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Diversity and Community Structure of Butterflies (Lepidoptera: Papilionoidea) in The Sigolo-Golo Tourism Area, Jombang, East Java

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Abstract

The Sigolo-golo natural tourism area is located in the Wonosalam district, Jombang. The environment in this area is still relatively well preserved because it has a variety of vegetation and habitats. There is very little information on the community structure of butterflies (Papilionoidea) in this area, so this research is needed to find the community structure of butterflies in Sigolo-golo tourism. The method used in this research is a visual encounter survey combined with the transect method, which is to carry out direct counts of species and individuals of butterflies that are often found. The research locations were divided based on different habitat types, namely plantations, forests, and riverbanks. This study found 43 species with 358 individuals from five families. The results of the data analysis show that the diversity index value at each location is in the high category. The diversity and revealing butterflies at each location explain why the community structure in Sigolo-golo tourism is still stable and well maintained.

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Introduction

Butterflies (Papilionoidea) belong to the Lepidoptera Order (Kawahara et al., 2023), which are one of the most common insects. Butterflies have around 18,000 identified species in almost all parts of the world (Graça & Solis, 2018) Most butterflies, at least 90%, inhabit tropical areas, including Indonesia (Bonebrake et al., 2010). Indonesia has approximately 2000–2200 species that have been identified (Peggie et al., 2022). The Indonesian archipelago, with its various types of habitat, is the main factor in the abundant diversity of butterflies (Ashari & Addiniyah, 2019). Butterflies can be found in forest areas, canopies, and open areas. Several factors that affect butterflies include vegetation composition, air temperature, air humidity, wind speed, and light intensity (Koneri et al., 2022).

Butterflies have a fairly vital role in the ecosystem (An & Choi, 2021) including as pollinators (pollinators), herbivores, bioindicators, food sources for predators, components

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of diversity, and food chains. Butterflies are one of the animals that are often used as cultural objects (Ghazanfar et al., 2016). Butterflies play an active role in pollinating flowering plants (Clark et al., 2007). In the larval stage, butterflies act as herbivores (phytophages) by eating host plants according to the need for secondary metabolites produced by plants (Bonebrake et al., 2010). Larvae eat plants to meet their needs before the pupal phase (Shahroni et al., 2022). In addition, the ecological function of butterflies is to provide a source of food for predators such as frogs, lizards, and birds, which are examples of predators that depend on the presence of butterfly larvae and imago (Paramanandham et al., 2021).

The various benefits and roles of butterflies are one of the important points to consider when considering the preservation of butterflies. Environmental issues such as urbanization, environmental pollution, land degradation, climate change, and global warming always threaten sustainability and have the potential to reduce butterfly diversity (Clark et al., 2007). So, conservation efforts need to be encouraged so that the butterflies are maintained. Research and data collection for butterflies are no less important in mapping their distribution, habits, and threats. With the existence of research data, it can be a consideration for the government in making policies regarding land management, utilization of natural resources, and conservation movements.

Research and data collection of butterfly species in the Sigolo-golo tourist area, Wonosalam, Jombang, have not been carried out. The habitat at this location is in the form of plantation areas, secondary forests and river areas. vegetation consists of lower plants, shrubs, fruit trees, and horticultural plants. Sigolo-golo is administratively located in Dusun Kraten, Desa (Village) Panglungan, Wonosalam District, Jombang Regency. The aim of this research is to fill in the gaps in butterfly data in the region. Sigolo-golo is a tourist attraction in the Jombang Regency that is relatively new and still developing. Therefore, data related to butterflies is needed so that in the future it can be used as material for consideration of land management, evaluation, environmental conservation efforts, and policymaking in the Sigolo-golo area.

Materials and Methods

Sample Collection

This research was conducted on several routes in the Sigolo-golo tourist area, Wonosalam district, Jombang, East Java, Indonesia. Sampling was carried out in February 2023 during active butterfly hours, namely 08.00–14.00 WIB, according to observations made (Zulaikha et al., 2022). The Sigolo-Golo Tourism area is secondary forest and agroforestry, some of which have been used by the community as plantation areas. The research location is divided based on the type of habitat, including plantation areas, secondary forest areas, and river banks.

