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Diversity of Insect Species in Production Forest in West Wara District, Luwu Regency, South Sulawesi, Indonesia

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Abstract

Insects are the most numerous groups of organisms in the phylum of Arthropods and have a very important role in the continuity of ecological functions. This study aims to determine the diversity of nocturnal and diurnal insect species in the production forest area of PT. Sumber Graha Sejahtera in West Wara District. The methods used in this study are plot and line transect. The traps used are light traps for nocturnal insects used in five plots and sweep nets for diurnal insects used in 3 line transects. The results showed that there were 36 species of insects consisting of 14 nocturnal species and 22 diurnal species. The diversity index of nocturnal insects was included in the medium category (2.57), with the highest population density found in the species Aedes albopictus, which is 0.0160 m^2. In contrast, the diversity index of diurnal insects was included in the high category (3.02), with the highest population density found in the species Valanga nigricornis, which is 0.0056 m^2.

Keywords: diurnal insect, diversity of insects, insect species, nocturnal insect

1. Introduction

Indonesia's biodiversity level is very high, making it known as a mega biodiversity country. This biodiversity includes the diversity of ecosystems, types within ecosystems, and germplasm (genetic diversity) within each species [1]. The diversity of insects is one aspect of Indonesia's biological wealth, with an estimated hundreds of thousands of insect species. However, not all these species have been identified yet [2].

Insects are the most diverse organisms compared to other groups within the phylum Arthropoda. To date, approximately 950,000 insect species have been identified worldwide, which accounts for about 59.5% of all described organisms [2]. The diversity of insects in an ecosystem affects the level of ecosystem stability. If insect presence is high, the ecosystem can be considered balanced or stable [3]. Insects also play a very significant role in ecosystems, with their roles being either beneficial or harmful. Beneficial roles include serving as pollinators, acting as natural enemies of pest insects, functioning as decomposers, and providing food or animal protein. Additionally, some insects are traded for their economic value and other potential uses, such as bait for fishing, honeybees, and weaver ants [4]. Harmful insects are those that cause damage to plants, leading to destruction or loss, and are categorized as pests [5].

The survival of insects depends on the availability of food. Additionally, their activities are influenced by their response to light, which is why insects are often active in the morning, afternoon, evening, or at night [6]. Insects active during the day, commonly called diurnal insects, engage in various daily activities such as visiting flowers, laying eggs, or feeding on plant parts. Examples include butterflies (Lepidoptera), rice beetles (*Leptocorisa acuta*), brown planthoppers (*Nilaparvata lugens*), and large grasshoppers (*Valanga nigricornis*). On the other hand, nocturnal insects spend most of their lives being active at night. They are highly attracted to bright light, as they often mistake the color of the light for the color of their food [7].

Diurnal and nocturnal insect species are found in Luwu Regency, South Sulawesi. This is because these insects find a supply of food and a supportive environment for their survival. The PT Sumber Graha Sejahtera production forest is in Padang Lambe Village, Wara Barat District. Based on observations conducted in this forest, various insects have been

encountered. However, many species of diurnal and nocturnal insects in the forest remain unidentified. Therefore, this study aims to determine the diversity of diurnal and nocturnal insect species in the PT Sumber Graha Sejahtera production forest.

2. Materials and Methods

2.1 Time and Location

This study was carried out on Mei 2023 in the Production forest of PT Sumber Graha Sejahtera in West Wara District, Luwu Regency, South Sulawesi Figure 2. The distance to the research site from Palopo was 23 km, with an estimated travel time of about 1 hour. The research focused on determining the diversity of nocturnal and diurnal insect species at the site.

2.2 Data Collection

Data collection was carried out using two methods: line transects and plots. The line transect method was used for daytime data collection, while the plot method was used for nocturnal data collection. The study utilized three transects and two plots. Each transect was 300 meters long and five meters wide, with 100 meters between each transect (Figure 1.a). The plots measured 20 × 20 meters, with 50 meters between each plot (Figure 1.b). Captured insects were collected, sorted, and placed in plastic bags for identification. The plot method was used for nocturnal insect data collection, with each plot containing five observation points. A 25-watt LED lamp was set up as a light source at each observation point. The lamp was placed inside a mosquito net tied to wooden poles, attracting insects into the net. Daytime insect data collection was performed using a sweep net with a handle length of 200 cm, a net diameter of 40 cm, a net length of 70 cm, and a circular rattan frame. The sweep net was operated by swinging it over plant surfaces. Captures occurred from 7:00 AM to 9:00 AM and in the afternoon from 2:00 PM to 4:00 PM WIB.

