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# ANT SPECIES DIVERSITY STUDY USING PITFALL TRAPS IN A SMALL YARD IN BOGOR BOTANIC GARDEN, WEST JAVA, INDONESIA

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## Abstract

The ant fauna in a small yard in Bogor Botanic Garden, West Java, Indonesia was investigated using pitfall traps. Regular sampling was carried out weekly or biweekly for 3.5 years from March, 2000 to November, 2003. The accumulation curve for the species number collected was asymptotic, indicating the completeness of the sampling. A total of 29424 individuals, represented by 55 species in 27 genera, 17 tribes and 6 subfamilies were collected. Myrmicinae was the most abundant with 19 species (34.6 %) and 19524 individuals (66.4 %), followed by Formicinae with 15 species (27.3 %) and 4470 individuals (15.2 %), and Ponerinae with 12 species (21.8 %) and 2880 individuals (9.8 %). Aenictinae, Dolichoderinae and Cerapachinae had 4 (7.3 %), 4 (7.3 %) and 1 (1.8 %) species, and 1716 (5.8 %), 832 (5.8 %) and 2 (0.01 %) individuals, respectively. The present results were compared with Ito *et al.* (2001), who collected ant species in Bogor Botanic Garden using 7 methods, including pitfall traps.

**Key words:** Ground ants; pitfall traps; species diversity; Bogor Botanic Garden; West Java; Indonesia

## INTRODUCTION

Ants are one of the ideal model organisms for measuring and monitoring biodiversity for many reasons. It is abundant and dominant in ecological systems as a predator and symbiont for plants and other organisms, relatively easy to collect in a standardized way, reasonably diverse at the site, identifiable and so on (*e.g.* Wilson 1976, Hölldobler & Wilson 1990, Agosti *et al.* 2000). Since most ant species are stationary and have a perennial nest with a restricted foraging range, they are also useful as indicators of environmental conditions (Chung & Mohamed 1996, Peck *et al.* 1998, Wang *et al.* 2000; Hashimoto *et al.* 2001, Andersen *et al.* 2002, Longino *et al.* 2002).

Studies on ant species diversity in lowland tropical rainforests in Southeast Asia have progressed gradually and a magnificent species diversity of ants has been reported (*e.g.* Brühl *et al.* 1998, Yamane 1996). In Indonesia, however, no solid information on the ant fauna has been published except for a study by Ito *et al.* (2001) (but see Dammermann 1948 for the Krakataus, cited in Ito *et al.* 2001). They investigated the ant fauna in Bogor Botanic Garden (Kebun Raya Bogor), West Java, using 7 sampling methods in 1985 and between 1990 and 1998. In total, they recorded 216 species in all 9 subfamilies known from the Oriental region. By comparing the results with that of Asian tropical rainforests, they mentioned that species composition in the garden was similar to that of lowland rainforests in West Java, but remarkably different from mountain forests. The number of ant species in the garden was lower than that in lowland primary forests (*e.g.* Brühl *et al.* 1998 and see Ito *et al.* 2001 for further reference). However, the garden, which is isolated in the center of an urban area with much human disturbance, harbors an ant diversity much higher than those in subtropical and temperate regions (*e.g.* 267 spp. for all Japan and 138 in a seasonal subtropical rainforest in western Australia) (Ito *et al.* 2001). It is important for studies of tropical insect communities and dynamics to investigate the ant fauna in this garden, because (1) many species were described as new species to science from Bogor (probably from the garden) in the late 19$^{th}$ and early 20$^{th}$ centuries but their descriptions were often inadequate and the type specimens are in poor condition, so specimens currently collected from the type locality will give important information to taxonomists; (2) most lowland rain forests have already been lost from West Java so Bogor Botanic Garden possibly harbors a part of the original ant fauna of such forests; (3) for the better understanding of most species-rich communities such as low land tropical rainforests, intensive surveys in artificial or disturbed areas are also necessary (see Ito *et al.* 2001 for references).

In this study, we collected ants weekly or biweekly in a small yard in Bogor Botanic Garden using pitfall traps from March 2000 to November, 2003.

We aimed to investigate (1) the species diversity and abundance of ground foraging ants, and (2) seasonal fluctuations in them. Pitfall trapping is a convenient way to estimate the species composition and abundance of ground surface-active ant workers in an area. It provides a measure of the relative abundance of ant species, though it is not very exact and often biased for many reasons (see Agosti *et al.* 2000 for review). In this study, although the study site was small, regular pitfall sampling for 3.5 years will clarify the features of the ground ant fauna by comparing the results with Ito *et al.* (2001). Results of seasonal fluctuations in ant populations will be published elsewhere.

