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Richness and diversity of insect pollinators in various habitats around Bogani Nani Wartabone National Park, North Sulawesi, Indonesia

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Abstract. *Koneri R, Nangoy MJ, Wakhid. 2021. Richness and diversity of insect pollinators in various habitats around Bogani Nani Wartabone National Park, North Sulawesi, Indonesia. Biodiversitas 22: 288-297.* The pollination of plants by insects is one of the most important and essential ecosystem services in natural and agricultural landscapes and Insect pollinators play an important role in this process. This is because they help to transfer pollen from the anther to the stigma, which leads to fertilization. This study aims to analyze the richness and diversity of insect pollinators in various habitats around the Bogani Nani Wartabone National Park, Toraut, North Sulawesi. It was carried out from June to August 2020 on three types of habitats around the National Park, namely forest edges, shrubs and agricultural land. For each habitat, four plots with a size of 50 m x 25 m were made with a distance of 100 m between them. The insect pollinator observation technique used was the scan sampling method. Furthermore, data analysis was carried out on abundance, richness index, diversity index, species evenness index, dominance index and the relationship between sampling locations and environmental factors. The results showed that there were 979 insect pollinators caught at the observation point, which consisted of 60 species from 16 families and 4 orders and the most common order was Hymenoptera with 31 species. The species which were found based on their relative abundance indicated that *Nomia strigata* was the most abundant followed by *Nomia melanderi, Apis dorsata, Ropalidia fasciata* and *Amegilla zonata*. Furthermore, the highest abundance of insect pollinators was found in shrub habitats, while the highest species richness and diversity were found at the forest edge. Therefore, it was concluded that different types of habitat affect the richness and diversity of insect pollinator species around the Bogani Nani Wartabone National Park. In addition, this proves that the forest area of Bogani Nani Wartabone National Park generally supports the abundance, richness, and diversity of insect pollinators, which were discovered in the surrounding habitats, namely shrubs and agricultural land.

Keywords: Bogani Nani Wartabone National Park, diversity, forest edge, insect, pollinator

INTRODUCTION

Insect pollinators play an important role in the pollination process of various types of flowering plants in natural and agricultural landscapes (Bentrup et al. 2019). The interaction between them is a form of mutualism symbiosis which occurs because flowers provide food for insects in the form of pollen and nectar, while plants themselves obtain an advantage from the pollination process. Pollination is one of the important services for increasing crop productivity, environmental conservation, and ecosystem balance (Ranjitha et al. 2019).

Over 90% of tropical plants are pollinated by pollinating agents, with two-thirds comprising of insects (IPBES 2016; Siregar et al. 2016). Insect pollinators are needed because these plants are not able to carry out self-pollination and the pollination process occurs due to their attraction to the flowers of the plant (Krishnan et al. 2020).

Insects that play a role in pollination are mostly from the order Hymenoptera (bees and wasps), Coleoptera (beetles), Lepidoptera (butterflies and moths), and Diptera (flies) (Soh and Ngiam 2013). They help to pollinate both wild and flowering plants and to humans, their role is to increase agricultural production and preserve plants in nature (Widhiono et al. 2016).

Therefore, the presence of insect pollinators is strongly influenced by the availability of flowering plants in habitat and the existence of these plants is strongly influenced by habitat fragmentation, conversion of natural habitats to agricultural land and the use of herbicides by farmers to eradicate weeds. This implies that a reduction in flowering plants leads to a decrease in insect pollinator species. Furthermore, several studies have reported that habitat conversion, especially from forest or natural habitats to cropland, contributes to habitat loss for insect pollinators, which consequently causes a decline in local pollinators (Burkle et al. 2013; Barral et al. 2015; IPBES 2016; Potts et al. 2016; Chiawo et al. 2017; Hallmann et al. 2017).

Other studies have reported that the reduction in insect pollinators is caused by the excessive use of pesticides in controlling pests on agricultural land (Whitehorn et al. 2012; IPBES 2016). In addition, increased use of pesticides has been shown to not only affect target pest populations but also harm non-target insects, such as pollinators (Park et al. 2015; Pisa et al. 2015). Therefore, habitat conversion and agricultural intensification place additional pressure on local pollinator communities, reduce insect pollinators and further decrease crop production through reduced visits to flowers (Garibaldi et al. 2013).

The area around the Bogani Nani Wartabone National Park consists of various habitats such as unspoiled forest edges, bush habitats which are abandoned agricultural land converted to forest land, and intensively managed agricultural land. Therefore, each type of habitat produces the richness and diversity of insect pollinator species that differ from the other.

The intensive management of agricultural land and the use of pesticides by farmers in eradicating pests on crops tend to reduce the insect pollinator population (M'Gonigle et al. 2015; IPBES 2016). Furthermore, the results of a survey on the use of pesticides on food crops carried out in 1990 showed that most farmers in North Sulawesi used insecticides with a number of treatments that exceeded the requirements (Sembel 2010). Consequently, this led to a reduction in the diversity of insect pollinators on agricultural land.

Presumably, studies and information on the richness and diversity of insect pollinators in various habitats around the Bogani Nani Wartabone National Park have never been carried out and published. Meanwhile, information and data on species richness and diversity will be of assistance to better conserve insect pollinators in natural and agricultural landscapes. Therefore, this study focuses on the richness and diversity of insect pollinators in various habitat types. The assumption made was that different types of habitat produce richness and diversity of different insect pollinator species. This study aims to analyze the richness and diversity of insect pollinator species in various habitats around the Bogani Nani Wartabone National Park, North Sulawesi, Indonesia.

MATERIALS AND METHODS

Study area and habitat types

This study was carried out from June to August 2020 and the sampling location was around the Bogani Nani Wartabone National Park, Toraut, Bolaang Mongondow District, North Sulawesi Province, Indonesia (Figure 1). Furthermore, the habitat for sampling was the forest edge around the Bogani National Park area, chili plantation area, and shrubs.

