and Mimosacea families (Koneri et al. 2022). Observations also showed that this butterfly was sucking nectar on plants of Asteraceae family, particularly yellow. This species showed a preference for areas with many bushes and was frequently observed flying around the tropical almond trees on Ndodang Forest riverbank.

The least number of species in the study site was *E. hypermnestra*, with 2 individuals, which belonged to Papilionidae family and was often found on turmeric leaves at forest edge with fairly tall grass and shrub vegetation. This butterfly moved quickly on relatively low foliage, but its presence was difficult to identify due to the dark color of the wings. According to a previous study (Ilhamdi et al. 2023) in the Lombok Forest Botanical Park, dark brown *E. hypermnestra* was perched on a banana leaf at the height of 1 m, flying fast and moving at a relatively low height. This species had a closed canopy habitat with little light and the dark color of the wings served as camouflage from predators including *Solenopsis invicta*, *Hemidactylus frenatus*, and *Rattus rattus* (Nacua et al. 2020). The scarcity of this butterfly was due to the type of host plant coming from the palm tribe (Arecaceae) (Iqbal et al. 2021), which caused the diversity to be limited in Ndodang Forest. The abundance of Rhopalocera originated from the richness of the herbaceous stratum and specific plant hosts for each Rhopalocera species (Laref et al. 2022). The distribution of host plant abundance for certain species affected their distribution level, both as a source of larval host food and nectar for Lepidoptera (Widhiono 2015; Koneri and Nangoy 2019).

Analysis of Lepidoptera species diversity

The data collected and analyzed for Lepidoptera were used to calculate the diversity, evenness, and dominance indices. The diversity index at Station III (riverbank) [H' = 2.856] was higher than Station I (in the forest) [H' = 2.747] and Station II (forest edge) [H' = 2.738]. These values classified the diversity into the medium category at the three stations in Ndodang Forest, as H'<1 indicated low, 1<H'<3 represented medium, and H'>3 showed high category (Sari et al. 2022). A higher value of H' in an area indicated greater diversity and a larger community within the area.

The evenness index at Station III (riverbank) [E = 0.8570] was higher than Station II (forest edge) [E = 0.8508] and Station I (in the forest) [E = 0.8433]. These values suggested a high degree of evenness, based on various criteria, where E<0.4 indicated low category, 0.4<E<0.6 represented medium, and E>0.6 was classified as large population. The three index data were almost close to the maximum value with a relatively small difference of 0.01. This was attributed to the mixed natural habitat type in Ndodang Forest, consisting of several tree species such as teak, Siamese cassia, and rosewood, as well as fresh pacing plants, bushes, and grasses that caused even distribution of Lepidoptera. Specifically, a large evenness value indicated a more evenly distributed Lepidoptera population, indicating the lower species dominance and vice versa.

The dominance index at Station III (riverbank) [D = 0.0818] was higher than Station II (forest edge) [D = 0.0656] and Station I (in the forest) [D = 0.0649]. These values indicated low dominance criteria at the three stations in Ndodang Forest, where D<0.5 or close to 0 was classified as low, and D>0.5 or close to 1 indicated a high category (Dar et al. 2021). The correlation of data between the dominance and the evenness indexes was negative or inversely proportional. Based on the results, a high Dominance Index showed a low level of Evenness of individuals in an area, while a low Dominance Index corresponded to elevated evenness. The similarity in vegetation habitat constituents across the three stations resulted in a lack of prominently dominant species. The tendency for certain Lepidoptera species to be found was also related to the vegetation structure of each habitat type, leading to low dominance levels in all stations (Nikmah et al. 2021; Mota et al. 2023).

