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Diversity and composition of ant species in different urban areas in Bogor, West Java, Indonesia

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Abstract. *Harahap IS, Asnan TAW, Widayanti S, Widhiastuti H. 2022. Diversity and composition of ant species in different urban areas in Bogor, West Java, Indonesia. Biodiversitas 23: 4090-4096.* Land use change, from natural to urban areas, is a threat to biodiversity because the disturbance created by human can destroy the habitat and decrease species richness. Ant is one of the most abundant animals in tropical habitats and most intrusive in an urban area. This research aims to determine the types of ants commonly found in various urban ecosystems in Bogor, West Java, Indonesia. Ant observation and sampling were carried out in Bogor City Areas at four different urban ecosystems, i.e., office area, shopping mall, housing area, and bus station. At each sampling location, ten observation plots were taken under different environmental conditions. Sampling was carried out for 6 months, from April to October 2021 with the direct collection and trapping method. The sample was then carried out to the laboratory for identification and data analysis process. The results of the species inventory obtained 7532 individuals and 28 species from 4 subfamilies, namely Dolichoderinae, Formicinae, Myrmicinae, and Ponerinae. The diversity of ant species at each location showed that the ant species in the bus station were not significantly different from the mall area. However, the diversity of ant species in three locations, namely bus stations, malls, and housing estates, showed significant differences with the diversity of ant species in office habitats. *Anoplolepis gracilipes* which is an invasive tramp species, is one type of ant found in all sampling locations with a relatively high abundance.

Keywords: *Anoplolepis gracilipes*, identification, species richness, urban ecosystem, urban pest

INTRODUCTION

Ants are a diverse group of eusocial insects, both morphologically and behaviorally, with about 13,000 described species and critical economically and ecologically (Bolton 2018; Siddiqui et al. 2019). A particular group of ants can be correlated with various environmental characteristics, such as disturbance level, daily temperature and resource availability, so it is considered a good bioindicator for those aspects (Franco and Feitosa 2018). Changes in the environment, such as those caused by urbanization, can affect their biodiversity through various threats such as pollution and increased spread of invasive species that can threaten local species extinction or population decline (Meyer and Sullivian 2013; Knop 2016). Urbanization may destroy the habitat of a wide array of unique endemic species and often creates an attractive habitat for relatively few species able to adapt to urban conditions (Buczkowski and Richmond 2012).

Groups of ants that can associate very closely with humans and are often found in disturbed habitats, agricultural areas, settlements, and generally outside their distribution areas are known as tramp ants (Kouakou et al. 2018). Tramp ant groups are known to not only harm humans with their disruptive invasion but can also have a negative impact on biodiversity. Although ants are known as one type of insect that can adapt to the human environment, not all ant species can adapt well. This phenomenon then creates competition between species and certain ant species that will be dominant in an area.

Tramp species are highly invasive and can adversely affect the native flora and fauna being invaded (Siddiqui et al. 2021) and become a pest that interferes with human life. A few ant species from an influential group of pests found in association with humans, harming them with their stings and bites, causing contamination of food, and acting as vectors of human diseases (Hulme 2014; Simothy et al. 2018). Urban environments can provide various habitats, from housing to parks and industrial areas, facilitating species' co-existence (Apfelbeck et al. 2020). The relationship between tramp species and habitat in urban areas has been widely studied, but research on the effect of urbanization itself on ants has not been widely studied (Rizali et al. 2008). In this study, Rizali et al. (2008) conducted sampling at 19 different locations, where sampling was carried out only once each sampling location. The sampling locations selected were dominated by household habitats, home gardens, and garbage dumps. However, in this study, sampling was carried out six times for six months (once per month) for each location and the same habitat. In addition, in this study, ants were sampled using two different types of bait at each location to increase the chances of trapping various types of ants that have preferences for different types of bait. The selected habitat is a habitat with a relatively high level of human activity and a relatively small number of plants, such as shopping malls and bus terminals. The impact of urbanization is typically inferred indirectly by comparing species diversity along spatial gradients, typically by examining diversity along urban-rural gradients at a single time point (Buczkowski and Richmond 2012). One of the results of research conducted in Macao (China), the region with the highest population shows that urban landscapes have limited conservation value but support the hypothesis that cities act as gateways for exotic species (Brassard et al. 2021).

