Songklanakarin J. Sci. Technol.
33 (2), 151-161, Mar. - Apr. 2011

SONGKLANAKARIN JOURNAL OF SCIENCE AND TECHNOLOGY
http://www.sjst.psu.ac.th

*Original Article*

# Diversity of ants (Hymenoptera: Formicidae) in two rubber plantations in Songkhla Province, Southern Thailand

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Received 25 November 2010; Accepted 30 April 2011

**Abstract**

Ants play important roles in tropical rainforest ecosystems. In southern Thailand, many such areas have been extensively logged and replaced by rubber plantations. Since changes to the environment can cause changes to the diversity of flora and fauna, the objectives of this study were to determine habitat influences on the ant composition between homogenous and heterogeneous rubber plantations, and to investigate if any environmental factors can be directly correlated with changes in the ant community. Three 100 m–line-transects, spaced 100 m apart, were laid out at two study sites. Four sampling methods, hand collecting (HC), leaf litter sampling (LL), honey bait (HB) and soil sampling (SS), were used to sample ants. Temperature, humidity, and precipitation were recorded. Samples were collected every two months from June 2004 to April 2005. The results showed that a total of six subfamilies (Aenictinae, Dolichoderinae, Formicinae, Myrmicinae, Ponerinaem and Pseudomyrmecinae), comprising 29 genera and 87 species were found in the two study sites. The dominant genera were *Pheidole* and *Crematogaster*, followed by *Pheidologeton* and *Pachycondyla*. The sampling methods used in this study indicated that LL and HC were most suitable for sampling ants, and any combination of sampling methods detected more ant species than a single method did. Detrended correspondence analysis (DCA) grouped ant species between the two types of rubber plantation, and also divided ant species into three groups by sampling method: HC group, SS group and LL+HB group. DCA did not group ant species by seasonal changes, however. Further, canonical correspondence analysis detected no effect of temperature, humidity, or precipitation on the ant community.

**Keywords:** diversity, ant, rubber plantation, sampling methods, southern Thailand

## 1. Introduction

Vast areas of tropical lowland rainforests are being logged around the world, causing extensive deforestation. Although such logging has been banned in Thailand, it still exists. Deforested land is converted to agriculture, mainly for cash crop production, e.g., fruit orchards (in general for plants produce eating fruit such as rambutan, durian, mangosteen ect.), or palm oil and rubber plantations. In southern Thailand rubber plantations are important as they generate a high annual income (Watanasit, 2003).

Deforestation of tropical rainforests causes a loss of taxonomic diversity in a wide range of plants as well as animals (Laurance and Bierregaard, 1997.), e.g., birds (Christiansen and Pitter, 1997), bats (Lane et al., 2006), dung beetles (Horgan, 2005), and other insects (Didham, 1996). Tropical forests have the highest range of biodiversity of any ecosystem on earth, but are being lost at the rate of approximately 1.2% per year in Asia (Whitmore, 1997). In Thailand, forest cover has been reduced from 53% of the country (Bhumibamon, 1986) to about 22.8% or 111,010 $km^2$ (FAO, 1997), causing habitat destruction and disturbance. In the lowlands, the natural forest cover has almost completely vanished, while the remaining forests have been fragmented and degraded (Graham and Round, 1994)

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Apart from the comparatively well studied influences of logging on some rainforest communities, there is little known about the communities that persist in forest-like plantation habitats such as the rubber and oil palm plantations (Brühl, 2001). These homogeneous plantation habitats are expected to be of low value to native rainforest dwellers. Bickel and Watanasit (2005) found that there was a substantial decline in ant diversity from the undisturbed forest towards a rural agricultural area along a gradient of environmental disturbances.

Logging in a forest of the Ton Nga Chang Wildlife Sanctuary was shown to have a big impact on ant diversity when compared to the primary forest (Boonroadpong, 1996) with a much higher diversity in primary than secondary forest. Similarly, the diversity of ants in a disturbed was lower than in an undisturbed habitat at the Klong U-Tapao Basin in southern Thailand (Watanasit *et al.*, 2007).

Rubber plantations can be classified into two types: homogeneous and heterogeneous plantations. Homogeneous plantations support only rubber plants without any other kind of plants, while heterogeneous plantations can have a mix of different plant crops. The heterogeneous plantations represent the old fashioned way of growing rubber in southern Thailand, but many owners have abandoned them. Consequently, plantations in these areas are composed of a variety of plant species.