Figure 1. Research site in different habitat around Bogani Nani Wartabone National Park (P1: forest edge plot 1; P2: forest edge plot 2; P3: forest edge plot 3. S1: shrub plot 1; S2: shrub plot 2; S3: shrub plot 3. C1: agricultural land plot 1; C2: agricultural land plot 2; C3: agricultural land plot 3)

A B C

Figure 2. Photographs of study sites (A) forest edge, (B) shrub, (C) agricultural land

The observed forest edge habitats were directly adjacent to the Bogani Nani Wartabone National Park. The dominant vegetation in forest edge habitat consists of trees, shrubs, bushes, and herbaceous (Figure 2.A). Trees that grow in this habitat include *Pholidocarpus ihur* (Arecaceae), *Intsia* spp. (Fabaceae), *Diospyros celebica* (Ebenaceae), *Piper aduncum* (Piperaceae), *Macaranga* sp. (Euphorbiaceae), *Magnolia champaca* (Magnoliaceae), and *Cananga odorata* (Annonaceae). Other vegetation that grows on the edge of the forest consists of *Chromolaena odorata* (Asteraceae), *Mikania micrantha* (Asteraceae), *Sphagneticola trilobata* (Asteraceae), *Spilanthes iabadicensis* (Asteraceae), *Wedelia chinensis* (Asteraceae), *Emilia sonchifolia* (Asteraceae), *Borreria laevicaulis* (Asteraceae), *Lantana camara* (Verbenaceae), *Oxalis barrelieri* (Oxalidaceae), *Rubus parviflorus* (Rosaceae), *Cleome rutidosperma* (Capparidaceae), and *Euphorbia heterophylla* (Euphorbiaceae).

The shrub habitats observed were former unused agricultural land (Figure 2.B). The shrub habitats were dominated by vegetation plants such as a *Mikania micrantha* (Asteraceae), *Chromolaena odorata* (Asteraceae), *Sphagneticola trilobata* (Asteraceae), *Stachytarpheta jamaicensis* (Verbenaceae), *Oxalis barrelieri* (Oxalidaceae), *Euphorbia heterophylla* (Euphorbiaceae), *Turnera ulmifolia* (Turneraceae), and *Hyptis capitata* (Lamiaceae).

The observed agricultural land habitat dominates by chili plantations (Figure 2.C). At the time of observation, the chili plantation had entered the flowering and fruiting phase. Furthermore, in this plantation *Cocos nucifera* (Arecaceae) coconut is found.

Insect sampling and measurement of environmental factors

The purposive random sampling technique was used and the sampling point was determined at the selected location based on the survey results. The area around the National Park was a habitat that consisted of forest edges, shrubs and agricultural land.

The study design was a modification of the standard protocol developed by the United Nations Food and Agriculture Organization (FAO) during a study on insect pollinators (Vaissière et al. 2011). For each type of habitat, three plots with a size of 50 m x 25 m were made with a distance of 100 m between them and the observation technique used were the scan sampling method. Furthermore, observations and collections of insect pollinators were carried out at sunset from 08.00-15.00 hours, while observations on each habitat were carried once a month for three months. The insect pollinators collected comprised of a specimen per species and when the same type is found in each species, the insect will be released again. Insects from the order Hymenoptera and Coleoptera such as bees, wasps, and beetles were stored in Eppendorf tubes filled with 70% alcohol. Meanwhile, the samples of the Lepidoptera order were stored in triangle papilot paper envelopes with a size of 30 cm x 20 cm with the wings folded over the body. Furthermore, the specimens were stored sorted and identified using the relevant taxonomic literature (Goulet and Huber 1993; Mead 2013; Sarwar 2020).

When taking insect samples, environmental factors were also measured, which include air temperature, air humidity, wind speed and light intensity using a thermometer, hygrometer, anemometer and Lux meter, respectively. Furthermore, coordinates and altitude from sea level were determined using the Global Positional System (GPS).

Data analysis

The abundance and richness of insect pollinators were tabulated for each habitat, while community structure attributes such as Shannon-Wiener diversity ($H' = -\Sigma$ pi ln pi), Simpson dominance ($D = \Sigma\ (ni/N)^2$) and Pielou evenness ($J = H'/\ln S$) were calculated based on each habitat (Bashir et al. 2019). Species richness estimation (Chao1) was used to estimate the number of species in each habitat. Furthermore, principal component analysis (PCA) between environmental factors (independent variables) and sampling locations (dependent variable) was carried out to determine the relationship between them, using the Paleontological Statistics software (PAST software v. 2.12) (Cuartas-Hernández and Gómez-Murillo 2015). In addition, the statistical analysis used was the Statistics program version 6, one-way Analysis Of Variance (ANOVA) and Tukey's test at the 95% confidence level (Koneri et al. 2019; Ajerrar et al. 2020). This was used to analyze the differences in abundance, species richness, species diversity values and species evenness in each habitat type.

RESULTS AND DISCUSSION

Insect pollinators and their composition

There were 979 pollinator insects caught at the observation point consisting of 60 species from 16 families and 4 orders (Table 1). The pollinating insects found in the Bogani Nani Wartabone National Park consisted of 31, 23, 5 and 1 species from the Hymenoptera, Lepidoptera, Diptera and Coleoptera order, respectively.

The order Hymenoptera, comprised of insect pollinators from the family Apidae (10 species), Vespidae (10 species), Halictidae (4 species), Sphecidae (4 species), Eumenidae (1 species), Megachilidae (1 species) and Scoliidae (1 species). Furthermore, the Lepidoptera order comprised of insect pollinators from the family Nymphalidae (9 species), Papilionidae (5 species), Pieridae (4 species), Hesperidae (4 species) and Erebidae (1 species). The order Diptera, comprised of insect pollinators from the family Syrphidae (3 species) and Calliphoridae (2 species). Lastly, the order Coleoptera, comprised of just one family i.e. Chrysomelidae and only 1 species was discovered (Tabel 1).

