



Diversity and Community Structure of Insects Associated with Vegetation at the Entrance of Kiskendo Cave, Kulon Progo, Indonesia

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ABSTRACT

Aerial insects perform essential ecological functions and serve as indicators of environmental change, particularly in ecotone habitats such as cave entrances. Kiskendo Cave represents a transitional ecosystem between surface and subterranean environments with unique environmental characteristics. However, tourism activities may disrupt the ecological balance through changes in vegetation, artificial lighting, and other anthropogenic disturbances. This study aimed to analyze the diversity, evenness, species richness, and dominance of aerial insects and to examine their community structure and ecological roles in the area. Sampling was conducted on May 16, 2026, at the entrance of Kiskendo Cave using the sweep-net method on surrounding vegetation, and specimens were identified to species level based on morphological characteristics. Community structure was analyzed using Shannon-Wiener, Evenness, Margalef, and Simpson indices. The results showed that the community consisted of six insect orders dominated by Lepidoptera, with a Shannon-Wiener diversity index ($H' = 2.342$) indicating moderate diversity, an evenness index ($E = 0.9456$) showing highly uniform distribution of individuals, a Margalef richness index ($R = 3.789$) indicating moderate species richness, and a Simpson dominance index ($D = 0.102$) indicating low dominance. These findings suggest that the aerial insect community in the study area remains relatively stable with a balanced community structure. Heterogeneous vegetation and supportive microclimatic conditions contribute significantly to the maintenance of insect diversity and ecosystem stability. Ecologically, the area supports multiple functional roles for insects, such as pollinators, herbivores, and predators, that interact to sustain ecosystem balance.

Keywords: aerial insects, community structure, diversity, ecology, Kiskendo Cave

INTRODUCTION

Insects are one of the most diverse groups of organisms within the class Insecta of the phylum Arthropoda; they can adapt to a wide

range of habitat conditions, resulting in a very high level of insect diversity (Jannah, 2023). Aerial insects are insects that live on land, have wings capable of flight, and play many roles, including as herbivores, parasitoids, predators,

pollinators, decomposers, and ecological bioindicators (Khoiriah & Falahudin, 2020).

Caves are among the most unique ecosystems, as their distinctive characteristics stem from environmental conditions that differ from those outside the cave, making them the most vulnerable ecosystems on Earth (Hidayaturrohman et al., 2021). Caves are one of the habitats of insects. Indonesia has many caves, including Kiskendo Cave in Kulon Progo. Based on light levels, caves are divided into three distinct zones: the light zone, the twilight/transition zone, and the dark zone. The light zone refers to the cave entrance or the area near the entrance where ample direct sunlight is present. This zone is where many aerial insects are found. The presence of aerial insects at the cave entrance also plays a crucial role as a source of nutrients and energy flow for obligate biota living in the pitch-black interior of the cave.

Kiskendo Cave has now become a tourist attraction in the Menoreh Hills. This attraction is a history-based and niche-interest destination (Indah & Rachmandani, 2020). The development of this tourist attraction could affect the ecosystem. Human activities such as the construction of tourist facilities, light pollution, and noise around the cave entrance have the potential to alter edaphic conditions and disrupt the structure of aerial insect communities that are sensitive to environmental changes. Insects can serve as indicators of changes in an ecosystem; for example, dragonflies (Odonata) (Yuditaningtyas et al., 2022).

A community structure is a collection of populations of different types that interact with one another, inhabiting a specific habitat integrated into the ecosystem (Husamah et al., 2016; Safitri et al., 2022). If changes occur in its constituent components due to environmental pressures, the ecosystem's balance will be disrupted. Therefore, changes in the structure of aerial insect communities can serve as an early indicator (bioindicator) of ecosystem degradation in cave areas. Although these aerial insects are crucial, information regarding

insect diversity in the ecotone zone of Kiskendo Cave remains very limited.