As an ectothermic organism, changes in habitat conditions can affect the life of ants and seasonal variations from ecological factors, such as temperature, rainfall, humidity, and food availability, which occur throughout the year. Climatic changes such as fluctuating temperature and humidity in different seasons, including tropics, can cause the corresponding modification in behavior and development of ants (Lopatina 2018). Soil surface temperature and relative humidity are the most critical variables influencing foraging in ants (Behrmann et al. 2017). In an ant colony, dominant individuals are known to have a narrower range of temperature tolerance, and thus they forage at optimal temperatures while subordinates forage at extreme temperatures (Roeder et al. 2022).

This research aims to study the diversity of ant species and their pattern of presence in several urban areas in Bogor, West Java, and in two different seasons, dry and rainy or wet season. The urban habitats selected in this study were shopping malls, institution offices, bus terminals, and housing estates, where the four locations have different disturbance characteristics. In addition, Bogor, which is known as a rain city, is known to have higher rainfall than other cities in Indonesia, even during the dry season. Thus, the possibility of differences in diversity and patterns of the existence of ant species in different conditions becomes an interesting fact to study.

MATERIALS AND METHODS

Study sites

This study was conducted at four urban ecosystems, namely Office area (O), Housing area (H), Shopping mall (M), and Bus Station (B), located in Bogor City, West Java (Figure 1). The distance between the farthest sampling locations, namely the office area and the bus station, is about 5 km. There were ten observation plots at each sampling location with different environmental conditions (Table 1). As seen in the satellite image, at the sampled urban ecosystem, there were still some wooded areas, so they are not entirely buildings or residential areas. Sampling was carried out during the dry and wet season, namely April-October 2021.

Collection method

Ant collection was carried out between 09.00 to 15.00 o'clock every week at the same location using the trapping method developed by Stringer et al. (2009) and Rizali et al. (2008). Environmental conditions such as temperature and humidity at each collection location are always recorded when the collection is carried out. The trapping method was conducted out using mineral water bottle caps (diameter 2.5 cm), as bait stations containing 25% sugar solution and ground beef as bait or attractant. Those bait stations then put on the floor or ground surface of the collection site with the amount of 10 bait stations (considered as replication) per collection site each month. The specifications for sampling points at each location can be seen in Table 1. Insect collection using traps was carried out for 30 minutes. The trapped ants were counted, then put into an Eppendorf bottle containing 70% alcohol to be taken to the laboratory for species identification.

