

Diversity of insect pollinators in the buffer zone of Mount Merapi National Park, Indonesia

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Abstract. Herdananta BY, Charsyah C, Putra CDH, Mumpuni CHY, Nofitasari H, Setyawan AD. 2025. Diversity of insect pollinators in the buffer zone of Mount Merapi National Park, Indonesia. *Asian J Agric* 9: 149-159. Pollinating insects have a significant impact on plant reproduction on land, accounting for almost 90% of their function. Both the environment and vegetation influence the presence of pollinating insects. This study aims to analyze the diversity of pollinating insects in several habitat types in the buffer zone of Mount Merapi National Park (MMNP), Tegalmulyo and Sidorejo Villages, Kemalang, Klaten, Indonesia. This research was conducted in March 2024 by taking 3 habitat types, namely forests, agricultural fields, and shrublands, each with 4 replicates. The research method used is a roaming research purposive random sampling technique, and the sampling point was determined at the selected location based on the survey results and accompanied by direct observation. Furthermore, data analysis was carried out on the species ecological index (diversity, richness and evenness), Species Accumulation Curve (SAC) and its relationship with abiotic factors. The results of the study found pollinator insects totaling 121 individuals consisting of 55 species, 26 families, and 5 orders, namely the order Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera. There are several flowering plants infested by pollinating insects; 15 plant species were obtained and divided into 11 different families. The results of the calculation of the pollinator species diversity index were 3.731, a species richness index of 11.26, and a species evenness index of 0.93. Based on the results of the SAC, we recommend to future researchers to make the number of transects more than 12 if conducting research in similar locations until there are no more species additions. The results of measuring abiotic factors from the three habitats have different temperatures, humidity, and wind speeds that can affect the presence of pollinating insects and flowering plants. Based on these results, the ecosystem at the research location is well-maintained, so it is still suitable as a habitat for insect pollinators.

Keywords: Abiotic factors, diversity, insect pollinators, habitat type

INTRODUCTION

Pollination network events in plants arise due to various interactions between thousands of species with their respective needs for survival. The network of interactions between plants and their pollinators is strong evidence of mutualism between them. Pollination is often mentioned from the point of view of ecosystem services that have various benefits for humans (Mathiasson and Rehan 2020). One of the animals included in pollinator animals is the insects because pollinating insects play an important role in the reproduction of almost 90% of plants on land. The existence of various types of host plants will also affect the variety of pollinator species to support their food sources and shelter (Wakhid et al. 2023). Therefore, the ecological role of pollinators carried out by insects is very important for plant biodiversity and all related organisms in the living chain, including maintaining agricultural sustainability and human food security (López-Urbe et al. 2020). Pollination as an ecosystem service (ES) has attracted considerable international attention as a result of the decrease in pollinator populations caused by the widespread use of pesticides and the simplification of landscapes on

community farmland. There is ample evidence to suggest that wild bees and other pollinators, such as flies, butterflies, and florivorous bats, may face similar challenges (Ghisbain et al. 2021). Research reports that the decline in pollinating insects is caused by the excessive use of pesticides in pest control on agricultural land (Sponsler et al. 2019). In addition, according to Nurlaila et al. (2021), land fragmentation can cause pollinator insects to lose their habitat because flowers are also less available as food for pollinator insects.

Many studies have evaluated how environmental factors affect pollinating animals. Examples of research conducted by Dyola et al. (2022) that identify various impacts of environmental factors on the presence of pollinating animals can differ greatly between climate/vegetation zones. According to research by Rahmi et al. (2020), the high diversity of pollinating insects in the buffer zone of Gunung Leuser National Park, which helps agricultural crops pollinate, indicates that the environmental conditions in the area are still natural and not exposed to many disturbances. The diversity and richness of pollinator insect species vary depending on their habitat. Research conducted by Koneri et al. (2021)

explained that the existence of plants as homes for pollinator insects affects the diversity of pollinator insects because pollinator activities in foraging will not be too far from the nest. In addition, the diversity of pollinators is also due to the many variations of flowers that feed pollinator insects (Katumo et al. 2022).

Mount Merapi National Park is a conservation area administratively located in 4 districts, namely Sleman District, Klaten District, Boyolali District, and Magelang District. Mount Merapi National Park is also divided into several resorts, namely Dukun Resort, Srumbung Resort, Pakem-Turi Resort, Cangkringan Resort, Kemalang Resort, Musuk-Cepogo Resort, and Selo Resort. Kemalang Resort is a resort that has hiking trails, namely the Sapuanging Hiking Trail, an area with many tourism opportunities, including camping, tracking, and plant education tours (Maghfiroh et al. 2023). The area around the Sapuanging Hiking Trail consists of various habitats, such as natural forest areas, shrublands, and agricultural fields. The fertile agricultural land in the Sapuanging area is due to its location at the foot of Mount Merapi so that various food, fruit, and plantation crops can be planted (Widhiastuti et al. 2023). This makes each region diverse and rich, and there are different species of pollinating insects. Therefore, this

study was conducted to analyze the diversity of pollinating insects in several habitat types in Mount Merapi National Park, Tegalmulyo, and Sidorejo Villages, Kemalang Subdistrict, Klaten District, Indonesia.

MATERIALS AND METHODS

Study area

This research was carried out in March 2024, and the sampling location was in the buffer zone of Mount Merapi National Park in Tegalmulyo Village with a coordinate point of 7°34'3.78 "N 110°28'4.47" E at an altitude of 1,350 masl and Sidorejo Village with a coordinate point of 7°34'29.3 "N 110°28'4.79" E at an altitude of 1,218 masl. Tegalmulyo Village and Sidorejo Village, Kemalang Subdistrict, Klaten District, Central Java Province, Indonesia (Table 1; Figure 1). Furthermore, the sampling habitat is in forest areas, agricultural fields, and shrublands (Figure 2). Forest areas are a habitat that contains various types of large woody plants that form a canopy. The shrublands are dominated by clustered undergrowth, and the agricultural fields are a field that is deliberately treated by the community to utilize its results.