Previous biological investigations at Kiskendo Cave have primarily focused on vertebrate fauna, such as the herpetofauna diversity reported by Qurniawan and Eprilurahman (2012) and bird species inventories across the surrounding tourism area (Ashari et al., 2019). However, research specifically targeting insect communities is lacking, particularly within the ecotone surrounding the cave entrance. The diversity, community structure, and functional roles of insects inhabiting the entrance vegetation remain completely unknown. Sampling this specific vegetation habitat is crucial because ecotones are highly sensitive to microclimatic fluctuations and human activities related to tourism. Beyond providing a simple species inventory, this study offers comprehensive insights into community structure, ecological indices (diversity, evenness, species richness, and dominance), and functional ecological roles (pollinators, predators, herbivores, and decomposers) of vegetation-associated insects, establishing vital baseline data for ecosystem monitoring in Kiskendo Cave.

Therefore, this study is important for analyzing ecological indices, including diversity, evenness, species richness, and dominance, of aerial insects in the vegetation at the mouth of Kiskendo Cave, as well as for determining the community structure and functional roles of aerial insects in that area.

METHODS

Observations were conducted on May 16, 2026, at the entrance area of Kiskendo Cave, Jatimulyo, Girimulyo District, Kulon Progo Regency, Special Region of Yogyakarta, Indonesia (7°44'52.00" S, 110°07'52.96" E). Insect sampling was carried out using the sweep net technique on vegetation around the cave entrance, by systematically sweeping the net across understory plants, shrubs, and other vegetation that potentially serve as habitats or activity sites for insects.

Sweeping Sampling

Sweeping was conducted with an insect net to capture insects both actively moving and resting on vegetation. The net was rapidly swept over the upper and side parts of the vegetation, trapping insects on the plants. Sampling was conducted by 6 collectors for 60 minutes between 08:00 and 10:00 WIB under sunny, dry conditions. Sampling effort was standardized at 10 sweeps per point, using a consistent figure-eight/180° sweeping motion at a steady speed of approximately [one sweep per second]. Sampling covered 5 points along a 50 m transect (approximately 100 m²), located 0-20 m from the cave entrance. The vegetation sampled consisted of herbaceous understory plants, shrubs, and grasses. Sampling was conducted in three replicates at each point. All collected specimens were transferred into sample bottles containing 70% ethano, labeled, and brought to the laboratory for identification.

Insect Identification

Identification was performed on all insect samples collected. Each specimen was examined for external morphological characteristics, including body shape, size, coloration, antenna type, leg type, wing type, and other diagnostic features. The identification process was conducted using a hand lens or a stereo microscope and referred to relevant taxonomic identification keys. Identification was performed stepwise, starting at the order level, then at the family level, and, when morphological characters allowed, at the genus or species level. The resulting identification data were compiled in tabular form, including taxonomic classifications and the Number of individuals.

Data Analysis

The collected data were analyzed using the Shannon–Wiener Diversity Index, Evenness Index, Margalef Species Richness Index, and Simpson Dominance Index to assess the structure and diversity of the species community.

Shannon–Wiener Diversity Index (H')

The Shannon–Wiener Diversity Index was used to assess species diversity by considering both species richness and the relative abundance of each species within the community (Table 1).

Formula: $H' = -\sum(p_i \ln p_i)$

$p_i = n_i/N$

Information:

H' = Shannon–Wiener Diversity Index

Σ = Summation across all species

p_i = Proportion of individuals species i

n_i = Number of individuals of species i

N = Total Number of individuals

Table 1. Benchmark values of species diversity index (Manalu *et al.*, 2025)

Value	Diversity
$H' < 1$	Low diversity
$1 < H' < 3$	Medium diversity
$H' > 3$	High diversity

Species Evenness Index (E)

The Species Evenness Index was calculated to evaluate the degree of uniformity in the distribution of individuals across species within the sampled community (Table 2).

Formula: $E = H' / \ln(S)$

Information:

S = total Number of species recorded

H' = Shannon Wiener's Index

Table 2. Benchmark values of the Evenness index (Manalu *et al.*, 2025)

Value	Diversity
$E < 0.4$	Low
$0.4 < E < 0.6$	Medium
$E > 0.6$	High

Margalef Species Richness Index (R)

Species richness was evaluated using the Margalef Species Richness Index, which estimates community richness based on the total Number of species and individuals observed (Table 3).

Formula: $R = (S - 1) / \ln(N)$

Information:

R = Margalef Species Richness Index

S = Total Number of species recorded

N = Total Number of individuals

Table 3. Benchmark values of the Richness Margalef index (Diniyatushoaliha et al., 2024).