The percentage of the order of insect pollinators in each habitat based on the abundance of the individual varied (Figure 3). The order Hymenoptera had the highest abundance in the three habitats observed from the total insects found. Furthermore, in the agricultural land habitat, the composition of insect pollinators dominated by Hymenoptera, reached 87% of the total existing insect pollinators and a similar observation was seen in the shrub habitats, where 68% of the total existing insect pollinators were of the same order. Furthermore, in the forest edge habitat, the composition of insect pollinators was dominated by the order Hymenoptera (50%) and Lepidoptera (40%). The order Hymenoptera, comprised of eight families with Apidae as the most abundant, while Lepidoptera, comprised of five families with Hesperidae and Nymphalidae as the most abundant. Meanwhile, from the order Coleoptera, only the Chrysomelidae family was found.

Table 1. Insect pollinations found in three habitats.

Order/Species/Family	Habitats			Σ	%
	Agricultural land	**Forest edge**	**Shrub**		
Coleoptera					
Chrysomelidae					
Chrysomela herbacea	0	3	0	3	0.31
Diptera					
Calliphoridae					
Chrysomya megacephala	0	11	0	11	1.12
Lucilia sericata	0	3	0	3	0.31
Syrphidae					
Eristalinus arvorum	0	8	30	38	3.88
Syrphus balteatus	11	5	0	16	1.63
Eristalinus megacephalus	4	1	0	5	0.51
Hymenoptera					
Apidae					
Apis dorsata	3	6	68	77	7.87
Amegilla zonata	48	0	1	49	5.01
Tetragonula laeviceps	0	8	33	41	4.19
Thyreus nitidulus	1	15	12	28	2.86
Ceratina cognata	0	26	0	26	2.66
Thyreus axillaris	0	2	11	13	1.33
Xylocopa latipes	0	6	7	13	1.33
Apis trigona	0	3	3	6	0.61
Xylocopa confusa	0	1	5	6	0.61
Amegilla cingulata	0	4	0	4	0.41
Halictidae					
Nomia strigata	65	4	16	85	8.68
Nomia melanderi	38	36	8	82	8.38
Lasioglossum malachurum	1	19	16	36	3.68
Nomia thoracica	0	1	0	1	0.10
Megachilidae					
Megachile centuncularis	2	0	2	4	0.41
Scoliidae					
Campsomeris plumipes	0	3	0	3	0.31
Sphecidae					
Sceliphron curvatum	0	0	7	7	0.72
Isodontia diodon	0	0	3	3	0.31
Isodontia sp.	0	1	0	1	0.10
Sceliphron caementarium	0	1	0	1	0.10
Vespidae					
Ropalidia fasciata	25	16	25	66	6.74
Rhynchium haemorrhoidale	2	4	22	28	2.86
Delta unguiculatum	6	0	9	15	1.53
Eumenes sp	0	4	9	13	1.33
Polistes dorsalis	7	3	0	10	1.02
Eumenes belli	0	0	9	9	0.92
Vespa tropica	2	4	3	9	0.92
Delta pyriforme	2	0	4	6	0.61
Allorhynchium argentatum	0	4	0	4	0.41
Vespa affinis	0	3	0	3	0.31
Delta companiforme	0	0	2	2	0.20
Lepidoptera					
Erebidae					
Amata trigonophora	0	0	4	4	0.41
Hesperiidae					
Potanthus omaha	7	21	14	42	4.29
Borbo cinnara	3	8	9	20	2.04
Potanthus fettingini	0	20	0	20	2.04
Taractrocera archias	4	0	3	7	0.72
Nymphalidae					
Ideopsis vitrea oenopia	0	26	4	30	3.06
Ideopsis juventa	0	13	6	19	1.94
Danaus ismare alba	0	5	9	14	1.43
Euploea leucostictos	0	2	11	13	1.33
Parthenos shylvia	0	3	1	4	0.41
Cethosia myrina	0	2	0	2	0.20
Junonia atlites	0	2	0	2	0.20
Euploea algae horsfieldi	0	1	0	1	0.10
Hypolimnas bolina	0	0	1	1	0.10
Papilionidae					
Graphium meyeri	0	18	3	21	2.15
Papilio gigon	0	4	3	7	0.72
Graphium agamemnon	0	2	4	6	0.61
Papilio memnon	0	3	1	4	0.41
Papilio jordani	0	0	1	1	0.10
Pieridae					
Catopsilia scylla asema	0	2	15	17	1.74
Eurema tominia	1	4	8	13	1.33
Delias descombesi	0	2	0	2	0.20
Hebomoia glaucippe	0	2	0	2	0.20
Total	**232**	**345**	**402**	**979**	**100.00**

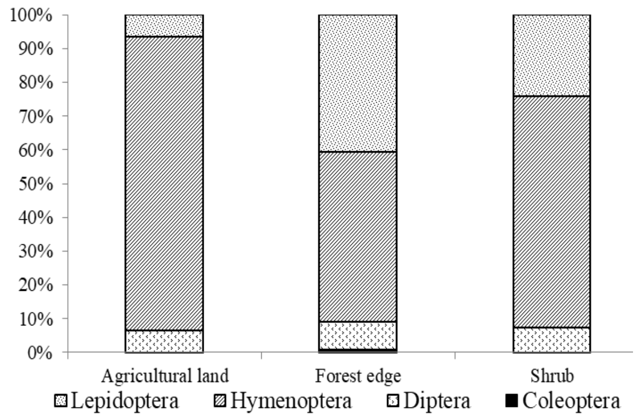

Figure 3. Composition of insect pollinations order according to number of individuals

Species ranking

The overall ranking of the 60 insect pollinator species based on their relative abundance showed that *Nomia strigata, Nomia melanderi, Apis dorsata, Ropalidia fasciata* and *Amegilla zonata* were ranked 1st, 2nd, 3rd, 4th and 5th with relative abundances of 8.68%, 8.38%, 7.87%, 6.74% and 5.01%, respectively (Figure 4). The next four species from rank 6-9 had a relative abundance range of 3.68%-4.29%. Furthermore, the low steepness of the curve indicated a high evenness of the species.

