HAYATI Journal of Biosciences, June 2008, p 77-84 Vol. 15, No. 2
ISSN: 1978-3019

Ants in Tropical Urban Habitats: The Myrmecofauna in a Densely Populated Area of Bogor, West Java, Indonesia

AKHMAD RIZALI[1*], MERIJN MARINUS BOS[2], DAMAYANTI BUCHORI[3], SEIKI YAMANE[4], CHRISTIAN HANSJOACHIM SCHULZE[5]

[1]Indonesian Nature for Conservation Foundation (INCF), Peka Indonesia Foundation, Kompleks IPB Sindang Barang II, Jalan Uranus Blok H No.1, Bogor 16680, Indonesia
[2]Louis Bolk Institute, Hoofdstraat 24, 6972 LA Driebergen, Netherlands
[3]Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural University, Darmaga Campus, Bogor 16680, Indonesia
[4]Department of Earth and Environmental Sciences, Faculty of Science, Kagoshima University, Korimoto 1-chome, Kagoshima, 890-0065, Japan
[5]Department of Population Ecology, Faculty of Life Sciences, University of Vienna, Althanstraße 14, A-1090 Vienna, Austria

Received February 20, 2008/Accepted June 26, 2008

Ants are the most abundant animals in tropical habitats and have been widely studied in natural and semi-natural tropical systems. However, species in urban tropical habitats remain poorly studied, despite their abundance and potentially important roles in urban ecosystems and pest dynamics. We investigated the ant fauna of Bogor and its surroundings to contribute to the characterization of the myrmecofauna of one of Southeast Asia's most densely populated regions. Ants were collected both by hand collection and from honey baits in the most common habitats: garbage dumps, households, and home gardens. In total, 94 species were recorded, over two thirds of which occurred in home gardens, which underlines the importance of vegetated habitats for urban planning to support complex ant assemblages. Twelve sampled species are well-known as tramp species that occur primarily in human-dominated landscapes. The two tramp species *Anoplolepis gracilipes* and *Paratrechina longicornis* dominated ant assemblages in all locations and most habitat types. The assemblages of tramp species were affected by habitat type, whereas that of non tramp species were not. Forty-five species were also recorded in the Bogor Botanical Garden and five species are also known to be common in cacao agroforests. Hence, research in urban tropical habitats can increase our knowledge of the occurrence of ant species, allowing us to better assess the biodiversity and conservation potential of semi-natural habitats.

Key words: ants, tramp species, invasive species, biotic homogenization, urban habitats

INTRODUCTION

Ants are the most abundant animal group in tropical forests (Wilson 1990), and frequently constitute over half of the insects collected from canopies (Erwin 1989; Stork 1991) and leaf litter (Adis *et al.* 1987; Agosti *et al.* 1994). In Malaysia for example, 6 hectares (ha) of rainforest was found to harbor over 500 different ant species, the highest number ever recorded per unit area (Brühl *et al.* 1998). Disturbed tropical habitats, such as cacao plantations, can also harbor hundreds of ant species (Room 1971; Bos *et al*. 2007).

Habitat changes are strongly correlated with changes in ant community structure. For example, increasing agricultural intensity, such as shade cover removal in agroforestry systems, can threaten ant diversity in tropical, semi-natural habitats (Philpott & Armbrecht 2006; Bos *et al.* 2007). Because of this sensitivity to habitat conditions, it has been suggested that ants are important biotic indicators of habitat disturbance (Andersen 2000). Room (1971) explained this sensitivity at the community level by competitive interactions ("ant mosaics") that can be indirectly driven by anthropogenic habitat change. For example, several species benefit from increases in temperature (e.g. as a result of canopy thinning) by increasing colony activity and abundance, which changes community structures through competition (see also Gibb & Hochuli 2003). Moreover, changes in the availability of nesting sites can affect ant communities. For example, soil-nesting species benefit from shade tree removal at the cost of canopy nesting species (Philpott & Foster 2005; Philpott & Armbrecht *et al.* 2006).

In contrast, a small subset of ant species is particularly well-adapted to anthropogenic environments. These tramp species are closely associated with humans and are most abundant in disturbed habitats, agricultural land and settlements, and by definition primarily occur outside their native distribution (McGlynn 1999). Tramp species have been widely studied because of their invasive habits and their often negative effects on the native flora and fauna (Suarez *et al.* 1998; Holway *et al.* 2002; Gibb & Hochuli 2003; O' Dowd *et al.* 2003; Bos *et al.* 2008).

Despite the obvious relationship between tramp ant species and human-dominated habitats, few studies have assessed effects of urbanization on ants in temperate and subtropical regions (Suarez *et al.* 1998; Schlick-Steiner &

*Corresponding author. Phone/Fax: +62-251-8621476, E-mail: a_rizali@peka-indonesia.org

Steiner 1999; McIntyre 2000; McIntyre *et al.* 2001; Smith *et al.* 2006). Even fewer studies have reported on the urban ecology and those that do primarily focused on flagship groups such as bats (Hourigan *et al.* 2006) and butterflies (Brown & Freitas 2002; Koh & Sodhi 2004; Collier *et al.* 2006) in parks and urban forests.