Because of their ecological significance in forest ecosystems, ants are considered suitable bioindicator species for biodiversity studies (Alonso, 2000). Maryati (1996) reported that ants improved the forest soil, assisted in the decomposition processes, served as food resources, and exerted a positive effect in the regeneration processes of forest trees. Moreover, ants have been used as biological agents of insect pests in agriculture in many countries such as Malaysia (Khoo and Chung, 1989), Thailand (Kritsaneeapiboon and Saiboon, 2000), Africa and Papua New Guinea (Way, 1954). Although ants have relatively low species diversity, they are the single most important arthropod group by their dominance in animal biomass (Alonso and Agosti, 2000) The most common methods used for ant sampling are hand collection (Romero and Jaffe, 1989; Samson *et al.*, 1997; Watanasit, 2003), leaf litter (Levings, 1983; Brühl, 2001), pitfall traps (Torres, 1984; Watanasit *et al.*, 2000), honey baits (Yamane and Hashimoto, 1999) and insecticide fogging (Wilson, 1987, Watanasit *et al.*, 2005b). Many studies have shown that a combination of different methods probably produces more accurate results especially in the evaluation of ant community composition, than does any single sampling method (Watanasit, 2003; Watanasit *et al.*, 2003; Noonanant *et al.*, 2005).

Environmental changes have an impact on macroarthropod abundance (Pearson and Derr, 1986; Adis and Latif, 1996). Many ant species are highly sensitive to the microclimate fluctuations and to habitat structure, and thus respond strongly to environmental change (Anderson, 1990; Alonso *et al.*, 2000).

Climatic factors such as temperature, precipitation and relative humidity vary seasonally, and may affect the diversity, distribution and abundance of many groups of insects (Samway, 1994). Watanasit et al. (2000) found that temperature, precipitation, and humidity can have both a positive and negative influence on the numbers of species.

## 2. Material and Methods

### 2.1 Study site

Two study sites, representing homogeneous and heterogeneous rubber plantations, were chosen in the area of Kho Hong Hill (7° 00.4' N, 100° 30.7' E) (detail see Watanasit *et al.*, 2005a). The homogenous plantation consists of rubber trees without any other tree species in the overstorey, and ground cover consisting of grasses and annual plants. The rubber trees are more than seven years old. They were planted in the uniform pattern with 8 m between two rows and 2.50 m spacing between trees in one row.

The heterogeneous rubber plantation is mixed with other tall plants such as *Barrintonia* sp. and *Artocarpus integer* (Thumb.) Merr. There is also an understorey consisting of a dense shrub layer. Thus, the homogeneous site was assumed to represent a disturbed area while the heterogeneous represented a less disturbed area.

### 2.2 Sampling and specimen processing

Ants were collected between June 2004 and April 2005. The ants were sampled every two months, for a total of six samples over the period of study. Three 100 m long line-transects, spaced >100 m apart were established at each study site for a total of six line transects per sampling period. A quadrate of 1 m x1 m was placed every 10 m alternatively to the right and left of the transect line, i.e., there were ten quadrates per line, with five on each side of the transect line. Four sampling methods, hand collecting (HC), leaf litter sampling (LL), honey bait (HB), and soil sampling (SS) were used to collect ants as follows:

1. Hand collecting: For each transect ants were picked up over a thirty minute period using forceps and an aspirator from lower vegetation within 5 m away from the line transect both left and right. The ant samples were collected to plastic containers (5.5 cm height with 2.5 cm in diameter).

2. Honey baits were used to collect ants feeding on nectar. A piece of cotton dipped in honey was placed on opposite sides of the quadrates, 50 cm from the line transect The cotton baits were left for 0.5 hrs before they were collected and placed in plastic containers as mentions above. A total of ten baits were used per transect.

3. Leaf litter samples were used to collect ground dwelling ants (some species of ants build their nest by using leaf on the ground, so this method can collect specific ant living on the ground. Moreover, it can collect ant which living on the other location for searching food on the ground). Leaf

litter was collected from each quadrate and placed in a sifter with a white pan (27x16x6 cm). Forceps and aspirator were used to collect ants from the pan. Ten samples per transect were collected.

4. Soil samples were used to collect ants living underground. A total of ten soil samples (20x20x10 cm), one per quadrate, were randomly taken along each line transect. A handy sifter (not a special make) with a white pan was used and collected ants were placed in vials (1.5 ml with 1 cm in diameter) using the forceps and aspirator.

### 2.3 Climatic data

The average monthly temperatures and relative humidity at both study sites were recorded by digital thermo-hygrometer, while the precipitation data were provided by the Meteorological Department at Hat Yai International Airport station (Table 1). The wet and dry seasons of sampling months were based on precipitation as defined by Whitmore (1990), i.e., rainfall >100 mm was defined as a wet month, while rainfall <100 mm was a dry month.

### 2.4 Data analysis

Detrended correspondence analysis (DCA) was used to discriminate between study sites and among the sampling methods used for ant species, and canonical correspondence analysis (CCA) was used to correlate environmental factors with ant species using PC-ORD (McCune and Mefford, 1997) . The frequency of ant species found had to be greater than 50% of a sampling collection, for inclusion in the calculation (100% frequency of ant species means ant species occur every time of sampling (6 sampling), thus 50% means that the ants occur only in 3 sampling times. This analysis makes the results more realistic. The frequency of ant species showed in Table 2).

The percentage of ant species was used for comparisons between and among combinations of sampling methods applying the following formula.

