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Diversity of Soil Insects on Hiking Trails in the Forest of Mount Prau

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Abstract

Soil insects are insects that carry out all their activities in or on the soil surface. Soil insects play a vital role as decomposers, predators, herbivores, and soil structure improvers. This study aims to investigate the diversity of soil insects along the hiking trails of Mount Prau with varying levels of hiking intensity, namely the Patak Banteng trail with high intensity, Dwarawati with medium intensity, and Purwosari with low intensity. The method used was the pitfall trap, with a total of 120 traps installed along the three trails. Insect identification was conducted in the laboratory using a stereo microscope, and environmental factors such as temperature, humidity, soil pH, light intensity, organic carbon (C) content, nitrogen (N), phosphorus (P), and soil texture were measured as supporting data. The results showed 20 soil insect species from 6 orders and 11 families, with a total of 445 individuals. The order Coleoptera was dominant in all plots, particularly the species *Xantholinus* sp. (Staphylinidae). The highest Shannon-Wiener diversity index was found in the medium intensity plot (H'=1.90), followed by low intensity (H'=1.82), and the lowest in hight intensity (H'=1.59). High evenness (E) values (>0.6) and low dominance (D). Based on the results of the study, soil insects have been proven to be sensitive bioindicators of changes in forest ecosystem stability.

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INTRODUCTION

Mount Prau is one of the main hiking destinations in Central Java with a rich mountain forest ecosystem (Alimah et al., 2021). Mount Prau is a mountain that has been inactive for 30 years with a peak altitude of around 2,565 meters above sea level (Masruri et al., 2017). There are several hiking trails leading to the summit of Mount Prau, such as the Patak Banteng, Wates, Dwarawati, Igirmranak, Dieng, and Kalilembu trails, which are officially managed by the community in collaboration with the forestry agency (Lustiyati et al., 2022). In 2018, the total number of climbers on Mount Prau was 125,000, and in 2019, it increased to 165,000 climbers. The high interest of tourists visiting Mount Prau has had a negative impact on soil quality and biodiversity (Umam et al., 2021). Several researchers have evaluated that the increasing number of tourists can disturb some species in the ecosystem, such as macroinvertebrates, mammals, and birds (Noriega et al., 2020). This will also impact soil biodiversity, particularly soil insects along the hiking trails.

Soil insects are a type of insect that carries out all its activities in or on the soil surface. Its life cycle takes place in the soil, enabling it to adapt well to the soil environment (Ferdiansyah et al., 2024). Soil insects play a vital role as decomposers, predators, herbivores, and soil structure improvers (Taradipha et al., 2019). The diversity of soil insects in an ecosystem is greatly influenced by ecological factors, including biotic factors such as animals and plants, as well as abiotic factors such as water, soil,

temperature, and light (Permatasari et al., 2024). High diversity indicates a healthy and stable soil ecosystem, while a decline in diversity can be an early sign of ecosystem degradation. These factors influence the distribution and abundance of soil insects, so soil insect diversity can be used as an indicator of ecosystem balance (Rosinta et al., 2021).

Research on soil insect diversity along the Gunung Prau hiking trail is expected to provide information on various potential biodiversity. The objectives of this study are to identify and analyze soil insect diversity along the Gunung Prau hiking trail and the influence of ecological factors on the existence of soil insects.

METHODS

This research was conducted on three climbing trails of Mount Prau. These trails were selected because they represent variations in tourist visitation levels. The Patak Banteng trail has a high intensity of climbers, Dwarawati has a moderate intensity, and Purwosari has the lowest intensity of visits. Data collection was carried out from May to November 2024. The data collection method used in this study was pitfall traps.

Fig.1 Location of the hiking trails in the forest of Mount Prau: A) HI: High Intensity, B) MI: Medium Intensity, and C) LT: Low Intensity

Insect Sampling

Soil insect sampling was conducted using the pitfall trap method, with 120 traps (40 traps per trail) placed at 30-meter intervals along a 300-meter transect on each trail. Each trap consisted of a plastic cup filled with a mixture of water and detergent, buried for 24 hours, and equipped with a plastic cover to prevent rainwater contamination.