Table 1. Location of the three type habitats

Type	Location	Coordinate	Note (Vegetation)
Forest	Basecamp of Sapu Angin, Deles Indah Tourist Area, Pine Forest Deles Indah	7°34'00.9"S 110°27'56.1"E, 7°34'25.0"S 110°27'59.2"E, 7°34'07.5"S 110°28'01.4"E	<i>Calliandra calothyrsus</i> Meisn., <i>Acacia decurrens</i> Willd., <i>Schima wallichii</i> (DC.) Korth. (Trees) and <i>Imperata cylindrica</i> L. (land cover)
Shrublands	Forest Basecamp of Sapu Angin and Deles Indah Reservoir	7°34'02.8"S 110°28'04.3"E, 7°34'20.8"S 110°28'01.2"E, 7°34'51.5"S 110°28'05.5"E	<i>Ageratum conyzoides</i> L., <i>Crassocephalum crepidioides</i> (Benth.) S.Moore, <i>Imperata cylindrica</i> L., etc. More detailed species in Table 3. (weeds)
Agricultural fields	Photo Spot of Sapu Angin and Deles Indah Monument	7°34'25.8"S 110°28'03.0"E, 7°34'29.6"S 110°28'07.4"E, 7°34'06.1"S 110°28'02.2"E, 7°33'59.8"S 110°28'12.1"E	<i>Capsicum annum</i> L. and <i>Coffea arabica</i> L. (main crops), <i>Rosa</i> sp. and <i>Pennisetum purpureum</i> Schumach. (side crops) and weeds

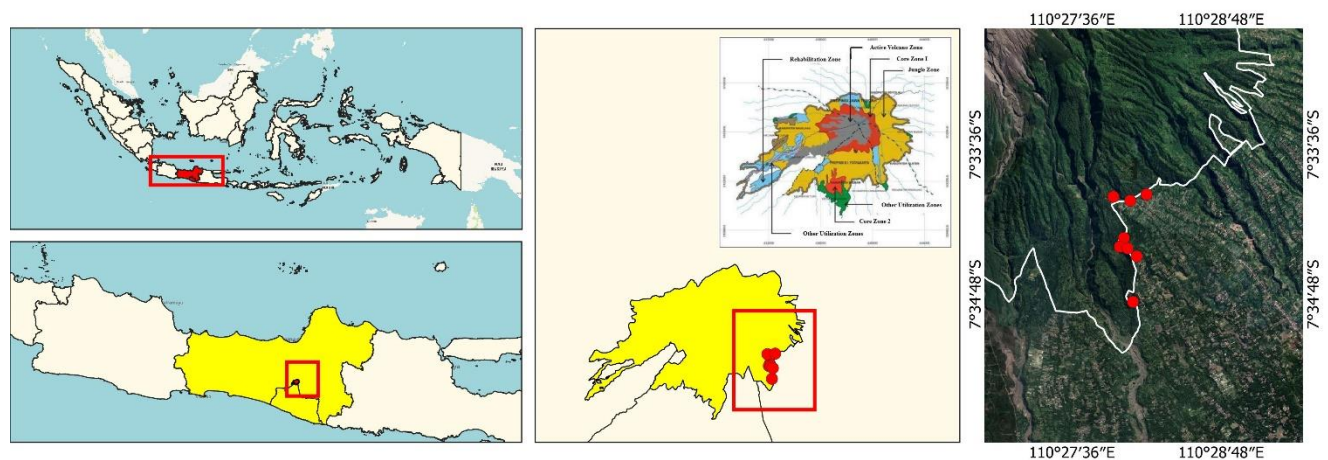


Figure 1. Location in the buffer zone of Mount Merapi National Park, Tegalmulyo and Sidorejo Villages, Kemalang Subdistrict, Klaten District, Central Java, Indonesia (Hermawan et al. 2010)



Figure 2. Photographs of study sites in the buffer zone of Mount Merapi National Park, Tegalmulyo and Sidorejo Villages, Kemalang Subdistrict, Klaten District, Central Java, Indonesia: A. Forest; B. Shrubland; C. Agricultural field

Procedures

The method used in this study was the exploration method purposive random sampling technique was used, and the sampling point was determined at the selected location based on the survey results accompanied by direct observation. The exploration method was carried out by observing along the track and recording each species found (Khoirurrais et al. 2021). The length of the track that became the research location was around 50-100 m in each habitat type in accordance with research conducted by Darsono et al. (2020). The total number of transects made at the research site was 12 transects consisting of 4 agricultural fields habitat type transects (2 morning and 2 noon), 4 shrublands habitat type transects (2 morning and 2 noon), and 4 forests habitat type transects (2 morning and 2 noon). The process of identifying insects obtained from the research site was documented directly. For insects that are difficult to identify, it was necessary to catch them using a sweeping net and photograph for documentation purposes (scan). Insects that have unknown species would be identified using several insect identification books, including Peggie (2006;2011;2014), Ilhamdi et al. (2020), Ruslan (2015), Ruslan and Dwi (2021), Rohman et al. (2019), Aprilia et al. (2018) and other sources from the internet, namely bugguide.net and the plant species identification are carried out based on databases of Plants of the World Online by the Royal Botanic Gardens, Kew (<http://www.plantsoftheworldonline.org/>) (POWO 2024) and the Global Biodiversity Information Facility by the world's governments (<https://www.gbif.org/>) (GBIF, 2024).

The tools needed were an insect net (sweeping net) for the purpose of catching and identification, a mobile camera for documentation, a lux meter to measure light intensity, a hygrometer to measure air humidity in the sampling area, and an insect identification book. The observation time is carried out at 08.00-15.00. This aims to determine the comparison of the abundance of pollinating insects in the morning and evening. This research included quantitative descriptive research.