The location was chosen according to the route on the Sigolo-golo tour, from the entrance to the Sigolo-golo river. These lines have different habitat characteristics, so they can be separated to see differences in butterfly composition at the study site. The plantation area spans from a parking lot to a 700-meter secondary forest area, with an open canopy of cultivated and wild plants between the plantations. The secondary forest covers a strip of forest at a distance of 800 meters, which is dominated by wild plants and large trees. There are few cultivated plants, such as coffee, durian, and banana, among the forest plants. The river bank is a secondary forest location with an open habitat type. The riverbank has a rock and sand substrate. Around the river flow many overgrown wild plants, such as reeds and ferns. The river habitat type has a distance of about 750 meters from the river lip.

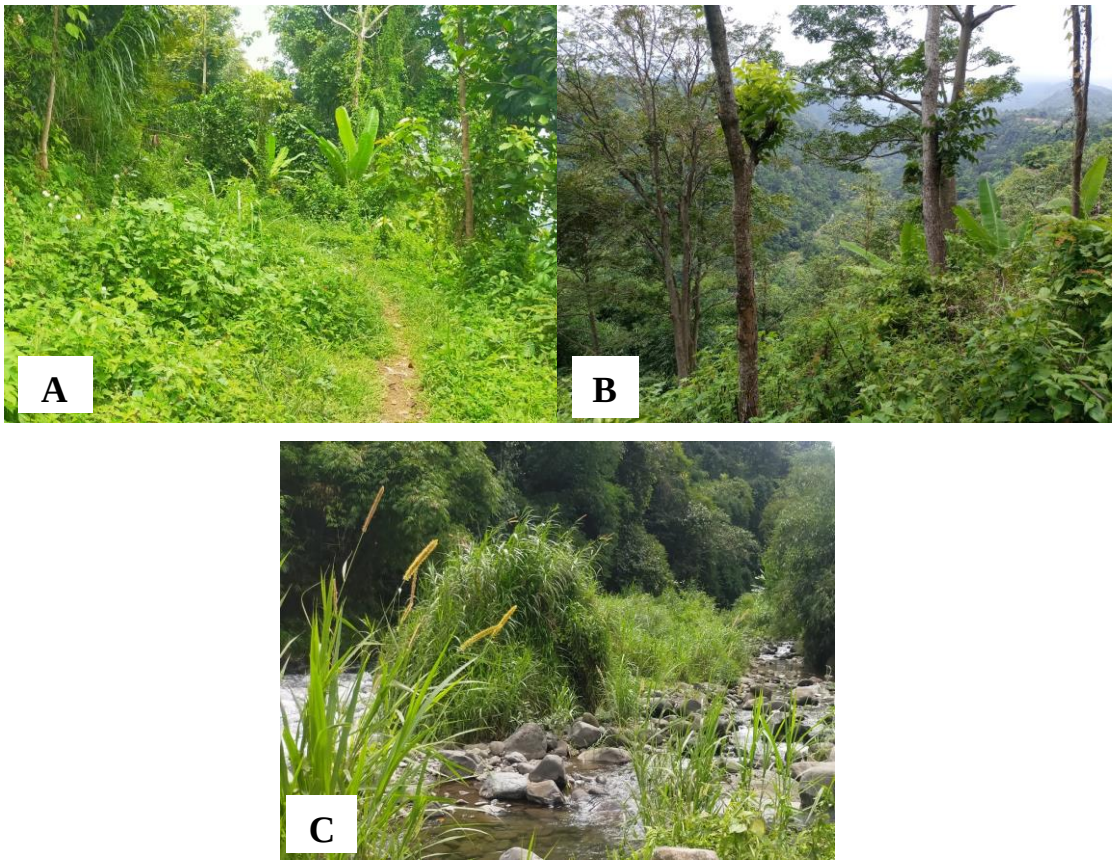

Figure 1. Research Locations (A) Plantation, (B) Secondary Forest, (C) Riverbanks

The choice of research route using a transect is to follow a path that starts from the parking area to the river area in the Sigolo-golo area. The butterfly sampling method was carried out using the VES (Visual encounter survey) method combined with a sweeping net. VES is an observational method by recording the number of species and the number of individuals encountered directly. This method was chosen because it is effective in active sampling to estimate the richness and abundance of butterfly (Freitas et al., 2021).