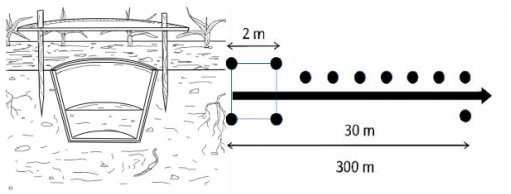

Fig.2 Illustration of pitfall trap placement on a hiking trail (Mugala et al., 2023)

Species Identification

Insect identification was carried out in the laboratory using a 20x magnification a stereo microscope. Identification was performed using an insect identification guidebook (Kanisius, 1991), the e-book Biological Control in Plant Protection (Helyer et al, 2022), articles and related journals. Environmental parameters measured include abiotic factors (air temperature, air humidity, soil pH, soil moisture, light intensity using a thermohygrometer, soil tester, and lux meter) as well as soil analysis (texture, organic C content, N, and P) at Balai Penerapan Standar Instrumen Pertanian (BPSIP) of Central Java.

Data Analysis

Data were analyzed using the Shannon-Wiener diversity index (H'), evenness index (E), and dominance index (D) to describe the structure of the organism community at the study site. The Shannon-Wiener index was used to determine the level of species diversity, the evenness index was used to see how evenly the number of individuals was distributed among species, while the dominance index was used to assess whether there were species that dominated the community.

RESULT AND DISCUSSION

Based on the results of the study, 20 species of soil insects were found on three hiking trails in the Gunung Prau forest, consisting of 445 individuals belonging to 6 orders and 11 families. The results of the identification of soil insects on the hiking trails can be seen in Table 1.

Table 1. Results of soil insect diversity identification on the hiking trail.

No.	Order	Family	Species	Plot			Total
				HI	MI	LI	
1	Coleoptera	Curculionidae	*Barypeithes* sp.	3	7	4	14
2		Carabidae	*Bembidion* sp.	1	3	2	6
3		Carabidae	*Chlaenius* sp.		5	5	10
4		Staphylinidae	*Dalotia* sp.		6	2	8
5		Nitidulidae	*Epuraea* sp.		1		1
6		Staphylinidae	*Isadelphus* sp.	1		5	6
7		*Staphylinidae*	*Ocypus* sp.		17	2	19
8		Carabidae	*Oxytrechus* sp.	1			1
9		Staphylinidae	*Staphylinus* sp.		6		6
10		Carabidae	*Trechus* sp.	16	7		23
11		Staphylinidae	*Xantholinus* sp.	2	66	2	70
12	Orthoptera	Gryllacrididae	*Gryllacris* sp.	1		10	11
13		Gryllidae	*Gryllus* sp.		18	1	19
14		Tetrigidae	*Tetrix* sp.	11	61		72
15	Hymenoptera	Formicidae	*Componatus* sp.			2	2
16		Formicidae	*Hypoponera* sp.			51	51
17		Formicidae	*Solenopsis* sp.	22	1	27	50
18	Hemiptera	Miridae	Sp.1			65	65
19	Blattodea	Blaberidae	*Panesthia* sp.			2	2
20	Dermaptera	Anisolabididae	*Euborellia* sp.		7	2	9
			N Individu (Total individuals)	58	205	182	445
			N Spesies (Total Species)	9	13	15	

Description: HI: High Intensity; MI: Medium Intensity; LI: Low Intensity; N Individuals: Total individuals; N Species: Total species.

On the HI trail, nine species of soil insects were found, with a total of 58 individuals, belonging to four orders and six families, making it the trail with the lowest species and individual abundance. In contrast, the MT trail recorded 13 species from 205 individuals belonging to 6 orders and 8 families, showing the highest abundance of individuals among the three trails. Meanwhile, the LT trail had the highest number of species, with 15 species from 182 individuals belonging to 6 orders and 9 families. The differences in abundance and diversity of soil insects in each trail are greatly influenced by the intensity of tourist visits. The HT trail, shows a decrease in the number of species and individuals, while the MI and LI trails, with lower visitation intensity, are able to maintain higher abundance and diversity of soil insects. Increased human activity in Trail 1 can disrupt the presence of soil insects. Soil insects are mobile and tend to move when there are changes or disturbances in their environmental conditions (Permatasari et al., 2024).