% of combination of n sampling methods = (N/T)x100

n = number of combination sampling methods

N = number of ant species found between n sampling methods

T = Total number of ant species

We count the total number species of ants in each sampling method and combination between sampling method.

## 3. Results

### 3.1 Ant composition and diversity

A total of 87 species of ants in 29 genera distributed among six subfamilies were identified from the homogeneous and heterogeneous plantations using all four sampling methods (Table 2). Sixty two species of ants in 24 genera and five subfamilies were found in the homogenous rubber plantation and 60 species in 25 genera and six subfamilies were from the heterogeneous rubber plantation (Table 2 and 3). The numbers of ants in each subfamily are also given in Table 3. At the genus level at both study sites, *Pheidole* had the highest number of 14 species (16.09%), followed by *Crematogaster* (11 species, 12.64%), *Pheidologeton* and *Pachycondyla* (6 species each, 6.89%) (Table 4).

### 3.2 Sampling methods and study sites

The number of ant species collected from the homogeneous rubber plantation by LL, HC, HB, and SS were 43, 36, 30, and 30, respectively, while the number of ant species collected from the heterogeneous rubber plantation by LL, HC, HB, and SS were 42, 30, 26, and 18, respectively (Table 2). This data show the overall species occurrence and the frequency used in the multivariate analysis.

A combination of ant sampling methods from the homogeneous plantation detected a higher number of species than did a single collection method. The combination of two methods (HC and LL) detected 58 species (93.54%) (Table 5) and the combination of three methods (SS, LL and HC or SS, HB and HC or LL, HB and HC) gave an even higher but equal number of species (61 species, 98.38%, see Table 6). A combination of ant sampling methods from the heterogeneous plantation also showed that the combination of two methods (HC and LL) detected a higher number of 55 species (91.66%, Table 7), while the combination of three methods (SS, LL and HC) detected 59 species (98.33%, Table 8). This is a descriptive analysis with the model of sampling method shown in Figure 2.

The study sites and sampling methods could be grouped by DCA according to the species of ants found. The

Table 1. The rainfall (mm) data of each month from June 2004 to April 2005 during sampling ant period (Source: Southern Meteorological Office, Hat Yai International Airport).

| Month | Jun 04 | Aug | Oct | Dec | Feb 05 | Apr |
|---|---|---|---|---|---|---|
| Rainfall (mm) | 150 | 79.2 | 263.2 | 152 | 1.8 | 16.4 |

Table 2. List of ant species, percentage of ants and frequency of occurrence collected by four sampling methods: LL (leaf litter samples), HB (honey bait), HC (hand collection) and SS (soil sampling): from a homogenous and heterogeneous rubber plantation between June 2004 to April 2005. Note: + = present, - = not present.

