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Comparison of Ants (Hymenoptera: Formicidae) Diversity in Dry Dipterocarp and Mixed-Deciduous Forests at Sri Nan National Park, Northern Thailand

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ABSTRACT.– The species diversity of ground ants (Hymenoptera, Formicidae) in a section of mixed deciduous and dry dipterocarp forests within the Sri Nan National Park, northern Thailand was investigated using hand collecting, leaf litter sifting, and pitfall traps. A total of 121 species belonging to 41 genera in 7 subfamilies was recorded. Thirteen species were recorded in the richest genus *Camponotus*. From the pitfall trap data, the means of ant species diversity indices in the mixed deciduous forest were significantly higher than those in dry dipterocarp forest ($p \leq 0.05$) in both the winter and summer (but not the rainy season), whilst the mean ant dominance indices were not significantly different between the mixed deciduous and dry dipterocarp forests in the summer and rainy seasons ($p \leq 0.05$). However, the mean dominance index was significantly higher in dry dipterocarp forest in winter than that in the mixed deciduous forest ($p \leq 0.05$). *Anoplolepis gracilipes* (Fr. Smith, 1857), an exotic species, and *Odontoponera denticulata* (Fr. Smith, 1858) were the most frequently found species in both forest areas. In summer, pitfall trap data indicated that the populations of both species were significantly higher in the mixed deciduous forest than in the dry dipterocarp forest ($p \leq 0.05$), but in the winter, *Anoplolepis gracilipes* populations were not statistically different between the two forests. The implication for using some ant species as bioindicators in each forest type as well as sampling methodology is discussed.

KEY WORDS: Ant diversity, dry dipterocarp forest, mixed deciduous forest, Sri Nan National Park, Thailand

INTRODUCTION

Ants are highly eusocial insects belonging to the family Formicidae of the order Hymenoptera. There are estimated to be approximately 20,000 living ant species, of which 12,629 species have been described and classified into 16 subfamilies (Bolton, 1994, 1995a, 2006; Hölldobler and Wilson, 1990). Due to their high diversity and abundance, ants are commonly used as indicator for biodiversity in several habitats (Agosti et al., 2000; Wiwatwitaya and Jaitrong, 2000).

However, there have been few studies of ant species diversity in Thailand and as such the biodiversity status of ants in Thailand is largely unknown or out of date. The estimated number of ant species in Thailand is 800 - 1,000 species (Wiwatwitaya, 2003), yet only 247 species have been described (24 – 30% of the proposed total) and classified into nine subfamilies (Jaitrong and Nabhitabhata, 2005). Globally almost double (~60%) that proportion of ant species has been described, thus either the ant fauna of Thailand is largely undescribed compared to elsewhere, or ant diversity within Thailand has been overestimated.

The aims of this research are to study the ant species diversity, analyzing the species structure and comparing the species density changes of the dominant species in two different forest types, mixed deciduous and

dry dipterocarp, within the Sri Nan National Park. These two forest types are the majority of remaining forest area in Thailand and particularly susceptible to human disturbance, especially to anthropogenic forest fire during the dry season when leaf litter is abundant. The information from this study will provide baseline data and voucher material for reference collections of ants in northern Thailand. These data are expected to create new understanding or further develop knowledge about ants in Thailand and will be useful in other areas of research including taxonomy, ecology, and diversity of organisms in head watershed forest ecosystems. Consequently, they will be helpful in conservation and management of head watershed forest areas.

MATERIALS AND METHODS

Study Site.– Ants were collected in the Sri Nan National Park, covered the area of Wiang Sa, Na Noi, and Na Muen Districts, Nan Province, in the northern part of Thailand (Fig. 1), which covers an area of 934 km^2. The national park consists of abundant head watershed forests and 60 km length of the Nan River.

Ant Collection.– The study was conducted in a mixed deciduous and a dry dipterocarp forests within the National Park (Fig. 1). Collecting ant specimens were performed by hand collecting, leaf litter sifting, and pitfall traps.

In each forest type, hand collecting was performed in three linear transects of 500 m in length and 2 m in height, whilst for leaf litter and top soil collecting thirty 1 × 1 m quadrats were set up along each linear transect placed alternately on its left and right sides 10 m away from the line . Within each quadrat, the leaf litter and soil samples at 1 - 2 cm depth were collected. The soil was sieved through a 2-mm sifter for leaf litter sifting. Additionally, ten unbaited pitfall traps were placed 10 m away from each other and left for 24 hours.

All of the caught ants were fixed in 70% (v/v) ethyl alcohol in the field before being brought back to the laboratory for identification.