The orders found in this study include Coleoptera, Orthoptera, Hymenoptera, Hemiptera, Blattodea, and Dermaptera. The Coleoptera order is the most dominant order with the largest number of species and wide distribution across all three trails, as well as the largest number of individuals, namely 164 individuals from 11 different species. The most commonly found species was *Xantholinus* sp. (Coleoptera: Staphylinidae) with a total of 70 individuals, predominantly distributed along the MT trail. Meanwhile, the species with the fewest individuals were *Epuraea* sp. (Coleoptera: Nitidulidae) and *Panesthia* sp. (Blattodea: Blaberidae), each found in only 2 individuals.

The order Coleoptera is the most dominant group of soil insects along the entire Mount Prau hiking trail, with 11 species and the highest number of individuals, particularly on Trails 2 and 3. The Staphylinidae family dominates due to its ability to adapt to moist soil environments. Staphylinidae are commonly found in forest litter, grasses, decaying fruits and wood, as well as animal feces. The presence of forest ecosystems plays a crucial role in maintaining the diversity of Staphylinid beetles (Atmowidi et al., 2016). The order Orthoptera, comprising *Gryllacris* sp., *Gryllus* sp., and *Tetrix* sp., is also abundant, playing a crucial role as herbivores and detritivores in the soil food chain and aiding in leaf litter fragmentation (Mathew et al., 2022).

The order Hymenoptera, especially from the family Formicidae such as *Solenopsis* sp and *Hypoponera* sp, are known as opportunistic species that are tolerant to environmental changes, enabling them to survive and even dominate in areas experiencing anthropogenic disturbance or pressure (Trianto & Salsabillah, 2021). This occurs because ants possess high adaptive capacity, good mobility, and flexible colony strategies, enabling them to utilize remaining resources in disturbed habitats and compete with other species.

The orders with the fewest species and individuals found were Hemiptera, Blattodea, and Dermaptera. The order Hemiptera was only found in the Purwosari corridor. The main factor influencing Hemiptera diversity is habitat heterogeneity. This habitat increases the number of food sources and opportunities for the formation of various habitats suitable for various Hemiptera species, especially since most Hemiptera are phytophagous insects. (Li et al., 2019). The order Blattodea (*Panesthia* sp.) is also only found in this corridor, playing an important role as a decomposer in the soil. Meanwhile, Dermaptera

(*Euborellia* sp.) is found in all corridors, although in small numbers, but still plays an important role as a small predator and detritivore, maintaining the balance of the soil insect community and aiding in the fragmentation of organic matter (Puspitarini & Fernando, 2021).

Table 2. Diversity Index, Evenness Index, and Dominance Index

	H'	E	D
HI	1,56	0,72	0,24
MI	1,90	0,74	0,21
LI	1,82	0,67	0,23

Description: HI: High Intensity; MI: Medium Intensity; LI: Low Intensity

The Shannon-Wiener diversity index (H') on the hiking trails of forest Mount Prau is moderate, with the highest H' found on the MI trail (1.90), followed by LI trail (1.82), and the lowest in HI trail (1.59). This pattern indicates that trails with lower tourist pressure tend to have higher soil insect diversity. This is consistent with Chaidir (2023) who states that anthropogenic pressure, such as tourist activity, can reduce soil insect diversity due to habitat disturbance, soil compaction, and a decrease in litter as a food source and microhabitat. The evenness index (E) for all three trails was also high, at 0.74 (MI), 0.72 (HI), and 0.67 (LI).

A high E value indicates a relatively even distribution of individuals among species, without extreme dominance by any particular species (Amrulloh et al., 2022). In this study, evenness was higher in the HT than in the MT and LT trails. This phenomenon is due to the smaller number of species in HT, but individuals are relatively evenly distributed among the remaining species. Thus, although diversity has declined due to the loss of sensitive species, no species dominates significantly, so the evenness value remains high. This condition aligns with the principle that evenness can remain high when species richness is low if the distribution of individuals among species is not extremely dominated.