| Taxa | Homogenous | | | | Heterogeneous | | | | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| | LL | HB | HC | SS | LL | HB | HC | SS | |
| Subfamily Aenictinae | | | | | | | | | |
| 1. *Aenictus laeviceps* (Fr. Smith) | - | - | - | - | - | - | + | - | 3 |
| Subfamily Dolichoderinae | | | | | | | | | |
| 2. *Dolichoderus thoracicus* (Fr. Smith) | - | - | + | - | + | - | + | - | 3 |
| 3. *Tapinoma melanocephalum* Fabricius | + | + | + | - | + | + | + | - | 6 |
| 4. *T.* sp.1 | + | + | + | + | - | - | - | - | 5 |
| 5. *T.* sp.2 | + | - | - | + | + | - | - | - | 3 |
| 6. *T.* sp.4 | + | - | - | + | - | - | - | - | 2 |
| 7. *Technomyrmex butteli* Forel | - | + | + | - | - | + | - | - | 5 |
| 8. *T. modiglianii* Emery | - | + | + | + | + | - | + | - | 4 |
| 9. *T.* sp.1 | - | - | - | - | + | + | - | - | 4 |
| 10. *T.* sp.2 | - | + | - | - | - | + | + | - | 4 |
| 11. *T.* sp.3 | - | + | + | - | - | - | - | - | 3 |
| Subfamily Formicinae | | | | | | | | | |
| 12. *Anoplolepis gracilipes* (Fr. Smith) | + | + | + | - | - | + | + | - | 6 |
| 13. *Camponotus (Colobopsis) leonardi* Emery | - | - | - | - | + | - | + | - | 4 |
| 14. *C.* (*Myrmosericus*) *rufoglaucus* (Jerdon) | - | - | + | - | - | - | - | - | 4 |
| 15. *C. (Tanaemyrmex)* sp.1 | - | - | + | - | - | - | - | - | 3 |
| 16. *C. (Tanaemyrmex)* sp.2 | - | - | - | - | + | + | + | - | 6 |
| 17. *Euprenolepis* sp. | + | + | + | - | + | - | + | - | 5 |
| 18. *Oecophaylla smaragdina* (Fabricius) | + | + | + | - | + | + | + | - | 6 |
| 19. *Paratrechina longicornis* (Latreille) | + | + | + | + | - | - | - | - | 6 |
| 20. *P. opaga* (Emery) | + | + | - | + | - | - | - | - | 2 |
| 21. *P.* sp.4 | + | + | + | + | - | - | - | - | 3 |
| 22. *P.* sp.6 | + | + | - | + | - | - | - | - | 2 |
| 23. *P.* sp.9 | + | + | + | + | - | - | - | - | 5 |
| 24. *Polyrhachis (Myrma) illaudata* (Walker) | - | - | - | - | - | + | + | - | 5 |
| 25. *P. (Myrmatopa)* sp. | - | - | + | - | + | - | - | - | 2 |
| 26. *Pseudolasius* sp. | - | - | + | - | - | - | + | - | 5 |
| Subfamily Myrmicinae | | | | | | | | | |
| 27. *Cataulacus horridus* Fr. Smith | - | - | - | - | - | - | + | - | 3 |
| 28. *Crematogaster (Crematogaster) rogenhoferi* Mayr | - | - | + | - | - | - | - | - | 4 |
| 29. *C. (Crematogaster)* sp.3 | - | - | - | - | - | - | + | - | 3 |
| 30. *C. (Crematogaster)* sp.4 | + | - | + | - | + | - | - | - | 2 |
| 31. *C. (Orthocrema)* sp.1 | - | - | + | - | + | + | + | - | 6 |
| 32. *C. (Orthocrema)* sp.2 | - | - | + | - | - | - | + | - | 4 |
| 33. *C. (Orthocrema)* sp.3 | - | - | - | - | + | + | + | - | 2 |
| 34. *C. (Orthocrema)* sp.4 | + | - | + | - | - | - | + | - | 6 |
| 35. *C. (Orthocrema)* sp.7 | + | - | + | - | - | - | - | - | 3 |
| 36. *C. (Paracrema) modigliani* Emery | - | - | + | - | + | - | + | - | 4 |
| 37. *C. (Paracrema)* sp.2 | - | - | - | - | + | - | + | - | 6 |
| 38. C. (*Paracrema*) sp.3 | - | - | - | - | - | - | + | - | 2 |
| 39. *Dilobocondyla* sp. | - | - | - | - | - | - | + | - | 2 |
| 40. *Monomorium* sp.2 | + | + | + | + | + | + | - | + | 4 |
| 41. *M.* sp.5 | + | - | + | - | - | - | - | - | 2 |
| 42. *M.* sp.6 | - | + | - | - | - | - | - | - | 1 |
| 43. *Oligomyemex* sp.4 | + | - | - | + | + | + | - | + | 6 |

Table 2. (Continued)