Data analysis

This study was analyzed in a quantitative descriptive manner. Quantitative descriptive analysis can describe data from calculations or measurements (Arisandy and Triyanti 2020). This study describes the results of the identification and calculation of pollinator insect diversity in several

habitats using the diversity index, species evenness index, and species richness index with the following formula:

Shannon-Wiener Diversity Index

Species diversity is determined using the Shannon-Wiener diversity index formula by Odum (Fachrul 2007):

$$H' = -\sum P_i \ln P_i$$

Where:

H': Species diversity index

P_i: Ratio of the number of individuals of a species for the whole species (n_i/N)

N_i: Number of individuals of one species i

N: Number of individuals of all species

The quantitative value of the diversity of a species can be classified in the following range of values:

If the diversity index (H') < 1.0 indicates low diversity

If the diversity index 1.0 ≤ (H') ≤ 3.0 indicates moderate diversity

If the diversity index (H') > 3.0 indicates high diversity

Evenness Species Index

The Evenness Index is utilized by Baderan (2021) to determine the evenness of each species in each community by using the following formula:

$$E = H' / \ln S$$

Where:

E: Evenness index (values between 0-1)

H': Shannon-Wiener species diversity index

S: Number of species found

The evenness index value ranges from 0-1 with the following categories:

0 < E ≤ 0.4: Small evenness, depressed communities

0.4 < E ≤ 0.6: Moderate evenness, labile community

0.6 < E ≤ 1.0: High evenness, stable community

Margalef Species Richness Index

The species richness index can be calculated using the 1958 Margalef formula (Kent (2012); Mawazin and Subiakto (2013), in Anjani et al. 2022):

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

Where:

R: Margalef species richness index

S: Number of species found

N: Number of individuals of all species

Criteria for the value of the Margalef Species Richness Index:

$R < 2.5$: Low species richness

$2.5 < R < 4$: Medium species richness

$R > 4$: High species richness

The Species Accumulation Curve (SAC)

The species accumulation curve is used to describe the increase in species with an increase in the number of samples (plots/attempts/transects). The SAC curve is used to assess the adequacy of sampling numbers and estimate species richness (Bevilacqua et al. 2018; Rong et al. 2020). The creation of the SAC curve is by connecting the number of plots/efforts/transects as the x-axis with the number of species as the y-axis so as to form a curve. The minimum number of transects can be determined using the SAC curve. If the increase in the number of transects does not cause an increase in the number of species, then the number of transects already represents the extent of the study (Astuti et al. 2020). According to Munthe (2013), the species accumulative curve is useful to show the representation system of the represented forest so that the biodiversity analysis carried out can represent the forest being studied and from the cumulative curve of the species can be determined the minimum plot/transect area or the minimum area used. The analysis of the species accumulative curve was carried out to determine whether the recorded species had represented the number of species in the study area.

RESULTS AND DISCUSSION

Identification of insect pollinators and their composition

Based on the results of the study, in three habitat types (forests, agricultural fields, and shrublands) obtained, 121 individuals of pollinator insects consisting of 55 species from 26 families and 5 orders (Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera). The pollinator insect species are presented in Table 2. Pollinator insects found in Mount Merapi National Park include 9 species of the order Coleoptera, 8 species of order Diptera, 2 species of order Hemiptera, 4 species of order Hymenoptera, and 32 species of order Lepidoptera. Order Coleoptera consisting of pollinator insects of the families Brentidae (1 species), Buprestidae (2 species), Carabidae (1 species), Chrysomelidae (2 species), Coccinellidae (2 species), and Scarabaeidae (1 species). Furthermore, the order Diptera consists of the families Muscidae (2 species), Polleniidae (1 species), Sarcophagidae (1 species), Syrphidae (2 species), Tephritidae (1 species), and Dolichopodidae (1 species). Then, the order Hemiptera, consisting of the families Cicadidae and Scutelleridae with 1 species, was found. Then, the order Hymenoptera consists of the families Apidae (1 species), Eumenidae (1 species), and Vespidae (2 species). Finally, the order Lepidoptera includes pollinator insects from the families Crambidae (2 species), Erebididae (3 species), Hesperidae (2 species), Lycaenidae (6 species), Nymphalidae (10 species), Papilionidae (1 species), Pieridae (6 species), Riodinidae (1

species), and Saturniidae (1 species). Several insect pollinator species in three habitat types around Mount Merapi National Park in Tegalmulyo and Sidorejo Villages have been documented (Figure 3).

Based on the results of insect observations, as shown in Table 2, pollinators are relatively more diverse in the morning compared to the afternoon. According to Mustakim et al. (2014), generally, pollinator insects visit in the morning starting from 07.00-10.00 a.m to coincide when the flowers bloom, where the volume or nectar in flowers is still relatively high, but over time towards noon and evening, the nectar content tends to decrease. These changes affect the degree of insect participation in plants in the process of pollinators. From the results of the research conducted, the number of pollinating insects most commonly found in the three habitats is the order Lepidoptera, with a total of 9 families and 32 species. This is due to suitable habitat and the availability of many food sources. Environmental conditions and food availability affect the presence of pollinator insects of the order Lepidoptera. The abundance of the order Lepidoptera is also supported by the presence of vegetation suitable for the survival of these pollinator insects, such as host plants and feed plants, both as a source of food and as a shelter (Yusup et al. 2023). Meanwhile, the least commonly found order is the Hemiptera order with 2 families, namely Cicadidae and Scutelleridae, and the Hymenoptera order with 3 families, namely Apidae, Eumenidae and Vespidae. Even though food is abundant at the location, there are ecological factors that could be more suitable for the life of this order. One of the reasons is the influence of environmental factors, namely when rainfall is observed to be quite high, which has an impact on the existence of these orders. Theoretically, animals will move from one environment to another when there is a temporary environmental change, such as rain. Animals will move towards an environment that better suits their needs. By moving from a changing environment, animals can inhabit environmental conditions that are most optimal for their survival (Pariyanto et al. 2019). Environmental factors in the form of rainfall can also influence the Lepidoptera order. However, the thing that might cause this order to be the most commonly found is the adaptability of the species in this order to environmental conditions. These adaptations may include the ability to shelter from rain, tolerance to high humidity, or flexible foraging behavior. The highest number of species in the Lepidoptera order is from the Nymphalidae family, which has 10 species. Based on Marlisa et al. (2022), the Nymphalidae family is cosmopolitan and widespread in many regions of the world. Species from the Nymphalidae family like to be in bright, open places with diverse vegetation. Therefore, Nymphalidae butterflies actively fly and are easy to find during the day. Apart from that, Nymphalidae butterflies like fruit-bearing plants such as in gardens and forests because they are also polyphagous. That is, they eat more than one type of plant (Ramadhani et al. 2024). This characteristic makes the Nymphalidae family from the Lepidoptera order have a high ability to survive in various types of habitats (Marlisa et al. 2022).