Here we study the ant diversity of Southeast Asian urban habitats in one of the world's most densely populated regions, the metropolitan area of Jabodetabek (Jakarta, Bogor, Depok, Tangerang, and Bekasi) in West Java, Indonesia. Within this inventory of ant richness we investigated the role of tramp ants in urban ant communities and for the first time assess ant diversity in common urban habitats in the tropics. Furthermore, we discussed the role of studying urban habitats as a means to increase our knowledge of species occurrences along the disturbance gradient from pristine to anthropogenic habitats in the tropics.

MATERIALS AND METHODS

Study Sites. This study was conducted at 19 different locations in the Bogor district (Figure 1) of the West Javanese Jabodetabek metropolitan area around Jakarta, the capital city of Indonesia. The human population density in this urban area can exceed 35,000 inhabitants/km2, and in adjacent rural areas can reach over 1,000 inhabitants/km2 (http://en.wikipedia.org/wiki/Jabodetabek). In each location, ants were collected from representative habitat types; the most common being households, home gardens and garbage dumps (Table 1). The area is characterized by annual rainfall of 4,000 mm/year and an average temperature of 26 ^{o}C (http://en.wikipedia.org/wiki/Jabodetabek). Until the 1930's the Bogor Botanical Garden (BBG) was connected with forests to the east, after which further deforestation led to the isolation of the Botanical Garden from surrounding forests (Diamond *et al.* 1987).

Ant Sampling. Ants were sampled from each habitat type at each location (Table 1) between April and June 2003 by hand collecting and from honey baits. Sites were visited from 07.00 am to 12.00 pm to standardize effects from the weather. Each location was sampled once, although in several locations which have many habitat types, sampling of each habitat type was conducted on different days in some cases (Table 1). Hand collection was conducted until no more new ant morphospecies were found for at least 30 minutes. In each habitat type at each location, 10 honey baits were placed on the ground and all ants attracted to the bait were collected until no more new species were collected (usually 30-60 minutes). Collected ants were stored in 70% alcohol, sorted, and identified using the available literature (e.g. Bolton 1994) and the reference collection of the Department of Earth and Environmental Sciences, Kagoshima University, Japan.

Data Analysis. The completeness of species collection was assessed with species accumulation curves (e.g. Magurran 2004) for overall species richness and tramp species richness for all locations and separately for the most common habitat types (i.e., households, home gardens and garbage dumps). Total species richness was estimated using the incidence-based coverage estimator (ICE), which was based on species presence-absence. Species accumulation curves and species richness estimators were calculated using EstimateS version 7.5 (http://www.purl.oclc.org/estimates) and

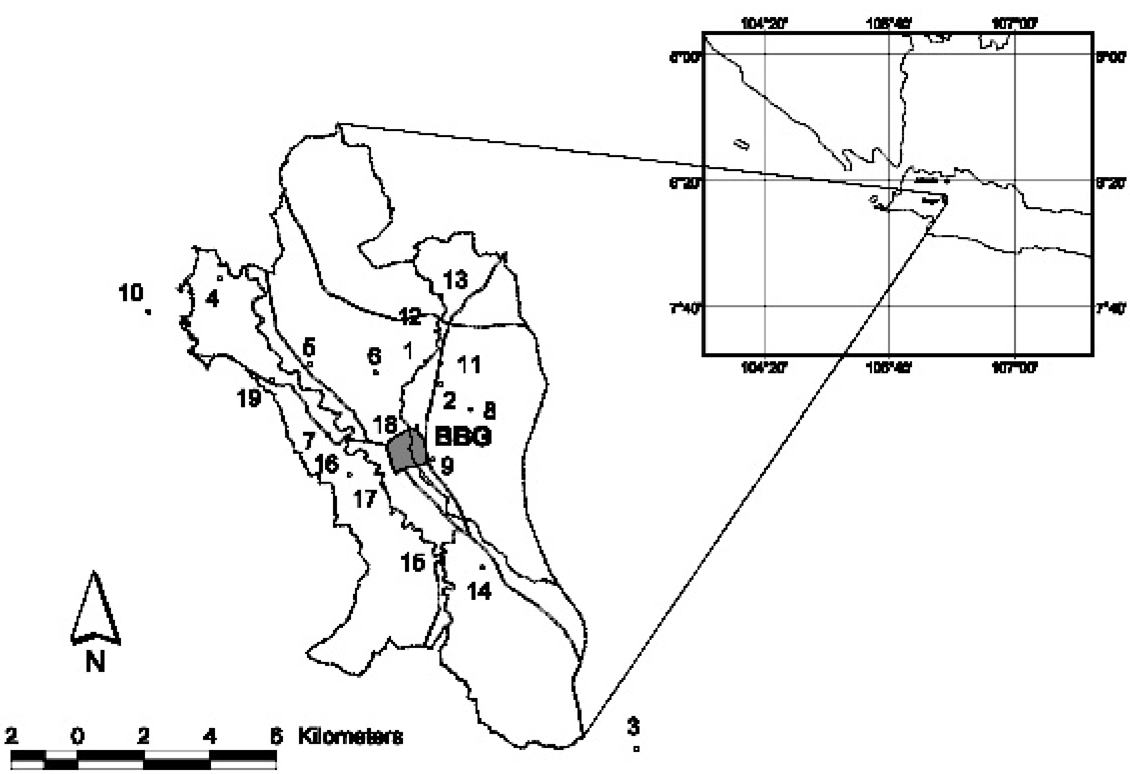

Figure 1. Map of study sites in the Bogor area, West Java, Indonesia. BBG: Bogor Botanical Garden; for names of sites 1-19 see Table 1.