2.3 Data Analysis

The collected data included insect species, which were then analyzed to determine the number of individuals per species by family, population density (K), Frequency (F), Frequency relative (FR) the Shannon-Wiener diversity index (H'), and relative abundance (KR)

$$Population\ density\ (K) = \frac{number\ of\ individuals\ of\ species\ A\ in\ a\ treasect}{Area\ of\ the\ transect\ (m^2)}$$

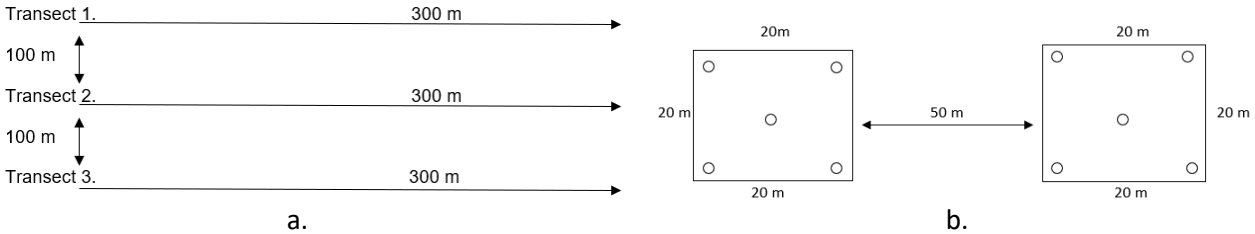
$$Frequency\ (F) = \frac{number\ of\ plot\ in\ which\ the\ species\ occurred}{Total\ number\ of\ plot}$$

$$Relative\ Frequency\ (FR) = \frac{Frequency\ of\ one\ species}{Total\ frequency\ off\ all\ species} \times 100$$

$$Relative\ abundance\ (KR) = \frac{The\ abundance\ of\ one\ species}{Total\ all\ species\ counted} \times 100$$

$$Diversity\ Index\ (H') = -\sum^{S}(pi)[\ln(pi)]$$

$S = number\ of\ species\ in\ community$
$pi = proportion\ of\ total\ abundance\ represented\ by\ individual\ species$



a. b.

Figure 1. a. Transect for diurnal insect species, b. Plot for nocturnal insect species were conducted at the production forest of PT Sumber Graha Sejahtera in the West Wara District of Luwu Regency.