Table 2. Pollinator insect species in three habitat types in the buffer zone of Mount Merapi National Park, Tegalmulyo and Sidorejo Villages, Kemalang Subdistrict, Klaten District, Central Java, Indonesia

Order	Family	Species name	Habitat type			Total individual	%	
			Forest	Agricultural field	Shrubland			
Coleoptera	Brentidae	<i>Perapion punctinatum</i> (J.B.Smith, 1884)	1	0	0	1	0.83	
	Buprestidae	<i>Chrysochroa fulgidissima</i> (Schönherr, 1817)	1	0	0	1	0.83	
		<i>Chrysochroa fulminans</i> (Fabricius, 1787)	1	0	0	1	0.83	
	Carabidae	<i>Lophyra striolata</i> (Illiger, 1800)	1	0	0	1	0.83	
	Chrysomelidae	<i>Aspidimorpha miliaris</i> (Fabricius, 1775)	2	0	0	2	1.65	
		<i>Aulacophora lewisii</i> (Baly, 1866)	1	0	0	1	0.83	
	Coccinellidae	<i>Coccinella magnifica</i> (Redtenbacher, 1843)	2	0	0	2	1.65	
		<i>Epilachna admirabilis</i> Crotch, 1874	0	0	2	2	1.65	
	Scarabaeidae	<i>Protaetia fusca</i> (Herbst, 1790)	0	0	1	1	0.83	
	Diptera	Muscidae	<i>Musca domestica</i> (Linnaeus, 1758)	6	1	5	12	9.92
<i>Musca vetustissima</i> (Walker, 1849)			0	0	3	3	2.48	
Polleniidae		<i>Pollenia rudis</i> (Fabricius, 1794)	1	0	0	1	0.83	
Sarcophagidae		<i>Sarcophaga</i> sp.	1	0	0	1	0.83	
Syrphidae		<i>Dideopsis aegrota</i> (Fabricius, 1805)	2	0	0	2	1.65	
		<i>Mesembrius vestitus</i> (Wiedemann, 1821)	1	0	0	1	0.83	
Tephritidae		<i>Rhagoletis pomonella</i> (Walsh, 1867)	2	0	0	2	1.65	
Dolichopodidae		<i>Chrysosoma crinicornis</i> (Wiedemann, 1824)	3	0	0	3	2.48	
Hemiptera		Cicadidae	<i>Huechys incarnata</i> (Germar, 1834)	6	0	0	6	4.96
		Scutelleridae	<i>Chrysocoris stollii</i> (Wolff, 1801)	1	0	0	1	0.83
Hymenoptera	Apidae	<i>Apis cerana</i> (Fabricius, 1793)	2	0	1	3	2.48	
	Eumenidae	<i>Delta campaniforme</i> (Fabricius, 1775)	1	0	0	1	0.83	
	Vespidae	<i>Ropalidia fasciata</i> (Fabricius, 1804)	5	0	0	5	4.13	
Lepidoptera	Crambidae	<i>Arthroschista hilaralis</i> (Walker, 1859)	2	0	0	2	1.65	
		<i>Scirpophaga incertulas</i> (Walker, 1863)	0	0	2	2	1.65	
	Erebidae	<i>Calliteara horsfieldii</i> (Saunders, 1851)	0	1	0	1	0.83	
		<i>Nyctemera coleta</i> (Stoll, 1781)	1	0	0	1	0.83	
		<i>Nyctemera adversata</i> (Schaller, 1788)	2	0	0	2	1.65	
	Hesperiidae	<i>Ampittia dioscorides</i> (Fabricius, 1793)	0	1	0	1	0.83	
		<i>Potanthus omaha</i> (Edwards, 1863)	0	1	0	1	0.83	
	Lycaenidae	<i>Flos anniella</i> (Hewitson, 1862)	3	0	0	3	2.48	
		<i>Heliophorus epicles</i> subsp. <i>latilimbata</i> (Fruhstorfer, 1908)	1	0	0	1	0.83	
		<i>Jamides celeno</i> (Cramer, 1775)	4	0	0	4	3.31	
		<i>Lampides boeticus</i> (Linnaeus, 1767)	0	0	3	3	2.48	
		<i>Udara ceyx</i> (Niceville, 1893)	1	0	0	1	0.83	
		<i>Udara dilectus</i> (Moore, 1879)	2	0	0	2	1.65	
		Nymphalidae	<i>Dryadula phaetusa</i> (Linnaeus, 1758)	1	0	0	1	0.83
			<i>Euploea climena</i> (Stoll, 1782)	2	0	0	2	1.65
			<i>Euploea eunice</i> (Godart, 1819)	0	0	2	2	1.65
			<i>Heliconius cydno</i> (H. Bates, 1864)	1	0	0	1	0.83
	<i>Hypolimnas bolina</i> (Linnaeus, 1758)		2	2	0	4	3.31	
	<i>Lethe confusa</i> (Aurivillius, 1897)		1	0	0	1	0.83	
	<i>Melanitis leda</i> (Linnaeus, 1758)		3	0	0	3	2.48	
<i>Mycalesis janardana</i> (Moore, 1857)	1		0	0	1	0.83		
<i>Ypthima pandocus</i> (Moore, 1857)	1	0	1	2	1.65			
Papilionidae	<i>Graphium sarpedon</i> (Linnaeus, 1758)	1	1	0	2	1.65		
Pieridae	<i>Cepora iudith</i> (Fabricius, 1787)	2	0	0	2	1.65		
	<i>Delias fojaensis</i> (van Mastrigt, 2006)	0	0	1	1	0.83		
	<i>Eurema brigitta</i> (Stoll, 1780)	1	1	0	2	1.65		
	<i>Eurema hecabe</i> (Linnaeus, 1758)	8	2	0	10	8.26		
	<i>Leptosia nina</i> (Fabricius, 1793)	0	2	0	2	1.65		
	<i>Pieris brassicae</i> (Linnaeus, 1758)	0	2	0	2	1.65		
	<i>Zemeros flegyas</i> (Cramer, 1780)	2	0	0	2	1.65		
Riodinidae	<i>Zemeros flegyas</i> (Cramer, 1780)	2	0	0	2	1.65		
Saturniidae	<i>Cricula trifenestrata</i> (Helfer, 1837)	0	0	1	1	0.83		
Total			83	14	24	121	100.00	