## MATERIALS AND METHODS

### 1. Study site and climatic conditions

Bogor is located 6$^o$ 37'S and 106 $^o$ 47'E at an altitude of 260 m at the eastern edge of the tropical rainforest climate. The average annual rainfall of Bogor is 3850 mm, ranging from 2000 to 5000 mm. June to August tends to be the driest period of the year and November to January the wettest period. In Bogor, cycles of dry and wet seasons are not prominent or regularly occurring, and severe droughts occur irregularly from time to time (Nakamura *et al.* 1994, 2001). Annual rainfalls in 2000, 2001, 2002 and 2003 were 2834 mm, 5194, 4575 and 4570, respectively. Monthly temperature ranged from about 25 to 28 $^o$C. The study site in Bogor was a small yard ground (15 x 20 m$^2$), surrounded by the south building of the Museum Zoologicum Bogoriense and other tall structures such as the Laboratory of Chemistry and birdcages. Thirty shoots of *I. carnea* (Convolvulaceae), a shrub-like morning glory growing as a weed in moist soil (1.5 cm in diameter and 20 cm in length) were planted in September 1999 in the study sites in Bogor.

### 2. Sampling methods

Foraging ant workers were collected using pitfall traps weekly from the 17$^{th}$ of March 2000 and thereafter biweekly until the 19$^{th}$ of November 2003 (115 sampling times). Plastic cups (12 cm in length and 7 cm in diameter with 70 % alcohol from March 2000 to February 2001 or sorbic acid from March 2001 to the 19$^{th}$ of November 2003 for preserving the specimens) were used as pitfall traps and located under 30 *I. carnea* plants. The traps were covered by 13 x 13 cm tin plate roofs against rain. The traps were set for 6 consecutive days and the samples were taken on the seventh day. Sampling dates were changed from weekly to biweekly from May 2001 until November 2003. In the laboratory, all samples were sorted and identified using available taxonomic keys and help from ant taxonomists (see acknowledgements). Voucher specimens are currently being kept in the author's collection at the Faculty of Science, Kanazawa University (Kanazawa, Japan).

### 3. Data analysis

Species accumulation curve and species diversity index

In social insects, species abundance or diversity should be compared and analyzed in units of the colony or nest because they live in a colony unit and the colony size and nest density are strongly dependent on the social structure and life history strategy of each species. In this study, we examined the number and species composition of workers in ground foraging ants and utilized them as parameters of species diversity. To inspect the completeness of the inventory, we plotted species accumulation curves as a function of the number of individuals collected (Figure 1). Since the shape of the species accumulation curve can depend on the ordering of the sample (Colwell & Coddington 1994), it was smoothed through the process of randomization. Species richness was estimated by Jackknife 1, a first order Jackknife estimator that employs the number of species that occur only in a single sample (Heltshe & Forrester 1983). We used EstimateS (version 7.0, Colwell 2004) for the randomization of the species accumulation curve and calculation of Jackknife estimators. We also computed the Shannon and Simpson diversity indices (Magurran 2004).

Arrangement of species abundance data

To process the information on the number of species and their relative abundance, we plotted the rank/abundance relationship for individual species (Figure 3) and the log normal distribution of species abundance (Figure 4). As Magurran (2004) recommended, 0.5 was added to the upper boundary of each $\log_2$ observed abundance class (that is the "octave" or doubling of species abundances) in order to assign observed species unambiguously. Ant species collected during the study period were arbitrarily categorized into 4 abundance classes, each of which covered 3 octaves as follows: "very rare" (upper boundary of $2^3 + 0.5$ or class I – III), "rare" ($2^6 + 0.5$ or class IV – VI), "common" ($2^9 + 0.5$ or class VII - IX) and "abundant" ($2^9 + 0.5 \sim$ ) (Figure 4). The expected distributions were calculated from the log normal distribution (See Magurran 2004 for further explanation and the calculations).

## RESULTS

### 1. Accumulation curves of individuals and species collected

The accumulation rate of individuals collected was higher at the beginning of the study (samples 1-10) and then it lowered and became almost constant until sample 72. A large number of individuals were suddenly collected in sample 73 (27th of March 2002, when the single species, *Pheidolegeton* sp. 1, appeared in the highest number: 447 individuals). The rate again remained constant until sample 106. A large number of individuals were suddenly collected in sample 107 (16th of July 2003, when the most dominant species, *Pheidole plagiaria*, was appeared with 1671 individuals) (Figure 1a). The accumulation rate of species number was higher in samples 1-10 and 30-40. Observed and smoothed species accumulation curves were asymptotic, indicating the completeness of the sampling (Figure 1b). The total number of species sampled reached 55. The estimate derived by Jackknife 1 was 57.97.