The dominance index (D) has an inverse relationship with the diversity index (H') and the species evenness index (E). When a species exhibits high dominance, the diversity and evenness decrease, whereas low dominance of species leads to an increase in both diversity and evenness within a habitat. The dominance index rises as the population size of a species increases in a habitat. Conversely, the presence of a greater number of species in a habitat correspondingly elevates the diversity index (H') and species evenness index (E) (Amrulloh et al., 2022).

LT trail shows a greater number of species compared to the MT trail, even though the H' index (1.82) is slightly lower than MT trail, indicating that habitats with minimal disturbance are more conducive to biodiversity. Conversely, HT has only 9 species, due to the impact of human activities such as soil compaction and litter damage, which reduce micro-humidity and the availability of essential microhabitats for soil insects.

Table 3. The environmental factors on the hiking trail of Mount Prau

Abiotic Factors	Location		
	HT	MT	LT
Air temperature (°C)	17-18	16-23	23-26
Air humidity (%)	64-65	92-100	77-89
Light intensity (Lux)	1333-3945	1226-2725	1244-3693
Soil pH	6,8-6,9	6,6-6,8	6,2-6,8
Soil moisture (%)	35-40	50-65	40-55
Organic C (%)	9,20	19,14	5,19
N (%)	0,78	1,17	0,39
P (ppm)	12,86	21,80	14,12

Description: HT: High Tourism, MT: Medium Tourism, LT: Low Tourism

Air temperature, humidity, and light intensity on the three trails of Mount Prau greatly affect the life of soil insects. HT trail has the lowest air temperature (17–18°C) and the lowest air and soil humidity, making it less than ideal for most soil insects. Only certain species, such as *Solenopsis* sp., are able to survive. Conversely, MT trail, with its high air and soil temperatures and humidity (92–100% and 50–65%), provides an optimal microhabitat, supporting the abundance of species such as *Xantholinus* sp. and *Euborellia* sp. The high light intensity in HT trails (1333–3945 lux) also limits the presence of photophobic soil insects.

The pH of the soil in the three plots ranged from 6.2 to 6.9, which is within the optimal range for soil insects. However, the effect of pH on the soil insect community is indirect and highly dependent on interactions with other environmental factors. At MT trails, despite the pH being close to neutral, low temperatures and minimal soil moisture reduce the effectiveness of the optimal pH. Conversely, at MT and LT trails, the slightly more acidic pH synergizes with high soil moisture and stable temperatures, creating conditions that support decomposer activity and food availability for soil insects.

Soil nutrient content also showed significant differences between trails. MT trail had the highest organic carbon, nitrogen, and phosphorus content, supported by high moisture and minimal human disturbance, creating a fertile environment for soil insects and decomposer microbes. HT trail experienced a decrease in organic carbon and nitrogen due to erosion and soil compaction. Meanwhile, LT trail despite its low hiking intensity, has the lowest organic carbon content due to clay soil texture that inhibits organic matter decomposition. According to Kleeberg (2024), clay minerals play a crucial role in forming stable complexes with organic compounds through cation bonds, making organic matter more resistant to decomposition. This physical and chemical protection causes the mineralization process to proceed slowly, so even though organic matter enters the soil, the organic matter content remains low, as does the available nitrogen content. For further research, seasonal studies (dry season-rainy season) are important to understand the effect of climate variation on soil insect communities.

CONCLUSION

The level of soil insect diversity on the Gunung Prau hiking trail is moderate, with 20 species from 6 orders and 11 families, and a total of 445 individuals. The highest Shannon-Wiener diversity index (H') was found on the MI trail (H'=1.90), followed by the LI trail (H'=1.82), and the lowest on the HI trail (H'=1.59). Factors such as air humidity, temperature, soil moisture, soil pH, organic carbon (C-organic) content, nitrogen (N), phosphorus (P), and soil texture play a significant role in determining the abundance and diversity of soil insects.

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