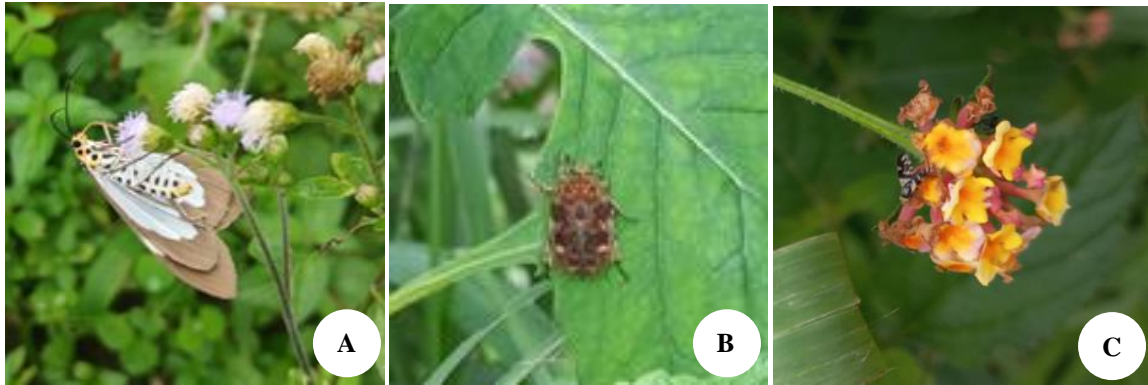


Figure 3. Insect profile of pollinator: A. *Nyctemera coleta*; B. *Protactia fusca*; C. *Rhagoletis pomonella*

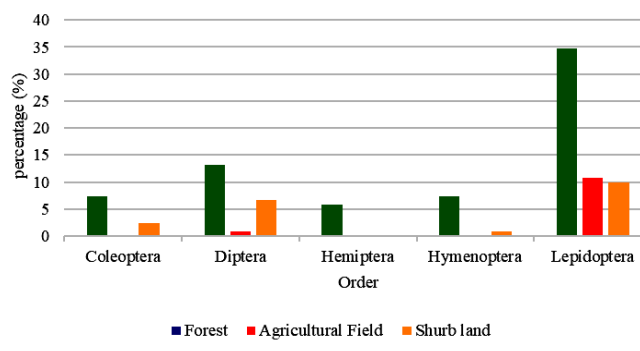


Figure 4. The composition of the order of pollinator insects according to the percentage of individual number

According to Febriyanti et al. (2020), the diversity of the number and type of pollinator insect populations is influenced by the availability of food sources, especially plants that produce fruit. The attractiveness of fruit to certain pollinating insects, which can be influenced by the color and aroma of the fruit, is a factor influencing pollinator diversity. Flowering plants can also affect the presence of pollinating insects. The number and shape of flowers of a plant have a close relationship with the availability of nectar and pollen produced. The more abundant nectar and pollen available on a flower, the higher the chance that pollinator insects will be present to visit the flower. In other words, the availability of nectar and pollen in flowers can be a determining factor in attracting and maintaining the presence of pollinating insects in an ecosystem (Hidayat et al. 2016). Favorable habitat conditions also play an important role, as many host plants support the life of pollinating insects such as honeybees, fruit flies, and their larvae, protecting them from predators and contributing to the survival of the ecosystem. In addition, environmental factors such as temperature, light, and humidity also affect the diversity and abundance of pollinating insects in an ecosystem (Purwantiningsih et al. 2012).

Of the 55 species of pollinator insects found in all habitat types, the highest abundance is a forest habitat type,

with species from the order Lepidoptera numbering 42 species, and the least found is a species from the order Hemiptera with 7 individuals found. The agricultural field habitat type is only found in 2 orders: Lepidoptera, which has as many as 13 individuals, and Diptera, which has only 1 individual. The type of shrublands habitat of the order Lepidoptera is the order with the most individuals, with 12 individuals, and the least is the order Hymenoptera, with only 1 individual. Overall, the species found based on the habitat type of the order Lepidoptera became the order with the most individuals, 55.37%. The lowest was the order Hemiptera, with a percentage of only 5.79%, while the other orders, Coleoptera, Diptera, and Hymenoptera, respectively, were 9.92, 20.66, and 8.26% (Figure 4).

