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Diversity of butterfly species (Order: Lepidoptera) in riparian ecosystems of Bromo Tengger Semeru National Park, Indonesia

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Abstract. *Fahlefi AR, Prasetya KN, Firdhausi NF, Bahri S. 2024. Diversity of butterfly species (Order: Lepidoptera) in riparian ecosystems of Bromo Tengger Semeru National Park, Indonesia. Intl J Bonorowo Wetlands 14: 66-73.* The existence of Bromo Tengger Semeru National (BTSN) Park, Indonesia is of utmost importance, as the function of the national park is to manage, convert, and preserve all flora and fauna and protect all ecosystems within the National Park Area. Forest fires have unfortunately occurred in Bromo Tengger Semeru National Park, leading to the destruction of several areas and causing habitat loss for various species, such as butterflies. This study, therefore, holds significant value as it aims to identify and analyze the diversity of butterfly species (Order: Lepidoptera) in BTSN Park Area, Indonesia, using the transect method combined with the Visual Encounter Survey method. The research location was divided into five locations: Ireng-ireng Area, Ranu Pani, Ranu Regulo, Ranu Darungan, and Trisula Riverbank; the measurement of factors supporting the presence of butterflies, such as temperature, humidity, and light intensity. Based on the research conducted, 46 butterfly species were found, with a total of 465 individuals from 5 families. Of the 46 species, 9 species were found to be endemic species and protected species. To determine the value of butterfly species diversity, it is calculated using the Shannon-Wiener diversity index. The results of the index analysis obtained from the five locations are: (Location 1) diversity index H'=3.32, (Location 2) diversity index H'=1.21, (Location 3) diversity index H'=1.39, (Location 4) diversity index H'=1.91, (Location 5) diversity index H'=2.55. These findings are crucial for understanding and conserving the biodiversity of this unique national park.

Keywords: Butterflies, endemic, forest fire, transect

INTRODUCTION

Species diversity is a characteristic of a community that indicates the level of diversity of the types of organisms present within it. Every organism in an ecosystem has a population that fluctuates over time and is never the same. Similarly, the ecosystem formed by populations and their physical environment continuously changes and evolves (Siregar et al. 2014). Species diversity can be marked by differences in color, size, shape, quantity, texture, appearance, and other characteristics (Ridhwan 2012). The diversity of species can also be seen through the similarities in traits among them. Recognizing living beings, especially animals, based on their characteristics. By observing morphological traits, habitat, reproduction methods, types of food, behavior, and several other observable features, one can gain a deeper understanding of species diversity (Peres et al. 2023).

Lepidoptera, with >150,000 species, are the second largest and most diverse. Lepidoptera are generally winged insects with layers of small scales. Butterflies belong to the Order Lepidoptera (Suhaimi et al. 2017). Butterflies are brilliantly colored and beautifully patterned organisms (Mayur et al. 2013). Butterflies are flying insects that have three parts: cephal, thorax, and abdomen (Rawat et al. 2023). Butterflies undergo complete metamorphosis (holometabolous), meaning they go through the stages of egg, caterpillar, pupa, and imago (Wellmann 2023). Butterflies play an important role in pollination (Martínez-Adriano et al. 2018). The relationship between flowering plants and flower-visiting insects is important for preserving terrestrial ecosystems and leads to different insect-plant and insect-herbivore interactions. Butterflies are considered the second pollinator after bees (Koneri et al. 2022). It was previously reported that butterflies are able to disperse in various habitats such as forests, gardens, grasslands, and metropolitan areas (Basri and Zakaria 2021). About 90% of butterfly species live in the tropics (Suwarno et al. 2018).

In Indonesia, it has been estimated that about 2500 species are found, while about 35% of them are endemic (Murwitaningsih and Dharma 2014). The diversity of butterfly species is different in each place and cannot be separated from the carrying capacity of its habitat. The presence of butterflies can be influenced by several factors, including host plants both as larval hosts and as nectar sources for imago; physical factors such as temperature, humidity, and light intensity are also important factors that limit the presence of butterflies in a place (Apriana et al. 2022). This is why not all places can be used as butterfly breeding grounds.

