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Abdul Hafiz Ab Majid
Household & Structural Urban Entomology Laboratory, School of Biological Sciences, Universiti Sains Malaysia, Malaysia.

Siti Salbiah Ellias
Household & Structural Urban Entomology Laboratory, School of Biological Sciences, Universiti Sains Malaysia, Malaysia.

Hamdan Ahmad
Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia. Malaysia.

Abu Hassan Ahmad
Entomology Research Laboratory, School of Biological Sciences, Universiti Sains Malaysia, Malaysia.

Hamady Dieng
Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.

Tropical household ants species composition and distribution in rapid urbanization area in Penang, Malaysia

Abdul Hafiz Ab Majid, Siti Salbiah Ellias, Hamdan Ahmad, Abu Hassan Ahmad, Hamady Dieng

Abstract
Ants are social insects that are commonly found in tropical ecosystems and have adapted well to the urban environment. They are among the most prevalent pests in households. This study demonstrates the abundance and prevalence of structure infesting ants in residential buildings in Penang Island, Malaysia. Three locations situated in urban, suburban and rural areas were surveyed. In each area, 15 houses were assessed using modified baiting method by using 15ml centrifuge tube baited with peanut butter (13.9% protein and 41% fat) and honey (75% carbohydrate). Two collections were performed, one in the daytime and one at night, with five samples used in each period, totalling ten samples for one house. The top five most common household ants species found from the surveyed houses are *P. longicornis* (22.09%), *T. indicum* (17.74%), *T. melanocephalum* (17.0%), *M. pharaonis* (10.61%), and *Pheidole spp.* (5.22%). The data generated from the study will provide background information for the management of household ants in Malaysia and its neighbouring countries in the years to come.

Keywords: household ants, species composition, urban, rural, urbanization, Malaysia

1. Introduction

Ants are social insects that are best adapted to the urban environment. They owe much of this adaptability to the ease of finding food, moisture and places to build their nests. The difficulty in reducing the availability of resources needed for their survival has made many programs to control ant pests challenging. Different ant species often exhibit varying behavioural characteristics including polygyny and fragmentation of colonies that favours their dispersal and adaptation in these environments [1-2] as well as different feeding preferences [3]. Therefore, information on species composition and correct identification of structure-infesting ants are essential to improved planning of an integrated control programme against these pests, despite of little known on the species composition of structure-infesting ants in Malaysia.

Some ants adapted to the urban environment can cause nuisance from simple things such as falling into your drink to a serious public health problem because, among social insects, ants are creatures that have numerous parasitic and mutualistic relationships and can develop multiple interactions with animals, plants, fungi and bacteria. Because of this, they are known to be a potential threat as carriers of pathogenic microorganisms found in our body, such as *Staphylococcus*, *Klebsiella*, *Acinetobacter Streptococcus*, *Enterococcus* and *Enterobacter* [4-7].

Based on another study conducted by Pecanha *et al.,* [8] "Ants as a vector for the spread of bacterial resistance in University Hospitals", besides, they also found that ants do not only carry bacteria but they also act as a major route of dispersion of drug resistance in intra-hospital ambience.

Urban Ants: Behaviour of species that invade the Brazilian cities by Bueno and Campos-Farina [1] is a study that suggested about 50 ant species adapted to the urban environment due to the heterogeneous habitats which provide greater variety of sites for nesting, food, microclimates and interspecific interactions (competition, predation, mutualism) [9-11] than less complex habitats and there are about 20-30 species of ants that can be considered as pests [1].

Since Penang Island has undergone rapid urbanization (changing in biodiversity status) and there is a lack of contemporary study as well as the relevance of the relationship between the richness of ants and the structural complexity of their environments [12-14], this study was aimed to survey the household ants species composition and diversity in relation to the different areas; urban, suburban and rural area in Penang Island as well as finding the five most

Correspondence
Dr. Abdul Hafiz Ab Majid
abdhafiz@usm.my
Household & Structural Urban Entomology Laboratory, School of Biological Sciences, Universiti Sains Malaysia, Malaysia.

frequently found household ant species in Penang Island as a whole. The findings of this survey would contribute to the understanding of the behaviour of these synanthropic insects in this region and also update the latest household ant species composition list in Penang Island.