| Taxa | Homogenous LL | Homogenous HB | Homogenous HC | Homogenous SS | Heterogeneous LL | Heterogeneous HB | Heterogeneous HC | Heterogeneous SS | Frequency |
|---|---|---|---|---|---|---|---|---|---|
| 44. *O.* sp.5 | + | - | - | + | - | - | - | + | 3 |
| 45. *O.* sp.7 | + | - | - | + | + | + | - | + | 4 |
| 46. *Pheidole aglae* Forel | + | - | - | - | + | + | - | + | 6 |
| 47. *P. annexus* Eguchi | - | - | + | - | - | - | - | - | 3 |
| 48. *P. aristotelis* Forel | - | - | - | - | + | - | - | + | 3 |
| 49. *P. butteli* Forel | - | - | - | - | + | + | - | + | 5 |
| 50. *P. cariniceps* Eguchi | - | - | - | - | + | - | - | - | 1 |
| 51. *P. hortensis* Forel | - | - | - | - | + | + | + | + | 5 |
| 52. *P. plagiaria* (Fr. Smith) | + | + | - | + | + | + | + | - | 6 |
| 53. *P. plinii* Forel | + | + | - | + | - | - | - | - | 5 |
| 54. *P .sauberi* Forel | + | + | - | - | + | + | - | + | 5 |
| 55. *P. tandjongensis* Forel | + | + | - | + | - | - | - | - | 4 |
| 56. *P.* sp.2 | - | - | - | - | - | + | - | + | 3 |
| 57. *P.* sp.8 | + | + | - | + | - | - | - | - | 6 |
| 58. *P.* sp.9 | + | + | - | - | - | - | - | - | 2 |
| 59. *P.* sp.16 | + | + | - | + | + | + | - | + | 6 |
| 60. *Pheidologeton affinis* (Jerdon) | - | - | - | - | + | - | - | + | 4 |
| 61. *P.* sp.1 | + | - | + | + | + | - | - | - | 6 |
| 62. *P.* sp.2 | + | - | + | + | - | - | - | - | 5 |
| 63. *P.* sp.3 | + | + | - | - | + | + | - | + | 3 |
| 64. *P.* sp.4 | - | - | - | - | + | - | - | - | 4 |
| 65. *P.*sp.5 | + | - | + | + | + | - | - | - | 5 |
| 66. *Pyramica* sp. | + | - | - | + | - | - | - | - | 5 |
| 67. *Strumigenys* sp. | - | - | - | + | + | - | + | - | 6 |
| 68. *Tetramorium pacificum* Mayr | - | - | - | - | + | + | + | - | 5 |
| 69. *T. kheperra* (Bolton) | - | - | - | - | + | - | + | - | 2 |
| 70. *T.* sp.9 | - | - | + | - | - | - | - | - | 3 |
| 71. *T.* sp.3 | - | - | - | - | + | - | + | + | 4 |
| Subfamily Ponerinae | | | | | | | | | |
| 72. *Anochetus* sp. | + | - | - | - | - | - | - | + | 2 |
| 73. *Diacamma sculpturata* (Fr. Smith) | - | - | - | - | + | + | - | - | 6 |
| 74. *Leptogenys* sp.1 | + | - | - | + | - | - | - | - | 4 |
| 75. *L.* sp.4 | + | - | - | + | - | - | - | - | 3 |
| 76. *Odontomachus similimus* (Fr. Smith) | + | + | + | + | - | - | - | - | 3 |
| 77. *Odontoponera denticulata* ( Fr. Smith) | + | + | + | - | + | + | + | + | 6 |
| 78. *O. transversa* ( Fr. Smith) | + | + | + | - | + | + | - | - | 5 |
| 79. *Pachycondyla (Bothroponera)* sp.1 | - | - | - | - | + | - | - | - | 1 |
| 80. *P. (Brachyponera) chinensis* Emery | + | + | - | + | - | - | - | - | 5 |
| 81. *P. (Ectomomyrmex)* sp.1 | - | - | - | - | - | + | - | - | 4 |
| 82. *P.* sp.1 | + | - | + | + | + | - | - | + | 5 |
| 83. *P.* sp.2 | - | + | - | + | - | - | - | - | 2 |
| 84. *P.* sp.4 | + | - | - | + | + | - | - | + | 6 |
| 85. *Ponera* sp. | - | - | - | - | + | - | - | - | 2 |
| Subfamily Psuedomyrmecinae | | | | | | | | | |
| 86. *Tetraponera attenuata* (Fr. Smith) | + | + | + | - | - | - | + | - | 6 |
| 87. *T.* sp.2 | - | - | + | - | - | - | + | - | 2 |
| Total of ant species | 43/62 | 30/62 | 36/62 | 30/62 | 42/60 | 26/60 | 30/60 | 18/60 | 87 |
| Percentage (%) | 69.35 | 48.38 | 58.06 | 48.38 | 70.00 | 43.33 | 50.00 | 30.00 | |

Table 3. Subfamilies, genera and species of ants from a homogeneous and heterogeneous rubber plantation by using a combination of 4 methods from June 2004 toApril 2005.

| Subfamilies | Homogeneous rubber plantation | | Heterogeneous rubber plantation | | Total | |
|---|---|---|---|---|---|---|
| | Genera | Species | Genera | Species | Genera | Species |
| 1. Aenictinae | - | - | 1 | 1 | 1 | 1 |
| 2. Dolichoderinae | 3 | 9 | 3 | 7 | 3 | 10 |
| 3. Formicinae | 7 | 12 | 6 | 7 | 7 | 15 |
| 4. Myrmicinae | 8 | 29 | 9 | 34 | 10 | 45 |
| 5. Ponerinae | 5 | 10 | 5 | 9 | 7 | 14 |
| 6. Psuedomyrmecinae | 1 | 2 | 1 | 2 | 1 | 2 |
| total | 24 | 62 | 25 | 60 | 29 | 87 |

Table 4. Species number and percentage of ants in each genera from both study sites (homogeneous and heterogeneous rubber plantations) by using a combination of 4 methods between June 2004 - April 2005,

| Genera | Species | % |
|---|---|---|
| *Aenictus* | 1 | 1.14 |
| *Dolichoderus* | 1 | 1.14 |
| *Tapinoma* | 4 | 4.59 |
| *Technomyrmex* | 5 | 5.74 |
| *Anoplolepis* | 1 | 1.14 |
| *Camponotus* | 4 | 4.59 |
| *Euprenolepis* | 1 | 1.14 |
| *Oecophylla* | 1 | 1.14 |
| *Paratrechina* | 5 | 5.74 |
| *Polyrhachis* | 2 | 2.29 |
| *Pseudolasius* | 1 | 1.14 |
| *Cataulacus* | 1 | 1.14 |
| *Crematogaster* | 11 | 12.64 |
| *Dilobocondyla* | 1 | 1.14 |
| *Monomorium* | 3 | 3.44 |
| *Oligomyemex* | 3 | 3.44 |
| *Pheidole* | 14 | 16.09 |
| *Pheidologeton* | 6 | 6.89 |
| *Pyramica* | 1 | 1.14 |
| *Strumigenys* | 1 | 1.14 |
| *Tetramorium* | 4 | 4.59 |
| *Anochetus* | 1 | 1.14 |
| *Diacamma* | 1 | 1.14 |
| *Leptogenys* | 2 | 2.29 |
| *Odontomachus* | 1 | 1.14 |
| *Odontoponera* | 2 | 2.29 |
| *Pachycondyla* | 6 | 6.89 |
| *Ponera* | 1 | 1.14 |
| *Tetraponera* | 2 | 2.29 |

eigenvalue of Axis I and Axis II were 0.4595 and 0.3144, respectively. A total of 48 species of ants were included in the analysis. The analysis could divide the ant species into two groups with 20 species present only in the homogeneous rubber plantation and 17 species only in the heterogeneous rubber plantation (Figure 1). The remaining 21 species were collected from both study sites.