Bromo Tengger Semeru National (BTSN) Park, Indonesia is one of the conservation areas with abundant biodiversity, both from flora and fauna. The research on

butterflies in BTSN Park is not the first of its kind. Research on butterfly diversity was conducted by Millah et al. (2020) on the diversity of butterflies (Lepidoptera: Rhopalocera) in the BTSN Park. This research was conducted at four observation points: Ranu Darungan, Ranu Pani, Ranu Regulo, and Ireng-ireng Area. The results of the research revealed that there are 41 species from 5 different families. The research shows that the Shannon-Wiener diversity index result is H'= 1.73.

Forest fires occur in BTSN Park; the destruction of several BTSN Park is the main cause of habitat loss for various species of animals. Changes often accompany forest fires and decreases in biodiversity. Organisms have beneficial interactions with local habitats. This interaction between organisms and habitats can be a reference for information related to how changes in natural habitats affect populations of organisms such as butterflies (Forister et al. 2019). The impact of the fires that occurred in BTSN Park can be the cause of changes in the existing ecosystem; therefore, it is important to conduct research to get the latest data on butterfly diversity in BTSN Park is very important. This study aims to determine the diversity of butterfly species (Order: Lepidoptera) in BTSN Park, Indonesia.

MATERIALS AND METHODS

Studi area

Data collection began in February and ended in April 2024 with three repetitions. Each month, one repetition was conducted at each research location to obtain valid data. Data collection was carried out during sunny conditions, with observation time from 07.00 WIB until 12.00 WIB. This observation was carried out in the Bromo Tengger Semeru National (BTSN) Park, Indonesia (Figure 1). The observation location in BTSN Park is divided into five locations: the Ireng-Ireng Area, Ranu Pani, Ranu Regulo, Ranu Darungan, and Trisula Riverbank (Table 1).