2. Materials and Methods
Description of the study sites
This study was done in three different environments within Penang Island; urban, suburban and rural area. This was done to understand the species composition and distribution of household ants around Penang Island. The areas were specified based on few characteristics. Urban areas consist of city scapes of commercial and residential neighborhoods, with a limited amount of planned green space and undeveloped areas. Suburban area is comprised of a mix of land use including developed and undeveloped land, planned and unplanned green space, and commercial and residential buildings. Rural areas are where there are minimum commercialized buildings and are mostly populated with housing areas on undeveloped land. So here, the rural area covers the Balik Pulau region, specifically Kampong Permatang Pasir and Kampung Sungai Rusa. The suburban area covers the Relau and Sungai Ara districts while the urban area is focused in Georgetown.

Field sampling
In each area, 15 houses were assessed using modified baiting method developed by Lee et al., [5] which is by using a 15ml centrifuge tube baited with peanut butter (13.9% protein and 41% fat) and honey (75% carbohydrate). Protein-loving ants respond best to a bait made of both protein and sugar. On the same day, two collections were performed; one in daytime and one at night, with five samples in each period, totalling ten samples for one house. The daytime collections were made from 8: 00h to 11: 00h whereas the night collections were made from 20: 00h to 23: 00h [16]. Each bait tube (samples) was placed near the location of the ant's trail and suspected nests inside the houses. Two batches of bait were put inside a house because the maximum foraging time for ants differs according to different species.

All the collected bait are then put inside a plastic container to prevent the ants from escaping before being collected the next day and brought back to the laboratory to be stored in a 70% ethanol solution for identification of species under a dissecting microscope using a variety taxonomic key of ants identification guide [17-19]. The number of samples found containing specific species of ants was recorded to determine the level of occurrence of the species compared to determining the total number of ants found. This is because, at some point, it is possible that the total number of specific ants found might be really high (e.g. 2000) in one house but far less in other houses (e.g. 230, 450, 40, 72). So in order to determine which species are found dominantly in most of the houses in Penang, the occurrence of the ants was recorded according to the number of the species found in the tube bait. For example, from 10 tubes of bait placed in the house, three tubes contain pharaoh ants, five contain crazy ants, and ghost ants. It does not matter if one tube contains more than two species; the number of tube baits will still be counted separately for each species. Thereafter the number of foraging ants in the 10 baits were combined and counted for record of extra data. Then, the percentage of the total foraging ants for each house is calculated.

Statistical analysis
Statistical analysis was performed using One-way ANOVA followed by Tukey test for post hoc comparison when appropriate, by using SPSS 12.0 software and $P<0.05$ was taken as an indicator of statistical significance.

3. Results
Results from the survey indicated that a minimum of thirteen species of ants was found in the living premises of the four study locations in Penang Island, Malaysia. Overall household ant population occurrence appeared to be higher in the suburban (Sg Ara & Relau) and rural (Balik Pulau) surroundings compared to the urban (Georgetown) location. The Balik Pulau area appeared to have the highest diversity of ant species among all the four locations surveyed, followed by Sg Ara and Relau (Table 1).

Table 1: Number of occurrence of household ant species in tube baits from 3 areas in Penang Island, Malaysia. Bait is by using peanut butter (13.9% protein and 41% fat) and honey (75% carbohydrate).

Species	Location (number of ant occurrence)			Total (%)	Mean ± SE	Range (min-max)	ANOVA
	Georgetown (urban) n = 150	Sg Ara & Relau (suburban) n = 150	Balik Pulau (rural) n = 150				
M. pharaonis	10	36	15	61 (10.61)	1.356 ± 0.391	0.00 - 9.00	
P. longicornis	38	29	60	127 (22.09)	2.822 ± 0.450	0.00 - 10.00	
Pheidole spp.	21	5	4	30 (5.22)	0.667 ± 0.220	0.00 - 6.00	
T. melanocephalum	48	26	24	98 (17.04)	2.178 ± 0.390	0.00 - 9.00	
T. indicum	23	49	30	102 (17.74)	2.267 ± 0.503	0.00 - 10.00	
C. vicinus	-	8	18	26 (4.52)	0.578 ± 0.287	0.00 - 8.00	F=7.512
Tetramorium sp.	-	20	7	27 (4.69)	0.600 ± 0.287	0.00 - 9.00	df =12
S. molesta	-	-	11	11 (1.91)	0.244 ± 0.172	0.00 - 6.00	P<0.001
M. floricola	-	-	23	23 (4.0)	0.511 ± 0.292	0.00 - 10.00	
Paratrechina sp.	-	-	12	12 (2.09)	0.267 ± 0.189	0.00 - 8.00	
S. invicta	5	3	20	28 (4.87)	0.622 ± 0.331	0.00 - 10.00	
S. geminata	3	9	17	29 (5.04)	0.644 ± 0.305	0.00 - 10.00	
L. humile	-	-	1	1 (0.0017)	0.022 ± 0.022	0.00 - 1.00	
Total number of ant occurrence per location (%)	148 (25.74)	185 (32.17)	242 (42.09)	575 (100)	0.983 ± 0.096	0.00 – 10.00	