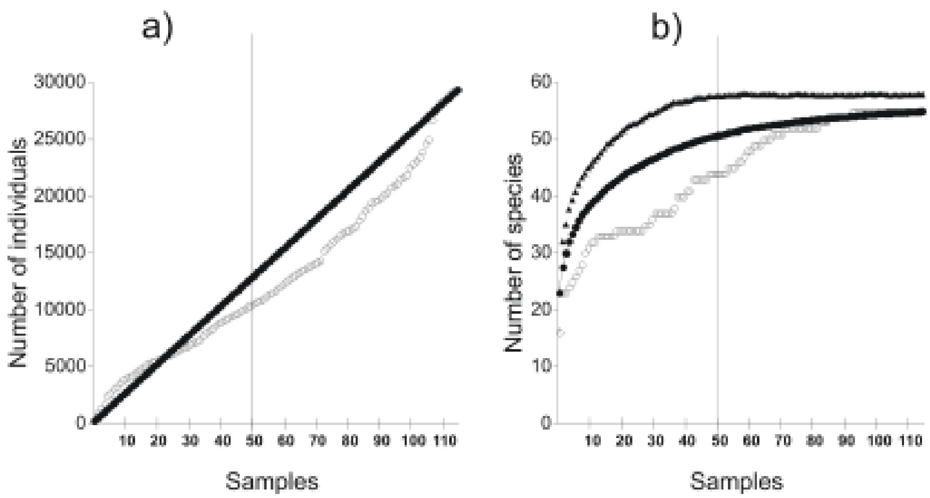


**Figure 1.** Accumulation curves of ants collected using pitfall traps during the study period in Bogor, West Java. Dotted vertical line indicates the changes in census interval from weekly to biweekly. (a) Number of individuals (o = observed, ● = smoothed), (b) Number of species (o = observed, ● = smoothed, s = Jackknife 1 estimated)

**2. Ant taxonomic composition**

Table 1 shows the list of species and the number of individuals collected using the pitfall traps. Overall, 29424 individuals, representing 55 species in 27 genera, 17 tribes and 6 subfamilies were collected. Corresponding information for these species published by Ito *et al.* (2001) is also given. Figure 2 shows the number of tribes, genera, species and individuals belonging to each subfamily.

Subfamily

Collected samples were composed of 6 subfamilies. Myrmicinae had the largest numbers of tribes (8, 47.1 %), genera (10, 37.1 %), species (19, 34.6 %) and individuals (19524, 66.4 %). Formicinae was the 2nd largest in terms of the number of species (15, 27.3 %) and individuals (4470, 15.2 %), followed by Ponerinae with 12 species (21.8 %) and 2880 individuals (9.8 %). Aenictinae, Dolichoderinae and Cerapachinae were in 4th, 5th and 6th places with 4 (7.3 %), 4 (7.3 %) and 1 (1.8 %) species and 1716 (5.8 %), 832 (2.8 %) and 2 (0.01 %) individuals, respectively (Table 1 and Figure 2).

Genus

The three most species rich genera were *Camponotus* (6 species), *Paratrechina* (4 species) and *Aenictus* (4 species). The first 2 genera belonged to Formicinae, and the third to Aenictinae. Only 1 species was recorded from 2 genera and 2 species from 3 genera (Table 1).

**Table 1.** List of the ant species collected using pitfall traps from March 2000 to November 2003 in Bogor, West Java

| Subfamily | Tribe | Species | Total number of individuals collected | Code | Abundance ranking | Records in Ito et al. (2001) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Name* | Collection methods** |
| Aenictinae | Aenictini | *Aenictus javanus* Emery | 173 | 1 | 17 | # | C, F |
| | | *Aenictus camposi* | 235 | 2 | 14 | | |
| | | *Aenictus dentatus* Forel | 46 | 100 | 25 | # | C |
| | | *Aenictus* sp. 1 | 1244 | 3 | 3 | | |
| Cerapachinae | Cerapachyni | *Cerapachys sp.* | 2 | 99 | 39 | | |
| Dolichoderinae | Dolichoderini | *Dolichoderus thoracicus* F. Smith | 761 | 22 | 7 | # | C, S, P, L,T |
| | | *Ochetellus* sp. 1 | 8 | 44 | 33 | | |
| | | *Tapinoma indicum* | 20 | 60 | 31 | # | C, L, S, T |
| | | *Tapinoma melanochepalum* | 43 | 61 | 26 | # | C, P, S |
| Formicinae | Camponotini | *Camponotus (Myrmanblys) reticulatus bedoti* Emery | 8 | 6 | 33 | # | C, T |
| | | *Camponotus (Myrmanblys)* sp. 1 | 13 | 7 | 32 | # | C, S, T |
| | | *Camponotus (Tanaemyrmex)* sp. 2 | 55 | 8 | 23 | (sp. 3) | C, B |
| | | *Camponotus* sp. 3 | 4 | 9 | 37 | | |
| | | *Camponotus* sp. 4 | 2 | 10 | 39 | | |
| | | *Camponotus (Tanaemyrmex* ) sp. 5 | 1 | 11 | 40 | (sp. 6) | C, T |
| | | *Polyrhachis (Myrmhopla) dives* F. Smith | 3 | 73 | 38 | # | C, P |
| | | *Polyrhachis (Myrma) proxima* Roger | 1 | 74 | 40 | # | C, T |
| | | *Polyrhachis (Myrma)* sp. 3 | 3 | 77 | 38 | (sp. 4) | T |
| | Lasiini | *Paratrechina* sp. 1 | 758 | 56 | 8 | (sp. 3) | C, B, P, L, S, T |
| | | *Paratrechina* sp. 2 | 25 | 57 | 30 | (sp. 17) | C, S |
| | | *Paratrechina* sp. 7 | 5 | 62 | 36 | (sp. 12) | C, S |
| | | *Paratrechina* sp. 9 | 1 | 103 | 40 | # | F |
| | Oecophylini | *Oechophylla smaradigna* Fabricius | 5 | 50 | 36 | # | C, P, L, S, T |
| | Plagiolepidini | *Anoplolepis gracilipes* ( F. Smith) (=*longipes* Jerdon) | 3586 | 5 | 2 | # | C, L, P, S, T |