Ant Identification.– Ant specimens were identified using the identification guides of Bolton (1994, 1995a, 2006), Eguchi (2001), Jaitrong and Nabhitabhata (2005), Ward (2001), and Wiwatwitaya and Jaitrong (2000). The ant species identification were also confirmed by direct comparison with reference material held at the Ant Museum in the Department of Forest Biology at Kasetsart University (AMK) and the Natural History Museum at Chulalongkorn University (NHMCU). When it was not possible to identify with certainty to species-level, morphotypes were assigned. Each species / morphotype was counted to calculate and analyze the species diversity indices, indices of dominance, similarity index, and density of dominant species among the two different forest types.

Data Analyses.– Species composition and species structure indices for both the mixed deciduous and dry dipterocarp forests were compiled by combining the list of ant species found and the number of species represented in each habitat resulting from both collecting methods. However, the population density of ant species was calculated from ant species captured only by pitfall traps.

The Shannon-Wiener function (Krebs, 1999) was used to calculate the species

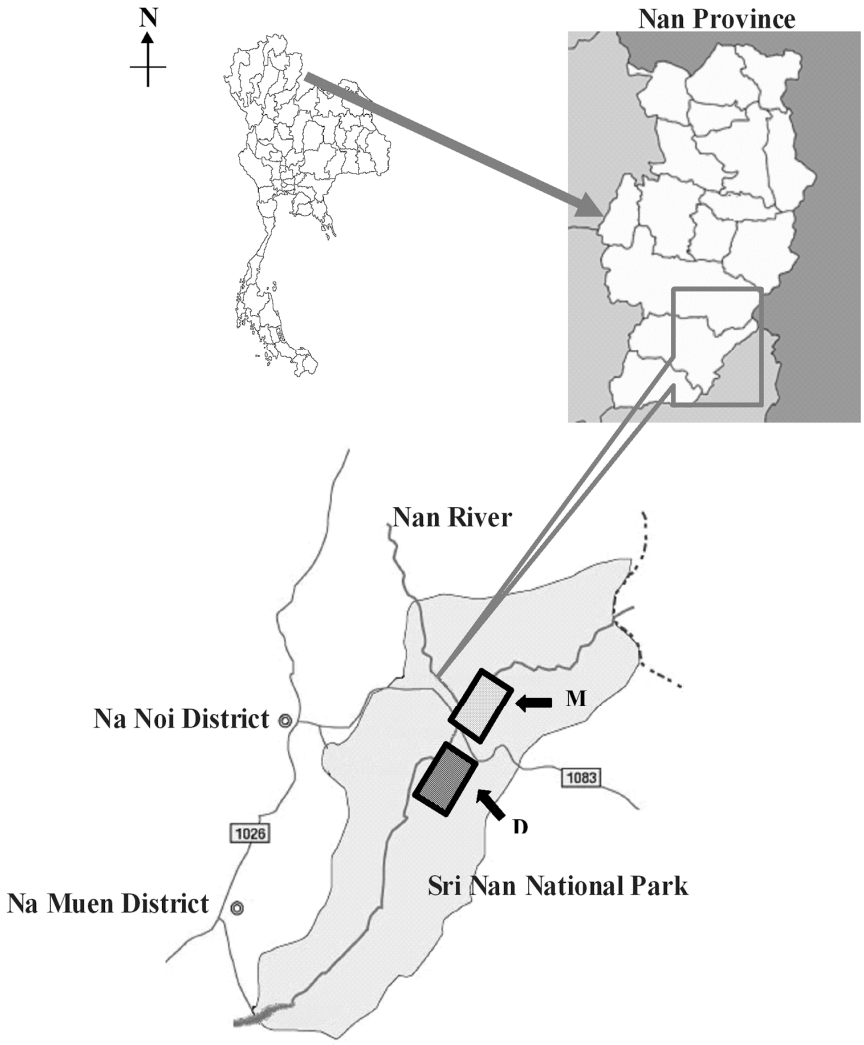


FIGURE 1. Map of Thailand illustrating the locations of Nan Province and Sri Nan National Park. Rectangles show the two sampled areas, where M = mixed deciduous forest and D = dry dipterocarp forest.

diversity indices of the ants living in each type of habitats as follows:

$$H = - \sum (p_i)(\log_2 p_i)$$

Where H = Index of species diversity

p_i = Proportion of the total sample belonging to i^{th} species

The measurement of species dominance (Krebs, 1999) in each habitat was calculated using the equation as follows:

$$D = \sum (p_i)^2$$

Where D = Index of dominance

p_i = Proportion of the total sample belonging to i^{th} species

To measure the similarity between two community samples, the coefficient of Sorensen (Krebs, 1999) was used, calculated as follows:

$$S_s = \frac{2a}{2a+b+c}$$

Where S_s = Sorensen's similarity coefficient

a = number of species in sample A and sample B (joint occurrences)

b = number of species in sample B but not in sample A

c = number of species in sample A but not in sample B

Additionally, Mann-Whitney U test and Kruskal-Wallis H were used to compare the mean indices and mean numbers of ants between the two forest types and among the winter, the summer, and the rainy seasons (Zar, 1999).