Value	Richness
$R \leq 3,5$	Low
$3,5 < R \leq 5$	Medium
$R > 5$	High

Simpson Dominance Index (D)

Species dominance was evaluated using the Simpson Dominance Index, which estimates the extent to which one or a few species dominate a community. The index is based on the probability that two individuals randomly selected from the sample belong to the same species (Table 4).

Formula: $D = \sum (p_i^2)$

$p_i = n_i/N$

Information:

D = Simpson dominance index

P_i = proportional abundance of species i

n_i = Number of individuals of species i

N = total Number of individuals

Table 4. Benchmark values of the Simpson Dominance index (Sulistiyani et al., 2014).

Value	Dominance
$D \leq 0,5$	Low
$0,5 < D \leq 0,75$	Medium
$0,75 < D \leq 1$	High

RESULTS AND DISCUSSION

Diversity and Composition of Insect Orders in the Kiskendo Cave Area

Identification results from Kiskendo Cave revealed 36 individual insects across six orders and 25 species. The order Lepidoptera dominated the species composition, accounting for 39%, significantly more than the other orders, followed by Orthoptera (22%), Hymenoptera (19%), Odonata (14%), and

Hemiptera and Coleoptera, each with only 3% (Figure 1). This dominance of Lepidoptera aligns with widely reported patterns in densely vegetated ecosystems around cave entrances, where butterflies and moths are often the most abundant groups due to the availability of diverse nectar sources and larval hosts (Iqbal et al., 2021). The high Number of species in this order is also evident in the variety of families found, ranging from Nymphalidae such as *Junonia almana* and *Ypthima spp.*, to Erebididae such as *Nyctemera coleta* and *Amata huebneri*, indicating that the light zone around the cave entrance still supports both diurnal and nocturnal insect activity.

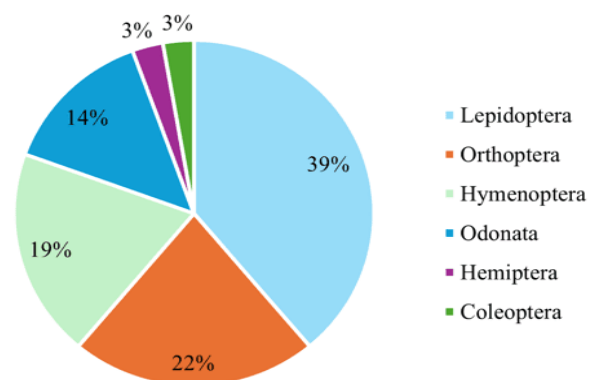


Figure 1. Percentage Species of Ordo

The abundance of Orthoptera, the second-largest order, is inextricably linked to the humid cave habitat, which is rich in rock crevices and litter, ideal conditions for grasshoppers and crickets to shelter and forage for food. The discovery of *Tagasta marginella*, with the largest Number of individuals (4), reinforces the notion that the microhabitat around the cave entrance provides stable shelter for this group. Similar conditions have also been reported in forested areas with high vegetation cover, where Orthoptera and Lepidoptera often co-occur as the two most dominant orders (Nugroho et al., 2021). Meanwhile, the presence of Hymenoptera, along with five ant and wasp species, such as *Diacamma sp.*, *Camponotus sp.*, and *Polistes sp.*, confirms this group's role as predators and decomposers of organic matter around the cave, which typically originates from litter or bat guano accumulated on the cave floor (Herawani, 2022).