| Subfamily | Tribe | Species | Total number of individuals collected | Code | Abundance ranking | Records in Ito et al. (2001) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Name* | Collection methods** |
| Myrmicinae | Crematogastrini | *Crematogaster* sp. 1 | 5 | 13 | 36 | | |
| | | *Crematogaster difformis* F. Smith | 3 | 15 | 38 | # | C, L, T |
| | Dacetonini | *Pyramica* sp. 1 | 38 | 84 | 28 | | |
| | | *Strumigenys* sp. 1, ? *kraepelini* Forel | 87 | 85 | 22 | (sp. 7) | C, F |
| | | *Strumigenys rogery* | 5 | 86 | 36 | # | C, L |
| | | *Strumigenys emmae* Forel | 6 | 87 | 35 | | |
| | Formixiocenini | *Cardiocondyla* sp. 5 | 3 | 93 | 38 | # | C, T |
| | Meranoplini | *Meranoplus bicolor* Guréin_Méneville | 5 | 33 | 36 | # | C, P |
| | Pheidologetonini | *Lophomyrmex opaciceps* Viehmeyer | 872 | 32 | 4 | # | C, P, L |
| | | *Pheidologeton affinis* Jerdon | 733 | 72 | 9 | # | C, P, L, T |
| | | *Pheidologeton* sp. 1 | 835 | 67 | 6 | | |
| | Pheidolini | *Pheidole plagiaria* F. Smith | 15703 | 64 | 1 | # | C, B, P, L, T |
| | | *Pheidole butteli* Forel | 34 | 70 | 29 | # | C, P, L |
| | | *Pheidole* sp. 1 | 7 | 65 | 34 | # | C, F |
| | Selenopsidini | *Monomorium destructor* Jerden | 624 | 34 | 10 | # | S |
| | | *Monomorium floricola* Jerden | 39 | 37 | 27 | # | C, P, L, S, T |
| | | *Monomorium pharaonis* Lin | 54 | 39 | 24 | # | S |
| | Tetramoriini | *Tetramorium pacificum* Mayr | 247 | 90 | 15 | # | C, L, S, T |
| | | *Tetramorium similinum* F. Smith | 224 | 91 | 16 | # | C, S |
| Ponerinae | Odontomachini | *Anochetus graefferi* Mayr | 98 | 4 | 21 | # | C, L |
| | | *Odontomachus rixosus* F. Smith | 3 | 45 | 38 | # | C, P, L |
| | | *Odontomachus simillimus* F. Smith | 559 | 46 | 12 | # | C, P, L, T |
| | Ponerini | *Diacamma rugosum* Le Guillou | 160 | 21 | 19 | # | C, P, S, T |
| | | *Hypoponera* sp. 1 | 359 | 23 | 13 | (sp. N2) | C, P, L |
| | | *Hypoponera* sp. 3 | 4 | 25 | 37 | (sp. N5) | C, L |
| | | *Leptogenys mutabilis* F. Smith | 564 | 27 | 11 | # | C, P, L |
| | | *Leptogenys* sp. 1 | 112 | 29 | 20 | (sp. 25) | C, P |
| | | *Odontoponera denticulata* F. Smith | 851 | 49 | 5 | # | C, P, L, S |
| | | *Pachycondyla (=Trachymesops) sharpi* Forel | 162 | 51 | 18 | # | C, P |
| | | *Pachycondyla (=Brachyponera) chinensis* Emery | 6 | 52 | 35 | # | C, P, L, T |
| | | *Pachycondyla (=Ectonomyrmex)* sp. 3, ?*javana* Mayr | 2 | 53 | 39 | # | C, P, L, T |
| | | Total number of individuals | 29424 | | | | |
| | | Total number of species | 55 | | | | |

*; #: the same scientific name as in this article. ( ): the code used in Ito et al., (2001).
**; T= tree trunk, L = litter sifting, P = pitfall traps, S = sugar baits, B = bamboo shoots, F = taken by only collection of foraging worker, C = colony collection