The thirteen species found, belonged to eight genera and three subfamilies. The species are *Monomorium pharaonis Paratrechina longicornis, Pheidole spp.*, *Tapinoma melanocephalum*, *Tapinoma indicum*, *Camponotus vicinus,* *Tetramorium sp., Solenopsis molesta, Monomorium floricola*, *Paratrechina sp., Solenopsis invicta, Solenopsis geminata* and *Linepithema humile.*

When all the locations are combined to find the top five most common household ant species, it can be concluded that the most frequently found species from the surveyed houses are *P. longicornis* (22.09%), *T. indicum* (17.74%), *T. melanocephalum* (17.0%), *M. pharaonis* (10.61%), and *Pheidole spp.* (5.22%) followed by *S. geminata* (5.04%), *S. invicta* (4.87%), *Tetramorium sp.* (4.69%), *C. vicinus* (4.52%), *M. floricola* (4.0%), *Paratrechina sp.* (2.09%), *S. molesta* (1.91%) and lastly *L. humile* (0.0017%) (Figure 1) (Table 1).
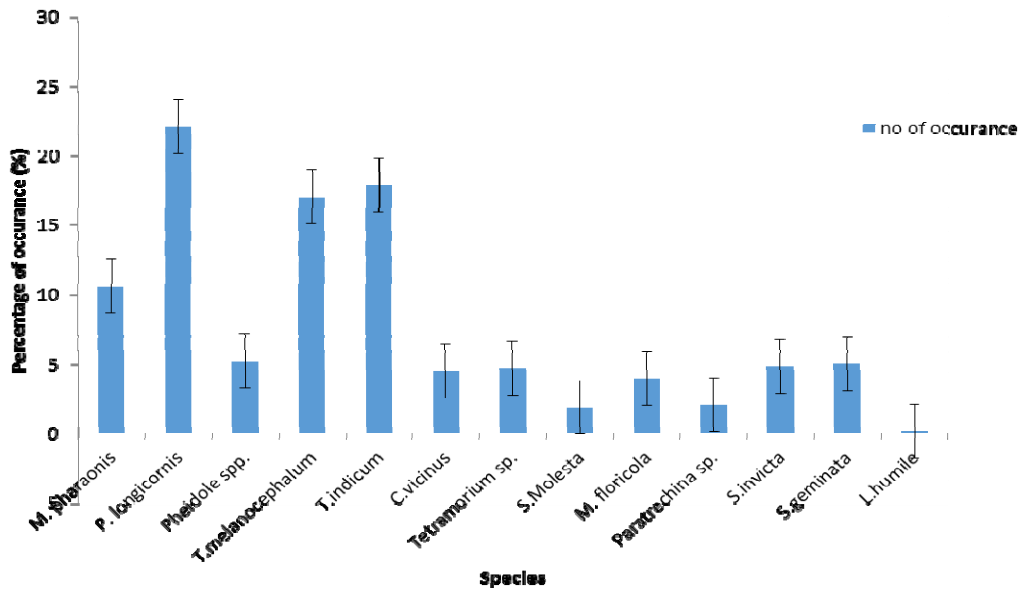