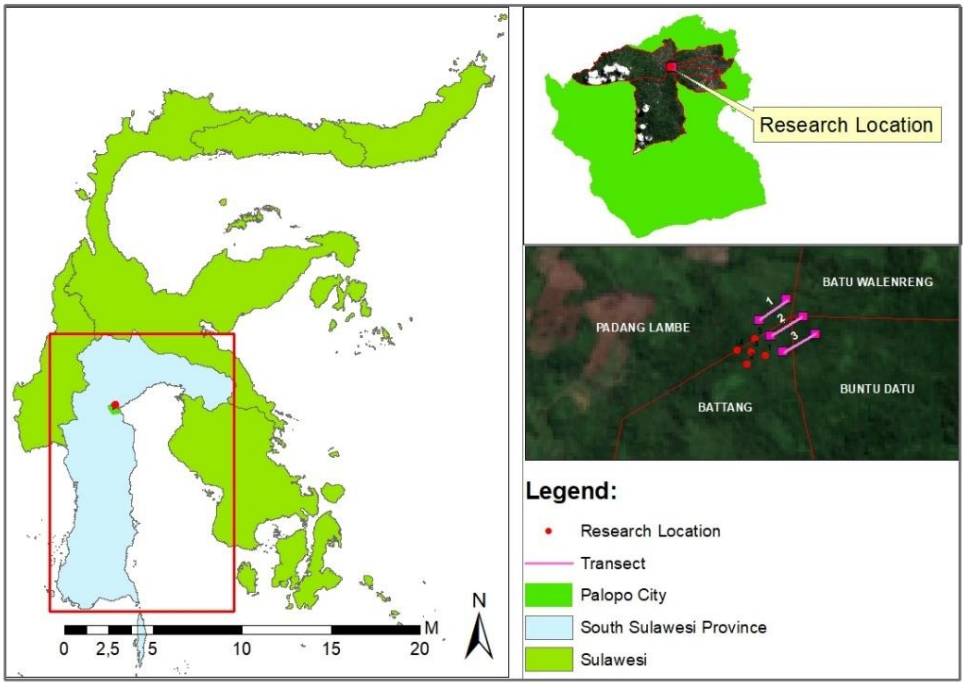


Figure 2. Diversity of Insect Species Site Study in production forest of PT Sumber Graha Sejahtera in West Wara District, Luwu Regency.

3. Results

3.1. Diurnal Insect Species

Based on the research results on the diversity of insect species found during the daytime (diurnal) in the production forest of PT Sumber Graha Sejahtera (SGS) in Lambe Village, Wara Barat District, Luwu Regency, 22 insect species were found from 16 families. Observations were conducted at three locations using light traps. The most species were found in transect 1, by 113 individuals, while the lowest number was in transect 3, by 94 individuals. The most abundant species was *Valanga nigricornis*, with 25 individuals, and the least abundant was Tenodera sinensis, with 4 individuals, as seen in Table 1.

Table 1. The diurnal insect species in the production forest of PT Sumber Graha Sejahtera

No	Family	Species	Transect			Total
			I	II	III	
1	Erebidae	*Amata hubneri*	4	6	8	18
2	Pentatomidae	*Loxa flavicollis*	3	5	7	15
3	Pieridae	*Catopsilia Scylla*	5	0	0	5
4	Nymphalidae	*Ideopsis juventa*	3	6	3	12
5	Nymphalidae	*Cirrochroa emalea*	6	0	3	9
6	Lycaenidae	*Jamides celeno*	7	3	5	15
7	Pieridae	*Catopsilia pamona*	4	7	0	11
8	Tipulidae	*Dolichopeza sp.*	5	3	3	11
9	Pyrgomorphidae	*Atractomorpha crenulata*	7	5	5	17
10	Acrididae	*Gesonula mundata*	6	8	5	19
11	Acrididae	*Miramella alpine*	4	3	6	13
12	Acrididae	*Valanga nigricornis*	10	7	8	25
13	Libellulidae	*Acisoma panorpoides*	5	7	4	16
14	Formicidae	*Camponotus pennsylvanicus*	4	2	4	10
15	Apidae	*Heterotrigona itama*	2	4	2	8

No	Family	Species	Transect			Total
			I	II	III	
16	Drosophilidae	*Drosophila melanogaster*	7	3	5	15
17	Libellulidae	*Orthetrum Sabina*	3	7	2	12
18	Formicidae	*Oecophylla smaragdina*	5	5	4	14
19	Rhinotermitidae	*Coptotermes gestroi*	9	8	5	22
20	Vestalis luctuosa	*Calopterygidae*	7	5	7	19
21	Kalotermitidae	*Neotermes tectonae*	7	7	8	22
22	Mantidae	*Tenodera sinensis*	0	4	0	4
	Total		113	105	94	312
	Average		5.1	4.8	4.3	14.2

The research results indicate that the insects found during the day and captured using sweep nets in the production forest of PT SGS are mostly from the species *Valanga nigricornis* (Figure **3**3), with 25 individuals. This is followed by the species *Coptotermes gestroi* and *Neotermes tectonae*, each by 22 individuals. Gesonula mundata and Hyblaea puera have the same number of individuals, 19 each, and the species *Amata hubneri* follows by 18 individuals. The species found in the least number is *Tenodera sinensis*, with only 4 individuals.

Among the three transects, the highest number of individuals was found in transect I, 113 individuals, followed by transect II, 105 individuals. In contrast, transect III had the lowest number of individuals, with 94. *Valanga nigricornis*, commonly known as the Wood Grasshopper, is an insect from Orthoptera and the family Acrididae. This species was found in the highest number because grasshoppers and their relatives inhabit various types of environments or ecosystems, including forests, shrubs, residential areas, agricultural lands, and so on [8]. This finding is consistent with the statement that most grasshopper species are in forest ecosystems [7]. Increasing vegetation diversity and the dense structure of forest canopies lead to high composition and presence of grasshoppers in the ecosystem [9].