Table 5. Identified Species in Kiskendo Cave

Ordo	Family	Species	Quantity
Lepidoptera	Lycaenidae	<i>Jamides celeno</i> (Cramer, 1775)	2
	Nymphalidae	<i>Junonia almana</i> (Linnaeus, 1758)	1
	Nymphalidae	<i>Ypthima philomela</i> (Linnaeus, 1763)	1
	Nymphalidae	<i>Ypthima pandocus</i> (Moore, 1857)	1
	Crambidae	<i>Diasemia accalis</i> (Walker, 1859)	1
	Hesperiidae	<i>Taractrocera archias I</i> (Felder, 1860)	1
	Lycaenidae	<i>Spalgis epius</i>	1
	Erebidae	<i>Nyctemera coleta</i> (Stoll, 1781)	2
	Pieridae	<i>Eurema blanda</i> (Boisduval, 1836)	2
	Erebidae	<i>Amata huebneri</i> (Boisduval, 1828)	1
	Geometridae	<i>Luxiaria mitorrhaphes</i> (Prout, 1925)	1
Odonata	Libellulidae	<i>Neurothemis fluctuans</i> (Fabricius, 1793)	1
	Libellulidae	<i>Pantala falvenscens</i> (Fabricius, 1798)	1
	Libellulidae	<i>Orthetrum sabina</i> (Drury, 1773)	3
Hemiptera	Coreidae	<i>Acanthocephala</i> sp. (Laporte, 1833)	1
Hymenoptera	Formicidae	<i>Diacamma</i> sp. (Mayr, 1862)	1
	Vespidae	<i>Labus</i> sp. (Saussure, 1867)	1
	Formicidae	<i>Camponotus</i> sp. (Mayr, 1861)	2
	Crabronidae	<i>Liris</i> sp. (Fabricius, 1804)	1
	Vespidae	<i>Polistes</i> sp.	2
Coleoptera	Coccinellidae	<i>Harmonia axyridis</i> (Pallas, 1773)	1
Orthoptera	Pyrgomorphidae	<i>Tagasta marginella</i> (Thunberg, 1815)	4
	Acrididae	<i>Chirista</i> sp. (Karsch, 1893)	2
	Acrididae	<i>Locusta migiatoria</i> (Linnaeus, 1758)	1
	Trigonidiidae	<i>Dianemobius nigrofasciatus</i> (Matsumura, 1904)	1
Σ Individual			36

The Odonata recorded, at 14%, were dominated by *Orthetrum sabina*, with three individuals (Table 5). This species is known to tolerate a variety of habitat types, including damp areas around waterways in karst areas. The presence of this dragonfly indicates a water source or relatively high humidity around Kiskendo Cave, as Odonata are highly dependent on their aquatic larval stage (Elisabeth & Hidayat, 2021). On the other hand, Hemiptera and Coleoptera were represented by only one species each, *Acanthocephala* sp. and *Harmonia axyridis*, indicating that these two groups are not primary inhabitants of the cave mouth zone but are likely only temporary visitors, attracted by the light and aroma of vegetation around the sampling site.

Overall, the distribution pattern of orders found in Kiskendo Cave reflects the typical characteristics of the twilight zone in karst cave ecosystems: a transitional region where sunlight still influences vegetation growth and attracts surface insects such as Lepidoptera and Orthoptera. The low Number of Hemiptera and Coleoptera individuals may be due to sampling methods and timing that did not fully capture seasonal or daily variations. This data is important as a baseline for understanding the ecological role of the Kiskendo karst area, given that caves often serve as important habitats for diverse fauna, including insects, which have not been systematically documented (Mongabay, 2023). Further research using more diverse sampling methods and encompassing the cave's dark zones will provide a more

comprehensive picture of the insect community in this karst ecosystem.

Habitat Characteristics of Cave Entrance Area

Kiskendo Cave is a natural tourist attraction located in Jatimulyo Village, Girimulyo Subdistrict, Kulon Progo Regency, Special Region of Yogyakarta. This cave has a unique environmental profile, serving as a transition zone between surface and subterranean habitats. This condition results in significantly greater environmental variation around the cave entrance than in the cave interior. Cave ecosystems and their transitional zones play an important role in supporting biodiversity by providing diverse microhabitats that organisms with different ecological needs can use (Agni et al., 2019).

The area around the entrance of Kiskendo Cave is still covered by vegetation consisting of trees, shrubs, and understory plants, forming a relatively heterogeneous habitat. This vegetation serves as a source of food, shelter, breeding sites, and activity space for various faunal groups, including insects. The complexity of vegetation structure is closely linked to increased insect species richness, as more diverse vegetation provides more ecological niches for organisms to occupy (Samways et al., 2020).