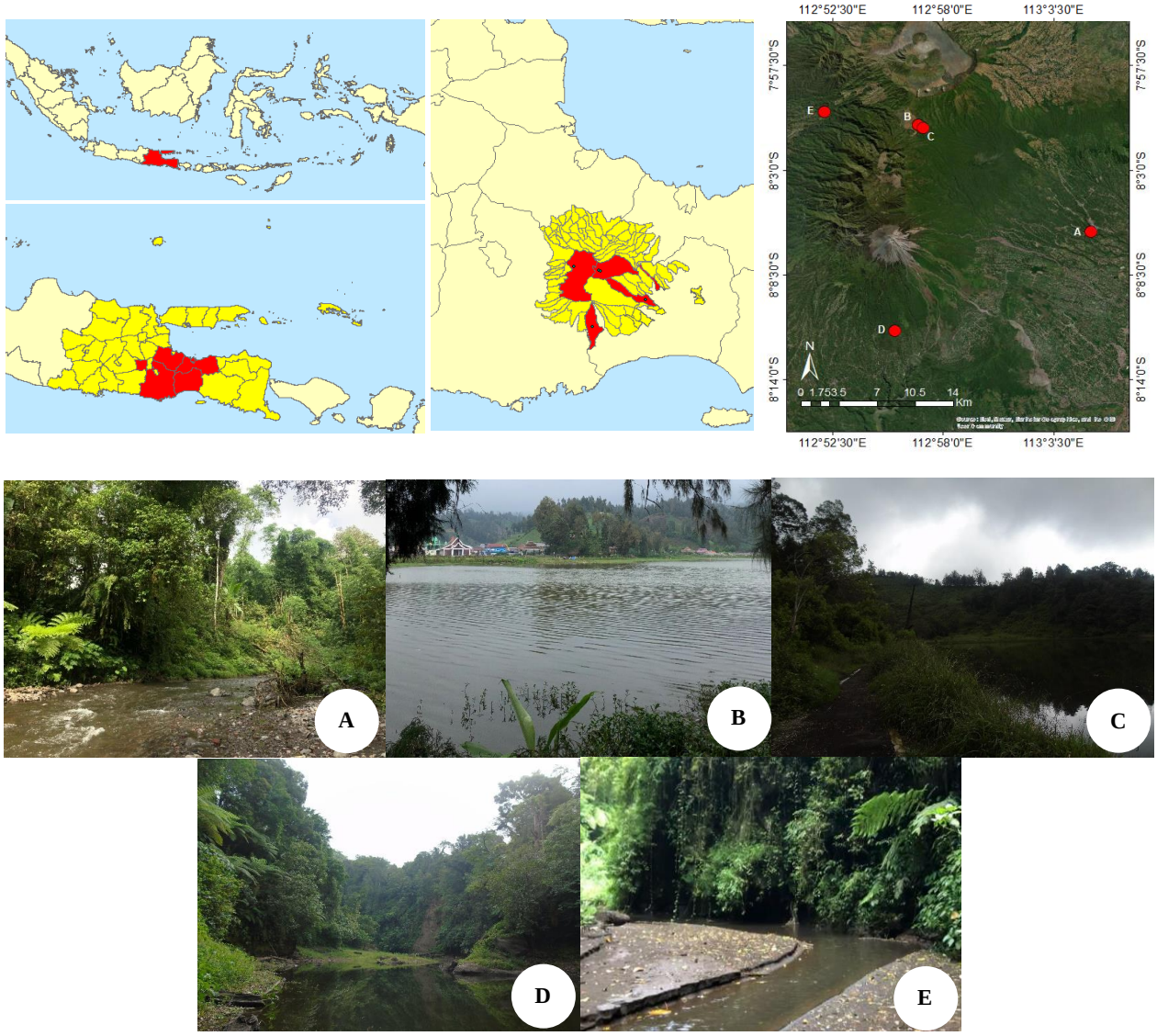

Figure 1. Research location of Bromo Tengger Semeru National Park, Indonesia. A. Ireng-ireng Area, B. Ranu Pani, C. Ranu Regulo, D. Ranu Darungan, E. Trisula Riverbank

Table 1. Description of location in Bromo Tengger Semeru National Park, East Java, Indonesia

Location	Description
L1 (Ireng-ireng Area)	The Ireng-ireng has an open canopy and a stream. This location has diverse vegetation and is located in the middle of the forest so there is no human activity.
L2 (Ranu Pani)	Ranu Pani has an open canopy, a non-flowing lake, and no dense vegetation. Humans often visit this location.
L3 (Ranu Regulo)	Ranu Regulo's canopy tends to be open, and there is a lake that does not flow. This location is covered by fog, making it difficult to make observations.
L4 (Ranu Darungan)	Ranu Darungan's canopy tends to be open, and there is a lake that does not flow. Diverse vegetation makes this location frequently visited.
L5 (Trisula Riverbank)	Trisula Riverbank has dense vegetation with a canopy that tends to be open, and a flowing water habitat type. This location does not detect human activity because it is located in the middle of the forest.

Data collection method

The observation method is done directly or the Visual Encounter Survey (VES) method (Lestari et al. 2018). Visual Encounter Survey is a method carried out by recording and counting the number of individuals of butterfly species encountered during active butterfly hours (Zulaikha and Bahri 2021). The transect method was combined with the VES method. Butterfly observation transects were also established along 10 meters of roadside paths. The transect route is divided into several observation points that provide information on the distribution of local butterflies (Priyono and Abdullah 2013).

After capturing the butterflies, identification was done with the help of an identification book (Rositawati 2016; Ilhamdi et al. 2018). This study was conducted in conjunction with measurements of abiotic factors, including temperature and humidity using a thermohygrometer; and light intensity using a lux meter. These factors were measured in the morning before starting the butterfly data collection. Research was also made on the type of vegetation and canopy surrounding the butterfly habitat.

Data analysis

The total individuals obtained were then calculated using the relative abundance formula to determine the percentage of species, then analyzed using Microsoft Excel software.