Figure 3. *Valanga nigricornis* (top left) and *Tenodera sinensis* (top right), *Jamidos celeno* (bottom left), *Loxa Flavicollis* (bottom right) as insect diurnal species were collected at production forest of PT Sumber Graha Sejahtera (SGS) in Lambe Village, Wara Barat District, Luwu Regency.

3.1.1. Ecological Indices of Diurnal Species

The analysis of the ecology index shows the population density of insects observed during the day. The study was conducted across three transects in the production forest of PT SGS. The highest population density was found for *Valanga nigricornis* at 0.0056 m², while the lowest was for *Tenodera sinensis* at 0.0009 m² (Table 2).

Table 2. The population density value of diurnal species in the production forest of PT Sumber Graha Sejahtera.

No	Family	Species	Total	K (individual/m²)	F	FR	H'	KR (%)
1	Erebidae	*Amata hubneri*	18	0.0040	1	0.0500	3,02	5.77
2	Pentatomidae	*Loxa flavicollis*	15	0.0033	1	0.0500		4.81
3	Pieridae	*Catopsilia Scylla*	5	0.0011	0.33	0.0167		1.60
4	Nymphalidae	*Ideopsis juventa*	12	0.0027	1	0.0500		3.85
5	Nymphalidae	*Cirrochroa emalea*	9	0.0020	0.66	0.0333		2.88
6	Lycaenidae	*Jamides celeno*	15	0.0033	1	0.0500		4.81
7	Pieridae	*Catopsilia pamona*	11	0.0024	0.66	0.0333		3.53
8	Tipulidae	*Dolichopeza sp.*	11	0.0024	1	0.0500		3.53
9	Pyrgomorphidae	*Atractomorpha crenulata*	17	0.0038	1	0.0500		5.45
10	Acrididae	*Gesonula mundata*	19	0.0042	1	0.0500		6.09
11	Acrididae	*Miramella alpine*	13	0.0029	1	0.0500		4.17
12	Acrididae	*Valanga nigricornis*	25	0.0056	1	0.0500		8.01
13	Libellulidae	*Acisoma panorpoides*	16	0.0036	1	0.0500		5.13
14	Formicidae	*Camponotus pennsylvanicus*	10	0.0022	1	0.0500		3.21
15	Apidae	*Heterotrigona itama*	8	0.0018	1	0.0500		2.56
16	Drosophilidae	*Drosophila melanogaster*	15	0.0033	1	0.0500		4.81
17	Libellulidae	*Orthetrum Sabina*	12	0.0027	1	0.0500		3.85
18	Formicidae	*Oecophylla smaragdina*	14	0.0031	1	0.0500		4.49
19	Rhinotermitidae	*Coptotermes gestroi*	22	0.0049	1	0.0500		7.05
20	calopterygidae	*vestalis luctuosa*	19	0.0042	1	0.0500		6.09
21	Kalotermitidae	*Neotermes tectonae*	22	0.0049	1	0.0500		7.05
22	Mantidae	*Tenodera sinensis*	4	0.0009	0.3333	0.0167		1.28
		Total	312		20			

The research results in Table 2 show a total number of 312 individuals, with 22 species, Table 2 also presents the frequency of individuals (Fi), the relative frequency of each insect species (FR), the relative abundance (KR), and the insect diversity index (H') for each species found in transects I, II, and III. The relative frequency indicates how often a particular insect species appears in its habitat and can illustrate its distribution. The highest dominant frequency (Fi) for all insect species was Fi=1, while the lowest was for the Mantidae family, specifically *Tenodera sinensis*, with Fi=0.3333. The highest relative frequency (FR) was 0.0500, and the lowest was 0.0167. The highest relative abundance (KR) was 7.05%, and the lowest was 1.28%. Insect abundance is significantly influenced by reproductive activity, supported by suitable environmental conditions and sufficient food sources. In tropical regions, the abundance and reproductive activity of insects are heavily influenced by seasons, as these affect food availability and insect survival, directly impacting abundance [10].