Table 1. Nineteen sampling sites in the Bogor District, West Java, Indonesia

Site	Habitat*	Latitude (°S)	Longitude (°E)	Date of sampling (2003)
Ahmad Yani	Garbage dump	6,5735	106,8064	21 May
	Home garden	6,5739	106,8045	21 May
	Household	6,5739	106,8045	21 May
Bantar Jati	Garbage dump	6,5740	106,8114	12 June
	Home garden	6,5800	106,8085	12 June
	Household	6,5800	106,8085	12 June
BPT-Ciawi	Home garden	6,6794	106,8624	13 May
	Household	6,6794	106,8624	13 May
	Rice field	6,6819	106,8620	13 May
CIFOR	Home garden	6,5492	106,7475	8 May
	Household	6,5492	106,7475	8 May
	Park	6,5514	106,7481	9 May
	Rice field	6,5530	106,7468	9 May
Cilendek	Garbage dump	6,5764	106,7721	11 June
	Home garden	6,5747	106,7728	11 June
	Household	6,5748	106,7728	11 June
Cimanggu	Home garden	6,5770	106,7907	23 May
	Household	6,5770	106,7907	23 May
Gunung Batu	Garbage dump	6,5958	106,7804	3 April
	Home garden	6,5885	106,7737	3 April
	Household	6,5885	106,7737	3 April
	Market	6,5940	106,7779	4 April
	Open area	6,5886	106,7727	4 April
	Park	6,5973	106,7819	9 April
Indraprasta II	Home garden	6,5869	106,8168	9 June
	Household	6,5869	106,8168	9 June
IPB Baranangsiang	Garbage dump	6,5997	106,8055	14 April
	Home garden	6,6022	106,8077	14 April
	Household	6,6022	106,8077	14 April
	Park	6,6011	106,8054	15 April
IPB Darmaga	Agroforest	6,5601	106,7225	6 May
	Park	6,5611	106,7281	7 May
Kalibata	Home garden	6,5743	106,8086	12 June
	Household	6,5743	106,8086	12 June
Kedung Badak	Home garden	6,5656	106,8072	22 May
	Household	6,5656	106,8072	22 May
Kedung Halang	Garbage dump	6,5570	106,8089	3 June
	Home garden	6,5561	106,8085	3 June
	Household	6,5561	106,8085	3 June
Pakuan	Home garden	6,6299	106,8201	10 June
	Household	6,6299	106,8201	10 June
Pamoyanan	Garbage dump	6,6297	106,8091	14 May
	Home garden	6,6287	106,8088	14 May
	Household	6,6287	106,8088	14 May
Pasir Kuda	Agroforest	6,6048	106,7838	29 April
	Household	6,6024	106,7892	29 April
Pulo Empang	Garbage dump	6,6089	106,7971	7 April
	Home garden	6,6051	106,7934	7 April
	Household	6,6051	106,7934	7 April
	Market	6,6048	106,7929	8 April
	Open area	6,6079	106,7948	8 April
	Rice field	6,6153	106,7916	8 April
Sempur	Home garden	6,5918	106,8015	17 April
	Open area	6,5918	106,8015	17 April
	Park	6,5892	106,8019	28 April
Sindang Barang	Home garden	6,5790	106,7614	30 April
	Household	6,5790	106,7614	30 April
	Rice field	6,5779	106,7605	1 May

*Habitat description: Agroforest = the only agroforest within the borders of the Bogor district, dominated by cacao and rubber; Garbage dump = garbage dumps along streets; Home garden = dominated by ornamental flowering plants, occurrence of fruit trees, banana, palms, and lawns; Household = the interior of buildings; Market = traditional daily market; Open area = field for sport activities; Park = park and botanical garden with ornamental vegetation; Rice field = wet paddy fields.

randomizing samples 50 times. Observed and estimated species richness per locality were compared between the most common habitat types in one-way ANOVA's and subsequent Tukey´s tests for comparisons with unequal sample sizes. This analysis was carried out using Statistica 5.0 for Windows (StatSoft 1995).

As a measure of similarity between each habitat type per location, Sørensen's indices were calculated using a Microsoft Excel macro (Messner 1997). Resulting similarity matrices for all ant species were reduced to a two-dimensional representation using non-metric multidimensional scaling (MDS; Clarke & Warwick 2001). We used Statistica 5.0 for Windows (StatSoft 1995) to run the data matrix with standard configuration based on Guttman-Lingoes and number of iteration of 6 for minimum and 50 for maximum.

RESULTS

In total, 94 ant species (Figure 2, Table 2) were collected; 93 species of these were collected by handcollecting, and 46 species were attracted to honey baits. These species belonged to 7 subfamilies and 45 genera (Table 2). The total observed number of ant species was 72.4% of the ICE estimate for total species richness.

Of the three most common habitat types, home gardens were the most ant species richness (Figure 3, one-way ANOVA for observed species richness: $F_{2,39} = 50.53$, $P < 0.001$, and estimated species richness: $F_{2,39} = 25.57$, $P < 0.001$. Sixty-five of all species and most unique species occurred in home gardens (Table 2).

In total, we found 13 ant species that could be designated as tramp species (Table 2). After collecting ants from 7 localities, no more new tramp species were recorded (Figure 2). The MDS based on Sørensen's similarity values for tramp ant communities showed clear differences between habitat types (Figure 4a), whereas there was no pronounced difference among habitat types for non tramp species (Figure 4b).