Fig 1: Overall percentage of occurrence of ant species in Penang, Malaysia

Based on ANOVA, the mean number of ant occurrences varied significantly between all the household ants species collected ($F = 7.512$; $df = 12$; $P < 0.001$), followed by differences between the compositions of household ant's species in the surveyed areas (Figure 2).
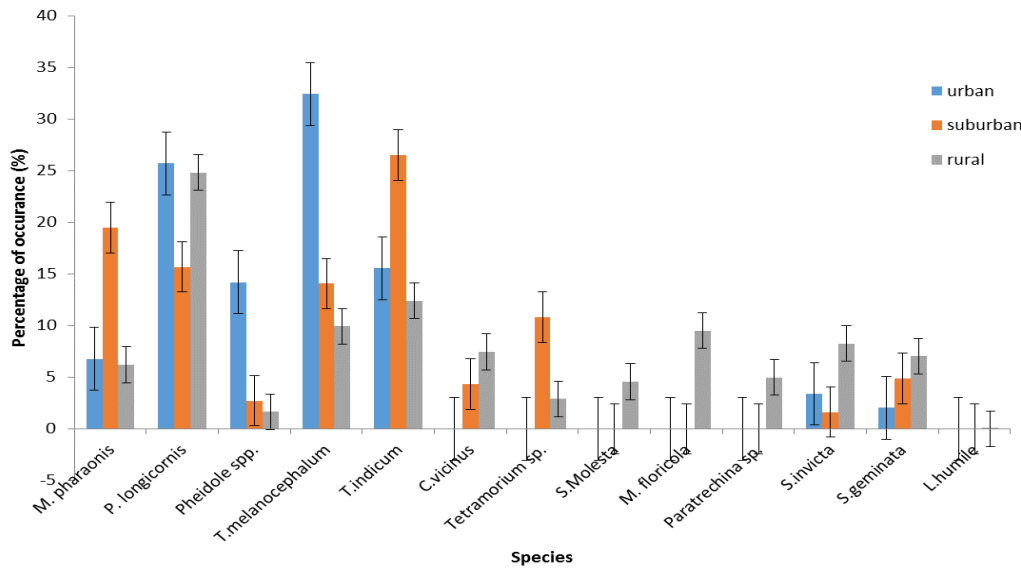

Fig 2: Percentage of occurrence of species from urban, suburban and rural area.

Mean difference of the species revealed that the top five species are *P. longicornis* 2.822±0.450 (range: 0.00-10.00), *T. indicum* 2.267±0.503 (range: 0.00-10.00), *T. melanocephalum* 2.178±0.390 (range: 0.00-9.00), *M. pharaonis* 1.356±0.391 (range: 0.00-9.00) and *Pheidole spp.* 0.667±0.220 (range: 0.00-6.00) followed by *S. geminate* 0.644±0.305 (range: 0.00-10.00), *S. invicta* 0.622±0.331 (range: 0.00-10.00), *Tetramorium sp.* 0.600±0.287 (range: 0.00-9.00), *C. vicinus* 0.578±0.287(range: 0.00-8.00), *M. floricola* 0.511±0.292 (range: 0.00-10.00), *Paratrechina sp.* 0.267±0.189 (range: 0.00-8.00), *S. molesta* 0.244±0.172 (range: 0.00 - 6.00), and lastly *L. humile* 0.022±0.022 (range: 0.00 - 1.00) (Table 1).

Between the top 5 species, the mean was compared to the highest occurring species which is *P. longicornis* using Post hoc Tukey test to know whether there are differences between those five species. It is found that from the five top species excluding *P. longicornis*, only *Pheidole spp.* (mean difference = 2.156; *P*<0.001) has significant difference while the other three do not have any significant difference with *P. longicornis*; *T. indicum* (mean difference = 0.556; *P*>0.001),

T. melanocephalum (mean difference = 0.644; *P*>0.001), *M. pharaonis* (mean difference = 1.467; *P*>0.001). This means that the other three species have approximately the same number of occurrences in the housing areas in Penang. *Pheidole spp.* has slightly lower number of occurrence and differs significantly from *P. longicornis*. However, it is still among the top five species.

When the species other than the top five are compared to the *P. longicornis*, there are significant differences between the number of occurrence of those species and *P. longicornis* where *L. humile* (mean difference = 2.80; *P*<0.001) has the biggest difference showing that *L. humile* is the least commonants in this survey. This is followed by *S. molesta* (mean difference = 2.578; *P*<0.001), *Paratrechina sp.* (mean difference = 2.556; *P*<0.001), *M. floricola* (mean difference = 2.311; *P*<0.001), *C. vicinus* (mean difference = 2.244; *P*<0.001), *Tetramorium sp.* (mean difference = 2.222; *P*<0.001), *S. invicta* (mean difference = 2.20; *P*<0.001) and *S. geminata* (mean difference = 2.178; *P*<0.001) (Table 1).