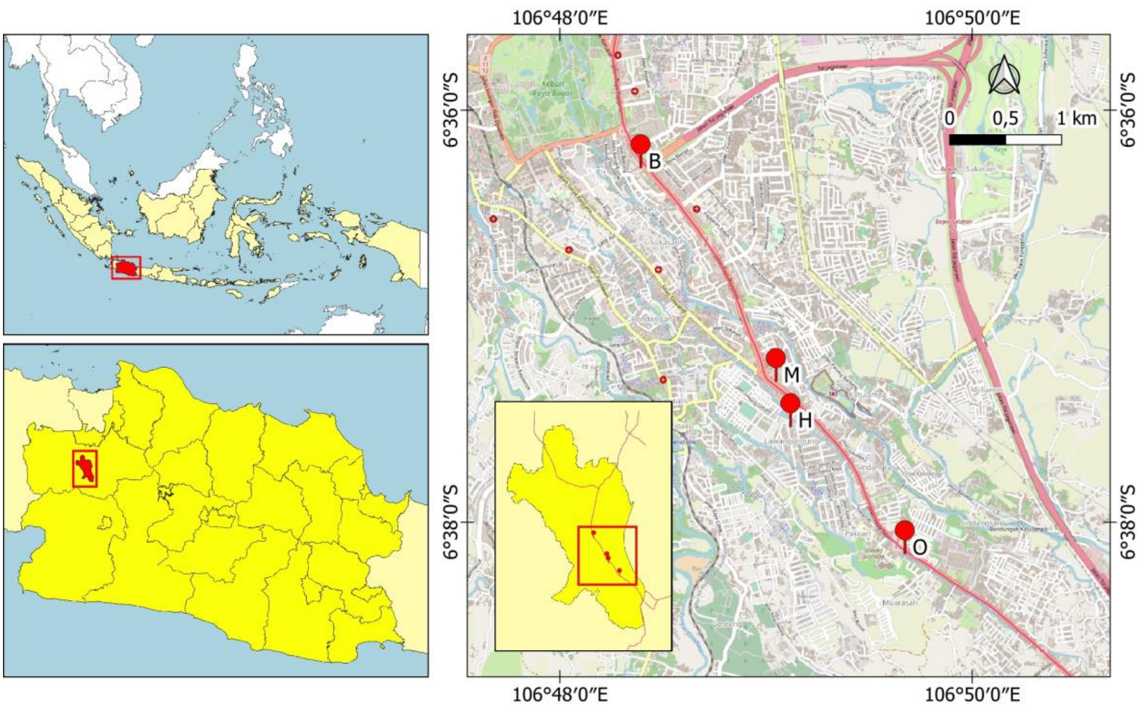

Figure 1. Map of study site in the urban ecosystems, Bogor City, West Java, Indonesia. O: Office; H: Housing; M: Mall; B: Bus Station

Table 1. Specifications of study site in the office area, shopping mall, housing area, and bus terminal

Sampling Point	Location of sampling area			
	Office (O)	**Shopping Mall (M)**	**Housing (H)**	**Bus Terminal (B)**
01	Laboratory corridor (office)	Front entrance 1	Security post	Back area 1
02	Parking area	Front entrance 2	Inner gate	Back area 2
03	Orange garden	Pavement garden 1	Central Post	Middle area 1
04	Teak garden	Pavement garden 2	Trash area	Middle area 2
05	The border between the teak garden and the parking area	Right middle entrance	In front of people's houses	Police Post
06	The outside area of the convention hall	Left middle entrance	Back post	Pavement
07	Park	Exit garden 1	Park	Front pavement 1
08	Guest house	Exit garden 2	Outside Park	Front pavement 2
09	Building yard	Exit 1	Front Post	Front pavement 3
10	Canteen	Exit 2	Gate	Front pavement 4

Identification of ant specimens

Species identification of collected ant specimens refers to the following references: Key to the workers of ant genera and 12 ant subfamilies of Borneo in English and Malay (compiled by Tom M. Fayle from Yoshiaki Hashimoto, with additional material from LaPolla et al. 2010 (*Prenolepis* group genera) and Zettel and Zimmerman 2007 ((*Forelophilus*)) and Generic synopsis of the Formicidae of Vietnam. Part 1-Myrmicinae and Pseudomyrmecinae (Eguchi et al. 2011) to determine the genus and morphospecies.

Data analysis

The data obtained from the collection was then formed into a database using a pivot table in Microsoft Excel software. Furthermore, the data were analyzed to determine the differences of ant diversity between ecosystems/ sampling locations using the species accumulation curve. In addition, an Ordihull analysis was carried out based on the Bray-Curtis dissimilarity index to determine differences in ant species composition between ecosystems.

The test of significant differences in the abundance of ant species in different seasons, namely April-August and September-October, was carried out through the Tukey test. Then a similarity analysis test (ANOSIM) was conducted at the 5% level to determine the effect of different ecosystems and the effect of seasonal differences on the composition of the ant. Then, ANOSIM tests on each ecosystem and different seasons were compared through multidimensional scale analysis (MDS). The results of the MDS analysis can provide a visual description of differences in the composition of ant species in urban ecosystems and seasonal differences through nonmetric multidimensional scale graphs (NMDS). All data analysis activities were carried out using R statistic software and SPSS.

RESULTS AND DISCUSSION

Effect of environmental conditions to the diversity and richness of ant species in Bogor

The number of ants that were collected during field collection was 7532 individuals, consisting of 4 subfamilies, 18 genera, and 28 morphospecies (Table 2). The highest morphospecies richness was found in the bus terminal, namely 21 morphospecies, while the least morphospecies was found in the office area, 17 morphospecies. A total of 7 ant morphospecies were found in all sampling locations, namely *Tapinoma melanocephalum, Dolichoderus thoracicus, Anoplolepis gracilipes, Paratrechina longicornis*, *Pheidole* sp. 01, *Monomorium floricola*, and *Tetramorium* sp. 01 (Figure 2).