Richness and diversity of insect pollinations

Among the three habitats observed, the habitat with the highest abundance of insect pollinators was the shrubs (134 individuals), followed by forest edges (115 individuals) and agricultural land (77.33 individuals) (Figure 5). Meanwhile, the highest species richness and diversity were found in forest edge habitats (30 species and 3.04) while the lowest was in agricultural land habitats (11.33 species and 1.78). Furthermore, based on the Pielou evenness index, there was no dominance of insect pollinator species among the three habitats observed, because they all had an index of > 0.6. The estimation of species richness based on Chao1 showed that insect pollinators in agricultural land habitat (13.61 species) and shrub habitat (28.32 species) were the closest to observed species richness.

In addition, the analysis showed that the mean species richness (ANOVA: F2, 8 = 11.53; P = 0.008) and Shannon diversity index (ANOVA: F2, 8 = 13.04; P = 0.006) differed between the three habitats (Figure 5). Conversely, the mean individual abundance (ANOVA: F2, 8 = 0.95; P = 0.438) and species evenness index (ANOVA: F2, 8 = 2.31; P = 0.179) was not different among the three habitats.

The influence of environmental factors

The average relative humidity showed a small variation between the three habitats with the lowest being in the agricultural land habitat (69.43%) and the highest in the forest edge habitat (79.14%) (Table 2). Furthermore, the mean temperature showed a small variation between the three habitats with the lowest being in the forest edge habitat (29.70°C) and the highest in the agricultural land habitat (30.70°C). The highest wind speed was found in agricultural land (2.17 m/s) and the lowest in forest edge habitat (0.55 m/s), while the highest light intensity was found in shrub habitats (14162.5 Lux) and the lowest was in forest edge habitats (9688.33 Lux).

The PCA results showed that shrub, agricultural land and forest edge habitats are characterized by high wind speed and light intensity, high air temperature, and low humidity and high humidity and low wind speed and light intensity, respectively (Figure 6). Furthermore, the ordination plot showed that the three habitats are separate from each other, which indicates the presence of different environmental factors.

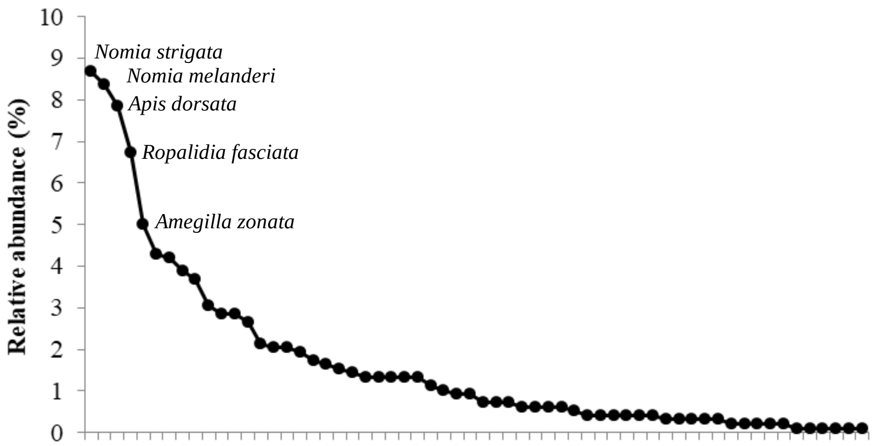

Figure 4. Rank-abundance curve of insect pollinations

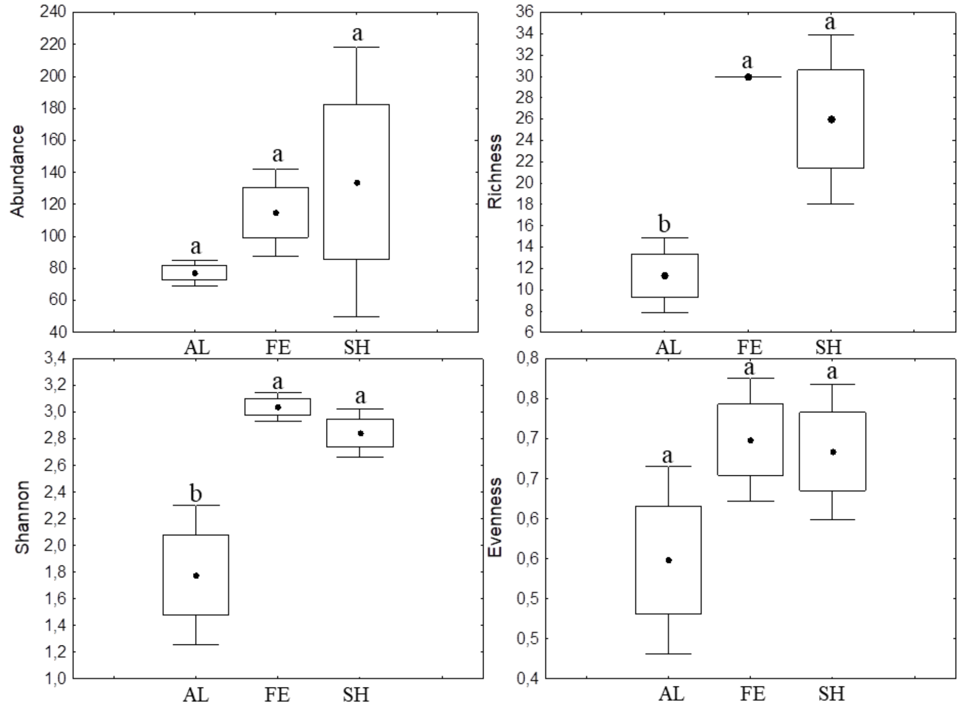

Figure 5. Community structure of insect pollinations in three habitats (AL: agricultural land; FE: forest edge; SH: Shrub). (●): Mean, (□) : ± SE, (⌶): ± SD. The same letter in the same picture does not differ significantly according to Tukey's test 95 % confidence level.

Table 2. Environmental factor of three habitats.