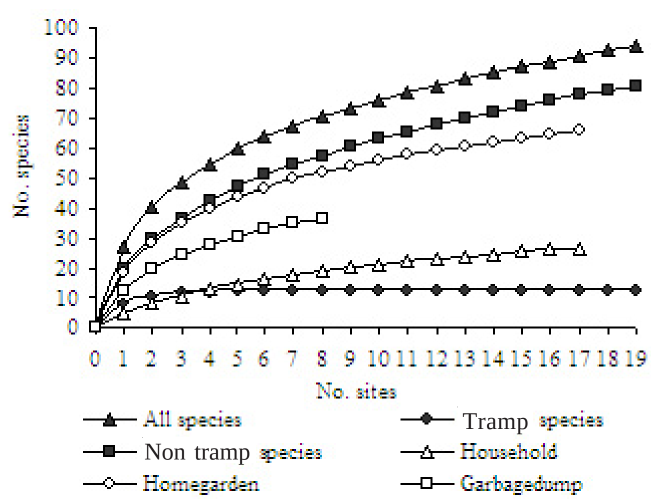

Figure 2. Species accumulation curves of ant species richness in the Bogor area. Curves are given for the total species richness of three common urban habitats and separately for tramp and non tramp species in 19 locations.

Table 2. The observed ant species collected from 8 different habitats at 19 sites in Bogor district, West Java, Indonesia

Subfamily/species	No. sites	Habitats*								Sampling methods**	Occurrence***
		Hg	H	Gd	Af	M	Oa	P	Rf		
Aenictinae											
Aenictus dentatus Forel	1				+					Is	BBG
Dolichoderinae											
Dolichoderus thoracicus (Smith)	17	+	+	+	+	+	+	+	+	Is, Hb	CAF, BBG
Tapinoma indicum Forel	18	+	+	+	+			+	+	Is, Hb	BBG
T. melanocephalum (Fabricius) ‡	10	+	+	+		+	+	+		Is, Hb	BBG
Technomyrmex albipes (Smith) ‡	8	+	+	+	+		+	+	+	Is, Hb	IC
Technomyrmex sp. 1	1							+		Is, Hb	IC
Dorylinae											
Dorylus laevigatus (Smith)	5	+		+						Is	BBG
Formicinae											
Acropyga acutiventris Roger	1	+								Is	BBG
Anoplolepis gracilipes (Smith) ‡	17	+	+	+	+	+	+	+	+	Is, Hb	CAF, BBG
Camponotus (*Calobopsis*) sp. 38 of SKY****	1							+		Is	BBG
Camponotus (*Myrmanblys*) sp. 1	4	+					+	+	+	Is, Hb	IC
Camponotus (*Myrmanblys*) sp. 2	1								+	Is	IC
Camponotus (*Tanaemyrmex*) sp. 1	12	+		+	+	+	+	+	+	Is, Hb	IC
Camponotus (*Tanaemyrmex*) sp. 72 of SKY	1							+		Is	BBG
Camponotus (*Tanaemyrmex*) sp. 82 of SKY	1							+		Is	IC
Echinopla lineata Mayr	1							+		Is	BBG
Gesomyrmex sp. 1	1							+		Is	IC
Oecophylla smaragdina Fabricius	7	+		+			+	+		Is, Hb	CAF, BBG
Paratrechina longicornis (Latreille) ‡	19	+	+	+	+	+	+	+	+	Is, Hb	CAF, BBG
Paratrechina sp. 1	11	+	+	+	+	+	+	+	+	Is, Hb	IC
Paratrechina sp. 2	10	+	+	+	+	+	+	+	+	Is, Hb	IC
Paratrechina sp. 3	10	+	+	+				+		Is, Hb	IC
Paratrechina sp. 4	2		+	+						Is	IC
Paratrechina sp. 5	2				+			+		Is, Hb	IC
Plagiolepis sp. 1	1						+			Is	IC
Polyrhachis (*Cyrtomyrma*) *laevissima* Smith	3	+							+	Is, Hb	BBG
P. (*Myrma*) *imbellis* Emery	11	+		+	+			+	+	Is, Hb	IC
P. (*Myrma*) *proxima* Roger	1	+								Is	BBG
P. (*Myrmhopla*) *abdominalis* Smith	1	+								Is	CAF, BBG
P. (*Myrmhopla*) *bicolor* Smith	1	+								Is	BBG
P. arcuata (Le Guillou)	2	+						+		Is, Hb	IC
Pseudolasius sp. 1	1				+					Is	IC
Myrmicinae											
Cardiocondyla emeryi Forel ‡	9	+	+	+		+	+	+	+	Is, Hb	BBG
Cardiocondyla nuda (Mayr) ‡	9	+		+			+		+	Is, Hb	BBG
Cardiocondyla sp. 4 of SKY	1	+								Is	BBG
Cardiocondyla wroughtonii Forel ‡	7	+	+						+	Is, Hb	BBG
Crematogaster (*Crematogaster*) sp. 1	1							+		Is	IC
Crematogaster (*Orthocrema*) sp. 1	3				+			+		Is, Hb	IC
Crematogaster (*Orthocrema*) sp. 51 of SKY	1	+								Is	BBG
C. (*Physocrema*) *difformis* Smith	5	+						+		Is	BBG
Crematogaster sp. 1	7	+		+	+		+	+	+	Is, Hb	IC
Crematogaster sp. 2	2							+		Is, Hb	IC
Lophomyrmex opaciceps Viehmeyer	1								+	Is	BBG
Meranoplus bicolor (Gurein-Meneville)	1						+			Is	BBG
Monomorium destructor (Jerdon) ‡	8	+	+	+		+	+	+		Is, Hb	BBG
M. floricola (Jerdon) ‡	15	+	+	+	+	+	+	+	+	Is, Hb	BBG
M. pharaonis (Linnaeus) ‡	6	+	+	+		+	+			Is, Hb	BBG
Monomorium sp. 1	2	+								Is	IC
Monomorium sp. 2	3	+		+						Is	IC
Monomorium sp. 3	16	+	+	+	+			+	+	Is, Hb	IC
Monomorium sp. 4	4	+		+			+	+		Is, Hb	IC
Monomorium sp. 5	16	+	+	+			+	+	+	Is, Hb	IC
Myrmecina sp. 1	5	+			+			+		Is	IC
M. brunnea Saunders	1				+					Is, Hb	BBG
Oligomyrmex sp. 1	4	+						+	+	Is, Hb	IC
Pheidole fervens Smith	1	+								Hb	IC
P. plagiaria Smith	17	+	+	+	+	+	+	+	+	Is, Hb	BBG
Pheidole sp. 1	10	+	+	+	+	+	+	+		Is, Hb	IC
Pheidole sp. 2	12	+	+		+		+	+	+	Is, Hb	IC
Pheidole sp. 3	11	+	+	+	+		+	+	+	Is, Hb	IC
Pheidole sp. 4	3			+					+	Is, Hb	IC
Pheidole sp. 5	2			+				+		Is, Hb	IC
Pheidologeton affinis (Jerdon)	2							+		Is	BBG