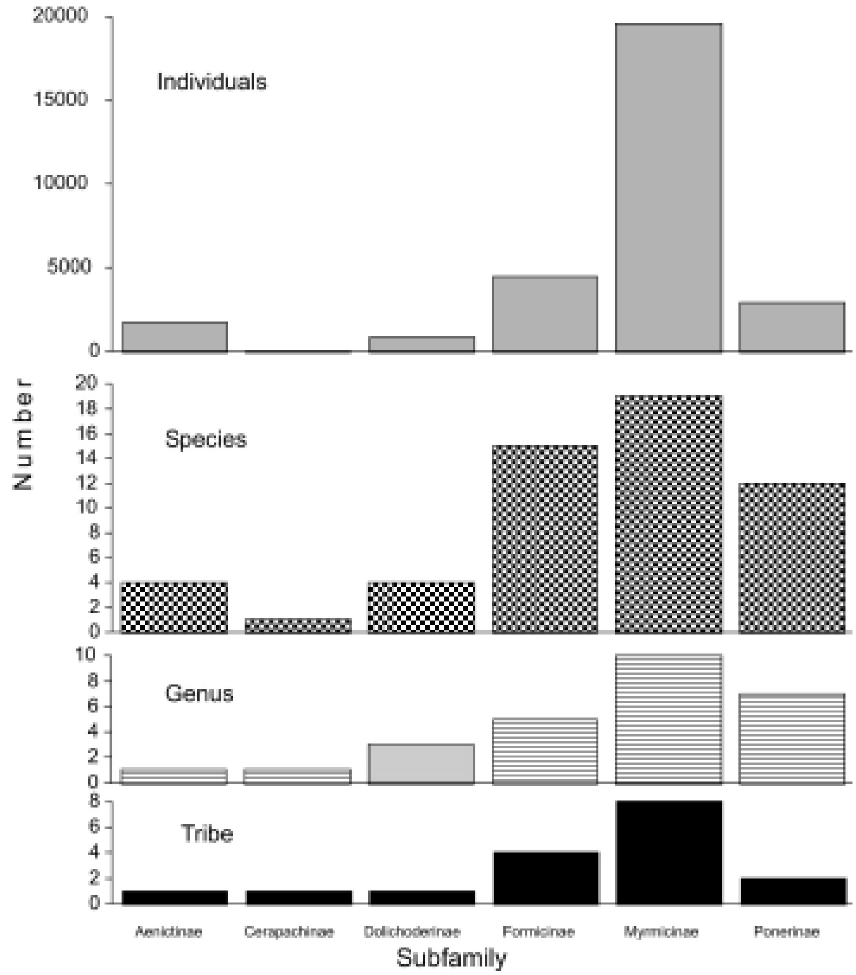


**Figure 2.** Number of tribes, genera, species and individuals of ants in each subfamily collected using pitfall traps during the study period in Bogor, West Java

Species

1. Rank abundance relationship

Figure 3 shows the rank/abundance relationship of ant species collected during the whole study period. The abundances of the 55 species varied largely from only 1 to 15703 individuals. As the line for expected values derived from geometric model indicates, the most dominant species was by far over presented (Figure 3).

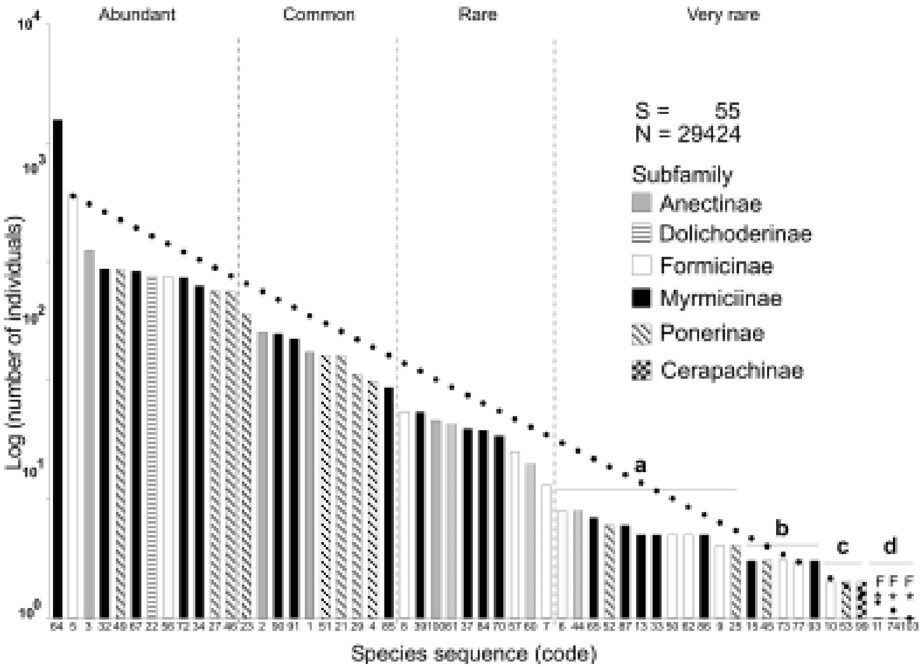


**Figure 3.** Rank - abundance relationships of ant species collected using the pitfall traps during the study period in Bogor, West Java. Numerals 1–103 on x-axis: species code (see Table 1). *N*: total number of individuals collected, *S*: total number of species collected. Vertical line indicates the border of abundance categories (i.e., ″very rare″, ″rare″, ″common″ and ″abundant″, see the text for explanations of the categories). In the very rare species, ″a″, ″b″, ″c″ and ″d″ indicate the species, of which 4 – 8 individuals, 3, 2, and 1, respectively, were collected during the study period. F in ″d″ of the very rare species indicates the Formicinae subfamily. Line with solid circle: the values expected by geometric series. Pattern of histogram refers to the subfamily