The different sampling methods separated the ant species into three groups. About 10 species and 6 species were the majority collected by HC and SS, respectively, while

Table 5. Comparison between the numbers of ant species from a homogenous rubber plantation collected using a combination of two sampling methods at Kho Hong Hill.

| | LL | HB | HC |
|---|---|---|---|
| SS | 46 (74.19%) | 44 (70.96%) | 55 (88.70%) |
| LL | - | 49 (79.03%) | 58 (93.54%) |
| HB | - | - | 50 (80.64%) |

Note: list of ant species see Table 2.

Table 6. Comparison between the numbers of ant species from a homogenous rubber plantation collected using a combination of three sampling methods at Kho Hong Hill.

| | HB | HC |
|---|---|---|
| SS+LL | 54 (87.09%) | 61 (98.38%) |
| SS+HB | - | 61 (98.38%) |
| LL+HB | - | 61 (98.38%) |

Note: list of ant species see Table 2.

Table 7. Comparison between the numbers of ant species from a heterogeneous rubber plantation collected using a combination of two sampling methods at Kho Hong Hill.

| | LL | HB | HC |
|---|---|---|---|
| SS | 46 (76.66%) | 33 (55.00%) | 45 (75.00%) |
| LL | - | 48 (80.00%) | 55 (91.66%) |
| HB | - | - | 44 (73.33%) |

Note: list of ant species see Table 2.

Table 8. Comparison between the numbers of ant species from a heterogeneous rubber plantation collected using combination of three sampling methods at Kho Hong Hill.

| | HB | HC |
|---|---|---|
| SS+LL | 50 (83.33%) | 59 (98.33%) |
| SS+HB | - | 50 (83.33%) |
| LL+HB | - | 58 (96.66%) |

Note: list of ant species see Table 2.

the rest was collected by both LL and HB (Figure 2). However, seasonal change could not distinguish between ant species in this study (Figure 3).

### 3.3 Climatic factors

The analysis of the relationship of the species and climatic factors was carried out by CCA. The first, second, and third axis had an eigenvalue of 0.083, 0.76, and 0.045, respectively. Thus, the first and second axis was used for predicting the correlation between species specific and climate factors. The ordination analysis of the species

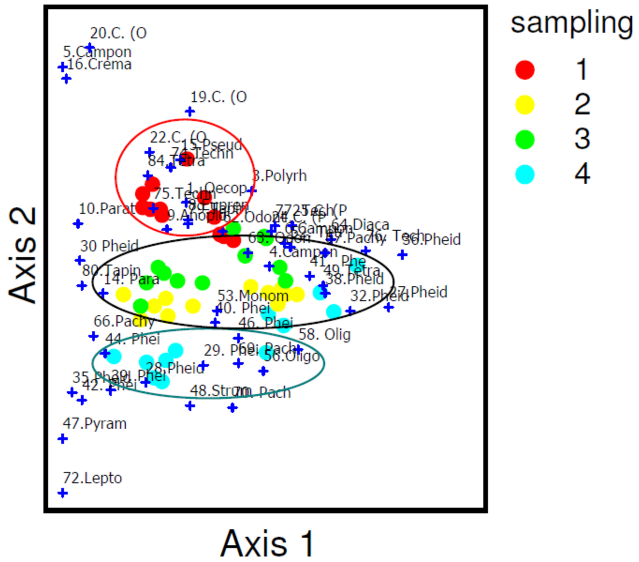


Figure 2. DCA ordination of 48 ant species among four sampling methods. (note: 1=hand collecting, 2=leave litter, 3=honey bait, 4=soil sampling)

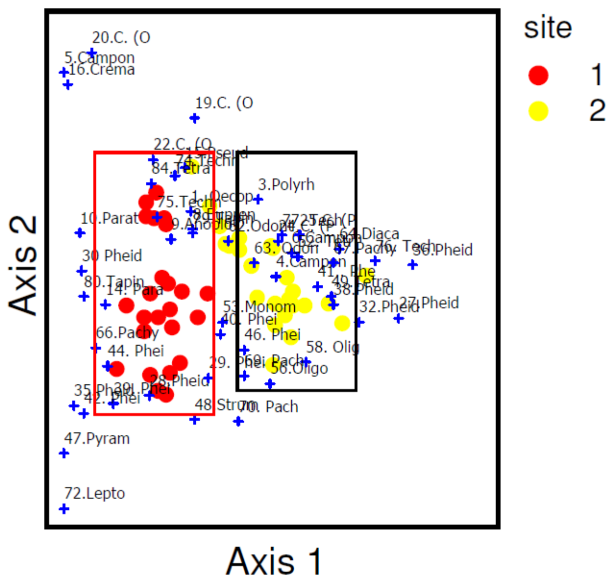


Figure 1. DCA ordination of 48 ant species between homogenous and heterogeneous rubber plantation.
(note: 1=homogenous, 2=heterogeneous rubber plantation)