Environmental factors	Agricultural land		Forest edge		Shrub	
	Mean	SE	Mean	SE	Mean	SE
Humidity relative (%)	69.43	2.76	79.14	2.96	74.63	3.55
Temperature (°C)	30.70	0.59	29.70	0.57	30.57	0.54
Wind velocity (m/s)	2.17	0.58	0.55	0.55	1.54	0.39
Light intensity (Lux)	11144	596.42	9688.33	778.68	14162.50	550.11

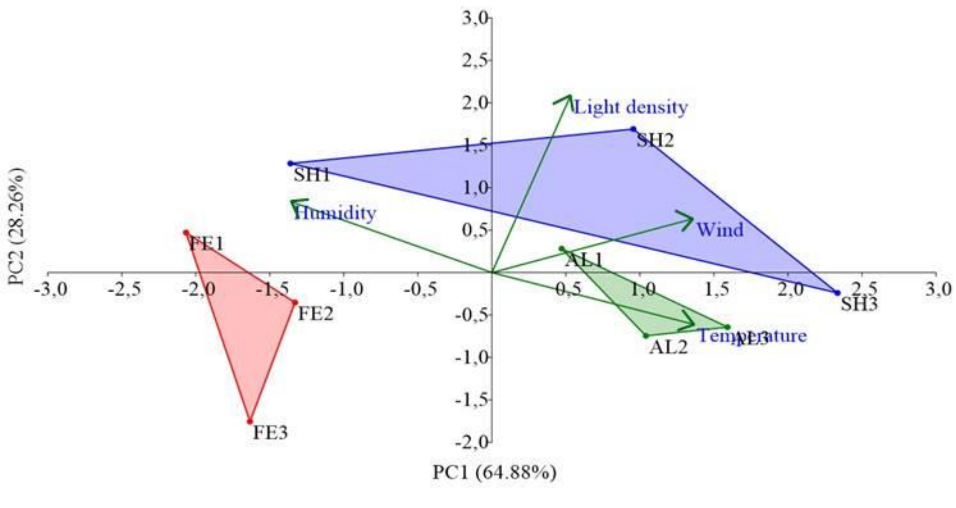

Figure 6. Diagram of principal component analysis (PCA) of three habitats. AL: agricultural land; FE: forest edge; SH: shrub

Discussion

Hymenoptera is an order of insect pollinators mostly found at the study location and dominant in all habitat types. The dominance of Hymenoptera is due to its ecological function i.e. efficiency in pollination, high color recognition capabilities and may have an innate preference for color. This explains its wide dominance among pollinating flowering plants. Furthermore, several studies have reported that the dominant insect pollinators found were the order Hymenoptera (Soh and Ngiam 2013; Choi and Jung 2015; Siregar et al. 2016; Bashir et al. 2019).

Apidae and Halictidae are families of Hymenoptera which have the highest abundance in all habitat types. Apidae is the most effective and generalist group of insect pollinators in the pollination process of many plant species (Siregar et al. 2016). This family has a relatively small body size, a lot of body hair, long proboscis and corbicula (pollen basket) on the outer surface of the hind limb tibia, which functions as a pollen carrier to facilitate the pollination process.

Half of the Halictidae individuals recorded are represented by one species of bee from the Genus *Nomia*, which consists of *Nomia strigata* and *Nomia melanderi* species and are the most abundant insect pollinators, especially in agricultural land. *N. strigata* generally visits flowers and nest in the soil, while *N. melanderi* has a small body size (< 1cm) and is a solitary bee. The body of the insect is metallic black with a combination of gray circles on the abdominal segment and is usually found in areas with moist soil, many nests and close to springs (Widhiono 2015). According to Moisset and Buchmann (2010), Hymenoptera insects from the Halictidae family generally have high adaptability to the environment. Furthermore, they are able to survive in humid environmental conditions and covered by tree canopies therefore, these insects also have a high abundance on forest edges.

The Chao1 estimation result, which was higher compared to the species richness observed in the three habitats, indicated that there are still some undiscovered species. This was because the sampling technique used was only the Sweep net therefore, an additional technique would increase the species richness, for example using yellow sticky traps and Malaise traps. Furthermore, it was necessary to increase the number of sample units or increase the sampling time to obtain better results. This was because the number of sample units used is directly proportional to the estimated value obtained (Colwell and Coddington 1994).

The highest abundance of insect pollinators was found in shrubs, while the highest species richness, diversity and evenness were found at the forest edge. The forest edge is defined as a transition zone between open habitat and forest and there is significant variability in its three-dimensional structure, such as width, shape and tree trunk density (Darsono et al. 2020). Shrubs are abandoned agricultural land overgrown by various flowering wild plants, while the forest edge is a natural habitat that provides a variety of nesting sites for insect pollinators. The vegetation of flowering plants found in shrubs habitat includes *Mikania micrantha* (Asteraceae), *Chromolaena odorata* (Asteraceae), *Sphagneticola trilobata* (Asteraceae), *Stachytarpheta jamaicensis* (Verbenaceae), *Oxalis barrelieri* (Oxalidaceae), *Euphorbia heterophylla* (Euphorbiaceae), *Turnera ulmifolia* (Turneraceae), and *Hyptis capitata* (Lamiaceae). The high abundance of insect pollinators in shrubs indicates that although these insects nest along forest edges, they prefer to forage in open fields such as shrub habitats. Furthermore, according to Bailey et al. (2014), insect pollinators are thermophilous therefore, they prefer warm open places to forage and also travel further out into the field to forage in open areas as well. Sheffield et al. (2013) reported that habitats with low human disturbance characteristics, such as forest edges and abandoned agricultural land (shrubs), have a higher abundance of insect pollinator species compared to intensively managed agricultural lands.