Butterflies that have not been identified are caught using a Sweep Net and put on papilot paper to make the identification process easier (Basri & Zakaria, 2021). Butterflies that are difficult to access are taken using a camera, to then be identified based on the results of the images. Identification was based on the morphological similarity of the samples taken, then matched using an identification book, Biodiversity Campus: Butterflies in the Dramaga IPB Campus Area (Mustari, 2016), and the Kupunesia application (Peggie et al., 2022). The process of measuring environmental conditions is also carried out simultaneously with the observation process. The abiotic parameters measured were environmental factors related to the way of life of butterflies including air temperature (^{o}C), light intensity (Lux), wind speed (m/s) and humidity (%) respectively measured using the tools provided, including a thermohygrometer, lux meter and anemometer.

Data Analysis

Data from observations were analyzed using the indices of diversity, evenness, dominance and frequency of presence. Observed butterfly species are presented in

tabulations or graphs and grouped by family and location of encounter, so as to produce data on the composition and structure of the butterfly community in the Sigolo-golo area.

Results and Discussion

The results of research in the Sigolo-Golo tourism area found 358 individuals with 43 species of butterflies from five families (Table 1). The butterfly families recorded are Nymphalidae, Pieridae, Lycaenidae, Hesperidae, and Papilionidae. The butterfly family with the highest number of individuals is the Nymphalidae group, which consists of 118 individuals from 18 species. The species in the Nymphalidae group with the highest number of individuals is *Ypthima philomela*. The family with the lowest number of individuals was Papilionidae, with 14 of the four species found. The Hesperiidae family in the Sigolo-golo area consists of six species; Lycaenidae consists of seven species; and Pieridae is found with eight species.

Table 1. List of species and relative abundance

Species	Plantation	Secondary forest	Riverbank	RA (%)
Hesperiidae				
Ancistroides nigrita (Latreille, 1824)	-	+	+	2.23
Koruthaialos rubecula (Watson,1893)	-	+	+	3.63
Iambrix stelifer (Fruhstorfer, 1910)	-	+	+	1.12
Oriens gola (Moore, 1877)	+	-	-	0.84
Potanthus omaha (Scudder, 1872)	-	+	-	0.28
Udaspes Folus (Cramer, 1775)	+	-	-	0.56
Lycaenidae				
Acytolepis puspa (Horsfield, 1828)	+	-	-	0.28
Caleta roxus (Godart, 1824)	-	-	+	0.84
Jamides Alecto (Felder, 1860)	-	+	-	0.84
Loxura atymnus (Stoll, 1780)	-	+	-	0.28
Cheritra freja (Fabricius, 1793)	-	+	-	0.56
Zeltus amasa (Hewitson, 1865)	-	+	+	3.63
Nacaduba Berenice (Herrich-Schäffer, 1869)	-	-	+	4.75
Nymphalidae				
Acraea issoria (Hübner, 1819)	-	-	+	4.19
Cyrestis nivea (Zinken, 1831)	-	-	+	2.23
Euploea mulciber (Cramer, 1777)	-	+	-	0.28
Faunis canens (Hübner, 1826)	-	+	-	1.12
Junonia hedonia (Linnaeus, 1764)	+	-	-	0.28
Junonia iphita (Cramer, 1779)	+	+	+	3.35
Ypthima philomela (Linnaeus, 1763)	+	+	+	6.98
Ypthima horsfieldii (Moore, 1884)	+	+	+	1.68
Ypthima pandocus (Moore, 1858)	+	+	+	0.84