Table 6. Environmental Parameters of Kiskendo Cave Mouth

Environmental Parameters	Aerial
Light Intensity (lux)	1,483
Air Temperature (°C)	30.4
Air Humidity (%)	85
Soil Temperature (°C)	31
Soil Moisture	Dry 1
Soil pH	6.5

Measurements of environmental factors indicate that the aerial habitat around the cave entrance has a light intensity of 1,4883 lux, an air temperature of 30.4°C, a relative humidity of 85%, a soil temperature of 31°C, a soil pH of 6.5, and dry soil conditions (Table 6). The relatively high light intensity indicates that the study area still receives sufficient sunlight to

support vegetation growth. The soil pH, which is close to neutral, also indicates conditions that remain suitable for plant growth and soil organism activity. These conditions indirectly contribute to the availability of resources required by the insect community around the cave entrance (Mammola et al., 2019).

Air temperature was measured using a digital thermometer-hygrometer (HTC-2; accuracy ± 1 °C for temperature and $\pm 5\%$ RH for relative humidity) at approximately 1 m above the ground. Light Intensity was measured using a digital lux meter (BENETECH GM1010; accuracy $\pm 3\%$ for readings below 10,000 lux and $\pm 4\%$ for readings above 10,000 lux), with the sensor positioned approximately 1 m above the ground and facing upward. Soil temperature was measured using a digital soil thermometer (TP101; accuracy ± 1 °C), while soil moisture and soil pH were measured using a digital 4-in-1 soil meter (KETOTEK; accuracy $\pm 5\%$ for soil moisture and ± 0.1 pH for soil pH), with the probes inserted to a depth of 10 cm. Each parameter was measured three times at each sampling point, and the mean values were used for analysis. Soil moisture was recorded according to the meter's scale.

Environmental conditions around the cave entrance differ from those inside the cave, which features extremely low light intensity or complete darkness in dark zones, lower temperatures, and higher humidity. These differences create a distinctive environmental gradient, resulting in a transitional habitat with more diverse characteristics. The combination of light availability, vegetation, and relatively high humidity makes the area around the entrance to Kiskendo Cave a habitat that supports various groups of aerial insects. Such habitat heterogeneity is known to play an important role in enhancing species richness and the complexity of insect communities within an ecosystem (Seibold et al., 2019).

Aerial Insect Species Diversity Index (H')**Table 7.** Analysis of the Diversity, Evenness, Richness, and Dominance Indices

Index	Results
Shannon Wiener (H')	3.107
Evenness (E)	0.965
Margalef (R)	6.697
Simpson Dominance (1-D)	0.051

Diversity Index, which is the Number of species divided by the total Number of individuals across all species present on Table 7. The diversity of a community is considered high if it consists of many species, and vice versa (Ambeng et al., 2023). Analysis using the Shannon-Wiener formula yielded a diversity index value of 3.107, indicating that the study area possesses a high level of diversity ($H' > 3$). The diversity index value is influenced by environmental factors affecting insect species diversity, which depend on both biotic and abiotic factors. The vegetation surrounding the cave entrance provides a complex habitat structure, thereby supporting a variety of aerial insects. Biotic factors influencing aerial insect diversity are also dependent on plant vegetation diversity (Salsabila et al., 2024). The greater the variety of plant species, the more diverse the insect communities inhabiting the study site (Faradila et al., 2020).

The Shannon-Wiener diversity index for insects associated with the vegetation near the mouth of Kiskendo Cave was recorded at 3.107, placing this community in the high diversity category ($H' > 3$). This high diversity value indicates that despite challenging microclimatic conditions characterized by high light intensity (1483 lux), warm air temperature (30.4°C), 85% air humidity, and dry soil conditions (31°C, dryness level 1), the vegetation ecosystem surrounding the cave entrance provides ample environmental carrying capacity and microhabitat complexity. Rather than limiting diversity, these warm, open abiotic factors act as a natural environmental filter, favoring insect groups with robust physiological and behavioral adaptations to temperature exposure, such as members of the orders Lepidoptera, Odonata, and Orthoptera, which efficiently utilize the

cave-mouth vegetation as their primary ecological niche.