Table 2. Continued

Subfamily/species	No. sites	Habitats*								Sampling methods**	Occurrence***
		Hg	H	Gd	Af	M	Oa	P	Rf		
Pheidologeton diversus	1				+					Is	IC
Pyramica sp. 1	2							+	+	Is	IC
Recurvidris kemneri (Wheeler & Wheeler)	1	+								Is	BBG
Rhopalomastix sp. 1	1	+								Is	IC
Rhoptromyrmex wroughtonii Forel	2	+								Is	BBG
Solenopsis sp.1	1	+								Is	IC
Strumigenys sp. 1	6	+			+			+	+	Is	IC
Tetramorium bicarinatum (Nylander) ‡	14	+	+	+	+	+	+	+	+	Is, Hb	IC
T. meshena (Bolton)	11	+		+	+			+		Is, Hb	BBG
T. pacificum Mayr ‡	9	+	+				+	+	+	Is, Hb	BBG
T. simillimum (Smith) ‡	17	+	+	+		+	+	+	+	Is, Hb	BBG
Ponerinae											
Amblyopone sp. 1	1							+		Is	IC
Anochetus graeffei Mayr	6	+		+	+					Is	BBG
Diacamma rugosum (Le Guillou)	4	+			+		+	+		Is, Hb	BBG
Gnamptogenys binghamii (Forel)	5	+						+	+	Is	BBG
Gnamptogenys sp. 1	2	+								Is	IC
Hypoponera sp. 1	1	+								Is	IC
Hypoponera sp. 2	2	+								Is	IC
Hypoponera sp. 3	3	+			+					Is	IC
Hypoponera sp. 4	9	+					+	+		Is	IC
Hypoponera sp. 5	5				+			+	+	Is	IC
Leptogenys peuqueti (Andre)	4				+			+	+	Is	BBG
Leptogenys sp. 6 of SKY	1				+					Is	IC
Odontomachus rixosus Smith	1	+								Is	BBG
O. simillimus Smith	14	+	+		+	+		+	+	Is, Hb	BBG
O. denticulata (Smith)	19	+	+		+		+	+	+	Is, Hb	BBG
O. transversa (Smith)	8	+	+		+			+	+	Is, Hb	BBG
Pachycondyla (*Mesoponera*) sp. 9. of SKY	1							+		Is	BBG
P. luteipes (Mayr)	4	+								Is	BBG
Ponera sp. 1	1							+		Is	IC
Pseudomyrmecinae											
Tetraponera sp. 1	2	+			+					Is	IC

*Hg = home garden, H = household, Gd = garbage dump, Af = Agroforest, M = market, Oa = open area, P = park, Rf = rice field; **Is = Intensive sampling, Hb = Honey bait; ***CAF = Cacao Agroforest (source: Bos *et al.* 2007), BBG = Bogor Botanical Garden (source: Ito *et al.* 2001), IC = incomparable (unidentified); ****This refers to the morphospecies number the species is assigned to in the collection of Seiki Yamane (pers.comm.); ‡: Tramp species (McGlynn 1999).