Ideopsis juventa (Cramer, 1777)	-	-	+	0.56
Lethe confuse (Aurivillius, 1897)	-	+	+	1.4
Melanitis zitenius (Herbst, 1796)	+	-	-	0.28
Mycalesis horsfieldi (Moore, 1892)	+	+	+	4.19
Symbrenthia hippoclus (Cramer, 1779)	-	+	-	1.12
Symbrenthia hypselis (Godart, 1824)	-	-	+	0.56
Neptis hylas (Linnaeus, 1758)	+	+	-	2.51
Orsotriaena medus (Fabricius, 1775)	+	-	-	0.56
Polyura Moori (Distant, 1883)	-	-	+	0.84
Papilionidae				
Graphium doson (C. & R. Felder, 1864)	-	-	+	0.84
Graphium Sarpedon (Linnaeus, 1758)	-	+	-	0.28
Troides Helena (Linnaeus, 1758)	-	+	-	0.28
Papilio Memnon (Linnaeus, 1758)	+	+	+	2.51
Pieridae				
Appias olferna (Swinhoe, 1890)	+	-	-	1.68
Catopsilia Pomona (Fabricius, 1775)	+	+	+	11.73
Delias belisama (Cramer, 1780)	+	+	-	5.59
Eurema blanda (Boisduval, 1836)	+	+	+	5.59
Eurema hecabe (Linnaeus, 1758)	+	+	+	8.94
Hebomoia glaucippe (Linnaeus, 1758)	+	+	+	2.79
Leptosia nina (Fabricius, 1793)	+	+	-	3.07
Saletara panda (Godart, 1819)	+	+	+	3.91

Note: RA= Relative Abundance. (+) Present, (-) Absence

Nymphalidae is a family with the highest number of individuals and species. This is because this group is known to have the highest number of species, a wide distribution, and is often found in open areas. The Sigolo-golo tourist area supports these criteria. This location has an open canopy type, extensive forest and plantation areas, supporting abiotic factors, and a diverse composition of vegetation that supports the life cycle of butterflies. According to Lestari et al., (2018), the Nymphalidae group is polyphagous, that is, it has two or more host plants. This increases the life potential of the Nymphalidae, so that the abundance of Sigolo-golo is higher than that of other species. Nymphalidae are known to choose host plants from Verbenaceae, Moraceae, Rubiaceae, Anacardiaceae, and so on (Han et al., 2021). Some of the plants that can be found at the study site and have the potential to become feed preferences for Nymphalidae include *Ficus* sp., *Lantana camara, Mangifera indica, Ageratina riparia, Ageratum conyzoides, Austroeupatorium inulifolium, Crassocephalum crepidioides* and *Pennisetum purpureum*. Several of these plant species were also discovered by Agustiningrum et al. (2022) which is said to have the potential to become a food plant and host, in Coban Rais Tourism, Batu.

The family with the least number of individuals and species in the Sigolo-golo tourist area is Papilionidae. The small amount of abundance is due in part to this group, which is a group of specialists that select one type of plant as a host (monophages). For example,

butterflies from the genus *Papilio* sp. are known to choose citrus plants to lay eggs. Other than that, the *Troides helena* species only choose *Aristolochia* sp., as a host plant (Soekardi, 2012). In addition, Papilionidae have the ability to fly and have a high cruising range, making it difficult to observe. As reported by Millah et al., (2020) who found the species *Graphium doson, Graphium sarpedon, Papilio memnon, Papilio paris, and Troides sp.* can be found in highlands such as the Bromo Tengger Semeru National Park Area. the low encounter was also influenced by the presence of host plants.

Figure 2. Documentation of species. A. *Ypthima philomela*, B. *Ypthima pandocus*, C. *Junonia iphita*, D. *Mycalesis horsfieldi*., E. *Melanitis zitenius*, F. *Neptis hylas*, G. *Orsotriaena medus*., H. *Symbrenthia hippoclus*, I. *Jamides alecto*, J. *Lethe confusa*, K. *Polyura moori*, L. *Cyrestis nivea*., M. *Zeltus amasa*, N. *Caleta roxus*, O. *Saletara panda* (Photo: M. Azmi Dwi Susanto, 2023)

Catopsilia Pomona is the species that has the highest relative abundance, namely 11.73%. This species is found in all three habitats, but the greatest number is found on river banks. As previously explained, butterflies need nutrition to mature sperm cells, thereby absorbing nutrients from the existing environment (Karlsson, 1996). This species is often found in this habitat because riverbank provide nutrition for several butterfly species including *Catopsilia Pomona*. The large number of species of this type may indicate that on the banks of the river there are plants from the Fabaceae or Amaryllidaceae families which are host plants for this species (Crossley, 2021)

According to Mishra et al., (2019), *catopsilia* is a species of polyphenism, that is color patterns that are influenced by photoperiod and environmental temperature. therefore, some individuals have several different color variations and patterns. In general, adult individuals have a wingspan of around 6 cm. The upper wings of males are white with black wing tips and bright yellow in the middle of the wings. The lower wings are pale yellow with random spots. while the female has pale yellow upper wings with black-spotted edges (termen) and blacker at the apex. The lower wings are white with many dark orange and random spots markings (Crossley, 2021).