Species richness, diversity and evenness were highest at the forest edge because these habitats are natural with little human disturbance. Forests generally have a wealth of flora and fauna, which is a lot more diversified compared to plantations. The vegetation of flowering plants found in forest edge habitat includes *Intsia* spp. (Fabaceae), D*iospyros celebica* (Ebenaceae), *Piper aduncum* (Piperaceae), *Magnolia champaca* (Magnoliaceae), *Cananga odorata* (Annonaceae), *Chromolaena odorata* (Asteraceae), *Mikania micrantha* (Asteraceae), *Sphagneticola trilobata* (Asteraceae), *Spilanthes iabadicensis* (*Asteraceae), Wedelia chinensis* (Asteraceae), *Emilia sonchifolia* (Asteraceae), *Borreria laevicaulis* (Asteraceae), *Lantana camara* (Verbenaceae), *Oxalis barrelieri* (Oxalidaceae), *Rubus parviflorus* (Rosaceae), *Cleome rutidosperma* (Capparidaceae), and *Euphorbia heterophylla* (Euphorbiaceae). The results of this study were in accordance with McKechnie et al. (2017); Chiawo et al. (2017); Darsono et al. (2020), which stated that the richness and diversity of insects pollinator species are higher in forest-edge habitats. Furthermore, Williams (2011) reported that forests have a very high diversity and abundance of insect pollinators compared to other areas such as plantations and rice fields. Therefore, ecosystems close to natural habitats such as forests will have more abundance and diversity of insect pollinators compared to those far off. In addition, Widhiono et al. (2016) reported that the highest diversity of insect pollinators was found in plantation forest habitat on Mount Slamet and the lowest on agricultural land. This difference is due to the lower diversity of flowering plants in agricultural land compared to other habitats.

The diversity of insect pollinators is highly dependent on the habitat quality, namely the diversity of flowering plants and the availability of flowers throughout the year as a source of food (Hodgson et al. 2011; Filgueiras et al. 2016; Ellis et al. 2017; Welti et al. 2017). Furthermore, the presence of plants affects the availability of nests for insect pollinators. This is because, generally, insects in their foraging activities will not be too far from their nests. Therefore, the diversity and number of flowering plants are directly proportional to the diversity of insect pollinators (Moisset and Buchmann 2010). In addition, the diversity of insect pollinators in a habitat is influenced by several factors, such as the number of flowers that will be the source of food, namely pollen and nectar, environmental factors, and vegetation around the observation area. Another factor is the attractive nature of flowers for a type of insect pollinator to visit. These attractive properties include color, shape, smell, and the availability of nectar and pollen as a source of food for flowers (Lestari et al. 2014).

Agricultural land is forest land with changed function and intensively managed with the use of herbicides and insecticides. Furthermore, it has low abundance, richness, diversity and evenness of species compared to forest and shrub habitats. The land-use change causes a change in the structure of plant vegetation from heterogeneous to homogeneous which leads to loss of species and original insect habitat, which has an impact on the existence of insect communities. In addition, changes in landscape structure due to changes in land use affect the distribution of resources, plants and nesting sites, changes in community composition, population dynamics and insect pollinator behavior (Mudri-Stojnić et al. 2012; IPBES 2016; Sánchez-Reyes et al. 2019).

When sampling is carried out in agricultural habitats, farmers use herbicides to remove weeds and pesticides in other to eradicate crop pests. However, the use of herbicides reduces the diversity of wild plants on the edge of agricultural land and causes the loss of flowering plants around the land. According to Basu et al. (2016), increased use of insecticides in agricultural land reduces the diversity of insect pollinators. Therefore, habitats with low pesticide use and more semi-natural habitats have a higher diversity of insect pollinators. The use of pesticides to control pests affect the abundance and activity of pollinating insects around agricultural land (IPBES 2016). Furthermore, Widhiono (2015) stated that the use of insecticides to control pests has an effect on the abundance of insect pollinators and activities around agricultural land. In addition, herbicides affect pollinator populations by destroying food sources for the larval period and safe nesting sites for insect pollinators.

The average relative humidity, air temperature, wind speed and light intensity indicate small variations between the three habitats. This is because the flight activity of insect pollinators is influenced by environmental parameters, such as air temperature, air humidity, wind speed, light intensity, and rainfall (Joshi and Joshi 2010).

Meanwhile, forest edge is characterized by lower temperatures compared to other habitats, due to the influence of tree canopy cover around the forest edge. Foster et al. (2011) showed that forest habitats have low temperatures and high humidity, while plantation habitats have high temperatures and low humidity. The high air temperature and humidity in plantation habitats including the high wind speed and light intensity in shrub habitats are thought to be related to low canopy cover. Conversely, high canopy cover in forest edge habitats affects the entry of sunlight, which causes low temperatures and high humidity. Therefore, high canopy cover in forest habitats causes low air temperature and high humidity, while low canopy cover in open areas causes high air temperature and low air humidity (Von Arx et al. 2012).

Temperature is an abiotic factor that determines the richness and diversity of insect pollinators, because they prefer to forage at higher temperatures and are very active at temperatures between 15°C and 40°C. Meanwhile, at temperatures below 12°C, foraging insect pollinators decrease below 21% (Bastian et al. 2013). The temperature in the three study habitats was around 29.70°C to 30.70°C therefore, the insect pollinators were still able to carry out their foraging activities. According to Widhiono (2015), air temperature is very influential on insect pollinators, because the amount of energy needed is highly dependent on environmental temperature. This is because, the ambient temperature and energy gain are in direct proportion. Therefore, insects increase the number of flowers visited, which in turn provide the amount of energy needed by insects. IPBES (2016) reported that the temperature increases can directly affect pollinators metabolism but there have also been significant temperature-related changes in the phenology of floral resources important for pollinators, including earlier flowering of most species, and changes in the seasonal availability of flowers that may also affect pollinator survivorship.

Humidity is one of the most important climatic factors which affect the diversity of insect pollinators and the forest edge habitat is characterized by high humidity. Furthermore, it directly affects the breeding, growth, development, and activity of insects, including the growth of host plants and indirectly, affects the diversity of insect pollinator species (IPBES 2016; Koneri et al. 2020).

Wind speed affects the diversity of insect pollinator species, where the higher the wind speed, the lower the diversity of insect pollinator species. The results from its measurements showed that it is lowest at the forest edge. Furthermore, according to Widhiono (2015), it affects the foraging activity of insect pollinators especially between 24-34 km/hour.