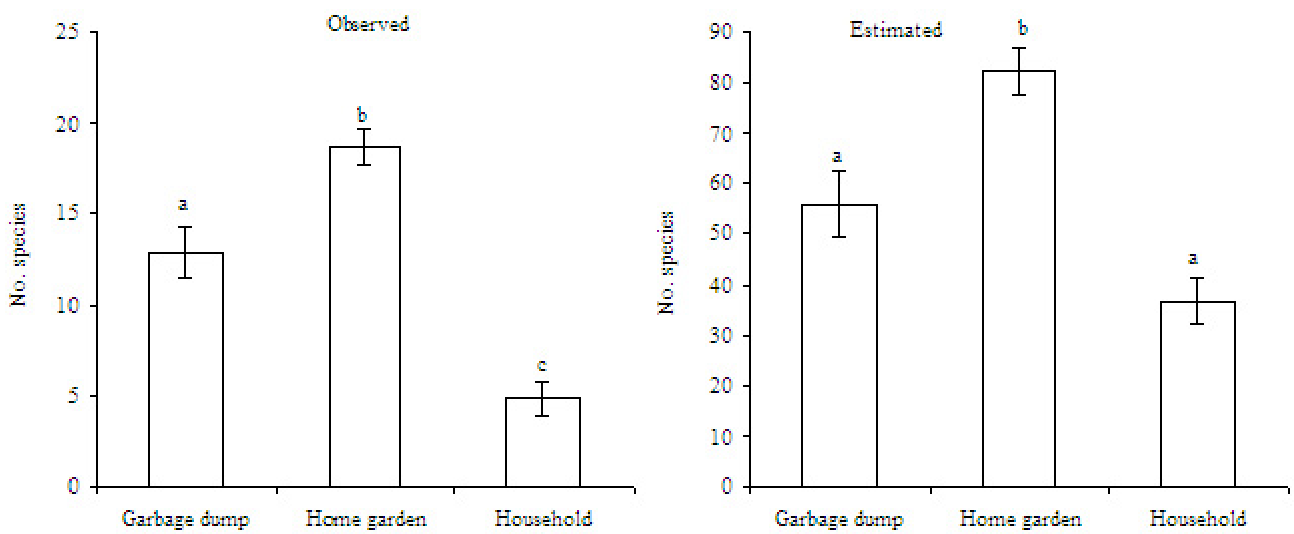

Figure 3. Mean number of ant species (a) observed and (b) estimated ± standard error in three common urban habitats (garbage dumps, home gardens, and households) in the Bogor area, West Java, Indonesia. Different letters indicate significant differences based on Tukey´s HSD posthoc tests.

Ant communities in households were dominated by *P. lonchicornis*, communities in home gardens by *A. gracilipes* and garbage dumps by *D. laevigatus*. Forty-five species were recorded during the intensive inventory of the BBG myrmecofauna by Ito *et al.* (2001), and 5 common species are also known as common species in cacao agroforests elsewhere

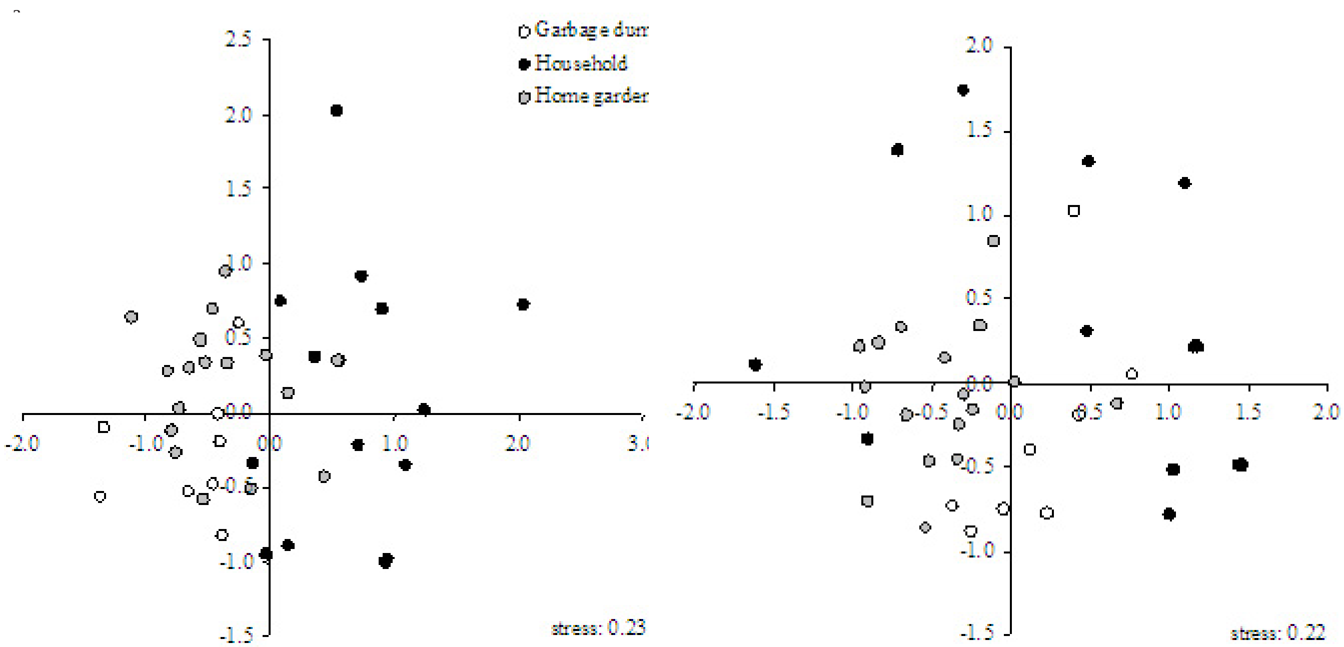

Figure 4. Multidimensional scaling plots based on Sørensen values quantifying the similarity of species composition of (a) tramp and (b) non tramp ant species between 19 locations and three habitat types.

in Indonesia (Table 2). The remaining species were not comparable because they could not be identified to the species level, though we suspect that several unidentified species were also found in the BBG and other tropical forms of land use as the collections continue to be worked upon taxonomically.