Overall, the daytime insect diversity in the production forest of PT SGS in Padang Lambe Village, Wara Barat District, Luwu Regency, falls into the high category. According to the diversity analysis criteria using the Shannon-Wiener diversity index, H’<1 indicates low species diversity, 1<H’<3 indicates moderate species diversity, and H’>3 indicates high species diversity. Based on the diversity index calculation, the total value was H’=3.02, indicating that the insects found during the day in the production forest of PT SGS are in the high diversity category. This is likely due to the natural habitat and heterogeneous vegetation that suits species like *Valanga nigricornis*. According to Abrori et al. [11], plant vegetation is closely related to Orthoptera populations, as plants are a food source for Orthoptera.

3.2. Nocturnal Species

The research on insect species diversity found during the night (nocturnal) in the production forest of PT Sumber Graha Sejahtera (SGS) in Lambe Village, Wara Barat District, Luwu Regency, revealed a total of 14 insect species from 14 different families. The survey, conducted using sweep nets at five different locations. The most abundant species was *Aedes albopictus* from the family Culicidae, with 32 individuals, while the least abundant was *Leptocorisa acuta* (Figure 4) from the family Alydidae, with only four individuals, as seen in Table 3.

Table 3. The Nocturnal insect species in the production forest of PT Sumber Graha Sejahtera

No	Family	Species	Plot					Total of Individuals
			I	II	III	IV	V	
1	*Erebidae*	*Asota heliconia*	2	2	4	2	5	15
2	*Histeridae*	*Apogonia expeditionis*	3	4	2	4	3	16
3	*Erebidae*	*Spilosoma sp*	2	3	2	5	4	16
4	*Noctuidae*	*Hulodes caranea*	1	3	4	3	3	14
5	*Lampyridae*	*Pteroptyx testacea*	5	4	2	1	2	14
6	*Geometridae*	*Pingasa chlora*	3	0	4	3	3	13
7	*Elateridae*	*Cryptalaus lacteus*	2	3	3	5	4	17
8	*Rutelidae*	*Anomala pallid*	4	3	3	1	2	13
9	*Tettigoniidae*	*Mecopoda elongate*	4	2	3	2	0	11
10	*Gryllidae*	*Gryllus veletis*	3	4	5	2	3	17
11	*Blattidae*	*Platyzosteria sp.*	5	4	5	3	4	21
12	*Culicidae*	*Aedes albopictus*	7	9	6	5	5	32
13	*Hyblaeidae*	*Hyblaea puera*	3	2	1	4	2	12
14	*Alydidae*	*Leptocorisa acuta*	0	0	0	2	2	4
		Total	44	43	44	42	42	215

Based on the results shown in Table 3, the production forest of PT SGS, surveyed across five plots, revealed 14 insect species from 14 families, with a total of 215 individuals. The highest number of individuals was found in plots I and III, each with 44 individuals, while the lowest number was found in plots IV and V, each with 42 individuals. The distribution of individuals across all plots was relatively even, likely due to the high-quality vegetation in the production forest. According to Rybicki et al. [12], plant species diversity in a habitat affects the diversity of species within it.

Aedes spp. mosquitoes tend to prefer relatively clean water for breeding, such as in jars, bathtubs, water drums, discarded tires, rainwater, or stagnant water in coconut shells, and in areas with abundant vegetation, which can influence the mosquitoes' microclimate and biology [13]. This condition is consistent with the study area, where many water puddles, sourced from rainwater, were found near the forest, making it suitable for breeding.

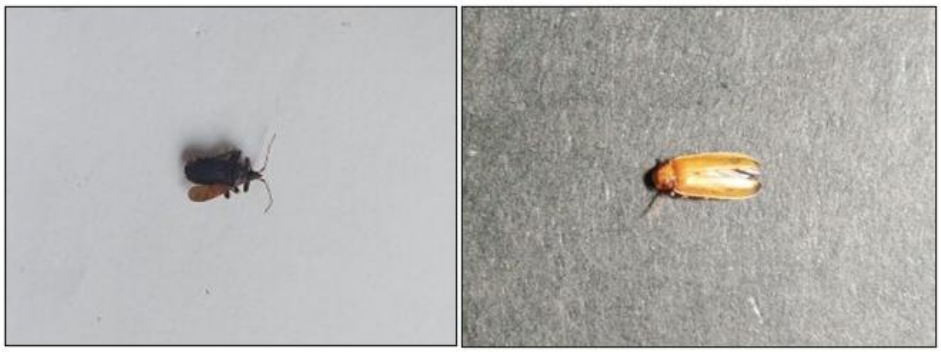


Figure 4. *Leptocorisa acuta* (left) and *Pteroptyx testacea* (right) as nocturnal species were collected at production forest of PT Sumber Graha Sejahtera (SGS) in Lambe Village, Wara Barat District, Luwu Regency.