Sunlight is needed indirectly by animals, but is used as a marker for certain activities. This is because insects take advantage of sunlight for the process of foraging, molting, reproduction or events related to their life history. Light affects the local distribution of an insect therefore, it moves according to the signal response from sunlight. Furthermore, high light intensity causes the volume of nectar secretion in flowers to decrease. In addition, sunlight affects air temperature and light intensity, which play an important role in the flying and foraging activities of insect pollinators (Bharti et al. 2015).

Based on the results of the study, it was concluded that differences in habitat types have an effect on the richness and diversity of insect pollinator species around the Bogani Nani Wartabone National Park. The forest area of Bogani Nani Wartabone National Park generally supports the abundance, richness and diversity of insect pollinators found in the surrounding habitats, namely shrubs and agricultural land. This was proven by the presence of insect pollinators from the order Hymenoptera, Lepidoptera, Coleoptera and Diptera on intensively managed agricultural land, although the numbers were less compared to the forest edge habitat.

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REFERENCES

Ajerrar A, Akroud H, Aabd NA, Qessaoui R, Amarraque A, Lahmyd H, Zaafrani M, Chebli B, Mayad EH, Bouharroud R. 2020. Pollination system and effective pollinators of *Argania spinosa* (L. Skeels). J Saudi Soc Agric Sci 19: 375-382. DOI: 10.1016/j.jssas.2020.04.002.

Bailey S, Requier F, Nusillard B, Roberts SPM, Potts SG, Bouget C. 2014. Distance from forest edge affects bee pollinators in oilseed rape fields. Ecol Evol 4: 370-380.

Barral MP, Benayas JMR, Meli P, Maceira NO. 2015. Quantifying the impacts of ecological restoration on biodiversity and ecosystem services in agroecosystems: A global meta-analysis. Agric Ecosys Environ 202: 223-231.

Bashir MA, Saeed S, Sajjad A, Khan KA, Ghramh HA, Shehzad MA, Mubarak H, Mirza N, Mahpara S, Rehmani MIA, Ansari MJ. 2019. Insect pollinator diversity in four forested ecosystems of southern Punjab, Pakistan. Saudi J Biol Sci 26: 1835-1842. DOI: 10.1016/j.sjbs.2018.02.007.

Bastian J, Baweja K, Clowney F, Schwartz M. 2013. The Effects of Temperature and Light Intensity on Pollination Frequency of *Prunus serotina* at Waldron Fen. University of Michigan Biological Station, Michigan.

Basu P, Parui AK, Chatterjee S, Dutta A, Chakraborty P, Roberts S, Smith B. 2016. Scale-dependent drivers of wild bee diversity in tropical heterogeneous agricultural landscapes. Ecol Evol 6: 6983-6992. DOI: 10.1002/ece3.2360.

Bentrup G, Hopwood J, Adamson NL, Vaughan M. 2019. Temperate agroforestry systems and insect pollinators: A review. Forests 10: 981-1000.

Bharti V, Ahlawat DS, Sharma SK, Singh NV, Jitender J, Singh N. 2015. Diversity, abundance and pollination efficiency of insect pollinators of fennel (*Foeniculum vulgare* Miller) and effect of abiotic factors on insect pollinator activity. J Nat Appl Sci 7: 786-793.

Burkle LA, Marlin JC, Knight TM. 2013. Plant-pollinator interactions over 120 years: Loss of species, co-occurrence, and function. Science 339: 1611-1615.

Chiawo DO, Kioko EN, Ogol CK, Gikungu MW. 2017. Bee diversity and floral resources along a disturbance gradient in Kaya Muhaka forest and surrounding farmlands of coastal Kenya. J Pollination Ecol 20: 51-59.

Choi SW, Jung C. 2015. Diversity of insect pollinators in different agricultural crops and wild flowering plants in Korea: Literature review. J Apic 30: 191-201.

Colwell RK, Coddington JA. 1994. Estimating terrestrial biodiversity through extrapolation. Philos Trans R Soc London Biol Sci. 345: 101-118.

Cuartas-Hernández SE, Gómez-Murillo L. 2015. Effect of biotic and abiotic factors on diversity patterns of anthophilous insect communities in a tropical mountain forest. Neotrop Entomol 44: 214-223. DOI: 10.1007/s13744-014-0265-2.

Darsono, Riwidiharso EDY, Santoso S, Sudiana E, Nasution EK, Aprilliana H, Chasanah T. 2020. Insect diversity in various distances to forest edge in small nature reserve: A case study of Bantarbolang Nature Reserve, Central Java, Indonesia. Biodiversitas 21: 4821-4828.

Ellis CR, Feltham H, Park K, Hanley N, Goulson D. 2017. Seasonal complimentary in pollinators of soft-fruit crops. Basic Appl Ecol 19: 45-55. DOI: 10.1016/j.baae.2016.11.007.

Foster WA, Snaddon JL, Turner EC, Fayle TM, Cockerill TD, Farnon Ellwood MD, Broad GR, Chung AYC, Eggleton P, Khen CV, Yusah KM. 2011. Establishing the evidence base for maintaining biodiversity and ecosystem function in the oil palm landscapes of South East Asia. Philos Trans R Soc London Biol Sci 366: 3277-3291. DOI: 10.1098/rstb.2011.0041.

Garibaldi LA, Steffan-dewenter I, Winfree R, Aizen MA, Bommarco R, Cunningham SA, Kremen C, Carvalheiro LG. 2013. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science 339: 1608-1611.

Goulet H, Huber J. 1993. Hymenoptera of the World: An Identification Guide to Families. Agriculture Canada, Ottawa.

Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, Stenmans W, Müller A, Sumser H, Hörren T. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS ONE 12: e0185809. DOI: 10.1371/journal.pone.0185809.

Hodgson JA, Moilanen A, Wintle BA, Thomas CD. 2011. Habitat area, quality and connectivity: Striking the balance for efficient conservation. J Appl Ecol 48: 148-152. DOI: 10.1111/j.1365-2664.2010.01919.x.

IPBES. 2016. The assessment report of the intergovernmental science-policy platform on biodiversity and ecosystem services on pollinators, pollination and food production. In: Potts SG, Imperatriz-Fonseca VL, Ngo HT (eds). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 556 pages.