RESULTS

All of the ants collected in the mixed deciduous and dry dipterocarp forests at Sri Nan National Park, were identified into 7 subfamilies, 41 genera, and 121 species. There were 2 species in 1 genus of subfamily Aenictinae, 1 species in 1 genus of Cerapachyinae, 13 species in 6 genera of Dolichoderinae, 35 species in 7 genera of Formicinae, 47 species in 17 genera of Myrmicinae, 19 species in 8 genera of Ponerinae, and 4 species in 1 genus of Pseudomyrmecinae. *Camponotus*, *Polyrhachis*, *Tetramorium*, *Crematogaster*, and *Pheidole* are the richest genera having 13, 11, 10, 7, and 7 species, respectively (Table 1). Of the 121 species collected, 48 morphotypes were identified only to the generic level. Within the mixed deciduous forest 106 species were found, of which sixty-four species, belonging to 28 genera in 7 subfamilies, were recorded from only this habitat. In contrast, within dry dipterocarp forest only 56 species were found, of which 15 species belonging to 12 genera in 4 subfamilies were recorded but were absent in mixed deciduous forest. The forty-two species found in both forest types belong to 23 genera in 5 subfamilies. The details of ant species found in different forest types and seasons are listed in Table 1.

Using the pitfall trap data, the mean of ant species diversity indices in the mixed deciduous forest was found to be significantly higher than that in the dry dipterocarp forest ($p \leq 0.05$) in both the winter and summer, whereas they were not statistically different between the two forests in the rainy season (Table 2), when the species diversity in both forests declined significantly (and the species dominance rose) suggesting either seasonal immigration of species into both forest types or, perhaps more likely, reflecting the lack of surface activity and associated likely reduced ability to catch many species in the rainy season. The mean dominance indices were not significantly different between the mixed deciduous and dry dipterocarp forests in summer and rainy seasons ($p \leq 0.05$), but was significantly higher in the dry dipterocarp forest in the winter than in the mixed deciduous forest ($p \leq 0.05$) (Table 2). The similarity index was 0.52 between the mixed deciduous forest and dry dipterocarp forest.

The comparison of the means of ant species diversity in the mixed deciduous forest in each season found that the lowest mean was in the rainy season ($p \leq 0.05$). On the other hand, the mean dominance index in the rainy season was found to be significantly higher than in other seasons

($p \leq 0.05$). In dry dipterocarp forest, the mean ant species diversity and dominance indices were not significantly different among these three seasons (Fig. 3).

TABLE 1. List of ant species collected in a mixed deciduous and a dry dipterocarp forests, within Sri Nan National Park, using hand collecting, leaf litter sifting, and pitfall traps.

Scientific Name	Site Found			Forest	Specimens (per ha)		
	G	T	U	Type	winter	summer	rainy season
Subfamily Aenictinae							
1. *Aenictus binghami* Forel, 1900	G			M	HC		HC
2. *Aenictus dentatus* Forel, 1911	G			M			HC
Subfamily Cerapachyinae							
3. *Cerapachys sulcinodis* Emery, 1889	G			M			HC
Subfamily Dolichoderinae							
4. *Bothriomyrmex* sp.1 of CUMZ		T		M		HC	
5. *Dolichoderus thoracicus* (Smith, F., 1860)		T		M, D	HC	HC	HC
6. *Dolichoderus tuberifer* Emery, 1887		T		M	HC	HC	HC
7. *Dolichoderus* sp.1 of AMK		T		M			HC
8. *Dolichoderus* sp.2 of AMK		T		M			HC
9. *Dolichoderus* sp.3 of AMK		T		D			HC
10. *Iridomyrmex anceps* (Roger, 1863)		T		M, D		HC	HC
11. *Philidris* sp.1 of AMK		T		M	11,000	10,125	1,250
12. *Tapinoma indicum* Forel, 1895		T		M, D	2,000	HC	HC
13. *Tapinoma melanocephalum* (Fabricius, 1793)		T		M, D	9,500	8,375	875
14. *Technomyrmex kraepelini* Forel, 1905		T		M	125	HC	HC
15. *Technomyrmex modiglianii* Emery, 1900		T		M	HC	HC	21,000
16. *Technomyrmex* sp.4 of AMK		T		M			HC
Subfamily Formicinae							
17. *Anoplolepis gracilipes* (Smith, F., 1857)	G	T		M, D	17,125	27,250	20,625

ABBREVIATIONS
CUMZ = Chulalongkorn University Museum of Zoology; AMK = Ants Museum of Kasetsart University; G = Ground surface; M = Mixed deciduous forest; T = Tree trunk; D = Dry dipterocarp forest; U = under leaf litter; HC = present in hand collecting, but absent from the both traps