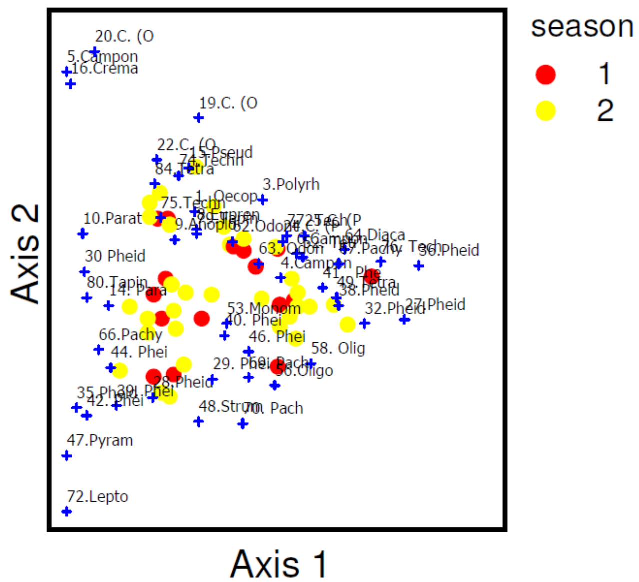


Figure 3. DCA ordination of 48 ant species between the wet and dry season.
(note: 1=wet, 2=dry season)

specific - climatic dataset showed that the three factors used are not good predictors of change in an ant community within these two rubber plantation types (Monte Carlo test for axis 1: P = 0.69 and axis 2: P = 0.31) (Figure 4).

## 4. Discussion

### 4.1 Ant composition and diversity

This topic tries to cover all of ant composition and diversity for further comparison study site and sampling methods on ant species. The diversity of living organism can be classified in level of organization such as order, family, genera and species.

The majority of the ant species (45) belong to the subfamily Myrmicinae, followed by Formicinae (15) and Ponerinae (14). These findings are supported by many studies (Wiwatwitaya, 2003a; Noon-anant et al., 2005). In a review by Shattuck (1999) he claimed that the Myrmicinae is the world's most diverse and dominant group of ants. In this study, it makes up 51.72% of the total ant species collected, so it is not surprising that Myrmicinae are dominant in this study.

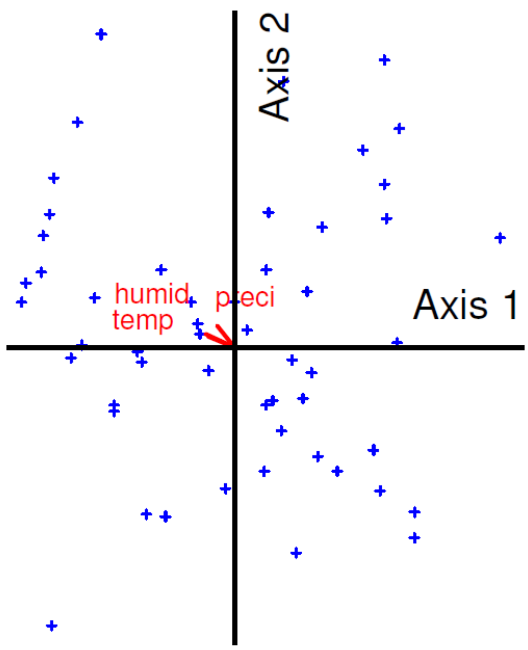


Figure 4. Bi-plot of a Canonical Correspondence Analysis (CCA) of ant species composition. The analysis deals with 48 ant species related to 3 factors (temperature, humidity and precipitation). A positive mark indicates the optima of individual species in the two-dimensional environmental space described by ordination axes 1 and 2, in which the relationships show no significant differences. Vectors show the correlations between an environmental factor and the two ordination axes, where the vector length indicates the strength of this correlation.

*Pheidole* and *Crematogaster* (both Myrmicinae), were the dominant genera in our study. Worldwide, these genera comprise more species than any others (Brown, 2000). Species in these genera are found in all geographic areas of Thailand (Jaitron and Nabhiabhata, 2005), and many species have been collected in high numbers. Moreover the habitat of this genus *Pheidole* is on the ground, among litter and underground (Shattuck, 1999). This finding corresponds with that of Noon-anant *et al.* (2005) and Wiwatwittaya (2003b) which studied ground dwelling ants.