## 2. Abundance classes

Table 2 shows the number of ant species in each subfamily belonging to different abundance classes. The most dominant Myrmicinae group, covering all the classes, was represented by 7 “very rare”, 4 “rare”, 3 “common” and 5 “abundant” species. The Formicinae group ranged from “very rare” (10 spp.), “rare” (3 spp.) to “abundant” (2 spp.), and Ponerinae from “very rare” (4 spp.), “common” (5 spp.) to “abundant” class (3 spp.). For minor subfamilies, Aenictinae contained 3 classes: “rare”, “common” and "abundant" (each had 1, 2 and 1 species, respectively), Dolichoderinae "very rare", "rare" and " abundant " (each had 1, 2 and 1 species, respectively) and Cerapachinae contained only 1 "very rare" species. Each abundance class comprised 3-5 subfamilies, *e.g.*, the "abundant" class was composed of Formicinae (2 spp.), Myrmicinae (5), Ponerinae (3) and Dolichoderinae (1), and the "very rare" class included the 3 dominant subfamilies, Dolichoderinae and Cerapachinae (Table 2).

The "abundant" class was represented by 12 species with a total of 27090 individuals (92.1 % of all ants collected, and the number of individuals per species ranged from 559-15703). *Pheidole plagiaria* (ant code 64, Myrmicinae) was the most abundant with 15703 individuals (53.4%), followed by *Anoplolepis gracilipes* (ant code 5, Formicinae) with 3586 individuals (12.2 %) and *Aenictus* sp. 1 (ant code 3, Aenictinae) with 1244 individuals (4.2 %). Fourth ranked *Lophomyrmex opaciceps* (ant code 32, Myrmicinae) and 5$^{th}$ ranked *Odontoponera denticulata* (ant code 49, Ponerinae) had 872 (3.0 %) and 851 (2.9 %) individuals, respectively. The "common" class contained 10 species with a total of 1875 individuals (6.4 %). The number of individuals of each species ranged from 87 to 359 individuals. The "rare" class contained 10 species with a total of 367 individuals (1.3 %). Each species had 13 to 55 individuals. The "very rare" class contained 23 species (41.8 % of all species). Only 1 individual was collected for 3 species (5.5 %), 2 individuals for 3 species (5.5 %), and 3 individuals for 5 species (9.1 %).

**Table 2.** Total number of ant species in each abundance category. The numbers in parenthesis are the percentage. The ant species are counted in each subfamily. See the text for abundance categories

| **Subfamily** | **Abundance class** | | | | |
|---|---|---|---|---|---|
| | **Abundant** | **Common** | **Rare** | **Very rare** | **Total** |
| Aenictinae | 1 (1.8) | 2 (3.6) | 1 (1.8) | | 4 (7.3) |
| Cerapachinae | | | | 1 (1.8) | 1 (1.8) |
| Dolichoderinae | 1 (1.8) | | 2 (3.6) | 1 (1.8) | 4 (7.3) |
| Formicinae | 2 (3.6) | | 3 (5.5) | 10 (18.2) | 15 (27.3) |
| Myrmicinae | 5 (9.1) | 3 (5.5) | 4 (7.3) | 7 (12.7) | 19 (34.5) |
| Ponerinae | 3 (5.5) | 5 (9.1) | | 4 (7.3) | 12 (21.8) |
| *Total* | 12 (21.8) | 10 (18.2) | 10 (18.2) | 23 (41.8) | 55 (100.0) |

3. Species abundance distribution

Figure 4 shows the log normal distributions of relative abundance for all ant species during the whole study period. Comparing the observed distribution with the expected log normal distribution, the proportion of classes II and III (“very rare” species represented by 4-8 individuals) and X (“abundant” species with 513-1024 individuals) were higher, but that of classes I (“very rare” species represented by 1-2 individuals), IV-VII (“rare” and “common” species with 9-128 individuals), IX (“abundant” species with 256-512 individuals) and classes XI and XIV (“abundant” species with more than 2048 individuals) were lower. The observed distribution was significantly different from the log normal distribution ($c^2 = 32.5$, $c^2$ tab = 19.675, $P > 0.05$) (Magurran, 1988).