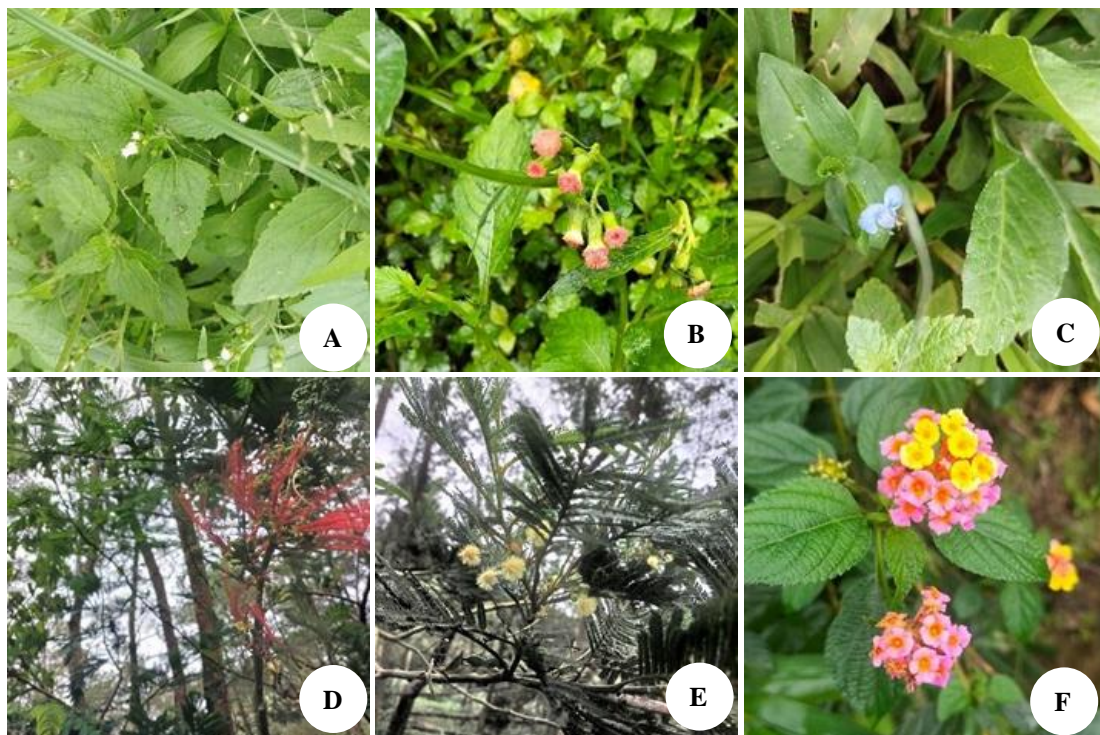
Pollinator insects have visited flowering plants

Based on the identification of plants visited by pollinating insects in several habitat types in Tegalmulyo and Sidorejo Villages (Table 3), 15 plant species were obtained and divided into 11 different families. The families are Asteraceae, Balsaminaceae, Commelinaceae, Fabaceae, Gramineae, Malvaceae, Poaceae, Rosaceae, Solanaceae, Theaceae, Verbenaceae. The families Asteraceae and Fabaceae are the largest, each with 3 species. According to Robson in Sukarsa et al. (2022), these two families are among the plant families most visited by pollinating insects because they have small flowers with colors favored by pollinating insects such as bees. The identification results showed that the flowers found had various colors, such as red in *kaliandra* flowers (*Calliandra calothyrsus*) (Figure 5.D), white in *bandotan* flowers (*Ageratum conyzoides* L.) (Figure 5.A), blue in *gewor* grass flowers (*Commelina benghalensis*) (Figure 5.C), yellow in *Acacia* flowers (*Acacia decurrens* Willd.) (Figure 5.E). In addition, the identification results also show that the flowers found have a distinctive and diverse aroma, such as the fragrant aroma of roses (*Rosa* sp.) and the distinctive scent of water henna flowers (*Impatiens walleriana*). The variety of colors and aromas in the flowers found can attract many pollinating insects to perch and directly help the pollinator's process (Syahbanuari et al. 2020).

Table 3. The results of the inventory and identification of flowers visited by pollinator insects in the buffer zone of Mount Merapi National Park, Tegalmulyo and Sidorejo Villages, Kemalang Subdistrict, Klaten District, Central Java, Indonesia

Family	Species name	Local name	T	P	Sp	S	IUCN
Asteraceae	<i>Ageratum conyzoides</i> L.	<i>Bandotan</i>	-	-	-	●	LC
Asteraceae	<i>Crassocephalum crepidioides</i> (Benth.) S.Moore	<i>Sintrong</i>	-	-	-	●	NE
Asteraceae	<i>Tithonia diversifolia</i> (Hemsl.) Gray	<i>Paitan</i>	-	-	-	●	LC
Balsaminaceae	<i>Impatiens walleriana</i> Hook.f.	<i>Pacar air</i>	-	-	-	●	NE
Commelinaceae	<i>Commelina benghalensis</i> L.	<i>Gewor</i>	-	-	-	●	LC
Fabaceae	<i>Calliandra calothyrsus</i> Meisn.	<i>Kaliandra</i>	●	●	-	-	NE
Fabaceae	<i>Acacia decurrens</i> Willd.	<i>Akasia</i>	●	-	-	-	NE
Fabaceae	<i>Coffea arabica</i> L.	<i>Kopi Arabika</i>	-	●	●	-	EN
Gramineae	<i>Imperata cylindrica</i> L.	<i>Alang-alang</i>	-	-	-	●	NE
Malvaceae	<i>Sida acuta</i> Burm.fil.	<i>Galunggung</i>	-	-	-	●	NE
Poaceae	<i>Pennisetum purpureum</i> Schumach.	<i>Suket Gajah</i>	-	-	-	●	LC
Rosaceae	<i>Rosa</i> sp.	<i>Mawar</i>	-	-	-	●	NE
Solanaceae	<i>Capsicum annum</i> L.	<i>Lombok ijo</i>	-	-	-	●	LC
Theaceae	<i>Schima wallichii</i> (DC.) Korth.	<i>Puspa</i>	●	●	-	-	LC
Verbenaceae	<i>Lantana Camara</i> L.	<i>Tembelean</i>	-	-	-	●	NE