There are several species with low RA values, including *Potanthus omaha, Acytolepis puspa, Loxura atymnus, Euploea mulciber, Junonia hedonia, Melanitis zitenius, Graphium Sarpedon, Troides Helena*. Some of these species are found in only 1 individual. This is likely because species such as *Graphium Sarpedon* and*, Troides Helena* are species with high mobility, so they are difficult to observe during observations (Sanjaya et al., 2016). Each species has its own specifications, for example *Melanitis* is a genus that is active in the evening (crepuscular) so it is difficult to find individuals in the morning (Kemp, 2002). Apart from that, some species breed in certain seasons so that species with small numbers may be influenced by seasonal factors (Grøtan et al., 2012).

The butterfly diversity index value can be influenced by biotic and abiotic factors. Biotic factors are interactions between other living things, such as the diversity of vegetation, competitors, parasites, and predators. Vegetation is an important factor for the survival of butterflies; the presence of host plants and forage plants determines the diversity of butterflies in a habitat. According to Aguirre-Gutiérrez et al. (2017) varied vegetation allows a higher level of butterfly diversity compared to vegetation that has a low level of diversity. Meanwhile, abiotic factors that affect butterfly diversity include air temperature, humidity, light intensity, and wind speed (Koneri et al., 2022)

The Sigolo-golo area is a tourist area that has the potential to become an ideal area for the survival of butterflies because it consists of several types of habitat with diverse vegetation, including plantations, forests, and rivers. Each habitat has varying characteristics, composition, and diversity. Aguirre-Gutiérrez et al. (2017), said diverse vegetation can increase the potential for higher butterfly presence and abundance because vegetation is an element that plays a vital role for butterflies as a breeding medium and food source.

The results of observations at the location show that the diversity index in the Sigolo-golo tourist area has a value of H' = 3.20 and evenness index has value E = 0.87. These values

have similarities to the research conducted by Murwitaningsih & Dharma (2014), which shows the diversity index on Mount Halimun Salak, West Java, with a value of H'= 3.05. These results indicate the value of diversity and evenness in the Sigolo-golo area, classified as having very high diversity, and represent that this location is a well-preserved environment with varied habitat types that support butterfly life. High diversity values indicate an ideal interaction between butterflies and the environment (Paramanandham et al., 2021).

The dominance index in this area shows a value of D = 0.04. This result shows a dominance index that is classified as very low, meaning that there are no species with a high number of individuals so that they do not dominate other species. Based on these results, a low dominance index value indicates an even distribution of species without dominance of a species. This is supported by the environmental conditions at the location, namely the presence of a variety of forage plants, hosts, types of open canopy, and vegetation cover. the availability of forage plants, host plants, resting places, and places to continue the life cycle are important factors for dominance, evenness, and species levels (Millah et al., 2023). The Sigolo-golo area is an area with supporting abiotic factors, according to the results of abiotic parameter measurements (Table 3).

Based on the analysis results for each habitat, the locations with the highest diversity and evenness index values were found in secondary forest areas. The diversity index value is H' = 3.06 (Figure 2), This value is high category. The evenness value in the secondary forest area is also relatively high, with E = 0.91 (Figure 3). A value close to 1 means that it is classified as high evenness. The secondary forest area is the location with the highest number of species, with 28 species (Figure 2). According to (Okamura et al., 2019), the level of diversity, evenness, and abundance of species can be affected by the composition of the vegetation.