Diversity index

According to Koneri et al. (2020), to determine the value of butterfly species diversity, it is calculated using the Shannon-Wiener diversity index formula as follows:

$$H' = -\sum pi\ Ln\ pi$$

Where:
H′: Diversity index
Pi: Total ni/N
ni: Number of individuals of type i
N: Number of individuals of all type
Ln: Natural logarithm

Evenness index

$$E' = \frac{H'}{lnS}$$

Where:
E: Evenness index
H': Diversity index
S: Number of species
Ln: Natural logarithm

Dominance index

$$D = \Sigma\ (ni/\ N)^2$$

Where:
D: Dominance index
ni: Number of individuals of a species
N: Number of individuals of all species

Relative abundance

$$RA = \frac{ni}{N} \times 100\%$$

Where:
RA: Relative abundance
ni: Number of individuals of a species
N: Number of individuals of all species

RESULTS AND DISCUSSION

Based on observations at five stations spread across BTSN Park, 46 butterfly species were found with 465 individuals in total. The butterfly species are included in five families: Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, and Pieridae. Nymphalidae is the family with the highest number of species found in this observation, with a total of 24 species. The large proportion of this family is due to Nymphalidae having more than one host plant. This can fulfill its need for host plants even though the main host plant is not available. This condition causes Nymphalidae to be found quite large in the observation location (Priyono and Abdullah 2013). The Hesperiidae was the least-found family in this observation, with a total of 3 species (Table 2).

The abundance of butterfly species in the BTSN Park area varies greatly at each observation station, but there is a dominant species at the observation station, namely *Ypthima pandocus* with a relative abundance value of 7.31%. *Mooreana trichoneura*, *Athyma selenophora*,

Vanessa cardui, and *Papilio arjuna* are species with the least relative abundance value of 0.22%. The *Y. pandocus* (Figure 2.D) is often found in diverse vegetation and streams. Mountain ecosystem conditions with high air humidity and low temperature with sunlight intensity so that this species is often found. This is supported by Sari et al. (2016), who stated the presence of Eupatorium odoratum plants, which are food plants in all habitat types, is one of the main reasons for the abundance of *Y. pandocus*. Of the 46 species, 9 species were found to be endemic species, namely *Cyrestis lutea* endemic to Java and Bali; *Mycalesis moorei* and *Delias aurantiaca*, endemic to Java; and *P. arjuna* (Figure 2.T), endemic to Indonesia. *Zizina otis*, *Junonia almana* (Figure 2.J), *V. cardui*, *Troides cuneifera*, and *Troides helena* (Figure 2.P) are classified as Least Concern (LC) species according to the IUCN (International Union for Conservation of Nature) Red List data.

Table 2. Observation data on butterflies in Bromo Tengger Semeru National Park, East Java, Indonesia