DISCUSSION

Our results demonstrate the importance of tramp species in shaping the myrmecofauna of tropical urban habitats. The 12 tramp species found in this study dominated ant assemblages in all 19 locations, and the well-known tramp species *A. gracilipes* (the "Yellow Crazy Ant") and *P. longicornis* (the "True Crazy Ant") were the most common species in the Bogor area. However, the assemblages of tramp species differed between the most common habitats, whereas the assemblages of the remaining 82 non tramp species did not seem to be affected by habitat type, which suggests other mechanisms underlie the occurrence of these species. This highlights the importance and scientific challenge of follow-up studies on ant assemblages and species interactions in urban tropical ecosystems, as part of an as yet underdeveloped line of ecological research (Whitten *et al.* 1996).

Although estimated species richness in our study was still about 30% higher than the observed species number, it is clearly lower than ant richness found in undisturbed tropical habitats such as rainforests (Brühl *et al.* 1998). Comparisons with other myrmecological studies in tropical urban habitats are, however, not possible due to the general lack of biodiversity inventories in urbanized habitats (see also Whitten *et al.* 1996).

In our study, the highest species richness occurred in home gardens where two-thirds of all observed species occurred. This habitat type was characterized by lawns, ornamental plants, planted fruit trees, banana and palms. This illustrates the importance of vegetated areas for the complexity of ant assemblages in urban ecosystems, which is underscored by the ant inventory of Ito *et al.* (2001) in the Bogor Botanical Garden. Using multiple collecting methods over several years, they revealed an ant fauna consisting of no less than 216 species; at least forty-five of these species also occur in surrounding urban habitats.

Nevertheless, the long history of urbanization in the Bogor area has resulted in homogenization of ant communities. A limited number of species is dominating all ant communities and the known distribution of most of those species extends beyond the biogeographic borders that are reflected in pristine Southeast Asian flora and fauna. Some of these tramp species have well-known invasive habits. For example, *A. gracilipes* has invaded disturbed areas throughout Southeast Asia and the Pacific Region where it can develop supercolonies (Abbott 2006), suppress native fauna, and cause cascades of further biodiversity loss (O'Dowd *et al.* 2003; Bos *et al.* 2008).

Tramp species were abundant in all studied habitat types in and around the city of Bogor, particularly in home gardens, which may be explained by the ornamental flowers and fruit trees that characterized that habitat type. Many tramp species interact with other insects such as homopterans, which mightalso be abundant in home gardens due to the presence of flowering and fruiting plants.

In contrast, the factors that influence the presence of the majority of non tramp ant species remain largely unknown. Semi-natural habitats such as agroforestry systems are often suggested to be an important alternative to natural systems for the conservation of biodiversity (e.g. Bos *et al.* 2007). By identifying the whole spectrum where species can occur, we can better characterize and value the biodiversity that is preserved in semi-natural systems.

Furthermore, ant species such as *A. gracilipes*, *D. thoracicus*, *O. smaragdina*, and *P. abdominalis* are also common in agroecosystems elsewhere in Southeast Asia, and have even been linked to the biological control of agricultural pests (Philpott & Armbrecht 2006). Thus, further studies on these ant species and their interactions with other fauna of urban ecosystems can increase our understanding of ecosystem dynamics that can include the dynamics of various pests like cockroaches and other insects in stored agricultural products and households (Kalshoven 1981; Whitten *et al.* 1996).

Biodiversity and ecosystems in tropical urban habitats remain poorly studied despite the fact that the world's most densely populated regions are in the tropics and population growth and urbanization still proceed at the fastest rates in the world. With this inventory of ant diversity in the Bogor area, West Java, Indonesia, we have illustrated how a baseline biodiversity inventory can contribute to the knowledge of species distributions across the spectrum from pristine to anthropogenic ecosystems. Further research that also includes interspecific interactions in urban habitats can increase understanding of how ants in particular and arthropods in general make use of urban environments, and what their roles are in urban ecosystems and pest dynamics.

ACKNOWLEDGEMENT

We are very grateful to Rosichon Ubaidillah (Research Centre for Biology, Indonesian Institute of Science - LIPI), Purnama Hidayat (Department of Plant Protection, Bogor Agricultural University), and Weeyawat Jaitrong (National Museum, Thailand) for their support during the progress of this study. Also many thanks to David Lohman for providing comment on an earlier version of this manuscript. This study was primarily funded by the Rufford Small Grant. The writing of this manuscript was part of a workshop in the framework of the German-Indonesian research project "STORMA –SFB 552".

REFERENCES

Abbott KL. 2006. Spatial dynamics of supercolonies of the invasive yellow crazy ant, *Anoplolepis gracilipes*, on Christmas Island, Indian Ocean. *Diversity Distrib* 12:101-110.

Adis JJ, de Morais JW, Guimarães de Mesquita H. 1987. Vertical distribution and abundance of arthropods in the soil of a Neotropical secondary forest during the rainy season. *Stud Neotrop Fauna Environ* 22:189-197.

Agosti D, Maryati M, Arthur CYC. 1994. Has the diversity of tropical ant fauna been underestimated? An indication from leaf litter studies in a West Malaysian lowland rain forest. *Trop Biodivers* 2:270-275.