Aerial Insect Evenness Index (E)

The evenness index is a measure used to describe the stability of a community by assessing the distribution of individuals of a species within that community (Firdausi & Setyawan, 2025). According to Habibi et al. (2022), the species evenness index indicates the degree of evenness in the abundance of insect individuals across each species. Based on the calculation of the evenness index, a value of 0.965 was obtained (Table 7). The analysis results show that the E value is close to 1.0, indicating that the evenness of aerial insect species in this study is very high. A high evenness value suggests that no single species exhibits extreme dominance, and the distribution of individual numbers among species is relatively balanced. Within this community, resource utilization appears well apportioned, without extreme population explosions of any specific species. Despite microclimatic conditions that are generally warm and dry, the aerial insect community exhibits a very high evenness index of 0.965. Ecologically, this near-uniform evenness indicates a balanced distribution of individuals among species under local environmental conditions. This homogeneous distribution is further supported by a very low Simpson Dominance value ($D = 0.051$; Simpson Diversity $1 - D = 0.949$), as well as soil acidity conditions (pH 6.5) within the neutral range that support secondary shrub vegetation. The open environmental characteristics, with strong sunlight exposure (1483 lux), appear to facilitate an even distribution of resources, enabling each insect order to share airspace through balanced ecological niche partitioning.

Aerial Insect Species Richness Index R

Species richness refers to the Number of species present within a particular area. The species richness index developed by Margalef combines information on the Number of species with the abundance or density of individuals in sampling units of equal size collected from the same habitat or community (Rachman & Hani,

2017). The Margalef species richness index yielded a value of 6.697, which falls within the high species richness category ($R > 5.0$) (Table 7). This high value indicates that the habitat around the entrance of Kiskendo Cave supports a diverse assemblage of species through the availability of varied resources and favorable structural microhabitats. Factors such as vegetation diversity, microclimatic conditions, food availability, and the presence of suitable shelter can all contribute to the Number of species recorded during the observation period (Rahmawati et al., 2025).

Although the calculated species richness is high, the observed species composition represents a snapshot of the community during the sampling period. Minor variations in recorded richness across different studies may be influenced by sampling duration, seasonal weather conditions, and the specific capture efficiency of the sweeping method used. Differences in daily activity patterns among insect groups may also affect their individual catchability.

Table 8. Simpson's Dominance Index

Order	Results
Lepidoptera	0.898
Odonata	0.560
Hemiptera	0
Hymenoptera	0.776
Coleoptera	0
Orthoptera	0.656

Aerial Insect Dominance Index (1-D)

Table 9. Simpson's Dominance Index

Order	Results
Lepidoptera	0.898
Odonata	0.560
Hemiptera	0
Hymenoptera	0.776
Coleoptera	0
Orthoptera	0.656

The dominance index is a parameter used to describe the degree to which a species dominates a community (Table 8). It reflects the extent to which one species exerts greater influence or abundance relative to other species

within the same community. Dominance may be concentrated in a single species, several species, or distributed among many species, as indicated by the magnitude of the dominance index. A higher dominance index value indicates a greater tendency for one or a few species to dominate the community (Nuraina et al., 2018).

Based on the results of the analysis, Lepidoptera exhibited the highest dominance index value (0.898), followed by Hymenoptera (0.776), Orthoptera (0.656), and Odonata (0.560) (Table 9). The high dominance value observed in Lepidoptera indicates that this group is dominated by one or a few species with substantially higher numbers of individuals than the other species present. This pattern may be influenced by the availability of food resources, habitat suitability, and the dominant species' adaptive capacity to the environmental conditions at the study site.

Hymenoptera, with a dominance index of 0.776, also showed a tendency toward dominance by certain species. This may be attributed to the social behavior of some of its members, particularly ants, which typically live in large colonies and therefore occur in much higher numbers than many other insect groups recorded during the study.

Orthoptera and Odonata exhibited dominance index values of 0.656 and 0.560, respectively, indicating the presence of dominant species within both orders. Although previous studies typically associate high Orthoptera abundance with humid environments, conditions at the cave entrance during sampling revealed a relatively dry ground surface and an air temperature of approximately 30.4°C. The continued presence of Orthoptera under these conditions suggests behavioral adaptations to the specific micro-environmental variations found at the cave entrance. Specifically, despite the warm and dry conditions, features such as rock crevices, shade-grown vegetation, and dust-covered leaves provided micro-refugia that offered cooling and mitigated desiccation. Furthermore, many Orthoptera species inhabiting ecotone areas can withstand

temperature fluctuations; this allows them to forage on vegetation within the cave interior during warmer periods while using cooler rock crevices as temporary shelters.