Note: T: Tree, P: Pole, Sp: Sapling, S: Seedling. NE: Not Evaluated, LC: Least Concern, EN: Endangered. ●: Include, -: Not Included

**Figure 5.** Plant profile infested with pollinator insect: A. *Ageratum conyzoides*; B. *Crassocephalum crepidioides*; C. *Commelina benghalensis*; D. *Calliandra calothyrsus*; E. *Acacia decurrens*; F. *Lantana camara*

Based on the identification results, it is known that the majority of flowering plants found in Tegalmulyo and Sidorejo Villages are seedling groups. This is because the flowering plants in the two villages are mostly flower and shrub plants that grow wild or are planted in fields and yards of houses. Additionally, several flowers have been observed growing in the Tegalmulyo and Sidorejo Villages, with Arabica coffee (*Coffea arabica*) being one of their most prominent crops. Arabica coffee has compound flowers and several white crowns and petals (Kurnia et al. 2023). The pollinator process in arabica coffee can be done alone but can also be assisted by several pollinating insects

such as honey bees (*Apis cerana*) (Sitompul et al. 2017). Among all flowering plants, Arabica coffee is the highest ranked IUCN red list category and is also part of the EN or Endangered category. It is crucial to consider all aspects of Arabica coffee plant cultivation, including pollinator insects that aid the pollination process, to ensure sustainability.

The index for diversity, richness, and evenness

The results of the calculation of the diversity index, richness index, and pollinator insect evenness index by order and overall in Tegalmulyo and Sidorejo villages can

be seen in Table 4. The species diversity index of all pollinator insects obtained was 3.731. Based on Shannon Wiener's diversity index classification in Hutami et al. (2022), a diversity index of more than 3 belongs to the high diversity group. The value of the species richness index of all species shows that the location has a high species richness, which is 11.26. The criteria for high wealth stated by Margalef in Nisa et al. (2022) states that it must be worth more than 4. While the evenness of existing species is 0.93, it can be said that the existing species are almost evenly distributed. The evenness index value close to 1 means that the distribution of species in the region is evenly distributed (Latumahina et al. 2020). The highest values of diversity, richness, and evenness indices are in the order Lepidoptera. In contrast, the lowest value of the diversity and richness index is the order Hemiptera. Meanwhile, the lowest value of the evenness index is the order Coleoptera.

These three index results are related to each other because, in general, diversity is a combination of aspects of richness and evenness (Rousseau et al. 1999). The higher the diversity there is, indicating the balance of the ecosystem. The formation of ecosystem balance affects the equitable index. The evenness of species indicates the stability of the environment because there is no one species that dominates, and this causes unequal competition between species. Based on the results of the study, although 2 species were obtained with a higher number of individuals than other species, based on the calculation of the evenness index analysis, a relatively high evenness value was obtained, so the existence of each species is in a stable condition. This also means that the uniformity of species in the environment has an even distribution of species (Septiningtyas et al. 2022). The diversity index is also an indicator of pollution because the index will decrease if there is environmental pollution in an increasing area (Hosokawa et al. 2021).

The Species Accumulation Curve (SAC)

The species accumulation curve (SAC) is another popular tool in the analysis of species abundance data. This survey is seen as a data collection process where more and more sampling efforts are being poured in. Individual-based SAC is the number of recorded species expressed as a function of the number of sampling attempts (Li and Li 2022). Using the species accumulation curve to assess whether the number of sampling is sufficient is based on the characteristics of the curve: if the curve has risen sharply, almost in a straight line, this indicates that the number of sampling is insufficient and the number of sampling needs to be increased; if the curve becomes an asymptomatic line after a sharp increase and then increases slowly, This indicates that sampling is sufficient and data analysis can be performed (Rong et al. 2020).

The results of making the SAC of this study are presented in Figures 6 and 7. SAC (Figure 6) is the location of each habitat type, a curve that forms an asymptotic line and increases slowly. The type of forest habitat shows the highest increase in the number of species so that it is drawn on a sharp upward line curve. SAC as a whole habitat is

presented in Figure 6. As a result, the curve forms an asymptotic line with a slow increase. The highest increase in the number of species occurred in transects 2, 3, 6, and 9. On the curve this is drawn with a sharp upward line.

Table 4. An index measuring the diversity, richness, and evenness of pollinators insects in the buffer zone of Mount Merapi National Park, Tegalmulyo and Sidorejo Villages, Kemalang Subdistrict, Klaten District, Central Java, Indonesia

Order	Species diversity index	Species richness index	Species evenness index
Coleoptera	0.44	1.67	0.20
Diptera	0.67	1.46	0.32
Hemiptera	0.19	0.21	0.27
Hymenoptera	0.30	0.63	0.22
Lepidoptera	2.13	6.46	0.62
Total	3.731	11.26	0.93

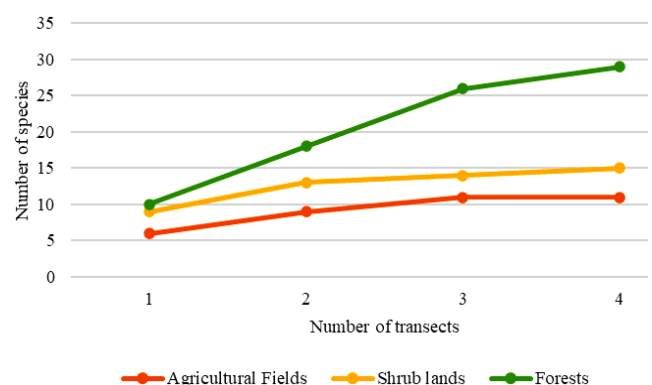


Figure 6. Species accumulation curve based on habitat type

Table 5. Three types of habitats and their environmental factors

Environmental factors	Forest	Agricultural field	Shrubland
Air temperature (°C)	22.1	24.2	24.9
Air humidity (%)	94.5	72	57.5
Light intensity (Cd)	14,750	27,000	28,750