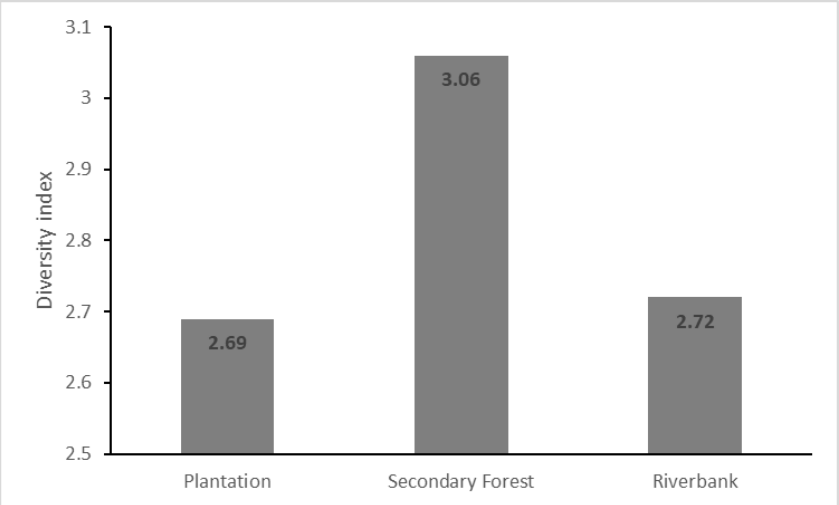

Figure 2. Butterfly diversity index in three different habitats

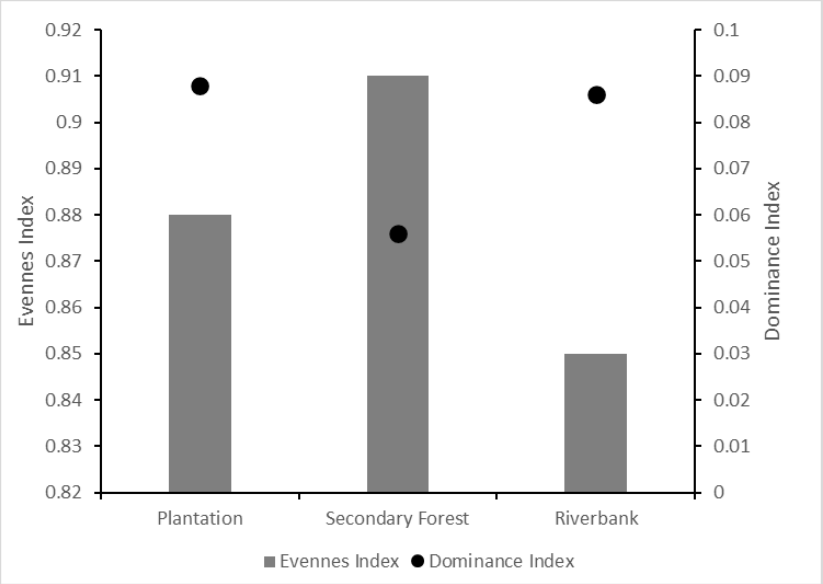

Figure 3. Butterflies' evenness and dominance index in three habitats

Secondary forest has a diverse composition of vegetation, some areas have been used for plantations, there are wild plants and large trees. Horticultural crops found in forest areas are taro (*Colocasia eskulanta*), banana (*Musa* sp.), durian (*Durio Zibethinus*), coffee (*Coffea* Sp.) and elephant grass (*Pennisetum purpureum*). Non-horticultural plants include herbs, grasses, ferns, mosses and trees. Vegetation is an important resource for butterflies as host plants and food sources. In addition, vegetation affects the cover/canopy of an area. The more divergent a vegetation is, the more varied the cover or canopy will be. Land cover contributes to supplying incoming sunlight. The open canopy type has a higher light intensity needed by butterflies for sunbathing and activities. While the closed canopy type is needed as long as the butterfly is perched to rest.