In contrast, Hemiptera and Coleoptera both had a dominance index value of 0. This indicates that no species within these two orders exhibited clear dominance during the observation period. This result is likely attributable to the very low Number of individuals and species recorded, or to the presence of only a single species represented by a limited number of individuals, resulting in the absence of a distinct dominance pattern.

Community Structure and Ecological Functions

The aerial insect community structure around the entrance of Kiskendo Cave exhibits a relatively diverse assemblage, with six recorded orders: Lepidoptera, Hymenoptera, Orthoptera, Odonata, Hemiptera, and Coleoptera. The Shannon-Wiener diversity index ($H' = 2.342$) indicates a moderate to high level of diversity. In contrast, the Margalef species richness index ($R = 3.789$) reflects the habitat's ability to support a wide range of insect taxa. These conditions suggest that the ecosystem surrounding the cave entrance possesses sufficient resource complexity to sustain a relatively stable aerial insect community (Maesyaroh et al., 2023).

Community composition is dominated by Lepidoptera, accounting for 11 species out of 25 recorded species. This dominance highlights the strong influence of vegetation as a primary driver shaping community structure. The dependence of Lepidoptera on flowering plants for nectar and on host plants during larval stages makes this group highly sensitive to vegetation conditions. The relationship between Lepidoptera diversity and vegetation complexity has been widely reported in tropical ecosystems, where increased vegetation structure is generally associated with higher butterfly species richness (Kurniawan et al., 2020).

Hymenoptera ranks second with five species, followed by Orthoptera, Odonata, Hemiptera,

and Coleoptera with lower species numbers. Differences in order composition reflect variation in ecological requirements and adaptive strategies in utilizing available habitat resources. The presence of insect groups in varying proportions indicates microhabitat heterogeneity around the cave entrance. Seibold et al. (2019) emphasized that habitat heterogeneity plays a key role in maintaining arthropod diversity by providing variation in structural complexity, microclimatic conditions, and resource availability for different functional groups.

A high evenness value ($E = 0.9456$) indicates a relatively balanced distribution of individuals among species, while the low Simpson dominance index ($D = 0.102$) suggests the absence of any strongly dominant species. These results reflect a well-balanced community structure in which resource utilization is relatively evenly distributed. Such stability indicates that interspecific competition is not overly intense, allowing multiple species to coexist within the same ecosystem (Maesyaroh et al., 2023).

The ecological roles of the aerial insect community around the entrance of Kiskendo Cave encompass several key ecosystem functions. Lepidoptera and some Hymenoptera act as pollinators that support the pollination of wild vegetation around the cave area. According to Noriega et al. (2018), pollinating insects play a crucial role in maintaining vegetation regeneration and the stability of tropical ecosystems through pollination services.

Orthoptera and Hemiptera serve as herbivores that contribute to energy flow by consuming plant biomass. These groups serve as a link between primary producers and higher trophic levels, thereby supporting food web dynamics in terrestrial ecosystems. (Jankielsohn, 2018), stated that herbivorous insects play an important role in nutrient cycling and biomass dynamics in terrestrial ecosystems. The presence of Odonata and some Hymenoptera as predators indicates the existence of natural biological control mechanisms regulating other

insect populations. This predatory function helps maintain trophic balance by preventing the overdominance of certain groups. Payow & Butarbutar. (2024) explained that predator and herbivore interactions contribute to ecosystem stability through population regulation and community dynamics control. The presence of insect taxa known to play functional roles, such as pollinators, herbivores, and predators, indicates that the insect community near the cave entrance is structurally diverse and holds functional potential within the local food web.

CONCLUSIONS

The aerial insect community in the entrance area of Kiskendo Cave consists of six insect orders, with a species composition dominated by Lepidoptera. The Shannon-Wiener diversity index ($H' = 3.107$) indicates high diversity, while the evenness index ($E = 0.965$) reflects a uniform distribution of individuals among species. The Margalef richness index ($R = 6.697$) reflects moderate species richness. The Simpson dominance index ($D = 0.051$, $1-D = 0.949$) indicates the absence of strong species dominance. These results indicate that the habitat surrounding the mouth of Kiskendo Cave supports an insect community characterized by a balanced species distribution and a diverse composition of functional groups. The presence of insect groups with diverse ecological roles, such as pollinators, herbivores, and predators, highlights the importance of the cave entrance area as a habitat that helps maintain ecosystem function and ecological balance.

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