Joshi NC, Joshi PC. 2010. Foraging behaviour of Apis spp. on apple flowers in a subtropical environment. New York Sci. J. 3: 71-76.

Koneri R, Nangoy MJ, Siahaan P. 2019. The abundance and diversity of butterflies (Lepidoptera: Rhopalocera) in Talaud Islands, North Sulawesi, Indonesia. Biodiversitas 20: 3275-3283

Koneri R, Maabuat PV, Nangoy MJ. 2020. The distribution and diversity of butterflies (Lepidoptera: Rhopalocera) in various urban forests in North Minahasa Regency, North Sulawesi Province, Indonesia. Appl Ecol Environ Res 18: 2295-2314.

Krishnan S, Wiederkehr Guerra G, Bertrand D, Wertz-Kanounnikoff S, Kettle CJ. 2020. The Pollination Services of Forests: A review of Forest and Landscape Interventions to Enhance Their Cross-Sectoral Benefits. Food And Agriculture Organization Of The United Nations, Roma.

Lestari MM, Widhiono I, Sudiana E. 2014. The diversity of insect pollinators in the strawberries plantation with *Borreria laevicaulis*. Scr Biol 1: 157. DOI: 10.20884/1.sb.2014.1.2.443. [Indonesian]

M'Gonigle LK, Ponisio LC, Cutler K, Kremen C. 2015. Habitat restoration promotes pollinator persistence and colonization in intensively managed agriculture. Ecol Appl 25: 1557-1565. DOI: 10.1890/14-1863.1.

McKechnie IM, Thomsen CJM, Sargent RD. 2017. Forested field edges support a greater diversity of wild pollinators in lowbush blueberry (*Vaccinium angustifolium*). Agric Ecosys Environ 237: 154-161. DOI: 10.1016/j.agee.2016.12.005.

Mead D. 2013. A guide to some bees and wasps of Indonesia. Sulang Language Data and Working Papers 11: 1-15.

Moisset B, Buchmann S. 2010. Bee Basics: An Introduction to Our Native Bees. Department Agriculture Forest Service and Pollinator Partnership, United States.

Mudri-Stojnić S, Andrić A, Józan Z, Vujić A. 2012. Pollinator diversity (Hymenoptera and Diptera) in semi-natural habitats in Serbia during summer. Arch Biol Sci 64: 777-786. https://doi.org/10.2298/ABS1202777S.

Park MG, Blitzer EJ, Gibbs J, Losey JE, Danforth BN. 2015. Negative effects of pesticides on wild bee communities can be buffered by landscape context. Proc Royal Soc B 282: 20150299.

Pisa LW, Amaral-Rogers V, Belzunces LP, Bonmatin JM, Downs CA, Goulson D, Kreutzweiser DP, Krupke C, Liess M, McField M. 2015. Effects of neonicotinoids and fipronil on non-target invertebrates. Environ. Sci Pollut Res 22: 68-102.

Potts SG, Imperatriz-Fonseca V, Ngo HT, Aizen MA, Biesmeijer JC, Breeze TD, Dicks LV, Garibaldi LA, Hill R, Settele J. 2016. Safeguarding pollinators and their values to human well-being. Nature 540: 220-229.

Ranjitha MR, Koteswara Rao SR, Rajesh A, Reddi Shekhar M. 2019. Insect pollinator fauna of coriander (*Coriandrum sativum* L.) ecosystem. J Entomol Zool Stud 7: 1609-1616.

Sánchez-Reyes UJ, Niño-Maldonado S, Clark SM, Barrientos-Lozano L, Almaguer-Sierra P. 2019. Successional and seasonal changes of leaf beetles and their indicator value in a fragmented low thorn forest of northeastern Mexico (Coleoptera, Chrysomelidae). ZooKeys 825: 71-103.
Sarwar M. 2020. Typical flies: Natural history, lifestyle and diversity of Diptera. In Life Cycle and Development of Diptera. IntechOpen, London. DOI: 10.5772/intechopen.9139.
Sembel DT. 2020. Biological Control: Tropical Insects Pests and Weeds. Andi Offset, Yogyakarta. [Indonesian]
Sheffield CS, Pindar A, Packer L, Kevan PG. 2013. The potential of cleptoparasitic bees as indicator taxa for assessing bee communities. Apidologie 44: 501-510. DOI: 10.1007/s13592-013-0200-2.
Siregar EH, Atmowidi T, Kahono S. 2016. Diversity and abundance of insect pollinators in different agricultural lands in Jambi, Sumatera. Hayati J Biosci 23: 13-17.
Soh ZWW, Ngiam RWJ. 2013. Flower-visiting bees and wasps in Singapore parks (Insecta: Hymenoptera). Nature in Singapore 6: 153-172.
Vaissière B, Freitas B, Gemmill-Herren B. 2011. Protocol to Detect and Assess Pollination Deficits In Crops: A Handbook For Its Use. Food And Agriculture Organization Of The United Nations, Roma.
Von Arx G, Dobbertin M, Rebetez M. 2012. Spatio-temporal effects of forest canopy on understory microclimate in a long-term experiment in Switzerland. Agric For Meteorol 166-167: 144-155. DOI: 10.1016/j.agrformet.2012.07.018.
Welti E, Helzer C, Joern A. 2017. Impacts of plant diversity on arthropod communities and plant-herbivore network architecture. Ecosphere 8:1-14. DOI: 10.1002/ecs2.1983.
Widhiono I. 2015. Pollinator Insect Conservation Strategy. Jenderal Soedirman University, Purwokerto. [Indonesian]
Widhiono I, Sudiana E, Sucianto ET. 2016. Insect pollinator diversity along a habitat quality gradient on Mount Slamet, Central Java, Indonesia. Biodiversitas 17: 746-752. DOI: 10.13057/biodiv/d170250.
Williams NM. 2011. Restoration of non-target species: Bee communities and pollination function in riparian forests. Restor Ecol 19: 450-459. DOI: 10.1111/j.1526-100X.2010.00707.x.