3.2.1 Ecological Indices of Nocturnal Species

The analysis of the ecology index shows the population density of insects observed during the night. The population density of insects found at night in the production forest of PT SGS in Padang Lambe Village, Wara Barat District, Luwu Regency, included 14 insect species from the following 14 families. Based on the data in Table 4, the highest population density is observed in *Aedes albopictus* at 0.0160 m^2, while the lowest density is found in *Leptocorisa acuta* at 0.0020 m^2. According to Westby et al. [15], more *Aedes albopictus* at night because they are primarily nocturnal feeders, taking advantage of cooler temperatures and increased humidity, which makes it easier for them to locate hosts. It is known that insects can perceive longer wavelengths of light than humans, with the ability to detect wavelengths ranging from 300-400 nm to 600-650 nm. Each color corresponds to different wavelengths: red has a wavelength of 650-700 nm, yellow 550-600 nm, green 500-550 nm, and blue 450-500 nm [16]. In each plot (I, II, III, IV, and V), it was found that the highest frequency of total number (F = 1) dominates across all species, including *Leptocorisa acuta, Apogonia expeditionis, Spilosoma sp., Hulodes caranea, Pteroptyx testaceum, Cryptalaus lacteus, Anomala pallid, Gryllus veletis, Platyzosteria sp., Aedes albopictus,* and *Vilius melanopterus*, while the lowest frequency (F = 0.4) was observed in *Leptocorisa acuta*. The highest relative frequency (FR) was 0.0769, and the lowest (FR) was 0.0308, while the highest relative abundance (KR) was 14.88%, and the lowest (KR) was 1.86%. According to Daniels et al. [14], dominant insects in a given area can have a significant impact because they often have better access to food sources, which supports their growth and reproduction. However, this dominance can also lead to high competition among individuals of the same species, potentially affecting reproductive success. Additionally, environmental factors, such as the availability of space and habitat conditions, play a crucial role in supporting their survival and distribution.

Generally, the diversity of nocturnal insects in the production forest of PT (SGS) in Padang Lambe Village, West Wara District, Luwu Regency falls into the moderate category. According to the diversity analysis criteria using the Shannon-Wiener diversity index, $H' < 1$ indicates a low diversity category, $1 < H' < 3$ indicates a moderate diversity category, and $H' > 3$ indicates a high diversity category. The Diversity Index obtained a total value of $H' = 2.57$, which means that the diversity of nocturnal insects in the production forest of PT (SGS) falls into the moderate category.

This finding is supported by Catella and Abbott [17], who noted that diversity not only considers the number of species in a community but also the number of individuals of each species. They found that a uniform community tends to have low diversity. The tendency towards low diversity can be influenced by abiotic factors and various pressures in the area. For example, environmental conditions such as temperature, humidity, and habitat structure, as well as anthropogenic pressures such as land use changes and pollution, can impact insect diversity. Thus, the moderate diversity observed in the production forest of PT SGS may reflect the balance between these factors and the adaptability of the nocturnal insect community to the local conditions.

Table 4. The population density value of nocturrnal species in the production forest of PT Sumber Graha Sejahtera