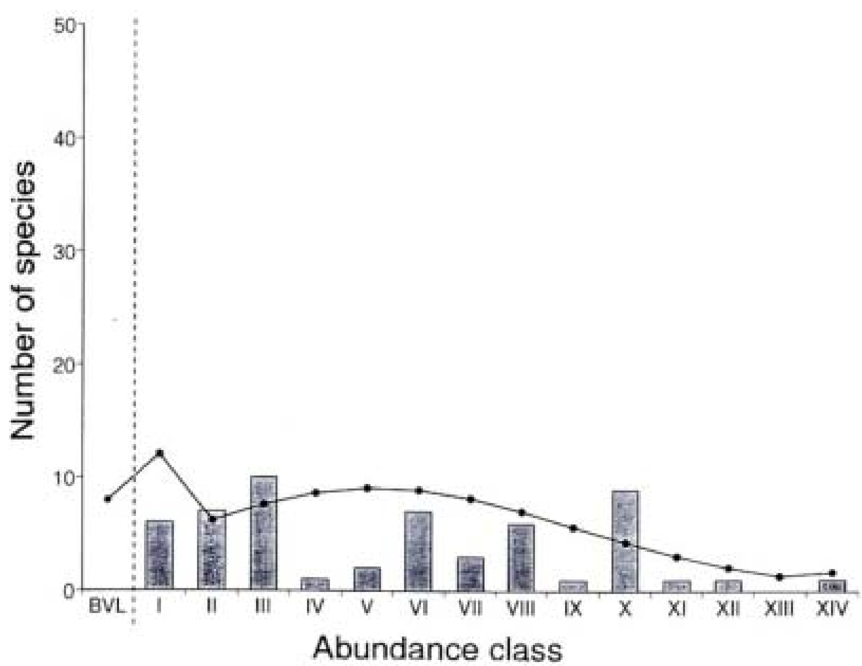


**Figure 4.** Species-abundance distribution in geometric series of the ants collected using pitfall traps during the study period in Bogor, West Java. Upper boundary of each class is as follows: Class I = $2^1$ +0.5, class II = $2^2$ +0.5, class III = $2^3$ +0.5,…, class XIV = $2^{14}$ +0.5 (see the text for further explanation). Closed column shows the number of species observed, and the line the expected number by log normal. BVL: veil line of the log normal distribution

4. Species diversity

Shannon and Simpson diversity indices, calculated for the whole ant sample in this study site, were 1.97 and 3.25, respectively.

## DISCUSSION

Ito *et al.* (2001) presented the species composition of ants in Bogor Botanic Garden. The study consisted of the results of pitfall trap sampling carried out once in 1985 at 16 sites across a variety of habitats (*e.g.* lawns**,** bare ground, vegetation, etc.) and those obtained by 6 sampling methods executed repeatedly between 1990 and 1998: (1) collection of ants on tree trunks, (2) collection of litter ants using a handy sifter, (3) sugar baits, (4) collection of ants on bamboo shoots, (5) searching for colonies, and (6) collection of foraging workers. Henceforth, the results obtained only using pitfall traps are referred to as "Ito-pitfall", and those obtained using the 6 methods combined with "Ito-pitfall" as "Ito-all". Their research efforts were considerably different among the methods, however, the combination of many methods provided an outline of ant fauna in the garden. Below, we will compare our results with theirs. We should remember the differences in the study methods between the 2 studies. Even though the two studies were very different concerning the sampling methods, the comparison revealed many interesting aspects, as shown below.

Ito *el al.* (2001) mentioned that the accumulation curve of ant species derived from "Ito-all" was still increasing in 1998, at the end of their study, because sampling by a combination of methods is efficient in adding new species (Longino & Colwell 1997, Agosti *et al.* 2000). While, in the present study, the curve reached a plateau because of the continuation of the same method (pitfall traps) in the small study site for a long time, resulting from, firstly, the relatively limited foraging range and/or dispersal power of ants and, secondly, the small size of the study site.

**Comparison between the ant species compositions of this study and "Ito-all"**

"Ito-all" collected 216 species in 61 genera of 9 subfamilies. Subfamilies Myrmicinae (78 spp.), Formicinae (60), and Ponerinae (54) accounted for 89% of the total ant species. We collected 55 species in 27 genera of 6 subfamilies. Myrmicinae (19 spp), Formicinae (15), and Ponerinae (12) accounted for 83.6 % of all species. In the former, the most species rich genera were *Polyrhachis* (25 spp.), *Pheidole* (14), *Camponotus* (13), *Paratrechina* (11), *Tetramorium* (10), *Hypoponera* (8), and *Strumigenys* (8). Species rich genera in this study were somewhat different and the number of species in 1 genus was lower, as shown below: *Camponotus* (6 spp.), *Paratrechina* (4), *Aenicus* (4), *Strumigenys* (3), *Polyrhachis* (3), *Pheidole* (3), *Pachycondyla* (3), and *Monomonium* (3). The present study recorded 10 species not recorded by "Ito-all", so that 226 species have been recorded so far from Bogor Botanic Garden. Among them 45 species were common in the 2 studies (Jaccard index is only 0.269). The low commonality between the species compositions of the two studies is probably more due to differences in the collection methods (Ito *et al.* 2001, Agosti *et al.* 2000) than to the rareness and/or to limited foraging range and stationary distribution of the ant species in the garden, as suggested by Ito *et al.* (2001) and this study (see below).