Species	Location					Total	RA%	Conservation status
	1	2	3	4	5			
Hesperiidae								
Mooreana trichoneura (C. Felder & R. Felder, 1860)	1	-	-	-	-	1	0.22	NE
Notocrypta paralysos (Wood-Mason & de Niceville, 1881)	8	-	-	-	4	12	2.58	NE
Potanthus trachala (Mabille, 1878)	8	-	-	-	3	11	2.37	NE
Lycaenidae								
Heliophorus epicles (Godart, 1823)	3	-	-	-	2	5	1.08	NE
Poritia erycinoides (Felder, 1865)	-	-	-	3	-	3	0.65	NE
Udara dilecta (Moore, 1879)	21	-	-	-	-	21	4.52	NE
Zizina otis (Fabricius, 1787)	23	-	-	-	5	28	6.02	LC
Nymphalidae								
Acraea issoria (Hübner, 1819)	-	7	2	-	-	9	1.94	NE
Athyma selenophora (Kollar, 1844)	1	-	-	-	-	1	0.22	NE
Cyrestis lutea (Zinken, 1831)	9	-	-	-	-	9	1.94	NE
Euploea mulciber (Cramer, 1777)	4	-	-	2	1	7	0.43	VU
Euthalia whiteheadi (Grose Smith, 1889)	2	-	-	-	-	2	0.43	NE
Faunis canens (Hübner, 1826)	2	-	-	-	-	2	0.43	NE
Hypolimnas bolina (Linnaeus, 1758)	2	-	-	1	-	3	0.65	NE
Ideopsis gaura (Horsfield 1829)	3	-	-	1	-	4	0.86	NE
Junonia almana (Linnaeus, 1758)	-	-	-	25	-	25	5.38	LC
Junonia atlites (Linnaeus, 1763)	-	-	-	28	-	28	6.02	NE
Junonia iphita (Cramer, 1779)	2	-	-	-	-	2	0.43	NE
Mycalesis moorei (C. Felder & R. Felder, 1867)	9	-	2	-	10	21	4.52	NE
Neptis hylas (Linnaeus, 1758)	13	-	-	1	3	17	3.66	NE
Neptis vikasi (Moore, 1899)	4	-	-	-	-	4	0.86	NE
Parantica aspasia (Fabricius, 1787)	4	-	-	3	-	7	1.51	NE
Symbrenthia hypselis (Godart, 1824)	14	-	-	-	1	15	3.23	NE
Symbrenthia lilaea (Hewitson, 1864)	8	-	-	-	1	9	1.94	NE
Tanaecia iapis (Godart, 1824)	7	-	-	-	-	7	1.51	NE
Tanaecia trigerta Moore, 1857	3	-	-	-	-	3	0.65	NE
Telchinia issoria (Fruhstorfer, 1914)	-	6	-	-	-	6	1.29	NE
Vagrans egista (Cramer, 1780)	2	-	-	-	-	2	0.43	NE
Vanessa cardui (Linnaeus, 1758)	-	-	-	-	1	1	0.22	LC
Ypthima nigricans Snellen	8	-	-	-	2	10	2.15	NE
Ypthima pandocus (Moore, 1857)	16	-	-	4	14	34	7.31	NE
Papilionidae								
Graphium antiphates (Cramer, 1775)	2	-	-	-	-	2	0.43	NE
Graphium doson (C. Felder & R. Felder, 1864)	-	-	-	2	-	2	0.43	NE
Graphium sarpedon (Linnaeus, 1758)	11	-	2	5	-	18	3.87	NE
Papilio arjuna (Horsfield, 1828)	-	1	-	-	-	1	0.22	NE
Papilio helenus (Linnaeus, 1758)	15	-	-	-	-	15	3.23	NE
Papilio memnon (Linnaeus, 1758)	12	-	-	2	1	15	3.23	NE
Papilio polytes (Linnaeus, 1758)	3	-	-	-	-	3	0.65	NE
Troides cuneifera (Oberthür, 1879)	8	-	-	-	-	8	1.72	LC
Troides helena (Linnaeus, 1758)	5	-	-	-	4	9	1.94	LC
Pieridae								
Appias olferna (Swinhoe, 1890)	6	-	-	-	4	10	2.15	NE
Cepora iudith (Fabricius, 1787)	5	-	-	-	-	5	1.08	NE
Delias aurantiaca (Doherty, 1891)	-	-	-	-	2	2	0.43	NE
Delias belisama (Cramer, 1779)	2	-	-	1	17	20	4.30	NE
Eurema blanda (Boisduval, 1836)	21	-	-	3	5	29	6.24	NE
Leptosia nina (Fabricius, 1793)	9	3	2	-	3	17	3.66	NE

Figure 2. A. *Symbrenthia lilaea*, B. *Notocrypta paralysos*, C. *Tanaecia iapis*, D. *Ypthyma pandocus*, E. *Ideopsis gaura*, F. *Euthalia whiteheadi*, G. *Hypolimnas bolina*, H. *Parantica Aspasia*, I. *Poritia erycinoides*, J. *Junonia almana*, K. *Junonia atlites*, L. *Neptis vikasi*, M. *Potanthus trachala*, N. *Eurema blanda*, O. *Heliophorus epicles*, P. *Troides helena*, Q. *Symbrenthia hipselis*, R. *Papilio helenus*, S. *Graphium sarpedon*, T. *Papilio arjuna*, U. *Euploea Mulciber*

The Ireng-Ireng Area, a location of significant importance in butterfly research, is where the highest number of butterfly species are found, with a diversity index value of H'=3.32 (Figure 3). The vegetation in this area makes the presence of butterflies abundant. The high diversity value is a result of the even distribution of individuals per species, indicating that all species in the community have approximately the same number of individuals. Station 1, with its abundant water sources for mineral purposes and a relatively open canopy with high light intensity compared to other stations (Table 3), supports a high diversity of butterfly species and a large number of butterflies that carry out activities optimally. The environmental support components, such as the availability of habitat, water, minerals, food, temperature, and humidity, play a crucial role in shaping the unique butterfly diversity of the Ireng-Ireng area, making it a valued area of study (Mas'ud et al. 2018).