4. Discussion
Many ant species captured in this study are tramp species that are of cosmopolitan distribution. Tramp ants are defined as ants that are polygynous, unicolonial, which reproduce by budding, are largely dispersed worldwide through human commerce and live in close association with humans [10, 20]

From this survey, it was found that long leg crazy ants and ghost ants are the most frequent species found in most of the surveyed houses followed by pharaoh ant, *Pheidole spp.* and then *S. geminata*, *S. invicta*, *Tetramorium sp.*, *C. vicinus*, *M. floricola* , *Paratrechina sp.*, *S. molesta* and lastly *L. humile.* This result differs with a survey by Lee et al [15] where the most dominant species was *Monomorium destructor* (Singapore ant) followed by ghost ants (*T. melanocephalum*), *Pheidole sp.*, *Monomorium floricola* and lastly crazy ants (*P. longicornis*). It seems that the crazy ants have drifted its status to the most influential urban ants, surpassing the other ants including ghost ants. This might be due to its behaviour which is highly adaptable to the environment as well as its ability to nest indoors and outdoors [21-22]. Crazy ants are also opportunists and are able to forage far away from the nest [21]. Apart from that, their feeding habits also aid their successful colonization. They are omnivorous and feed on wide range of items that favour their survival starting from the very own household foods in the house to the dead insects and fruits in or outside houses [21]

On the other hand, ghost ants are known for its tiny size and the bad odour it emits when crushed. This species are actually outdoor species. However, they can also be found nesting indoors near to sources of moisture such as under potted plants, water taps and etc.

When the ant diversity from each area are compared, it was found that the diversity of ants is the highest in the rural area followed by the suburban area and the lastly, the urban area. This suggests that the diversity of the ants increases as the density of flora and architecture of the vegetation increases [10, 23]. As the rural area and suburban areas are mainly surrounded by vegetation and shrubs, the chances of ants to be introduced into houses are higher than those surrounded by floors and buildings (e.g. urban area). The reduction of habitat, especially its fragmentation into small remnants, such as the expansion of the urban area coupled with human disturbance on microclimate and vegetation require changes in the adaptive strategies of many species to colonize urban ecosystems and agro-ecosystems, thus eliminating species that is not strong enough to compete [24-25]. Furthermore, nesting in unstable habitat in the human environment requires frequent migration, and becomes a unique characteristic and a major factor in aiding their survival especially in the urban ecosystem [20].

Many studies have observed a positive relationship between diversity of ant communities and the complexity of the environment, even when comparing areas with vegetation complexity [10, 23] plant density and richness [23], different successional stages [12, 26], vegetation types [13], altitude [27-28] and latitude [9]. In fact, habitat characteristics are important in determining the composition of the biota. Thus, as Penang Island undergoes rapid urbanization, the ant biodiversity and composition also changes through time. As of date, the crazy ant is the dominant species followed by ghost ants, pharaoh ants and *Pheidole spp*. However, this rank can easily rotate again in a few years to come due to the advance behaviour of ants; their adaptability and evolution.

This study demonstrated the abundance and prevalence of structure-infesting ants in residential houses in Penang Island, Malaysia. Five most frequent species were determined before proceeding to the next experiment. These species are *Paratrechina longicornis* (22.09%), *Tapinoma indicum* (17.74%)*, Tapinoma melanocephalum* (17.0%), *Monomorium pharaonis* (10.61%), and *Pheidole spp.* (5.22%). Further studies on the bionomics and economic importance of the household ants in different parts of Malaysia or at least in Penang state are needed for ant control which will definitely be on the increase due to rapid socio-economic development in this region especially when there is a difficulty in reducing the availability of resources needed for the survival of these insects. Other contributing factors include the polygyny characteristic and fragmentation of colonies themselves that favour their dispersal and adaptation in the household environments [1-2]. Such information generated from those studies will provide the basic background information for the management of household ants in Malaysia and neighbouring countries in the years to come.

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