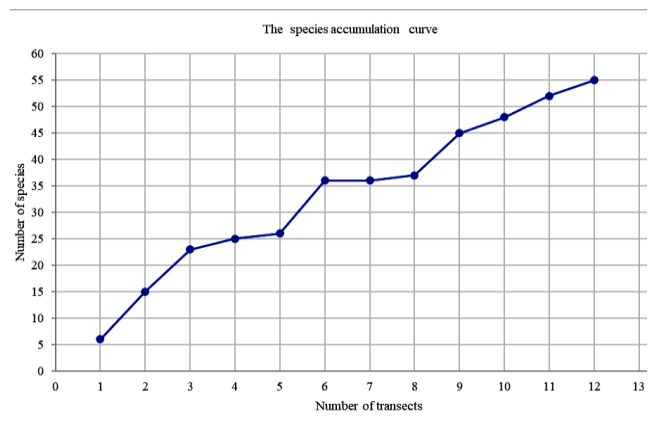


Figure 7. Species accumulation curve (SAC)

The results showed that the two curves drawn had enough sampling to be analyzed. In the curve of Figure 6, the forest habitat type is the location with the highest addition of species, namely transect 1, then shrubland in transect 2 and finally agricultural field that increases continuously 3 species from transects 1, 2, 3, and 4 there is no addition of any more species. This shows that the research location with the type of agricultural field habitat is enough to make a total of 4 transects can represent the habitat type, while for other habitat types, it is recommended to make transects more than 4 because there are still additional species. Overall, SAC the research location is presented in Figure 7. The highest increase in the number of species occurred in transects 2, 3, 6, and 9 respectively, the number of species was 9, 8, 10, and 8. The number of transects 12 made is still an addition of species so that for further research it is recommended to make transects more than 12.

Abiotic environmental factors

Abiotic factors that influence the presence of pollinating insects in the three habitat types measured are air temperature, air humidity, and light intensity (Table 5). Air temperature and light intensity in forest habitat types taken directly at that time were lower than the other two habitat types, namely 22°C and 14,750 Cd. This is because, in forest habitat types, sunlight is blocked by trees that shade the area, so the air temperature is also low. This is also related to the measured air humidity. The air will tend to be more humid in an environment that gets little sunlight. These environmental factors also affect the presence and activity of pollinating insects in the vicinity. Pollinating insects have ecological thresholds that limit their foraging activities (Abrol et al. 2019).

Table 5 shows the result of measuring environmental factors at the research site in the form of air temperature, air humidity, and light intensity. The highest air temperature at the time of measurement of environmental factors was found in shrublands, which was 24.9°C, while the lowest air temperature was 22.1°C, which was found in the forest. According to Bhatnagar et al. (2010), pollinator activity in flowering is strongly influenced by temperature factors. The average air temperature in three habitat types is included in the optimal temperature range for active pollinators, namely 15 to 40°C (Koneri et al. 2021). However, exposure to higher temperatures impacts flowers, so flowers become less attractive to pollinating insects, leading to decreased intensity of pollinator visits (Descamps et al. 2021). The next factor affecting the activity and appearance of pollinators is the intensity of light. Light intensity that was measured in three habitats of this study is in the range of 14,750-28,750 Cd. In addition, sunlight is a crucial need for plants. Exposure to optimal light intensity can increase flower productivity so that it can attract pollinators. In addition, light intensity is important for pollinators such as bees to aid navigation in searching for flowers (Hilário et al. 2000 in Usha et al. 2020). The intensity of sunlight and temperature affect the

humidity of the air. The higher the intensity of sunlight and temperature, the lower the air humidity, or it can be said that the air is relatively drier and vice versa. The last environmental factor that was measured was air humidity. In this study, the highest air humidity was 94.5, which was found in the forest, and the lowest air humidity was 57.5, which was found in shrublands. The form of land cover influences the result of the measurement of air humidity. Therefore, the humidity in the air is higher than in the shrublands. Air humidity significantly affects the blooming time of flowers that are appealing to pollinators, as demonstrated by Sukariawan's research (2023). The transpiration process is a factor in flower buds' blooming.

Based on research that has been conducted in three different habitats in Tegalmulyo and Sidorejo Villages, 121 pollinator insects were found consisting of 55 species, 26 families, and 5 orders, namely Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera. The order Lepidoptera is the most common pollinator insect found in all three habitats, consisting of 9 families and 32 species. This is because environmental conditions and food availability in the area are very suitable for the survival of Lepidoptera. Several flowering plants are infested with pollinator insects; 15 plant species were obtained and divided into 11 different families. The families Asteraceae and Fabaceae are the families with the highest number of species visited by pollinating insects because they have small flowers with colors that are attractive to pollinating insects. Based on the calculation of several ecological indices in all habitats, pollinator insects that have been identified have a species diversity index value of 3.731, a species richness index of 11.26, and a species evenness index of 0.93. The results indicate that the identified pollinating insects have high diversity and species richness, with a fairly high level of evenness. Based on the results of the SAC, we recommend to future researchers to make the number of transects more than 12 if conducting research in similar locations until there are no more species additions. Based on the results of measurements of abiotic factors, the three habitats have different temperatures, humidity, and light intensities that can affect the presence of pollinating insects and flowering plants. In addition, the research location has a good ecosystem for pollinator insect habitats so that it can increase agricultural productivity to support food security.

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