Severns (2008) said that the butterfly population in a community is influenced by light intensity. Station 1 has the most species diversity because it has the highest light intensity than other stations (Table 3). This is supported by Nurjannah (2010), who said that the appropriate light intensity for butterfly development is 2,000-7,500 lux. Butterflies are animals with scaly wings (Lepidoptera) that are active during the day when light intensity is high. High sunlight intensity is necessary because butterflies utilize the sun's heat when flying. When the weather is dark or rainy, butterflies will take shelter behind leaves. Butterflies need light because butterflies are cold-blooded (poikilotherm) (Nuraini et al. 2020). Light will provide heat energy so as to increase body temperature, and metabolism becomes faster; in butterfly larvae, an increase in body temperature will accelerate the development of butterfly larvae (Rahayu and Basukriadi 2012).

At the Ranu Pani location, *P. arjuna* species was found absorbing minerals in the soil (Figure 2.T). The *P. arjuna* that is distributed in Sumatra and Java. This change is based on research conducted by Condamine et al. (2023), which suggested that *P. arjuna* is an independent species because it has undergone speciation. This species is now endemic to Indonesia. Ranu Pani is the research location that has the smallest diversity index value, H'=1.21. This is due to the temperature at this location being very low compared to other locations. The impact of temperature on butterfly activity, distribution, growth, and breeding cannot be overstated. Based on the measurement of environmental factors, it is found that temperature is inversely proportional to humidity (Table 3). This is in accordance with Febrita et al. (2014) that the high and low value of air humidity in an area is influenced by air temperature in the area, where temperature is inversely proportional to humidity. The higher the ambient temperature, the lower the humidity, and vice versa.

Ranu Regulo is a location surrounded by mist, the main cause of humidity. The vegetation found in this area is not varied. At the Ranu Regulo location, 4 species were found consisting of *Acraea issoria*, *M. moorei*, *Graphium sarpedon*, and *Leptosia nina*. Ranu Regulo has a diversity index value of H'=1.39. *A. issoria* species, with its unique habit of perching in bushes and slow flying ability, has a relative abundance value of 1.94%. The species *M. moorei* was found perching on its host plant. The genus *Mycalesis* generally uses Poaceae as its host plant (Rositawati 2016). *M. moorei is* endemic to Java. This species is classified as Not Evaluated in the IUCN Red List. Species *G. sarpedon* (Figure 2.S) has been found absorbing minerals from the soil and engaging in an activity known as puddling. The *L. nina* species, with its unique ability to fly low and slow, is often found resting in bushes (Rositawati 2016).

Ranu Darungan has dense vegetation and an open canopy, with 14 species and 81 individuals recorded. Ranu Darungan has a diversity index value of H'=1.91. *Junonia atlites* species dominated this location with a relative abundance value of 6.02%. The *J. atlites* species were found perched on the grass (Figure 2.K). The host plants of *J. atlites* include several, such as wild rice (*Oryza* sp.), *landep* (*Barleria* sp.), and *kunang* plants (*Strobilanthes* sp.) (Kurniawan and Samani 2023). Species *Graphium doson* is only found in the Ranu Darungan location, with a total of 2 individuals. The *G. doson* was found mating in a flying position. Its wings have a black base color with blue spots.

Trisula Riverbank is a location that has a diversity index value of H'=2.55. The *D. aurantiaca* was the only species found at Trisula Riverbank. During observation, this species was found flying with *Delias belisama*. This species is a type of butterfly that only exists in Indonesia on the island of Java (endemic Java). A rare and protected species was also found at this location, *T. helena* and *T. cuneifera*. This butterfly is often seen staying longer on plant flowers (Figure 2.P).