### 4.2 Sampling methods and study

Comparing the methods used for collection of specimens (Table 2), this corresponds to the results of Noon-anant *et al.* (2005) and Watanasit (2003). They showed that LL was the most reliable technique for estimating the number of ant species in rubber plantations (Watanasit, 2003) and a lowland tropical rain forest at Hala-bala Wildlife Sanctuary (Noon-anant *et al.*, 2005). Many studies have shown that different methods might be suitable for a particular purpose of study or for a particular habitat. For example, LL was found to be more useful than pitfall trapping to survey the ant fauna in a tropical rainforest in Costa Rica (Olson, 1991); pitfall trapping was more effective than HC at sites of high elevation gradients in the Philippines (Samson *et al.*, 1997); HC was the best technique for estimating the numbers of ant species in the mainland savannas of Venezuelan Llanos (Romero and Jaffe, 1989), and also HC could detect most of the ant species in the temperate region (Yamane and Hashimoto, 1999).

It was not surprising to us that a combination of sampling methods to evaluate ant species produced a better yield. This was evident from the results from both homogeneous and heterogeneous rubber plantations that the combination of LL, HC and SS provided the best evaluation of ant species. Many previous studies have reached similar conclusions (e.g. Yamane and Hashimoto, 1999; Watanasit, 2003; Watanasit *et al.*, 2005a; Noon-anant *et al.*, 2005). In this study we also found that the sampling methods can separate ant species into three groups (Figure 2). It is clear that HC is the best methods used for collected ants living on tree trunks, leaves and flowers of under-storey plants but SS is best used for collecting ants living on the ground and soil surface. In this study *Cataulacus horridus* was caught mainly by HC because of ants in this genus nest in hollow spines and hollow stem of internodes of plants thus the HC is beneficial method to collect this species (Hölldobler and Wilson, 1990). On the other hand, *Pheidole* spp nest in the ground and forage on the soil surface; therefore SS is the appropriate method for collecting them (Hölldobler and Wilson, 1990). Moreover, we found that for ants living in leaf litter or feeding on honey on the ground, both LL and HB can be used. Thus, sampling methods can bias the ant species collected. Some ant species, e.g., *Paratrechina longiconis*, *Odontomachus similimus* and *Monomorium* sp. 2 can be collected by all sampling methods (Hookgong, 1999). This is particularly true for *Paratrechina* spp. that nests in a wide variety of habitats, feed on a range of food resources, and are involved in symbiotic relationships with other insects (Hölldobler and Wilson, 1990).

Regarding the study sites, ants can be used as bio-indicators and have been claimed to be a suitable taxon for monitoring environmental change (Shattuck, 1999; Kaspari and Majer, 2000). In our study the ant species *Odontomachus similimus, Pheidole tandjangensis, Pheidole annexus, Pheidologeton sp, Paratrechina longiconis, Paratrechina opaga* and *Leptogenys* sp. occurred only at the homogenous rubber plantation. A homogenous rubber plantation represents a frequently disturbed area because competing plants under the rubber tree are cleared away every year.

Komthong and Jaitron (2004) showed that the habitat of the ants exclusive to the homogenous rubber tree plantation in our study is in areas disturbed by clearance. They also stated that *Leptogenys* sp. and *Pheidole* species can collect from disturbed area. On the other hand, *Aenictus laeviceps, Diacamma sculpturata, Camponotus (Colobopsis) leonardi, Camponotus (Tanaemyrmex)* sp., *Dilobocondyla* sp and *Dolichoderus thoracicus* were only detected at the heterogeneous rubber plantation, a less disturbed area. Wiwatwitaya (2003b) reported that all these ant species live on the ground, leaves and tree trunks in rarely disturbed deciduous or tropical forests. We did find the weaver ant, *Oecophylla smaragdina*, at both study sites but it was more dominant in the homogenous rubber plantation than in the heterogeneous rubber plantation. Wiwatwitaya (2003b) showed that *Oecophylla smaragdina* generally inhabits open and disturbed areas, e.g., cleared areas and areas of homogenous cultivation (Watanasit *et al.*, 2007). Thus we can use ants to assess how severely an area affecting by disturbance relative to the natural state.

### 4.3 Seasonal changes

In this study we found that the seasonal changes in temperature, humidity and precipitation did not result in significant changes in the ant species collected. This finding supports the view that there is no significant correlation between ant species and these three climatic factors. The reason is that the environmental factors in this area did not fluctuate very much, moreover, nest of found ant species are not temporary nest like some species of army ants and driver ants (Hölldobler and Wilson, 1990). However, there is only one species of army ant, *Aenictus laeviceps* occurred in this study. Thus the community of ants in this area can adapt themselves very well at both study sites and microclimatic changes.

## Acknowledgments

This work was supported by the Centre for Biodiversity of Peninsular Thailand (CBIPT), Faculty of Science, Prince of Songkla University. We thank to N. Noon-anant for helping with ant identification; we thank B. Hodgson for his comments on the first draft of the manuscript and also the anonymous referees for their comments.

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