Analysis of significant differences in the diversity of ant species at each location was carried out through the Tukey test with a 95% confidence level. The result showed that the diversity of ant species in the bus terminal was not significantly different from the mall area. However, the diversity of ant species in three locations, namely bus terminals, malls, and housing estates, showed a significant difference from the diversity of ant species in office habitats (Table 3, Figure 3A). Meanwhile, the results of the analysis of Chao's estimation showed that, in general, the collection method used was appropriate and successful because most of the ant species found in each location had been successfully collected with Chao's estimated values in office locations, bus terminals, malls, and housing estates were 85%, 100%, 95%, and 82%, respectively (Table 3). The lowest estimates for residential and office habitats indicate that the potential ant diversity in these two locations should be higher than the ant diversity obtained. This is also shown by the species accumulation curve, where the number of species found during the five months of observation showed a continuous increase (Figure 3B).

Overall, the environmental conditions of an urban area can affect the richness of the ant morphospecies found. The analysis of variance in the number of ant species found in 4 habitats was significantly different. The results of the similarity analysis of species composition carried out on each plot using the Bray-Curtis index showed a significant difference, where differences in residential environmental conditions affected the species composition detected between each environment (ANOSIM, R: 0.1875. P < 0.001) (Figure 4).

Figure 2. The types of ants found in all sampling locations. A. *P. longicornis*, B. *A. gracilipes*, C. *D. thoracicus*, D. *T. melanocephalum*, E. *Tetramorium* sp. 01, F. *Pheidole* sp. 03, and G. *M. floricola*

Table 2. Diversity of ants in different urban areas in Bogor, Indonesia

Subfamily Species	Functional group[a]	O[b]		B[b]		M[b]		H[b]	
		Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
Dolichoderinae									
*Tapinoma melanocephalum**	Op[×]	113	3	60	182	75	57	124	-
Tapinoma sp. 01	Op[×]	-	40	4	22	3	57	33	-
Dolichoderus thoracicus	DD[×]	72	404	128	102	223	110	-	219
Technomyrmex sp.	Op[×]	-	2	-	-	-	-	-	-
Leptomyrmex sp.	TCS[××]	-	-	-	5	-	-	-	-
Formicinae									
*Anoplolepis gracilipes***	Op[×]	180	251	4	46	91	37	118	97
Camponotus sp.	SC[×]	-	-	1	-	2	-	-	-
Nylanderia sp. 01	Op[××]	-	17	11	2	-	8	2	-
Nylanderia sp. 02	Op[××]	-	7	6	-	-	8	-	-
Nylanderia sp. 03	Op[××]	-	-	15	5	1	1	11	3
Oecophylla smaragdina	TCS[××]	-	-	-	-	-	-	-	19
Paraparatrechina sp.	Op[××]	-	-	13	-	-	-	-	6
*Paratrechina longicornis***	Op[×]	-	71	66	101	10	142	209	152
Polyrhachis amana	SC[×]	-	-	-	-	-	-	-	8
Myrmicinae									
Cardiocondyla sp.	Op[×]	-	8	-	-	-	-	-	-
Lophomyrmex birmanus	TCS[××]	-	-	33	-	-	-	-	-
*Monomorium floricola**	GM[×]	-	10	51	35	-	19	155	7
Monomorium sp. 01	GM[×]	-	-	-	-	-	-	40	-
Monomorium sp. 02	GM[×]	35	-	21	30	1	-	35	-
Pheidole sp. 01	GM[×]	-	38	-	-	15	-	21	-
Pheidole sp. 02	GM[×]	1	51	-	721	1	53	225	175
Pheidole sp. 03	GM[×]	111	6	4	160	42	75	244	260
Pheidole sp. 04	GM[×]	-	-	59	-	370	118	-	-
Tetramorium lanuginosum	Op[×]	101	-	28	84	-	-	-	-
Tetramorium sp. 01	Op[×]	1	66	21	45	43	20	-	62
Monomorium sp. 03	GM[×]	-	-	5	21	6	-	31	-
Ponerinae									
Odontoponera sp. 01	SP[××]	1	-	-	-	-	-	5	-
Odontoponera sp. 02	SP[××]	-	-	2	-	-	1	-	-