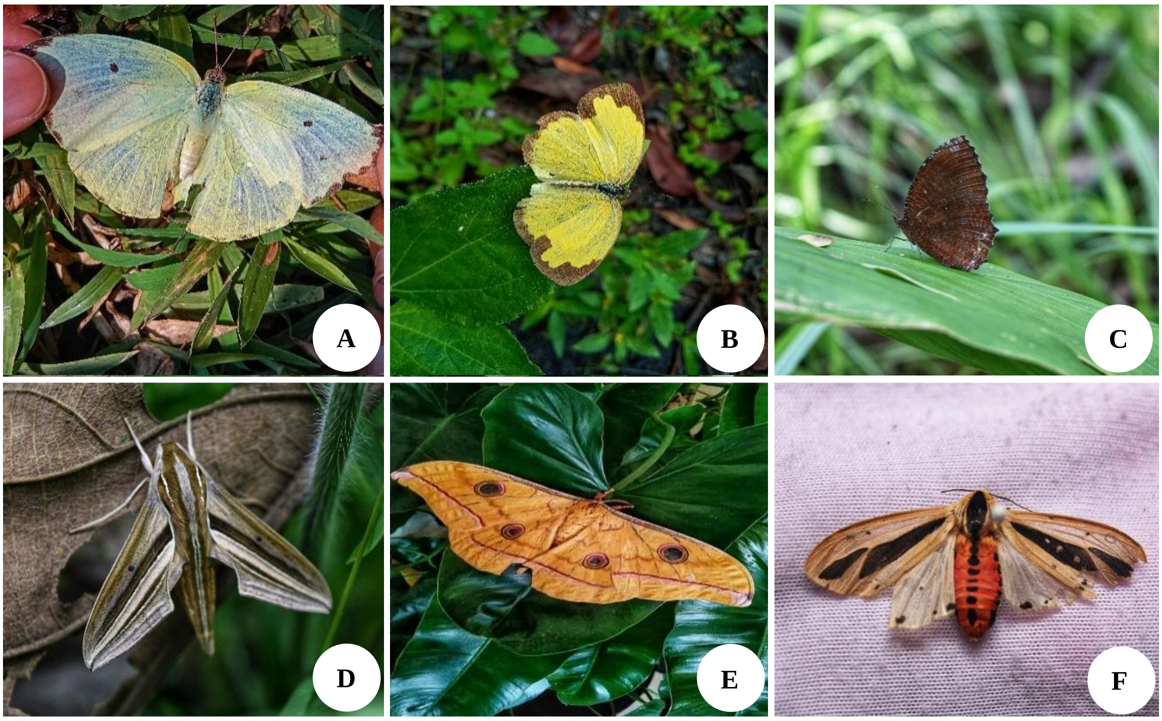

Figure 3. Butterfly species: A. *Catopsilia pomona*; B. *Eurema hecabe*; C. *Elymnias hypermnestra*. Then, moth species: D. *Theretra oldenlandiae*; E. *Antheraea paphia*; F. *Creatonotos gangis*

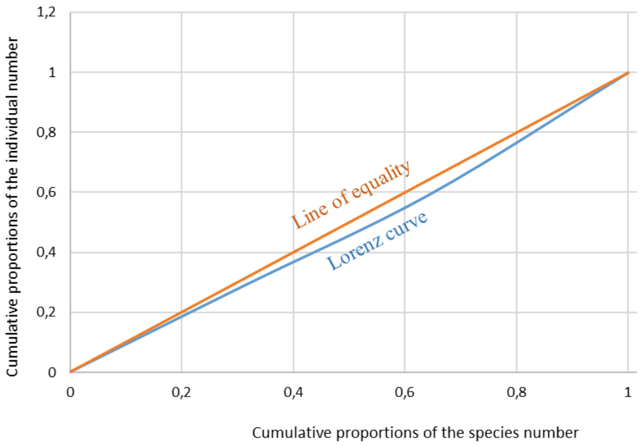

Figure 4. Unequal distribution of butterfly species in the Ndodang Forest, Ngawi District, East Java, Indonesia

The disparities in diversity, abundance, and dominance of Lepidoptera were caused by vegetation types, host plant food sources, and environmental conditions (Ismail et al. 2020). Previous investigations reported that low plant vegetation decreased the number of Lepidoptera, while diverse vegetation increased the species diversity (Basri et al. 2021; Mairawita et al. 2023). In this study, the high diversity observed at Station III was attributed to the more diverse constituents of plant vegetation, such as several species from the family of Poaceae, Asteracea, Pabaceae, Loranthaceae, Amaranthaceae, and Liana plants, including the presence of a river for mineral needs. The condition of the natural vegetation environment of Station II was more homogeneous than Station I, as it was dominated by teak plants, Siamese cassia plants, the Poaceae family, and the Zingiberaceae family (turmeric). At Station I, the vegetation was more diverse, consisting of the Loranthaceae family, Poaceae, teak, rosewood, Siamese cassia, fresh pacing, quite tall bushes, and streams flowing in the forest. The condition of the vegetation environment caused differences in diversity in the three study sites. This was consistent with the statement of Subedi et al. (2021) that higher plant species richness in an area increased the diversity of Lepidoptera species.

The Lorenz curve is a graph that illustrates the size of the gap between research species findings and actual species in a particular area (Figure 4). Based on Lorenz curve calculation data, the diversity of Lepidoptera in the Ndodang Ngawi Forest at three research stations was obtained in the following graph. The diagonal line or equality depicts the distribution of perfect evenness, which is shown in "orange", while the Lorenz curve depicts the distribution of Lepidoptera diversity in the Ndodang Forest, which is shown in "blue."