N0	Family	Species	Total of Individuals	K (individual/m²)	F	FR	H'	KR
1	Cicadelidae	*Dundubia manifera*	15	0.0075	1	0.0769	2.57	6.98%
2	Histeridae	*Apogonia expeditionis*	16	0.0080	1	0.0769		7.44%
3	Erebidae	*Spilosoma sp*	16	0.0080	1	0.0769		7.44%
4	Noctuidae	*Hulodes caranea*	14	0.0070	1	0.0769		6.51%
5	Lampyridae	*Pteroptyx testacea*	14	0.0070	1	0.0769		6.51%
6	Geometridae	*Pingasa chlora*	13	0.0065	0.8	0.0615		6.05%
7	Elateridae	*Cryptalaus lacteus*	17	0.0085	1	0,0769		7,91%
8	Rutelidae	*Anomala pallid*	13	0.0065	1	0,0769		6,05%
9	Tettigoniidae	*Mecopoda elongata*	11	0.0055	0.8	0,0615		5,12%
10	Gryllidae	*Gryllus veletis*	17	0.0085	1	0,0769		7,91%
11	Blattidae	*Platyzosteria sp.*	21	0.0105	1	0,0769		9,77%
12	Culicidae	*Aedes albopictus*	32	0.0160	1	0,0769		14,88%
13	Reduviidae,	*Vilius melanopterus*	12	0.0060	1	0,0769		5,58%
14	Alydidae	*Leptocorisa acuta*	4	0.0020	0.4	0,0308		1,86%
		Total	215		13			

4. Discussion

The diversity of nocturnal and diurnal insects are important factors for observing the dynamics of an ecosystem. Findings revealed a moderate diversity index for nocturnal insects (H' = 2.57), with the highest population density observed in *Aedes albopictus* at 0.0160 m². In contrast, the diurnal insect diversity index was categorized as high (H' = 3.02), with *Valanga nigricornis* showing the highest population density at 0.0056 m². These findings suggest notable differences in insect community structure between nocturnal and diurnal species in the study area. The diversity index of nocturnal insects in this study falls into the moderate category, which is consistent with the research by Beatrice R et al. [18], where nocturnal insect diversity ranged from low to moderate, with *Aedes albopictus* species contributing significantly to the total population. The relatively low diversity index for nocturnal insects in this study may be due to the dominance of a few species, such as *Aedes albopictus*, which has a strong adaptation to disturbed environments [19].

Conversely, the high diversity index observed for diurnal insects in this study is in line with findings from Becerra, [20], who reported higher diversity of diurnal insects in tropical forest ecosystems. This can be attributed to the variety of ecological niches available during the day, supporting a greater number of species across different insect families. The higher diversity (H' = 3.02) and the presence of species like *Valanga nigricornis* could be indicative of a more stable and diverse diurnal ecosystem, which may benefit from factors such as vegetation diversity and availability of food resources during daylight hours. The relative abundance (KR) of *Aedes albopictus* in the nocturnal survey (14.88%) is relatively high compared to other species. This is consistent with the study by Reinhold et al. [21], which noted that *Aedes albopictus* is a resilient species capable of thriving in areas influenced by both natural and anthropogenic factors. Meanwhile, the lower relative abundance of diurnal insects, such as *Valanga nigricornis* (KR = 8.01%), reflects the competitive dynamics among species within the diurnal insect community, where an increasing number of species leads to a more evenly distributed population.

The relative frequency (FR) of nocturnal insects (0.0769) was found to be slightly higher than that of diurnal insects (0.0500), suggesting that nocturnal insects, though less diverse, might exhibit more stable occurrence across the study sites. The difference in relative frequency between nocturnal and diurnal insects can be explained by the different temporal and environmental factors influencing insect behavior. As nocturnal insects are generally more active during cooler, darker periods, they may face fewer predators and competition, allowing them to occupy ecological niches that diurnal insects cannot exploit.

5. Conclusions

The results of this study can be concluded that the diversity index of nocturnal insects falls into the moderate category, with the highest population density found in the species *Aedes albopictus* at 0.0160 m^2. The diversity index (H') is 2.57, with a relative abundance (KR) of 14.88% and a relative frequency (FR) of 0.0769. Meanwhile, the diversity index of diurnal insects falls into the high category, with the highest population density found in the species *Valanga nigricornis* at 0.0056 m^2. The diversity index (H') is 3.02, with a relative abundance (KR) of 8.01% and a relative frequency (FR) of 0.0500.

Author Contributions

AUBP: Conceptualization, Methodology, Investigation, Writing - Review & Editing; **W**: Conceptualization, Methodology, Investigation, Writing – original draft. **L**: Conceptualization, Methodology, Writing - Review & Editing, Supervision; **RB**: Investigation, Writing – original draft, **NHS**: Writing - Review & Editing, and **M**: Writing - Review & Editing.

Conflicts of interest

There are no conflicts to declare.

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