Note: [a] Functional group abbreviations; Op: Opportunist, DD: Dominant Dolichoderinae, SC: Subordinate Camponotini, GM: Generalized Myrmicine, TCS: Tropical Climate Specialist, SP: Specialized Predator. [b]O: Office area, B: Bus Station, M: Shopping mall, H: Housing area. Inventory data from 10 sampling points for five months of observation. D: Dry season (May-August). R: Rainy season

(September-October).*: group of tramp ant. **: Group of tramp ant and invasive. [x]Classification of the ant genera inti functional groups based on McGlynn (1999) and [xx] Brown (2000)

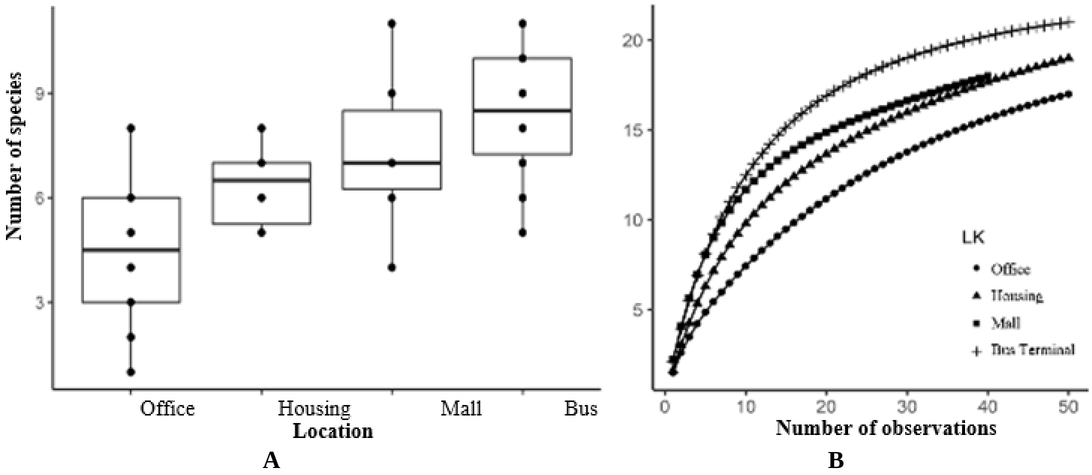

Figure 3. The diversity of ants found in each type of urban area in Bogor, Indonesia. A. Data using the same number of plots (n: 10); B. Accumulation curves of ant species found in different urban areas

Table 3. Number and estimated number of ant species (based on Chao estimates) from different urban areas in Bogor, Indonesia

Habitat	Number of species[a]	Estimation (Chao)
Office area	17 ± 2.057 c	20 (85%)
Bus Terminal	21 ± 1.636 a	21 (100%)
Shopping Mall	19 ± 1.075 ab	20 (95%)
Housing Area	18 ± 2.424 bc	22 (82%)

Note: [a]The numbers in the same column and followed by the same letter show results that are not significantly different based on the Tukey multiple interval test at the level = 5%

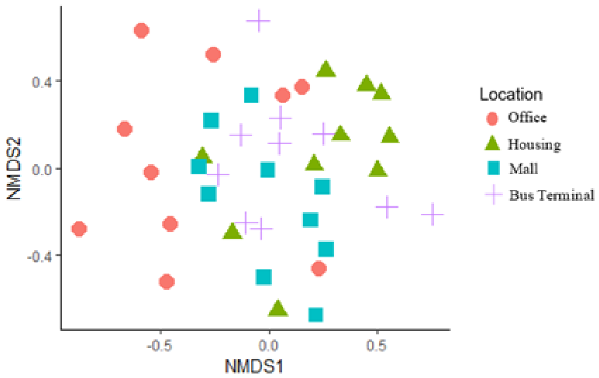

Figure 4. NonMetric Dimensional Scale (NMDS) ordination from ant species composition at four different areas. Office area (O), Housing area (H), Shopping mall (M), and Bus Station (B)