**Comparison between the ant species compositions of this study and "Ito-pitfall"**

"Ito-pitfall" collected 56 species in 32 genera and 6 subfamilies (1264 individuals) using pitfall traps. Myrmicinae (25 spp., 44.6 % of the species collected by this method) was most abundant, followed by Ponerinae (19 spp., 33.9 %) and Formicinae (7 spp., 12.5 %). In the present study, Myrmicinae (19 spp., 34.6 %) was the most abundat, followed by Formicinae (15 spp., 27.3 %) and Ponerinae (12 spp., 21.3 %). Dominant subfamilies were the same in the 2 studies. It should be noted, however, that species commonness was low between the two studies: only 6 species in Mirmicinae and 4 in Formicinae, however, 10 were common in Ponerinae. As a whole, 22 species in 17 genera were common in the 2 studies: in *Pheidole,* 8 and 3 species were sampled by

"Ito-pitfall" and the present study, respectively, and all of them were common. In *Pachycondyla*, 5 and 3 species were sampled and all were common. In *Leptogenys*, 5 and 2 species were sampled and 2 were common (Table 1). Two *Camponotus* species, 2 *Aenictus* species, 1 *Cerapachys* species, 1 *Crematogaster* species, 1 *Strumigenys* species, 1 *Pyramica*, 1 *Pheidolegeton* and 1 *Ocethelus* species, which were trapped in the present study, were not collected even in "Ito-all". Most of them were "very rare" species with only 1 to a few individuals sampled during the study period.

**Abundance of each species**

Ito *et al.* (2001, Table 2) listed 9 most abundant species, collected by pitfall traps. We collected all but 1 of those species in this study. Two *Odontoponera* species (we treated them as 1 species, *O. denticulata,* in this article) were most dominant in Ito's Table 2. In the present study, *Odontoponera* was ranked 5th in number. *Lophomyrmex opaciceps, Leptogenys mutabilis, Anoplolepis gracilipes, Pheidole butteli*, *Hypoponera* N2 (sp. 1 in this study) and *Pheidolegeton affinis*, ranked 3$^{rd}$ to 9$^{th}$ in Ito's Table 2, were ranked 4$^{th}$, 11$^{th}$, 2$^{nd}$, 29$^{th}$, 13$^{th}$ and 9$^{th}$, respectively, in the present study. Table 3 contrasts the sampling records of the ant species in the present study with those of Ito *et al.* (2001). Nine of 12 abundant species in this study were also collected by 1 to 6 methods, including pitfall traps, by Ito *et al.* (2001). Of 10 common species, 9 (90.0 %) were collected by some methods and 4 (40.0 %) by pitfall traps, respectively. The corresponding values of 23 very rare species were only 15 (65.2 %) and 6 (26.0 %), respectively. Table 3 indicates that the "abundant" species in the present study were truly abundant and active over a wider range of the garden. They were collected from habitats other than on the ground by "Ito-all"; on the other hand, the "very rare" species were truly very rare and localized. It should be noted that, firstly, *Aenictus* sp. 1, one of the"abundant" species ranked 3 with 1244 individuals in this study (Table 1), was not collected by "Ito-all". *Pheidolegeton* sp. 1, ranked 6 with 835 individuals and *Aenictus camposi*, ranked 14 with 253 individuals, were also not collected by "Ito-all". *Aenictus* species is nomadic and performs group raiding on other ant species (Ito *et al.* 2001, and see the reference cited therein). *Pheidolegeton* species probably also has the same habit (Hölldobler &Wilson 1990). Ito *et al.* (2001) mentioned the low density and species paucity of the ant hunter genus *Aenictus* in Bogor Botanic Garden. However, in the present study, *Aenictus* sp. 1 and *Pheidolegeton* sp. 1 suddenly formed high peaks with about 504 and 447 individuals, respectively, once during the present study. They were collected sporadically in small numbers during other periods of this study. When the mass raiding routes of these species crossed the study site, the peaks were formed. *Aenictus camposi* peaked in number gradually with about 10-40 individuals from time to time, and *Aenictus dentatus* was never found until September 2002. Seasonal changes in the numbers of each ant species will be presented elsewhere.

There is always a difficulty in classifying collected specimens into biological species because several ant species show a remarkable morphological dimorphism or variation among workers. In pitfall samples, ants derived from different colonies are mixed, and we are never confident of the combination of minors and majors (Ito *et al.* 2001). To understand the present status of ant diversity and its fluctuation over time in the present study, we need to continue monitoring by pitfall traps, coupled with different sampling methods from time to time. The collection of colonies and gathering of biological data (*e.g.* social structure, foraging habit, and life history pattern) are also necessary.

**Table 3.** Contrasting the sampling records of ant species collected using pitfall traps in the present study with those of Ito et al. (2001). The ant species are classified into four abundance classes. ( ): %, [ ]: range for the species collected at least once

| **Ant species in the present study** | | **Corresponding records of the ant species of Ito *et al.* (2001)** | | |
|---|---|---|---|---|
| **Abundance class** | **No. of species** | **No. of species collected using pitfall traps** | **No. of species collected by any methods in Ito et al. (2001)** | **Average no. of methods in which the ants species were collected** |
| Abundant | 12 | 9 (75.0) | 10 (83.3) | 3.9 [1-6] |
| Common | 10 | 4 (40.0) | 9 (90.0) | 2.5 [2-4] |
| Rare | 10 | 3 (30.0) | 9 (90.0) | 2.6 [1-5] |
| Very rare | 23 | 6 (26.0) | 15 (65.2) | 2.6 [1-5] |
| Total | 55 | 22 (40.0) | 43 (78.1) | - |

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