Based on the graph above, the Lorenz curve is close to the diagonal line. The closer the Lorenz curve is to the diagonal line; it means that the diversity of Lepidoptera in the Ndodang Ngawi Forest has an even distribution of species in that area. From this it can be concluded that the diversity of Lepidoptera in the Ndodang Ngawi Forest has quite small disparities at the three research stations so that the distribution of Lepidoptera in the area is even for several species. The similar condition of some vegetation from the three research stations is also a supporting factor for the even distribution of populations of several Lepidoptera species in the Ndodang Forest.

Environmental physicochemical factors

Biotic and abiotic factors such as environmental physicochemical conditions, including the air temperature also support the presence of Lepidoptera in an area. During the investigation conducted in Ndodang Forest, air temperatures at the three stations ranged from 26.5-31°C for butterfly and 20°-24°C for moth. The environmental temperature that supported butterfly activity ranged from 30-32°C (Sari et al. 2023). Meanwhile, the conditions suitable for moth occurred during the night when air temperature was not excessively cold, stable, and with moderate wind (Delabye et al. 2022). The high temperature recorded at the site was due to measurements taken in the morning during the sampling process.

Another factor affecting butterfly survival in Ndodang Forest is light intensity. Based on the results, the light intensity across all sites ranged from 1192 to 7409 lux for butterfly and 421 to 2084 lux for moth. This indicated that Lepidoptera required light for their survival, as butterfly used light to bask to increase temperature metabolism (Ilhamdi et al. 2023), mate searching, mating, and pollination processes (Bergman et al. 2015; Seymoure 2018). Light intensity that supports butterfly activity in an area started from 654 lux (Panjaitan et al. 2016), while moth were between 3-500 (Li et al. 2019). The habit of moth doing activities around light sources represented a positive phototactic expression behavior due to their attraction to light (Jägerbrand et al. 2023). Light for moth is also essential for moth mating (Boyes et al. 2021) and egg-laying behavior (Li et al. 2019).

Air humidity also affected butterfly survival in Ndodang Forest. This study recorded air humidity levels at the three stations, ranging from 55-77.5%RH for butterfly and 75-87.5%RH for moth. Previous research (Sari et al. 2023) showed that environmental humidity during butterfly analysis reached 50-60%, while Mangrio et al. (2023) recorded a value of 65.5%. Although air humidity between 70-85%RH supports the development and survival of moth (Demissie et al. 2014), all types of insects can breed and survive at a maximum value of 85-94%RH (Andreadis et al. 2017).

The tree canopy density caused by tall plant vegetation affected physical environmental factors such as light intensity (Panjaitan et al. 2016), which was directly proportional to temperature and inversely correlated with humidity. Generally, lower light intensity leads to reduced temperature and higher humidity, thereby affecting the diversity of plant vegetation and correlates with the number of Lepidoptera species found (Mairawita et al. 2023).

The high diversity of Lepidoptera species found at station III was due to the relationship between the physicochemical effect of the environment and plant vegetation. Lepidoptera has a high preference to visit habitats with temperatures, tree crowns, and light intensity with sufficient sunlight, as these conditions promote the growth of flowering plants will grow abundantly enough to meet their food and shelter requirements (Ariyani et al. 2018). This is in line with the environmental conditions at Station III on riverbank, where the supply of temperature and light intensity is higher and humidity is low, resulting in more diverse plant vegetation compared to the two stations.

Light intensity affected the diversity of butterflies in the study area, where more diverse species were found at Station I (in the forest) compared to Station II (forest edge). Generally, butterfly was found in open places with sunny weather (Caraka et al. 2020). Although the light intensity was lower at Station I, the diversity of Lepidoptera species was higher than in Station II due to more heterogeneous plant vegetation and water flow in the forest. Previous research (Lestari et al. 2018) showed that butterfly diversity in the Cirengganis area was relatively more diverse than in the Cikamal Grassland area. Despite the lower intensity of sunlight in the Cirengganis area, the richness of plant vegetation was higher than in the Cikamal grassland area.

In conclusion, this study showed that Lepidoptera in Ndodang Forest area consisted of 9 families, comprising 5 sub-orders Rhoplaocera and 4 Heterocera, with a total of 28 species recorded. The most common species was *C. pomona*, with 60 individuals recorded during the observation, while the least was *E. hypermnestra*, consisting of 2 individuals. The diversity of Lepidoptera in Ndodang Forest was classified as medium, with an Evenness Index showing an even distribution of populations, resulting in a low dominance index in the area. The species diversity was also affected by vegetation as a food source and environmental physicochemical factors, including air temperature, light intensity, and air humidity. The results indicated that more diverse types of vegetation providing food sources for Lepidoptera in a study site led to a greater diversity of the species.

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