Effect of seasons on the diversity and species richness of ants in Bogor City

Based on the sampling results, the number of individuals and genera found in the rainy season (R) was higher (4249 individuals, 40 genera, 55 morphospecies) compared to the dry season (D) (3283 individuals, 35 genera, 56 morphospecies). The results of the analysis of variance carried out on the species richness of ants in the sampling range in the dry season (April-August) and the rainy season (September-October) were significant. In addition, based on the results of the Nonmetric multidimensional scale (NMDS) analysis, sampling conducted during the selected dry season and rainy season did not affect the composition of ant species at each location, where the value of ant species similarity (ANOSIM) in the rainy season and dry season was the same, namely R: 0.1125. P<0.001, Significance: 0.0121 (Figure 5).

Discussion

The presence of invasive tramp ants, such as *Anoplolepis gracilipes* and *Paratrechina longicornis*, which are highly adaptable to disturbed habitats, also can cause the loss of other ant species from a habitat due to competition. This can be seen in the inventory results in the office habitats, where sampling is carried out in office buildings, gardens, and parks around the offices in the office area. The inventory results at that location showed a very high and quite dominant abundance of tramp ants, namely *A. gracilipes*. This may be one of the reasons for the low number of other ant species found in the area (Table 2).

Several species that were found in all locations, namely *T. melanocephalum* and *M. floricola* are groups of tramp ants, while *A. gracilipes* and *P. longicornis* are groups of tramp ants and are invasive. Tramp groups of ants have a habit of invading other areas, especially areas outside their distribution and their presence is closely related to human life, and their numbers can be very abundant in disturbed habitats, agricultural land, and urban areas (Siddiqui et al. 2021). The existence of tramp ant groups has also been very abundant in all types of habitats around the city of Bogor, especially in the yard of the house, where there are generally ornamental flowers and fruit plants that strongly support their habitat. In addition, some tramp ants also interact and associate with other insects, such as homopterans, which may be very abundant in fruiting and flowering plants in home gardens (Rizali et al. 2008; McPhee et al. 2012).

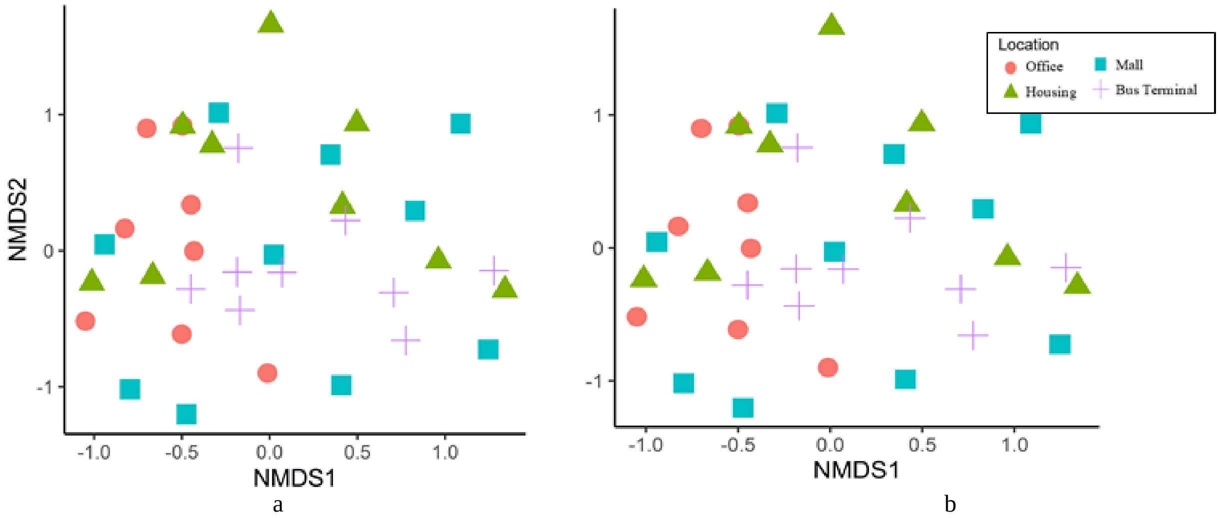

Figure 5. Nonmetric Multidimensional Scale (NMDS) ordination from ant species composition at four different areas in dry (A) rainy season (D)