Table 3. Abiotic factor data

Location	Temperature (°C)	Humidity (%)	Light intensity (lux)
1 (Ireng-Ireng Area)	25-26	80	2854
2 (Ranu Pani)	11-12	94	1347
3 (Ranu Regulo)	19-20	92	1354
4 (Ranu Darungan)	25-26	90	1470
5 (Trisula Riverbank)	17-19	97	1132

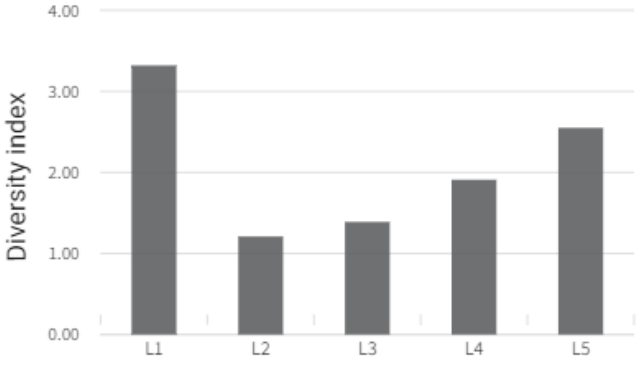

Figure 3. Diversity index

Troides helena can almost be found at all altitudes, especially at an altitude of 200-1,500 masl, in various types of forest habitats and is even sometimes seen in rural areas and city parks. Species *T. cuneifera* have a black body. The back wings are golden and have black spots. The female butterfly is dark brown and larger than the male butterfly. This bird has a high flying ability and is very fast. The species *T. helena* generally has a greater abundance of female *T. helena* butterflies compared to male butterflies. The flying activity of the *T. helena* species is very high (Harmonis 2021). Both of these species are classified under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix II, which means that their trade is prohibited.

Based on the results of the evenness index analysis on butterfly species in the BTSN area, there is a value of 0.92 at Location 1, Location 2 at 0.87, Location 3 at 1.00, Location 4 with a value of 0.72, and Location 5 at 0.87 (Figure 4). The average value of the butterfly evenness index at the observation site is 0.88. The evenness index in this area is classified in the high evenness category. Thus, the five locations have high evenness and stable communities. The dominance index is an index used to obtain data on butterfly species at the observation site that dominate in a community. The dominance index of butterfly species at the observation site can be seen in Figure 4. The results of the analysis of the dominance index of butterfly species at Location 1 are 0.04, at Location 2 it is 0.33; Location 3 it is 0.25, then Location 4 with a value of 0.23, and at Location 5 it is 0.11. The average butterfly dominance index value is 0.19. The butterfly dominance index value is low.

The dominance index obtained shows that from the abundance of individuals of butterfly species there is no very prominent dominance. This is in accordance with the statement of Purwowidodo (2015), that the dominance is not prominent because good habitat conditions at each station have the availability of living resources such as food, host plants, shelter, and breeding that are quite varied or heterogeneous for butterflies.

Figure 4. Evenness index and dominance index

The dominance index and evenness index formulas actually have a negative correlation. The dominance index is inversely proportional to the evenness index, meaning that if the dominance index is high, it indicates that a habitat has a low level of evenness of individuals; on the other hand, a low dominance index indicates a tendency for the abundance of individuals of butterfly species to be evenly distributed in a habitat. If the evenness is close to zero, it means that the evenness between species in the community is low. On the other hand, evenness close to one can mean that the evenness between species is relatively even or equal. This evenness index can be interpreted as the degree of evenness in the abundance of individuals between species (Nuraini et al. 2020).

The results of the research in BTSN Park revealed 46 species of butterflies with a total of 465 individuals from 5 families. Families that include Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, and Pieridae. Of the 46 species, there are endemic species such as *C. lutea*, endemic to Java and Bali; *M. moorei* and *D. aurantiaca*, endemic to Java; and *P. arjuna* endemic to Indonesia. The species *Z. otis*, *J. almana*, *V. cardui*, *T. cuneifera*, and *T. helena* are classified as low risk or Least Concern (LC) according to the IUCN Red List data. The species with the highest number of individuals is *Y. pandocus*, with a total of 34 individuals. The Diversity Index is classified as high, with a value of H'=3.47.

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