Table 2. abiotic parameter measurement results

Location	Temperature	Humidity (%)	Light intensity	Wind velocity(m/s)
Plantation	31.1	60	163	0.1
Forest area	32.6	59	205	0.3
Riverbank	33.6	51	217	0.1

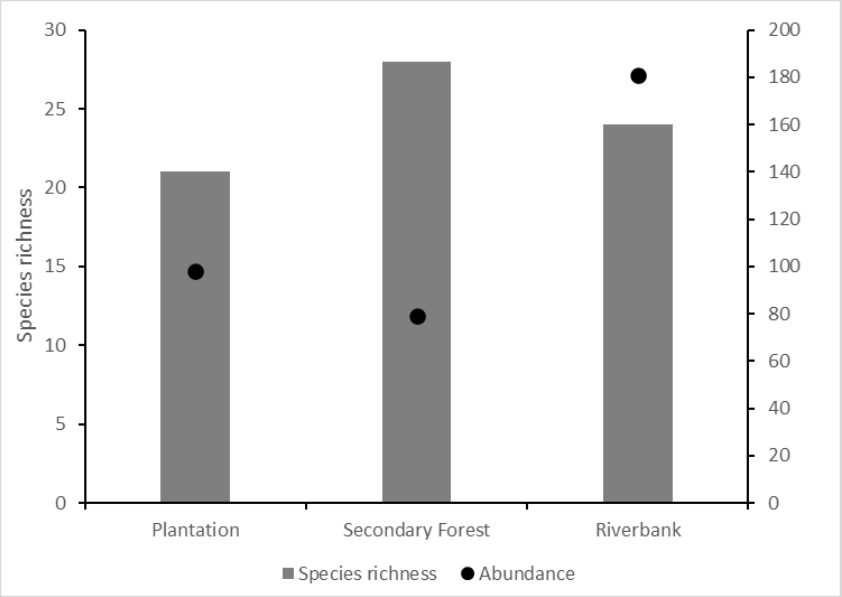

Figure 4. The abundance and richness of butterfly species

Locations Riverbank are the locations with the highest number of individuals. The butterflies found were 181 individuals (Figure 4). The high number of individuals can be affected by high light intensity. Among other locations, the riverbank has a higher intensity at 217 lux (Table 2). Butterflies tend to choose more open places, such as river areas, to regulate body temperature. This location is an open area. Plants are only found around the edges in the form of herbaceous plants (Amaranthaceae and Asteraceae), tall grasses (Poaceae) and several cultivated plants, which support the life of butterflies. There is a clear river that has a swift current, with andesite sedimentary rocks and sand which is often visited by butterflies for mud-puddling.

Dominance index values for several habitats in Sigolo-Golo tourism are included in the low category. The highest value is in the plantation area with a value of D = 0.088. The low dominance value indicates a relatively even distribution in each habitat. The plantation area is a location that has relatively homogeneous vegetation because there are cultivated or horticultural plants, which are deliberately cultivated by residents. Plants in this area include forage plants, such as elephant grass (*Pennisetum purpureum*), fruit trees, such as durian, avocado, and banana, as well as wood-producing plants such as teak (*Tectona* sp.), sengon (*Paraserienthes falcataria* (L), Calliandra sp., mahogany (*Swetenia* sp.) and other. In addition to cultivated plants, there are many wild plants in the form of grass, herbs and trees found at this location. Butterflies that are found in plantation areas include types of butterflies that are usually associated with grass plants (Poaceae) and cultivated plants such as *Delias Belisama, Acytolepis puspa, Junonia hedonia, Ypthima pandocus, Melanitis zitenius,* and *Hebomoia glaucippe*.

Sigolo-golo is an ideal habitat to support the life of butterflies, this can be reviewed based on observations, the number of species and individuals encountered, the presence of several habitat types, a supportive microclimate level, and the absence of dominance between species. These results can be used as consideration for researchers who will research Papilionoidea diversity further, assist the government in considering policies related to similar areas, and sensitize the public to preserve nature in a holistic manner.

Conclusion

Based on the research results, there were 43 species, with 358 individuals from five families found. The diversity index in the Sigolo-Golo tourist area is high, with a value of H' = 3.20. Each type of habitat has a different community structure. The highest diversity index value is found in forest areas with H' = 3.06, riverside areas with H' = 2.74, and plantation areas with H' = 2.69. The diversity index in each type of habitat is high. This is supported by biotic and abiotic factors that support the survival of butterflies in the Sigolo-golo area. The community structure at this location is still stable and well-maintained.

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