In general, ant species diversity in the habitat is strongly influenced by the level of disturbance of the habitat. The higher the level of habitat disturbance, the greater the diversity, and the presence of ant species tends to increase. The habitats with high disturbance intensity are generally only able to facilitate the existence of tramp ant species that can adapt to human disturbances (Hasriyanty et al. 2015). In this study, the level of disturbance at the four sampling locations tends to be the same. All of these locations are urban areas with relatively high human activities. However, the differences in the number and composition of species found at the four locations may be due to the condition of the bait stations placement points or the microclimate at each ant sampling point in each location. A sampling at the location with the highest number of species, namely the bus terminal, was carried out around the bus parking area, a very open area, and the sidewalk area along with the bus terminal (Table 1). Along the side of the bus terminal parking area, there are large trees that are pretty shady. In addition to the bus terminal sidewalk area, there is a garden with various ornamental plants. This condition is then suspected to be suitable for various ant species, thus causing the highest diversity of ants at this location. Meanwhile, sampling in office areas that tend to be dominated by tramp ant groups was carried out inside the office, parks, parking areas, teak gardens, and citrus gardens. The low diversity of ant species at this location, apart from the high dominance by tramp ants, also most of this area is in the form of buildings which may not be suitable for ant habitat.

In addition to the tramp and invasive ant groups, a relatively high abundance of ant species was found in the *D. thoracicus*. This type of ant is found in all urban areas with a quite high abundance, especially in the office area. The *D. thoracicus* is a common ant species in the agroecosystems in Southeast Asia. These ants are known as one of the natural enemies that can be used to control *Conopomorpha cramerella* and *Helopeltis antonii* (Philpott and Armbrecht 2006; Saleh 2013). Meanwhile, the highest abundance of tramp and invasive ant species in the office area was *A. gracilipes*. *Anoplolepis gracilipes* is widely distributed in Australia, Indonesia, and Malaysia by occupying various nests and areas with diverse populations densities (Apriyadi et al. 2016). These ants have a different character from other ants, namely the ability to build their nests. Places used as nests are tree cavities, spaces under piles of leaves, and even nests in burrows that were former nests of other animals. *Anoplolepis gracilipes* is also known to be very aggressive toward other ant species and is easily involved in deadly fights. The aggression of *A. gracilipes* also occurs in individuals within the same species and is known as intraspecific aggression. Intraspecific aggression arises due to the unknown individual *A. gracilipes* as part of the same colony. This makes the *A. gracilipes* colony boundary the area with the highest level of aggression because of the potential for encounters between colony boundaries (Gruber et al. 2012; Apriyadi et al. 2016).

However, there are differences in the abundance of the two types of ants in two different seasons. In the dry season, the abundance of *A. gracilipes* was higher than *D. thoracicus*. However, in the rainy season, the opposite occurred, where the abundance of *D. thoracicus* ants was higher than *A. gracilipes*. The differences in the abundance of the two types of ants in the dry and rainy seasons is almost doubled on average. This may indicate the existence of competition between the two species. When one species has already mastered the habitat with the support of suitable environmental conditions such as temperature and humidity, the other species will tend to lose, and their abundance decreases. *Dolichoderus thoracicus* will usually become immobile and open their jaws wide as a form of defense when interacting with *A. garcilipes*. In addition, *A. gracilipes* can eliminate up to 40% of the population of other ant species, such as *Oecophylla smaragdina*, *P. longicornis*, and *D. thoracicus*, due to the influence of formic acid and are killed by *A. gracilipes* ants (Chong and Lee 2010).

In general, the analysis of the diversity of ant species at each location showed that the ant species in bus terminal habitats were not significantly different from the mall area. However, the diversity of ant species in three locations, namely bus terminals, malls, and housing estates, showed significant differences with the diversity of ant species in office habitats. The study of seasonal differences did not show any effect on the diversity of ant species in each location.

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