Andersen AN. 2000. Global ecology of rainforest ants: functional groups in relation to environmental stress and disturbance. In: Agosti D, Majer JD, Alonso LE, Schultz TR (eds). *Ants: Standard Methods for Measuring and Monitoring Biodiversity*. Washington: Smithsonian Institution Pr. p 25-34.

Bolton B. 1994. Identification Guide to the Ant Genera of the World. London: Harvard Univ Pr.

Bos MM, Steffan-Dewenter I, Tscharntke T. 2007. The contribution of cacao agroforests to the conservation of lower canopy ant and beetle diversity in Indonesia. *Biodivers Conserv* 16:2429-2444.

Bos MM, Tylianakis JM, Steffan-Dewenter I, Tscharntke T. 2008. The invasive yellow crazy Ant in Indonesian cacao agroforests and the decline of forest ant diversity. *Biol Invasions* (in press). DOI: 10.1007/s10530-008-9215-4.

Brown Jr. KS, Freitas AVL. 2002. Butterfly communities of urban forest fragments in Campinas, São Paulo, Brazil: Structure, instability, environmental correlates, and conservation. *J Insect Conserv* 6:217-231.

Brühl CA, Gunsalam G, Linsenmair KE. 1998. Stratification of ants (Hymenoptera, Formicidae) in a primary rain forest in Sabah, Borneo. *J Trop Ecol* 14:285-297.

Clarke KR, Warwick RM. 2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. Plymouth: Primer-E.

Collier N, MacKay DA, Benkendorff K, Austin AD, Carthew SM. 2006. Butterfly communities in South Australian urban reserves: estimating abundance and diversity using the Pollard walk. *Australian Ecol* 31:282-290.

Diamond JM, Bishop KD, van Balen S. 1987. Bird survival in an isolated Javan woodland: Island or mirror? *Conserv Biol* 1:132-142.

Erwin TL. 1989. Sorting tropical forest canopy samples (an experimental project for networking information). *Insect Collect News* 2:8.

Gibb H, Hochuli DF. 2003. Colonisation by a dominant ant facilitated by anthropogenic disturbance: affects on ant assemblage composition, biomass and resource use. *Oikos* 103:469-478.

Holway DA, Lach L, Suarez AV, Tsutsui ND, Case TJ. 2002. The causes and consequences of ant invasions. *Annu Rev Ecol Syst* 33:181-233.

Hourigan CL, Johnson C, Robson SKA. 2006. The structure of a micro-bat community in relation to gradients of environmental variation in a tropical urban area. *Urban Ecosys* 9:67-82.

Ito F *et al*. 2001. Ant species diversity in the Bogor Botanical Garden, West Java, Indonesia, with descriptions of two new species of the genus *Leptanilla* (Hymenoptera: Formicidae). *Tropics* 10:379-404.

Kalshoven LGE. 1981. *Pests of Crops in Indonesia*. Jakarta: Ichtiar Baru.

Koh LP, Sodhi NS. 2004. Importance of reserves, fragments, and parks for butterfly conservation in a tropical urban landscape. *Ecol Appl* 14:1695-1708.

Magurran AE. 2004. *Measuring biological diversity*. Malden: Blackwell.

McGlynn TP. 1999. The worldwide transfer of ants: geographical distribution and ecological invasions. *J Biogeography* 26:535-548.

McIntyre NE. 2000. Ecology of urban arthropods: A review and a call to action. *Entomol Soci America* 93:825-835.

McIntyre NE, Rango J, Fagan WF, Faeth SH. 2001. Ground arthropod community structure in a heterogeneous urban environment. *Landscape Urban Plan* 52:257-274.

Messner S. 1997. *Biodiversity Calculator*. Würzburg: Universität Würzburg.

O'Dowd DJ, Green PT, Lake PS. 2003. Invasional 'meltdown' on an oceanic island. *Ecol Lett* 6:812-817.

Philpott SM, Foster PF. 2005. Nest-site limitation in coffee agroecosystems: artificial nests maintain diversity of arboreal ants. *Ecol Appl* 15:1478-1485.

Philpott S, Armbrecht I. 2006. Biodiversity in tropical agroforests and the ecological role of ants and ant diversity in predatory function. *Ecol Entomol* 31:369-377.

Room PM. 1971. The relative distribution of ant species in Ghana's cocoa farms. *J Animal Ecol* 40:735-751.
Schlick-Steiner BC, Steiner FM. 1999. Faunistisch-ökologische Untersuchungen an den freilebenden Ameisen (Hymenoptera: Formicidae) Wiens. *Myrmecologische Nachrichten* 3:9-53.
Smith J, Chapman A, Eggleton P. 2006. Baseline biodiversity surveys of the soil macrofauna of London's green spaces. *Urban Ecosys* 9:337-349.
Statsoft. 1995. *Statistica for Windows Release 5.0*. Tulsa: StatSoft.
Stork NE. 1991. The composition of the arthropod fauna of Bornean lowland rain forest trees. *J Trop Ecol* 7:161-180.
Suarez AV, Bolger D, Case TJ. 1998. Effects of fragmentation and invasion on native ant communities in Coastal Southern California. *Ecol Soci America* 79:2041-2056.
Whitten T, Soeriaatmadja RE, Afiff SA. 1996. The ecology of Java and Bali. Hong Kong: Periplus.
Wilson EO. 1990. *Success and Dominance in Ecosystems: The Case of Social Insects*. Olderdorf/Luhe: Ecology Institut.