TABLE 1. (continued)

Scientific Name	Site Found			Forest	Specimens (per ha)		
	G	T	U	Type	winter	summer	rainy season
18. *Camponotus camelinus* (Smith, F., 1857)	G	T		M		HC	
19. *Camponotus lasiselene* Wang & Wu, 1994	G	T		M		HC	
20. *Camponotus leonadi* Emery, 1889	G	T		M	HC	HC	HC
21. *Camponotus nicobarensis* Mayr, 1865	G	T		M	125	125	HC
22. *Camponotus rufoglaucus* (Jerdon, 1851)	G	T		M, D	125	22,250	6,500
23. *Camponotus sericeus* (Fabricius, 1798)	G	T		D	HC	HC	HC
24. *Camponotus singularis* (Smith, F., 1858)	G	T		M	HC	HC	HC
25. *Camponotus* (*Myrmembly*) sp.1 of AMK	G	T		M		HC	
26. *Camponotus* (*Myrmembly*) sp.5 of AMK	G	T		M		HC	HC
27. *Camponotus* sp.7 of AMK	G	T		M, D	1,750	8,375	500
28. *Camponotus* sp.1 of CUMZ	G	T		M		HC	HC
29. *Camponotus* sp.2 of CUMZ	G	T		M			HC
30. *Camponotus* sp.3 of CUMZ	G	T		M			125
31. *Lepisiota* sp.3 of AMK		T		D	HC	HC	
32. *Oecophylla smaragdina* (Fabricius, 1775)	G	T		M, D	6,500	750	875
33. *Paratrechina longicornis* (Latreille, 1802)	G	T		M, D	1,875	3,625	58,375
34. *Paratrechina* sp.1 of AMK	G	T		M, D		3,000	HC
35. *Paratrechina* sp.4 of AMK	G	T		M	HC	125	HC
36. *Paratrechina* sp.7 of AMK	G	T		M	HC		HC
37. *Paratrechina* sp.8 of AMK	G	T		M, D	125	6,750	
38. *Paratrechina* sp.9 of AMK	G	T		D	125		HC
39. *Plagiolepis* sp.1 of AMK	G			M, D	125	HC	HC
40. *Plagiolepis* sp.2 of AMK	G			M	2,625	125	
41. *Polyrhachis abdominalis* Smith, F., 1858	G	T		M	HC	HC	HC

TABLE 1. (continued)

Scientific Name	Site Found			Forest	Specimens (per ha)		
	G	T	U	Type	winter	summer	rainy season
42. *Polyrhachis armata* (Le Guillou, 1842)	G	T		M	HC	HC	
43. *Polyrhachis dives* Smith, F., 1857	G	T		M	HC	HC	HC
44. *Polyrhachis halidayi* Emery, 1889	G	T		M			HC
45. *Polyrhachis laevissima* Smith, F., 1858	G	T		M	HC	HC	
46. *Polyrhachis proxima* Roger, 1863	G	T		M, D	HC	125	125
47. *Polyrhachis rastellata* (Latreille, 1802)	G	T		M		HC	
48. *Polyrhachis* (*Myrma*) sp.1 of CUMZ	G	T		M		HC	HC
49. *Polyrhachis* (*Myrma*) sp.2 of CUMZ	G	T		M		HC	
50. *Polyrhachis* (*Myrma*) sp.3 of CUMZ	G	T		M			HC
51. *Polyrhachis* (*Myrmhopla*) sp.1 of AMK	G	T		M		HC	
Subfamily Myrmicinae							
52. *Cardiocondyla emeryi* Forel, 1881	G		U	M, D	125	HC	125
53. *Cardiocondyla nuda* (Mayr, 1866)	G		U	D	125		HC
54. *Cardiocondyla wroughtonii* (Forel, 1890)	G		U	M		HC	
55. *Carebara* sp.1 of AMK			U	M		HC	
56. *Cataulacus granulatus* (Latreille, 1802)		T		M	HC	HC	HC
57. *Crematogaster rogenhoferi* Mayr, 1879	G	T		M, D	HC	1,125	250
58. *Crematogaster* (*Orthocrema*) sp.2 of AMK	G	T		D			HC
59. *Crematogaster* (*Physocrema*) sp.3 of AMK	G	T		M, D	750	3,375	1,500
60. *Crematogaster* sp.2 of AMK	G	T		D	125		6,000
61. *Crematogaster* sp.5 of AMK	G	T		M	HC	250	HC
62. *Crematogaster* sp.6 of AMK	G	T		D		HC	HC
63. *Crematogaster* sp.9 of AMK	G	T		M, D	HC	1,875	250

TABLE 1. (continued)

Scientific Name	Site Found			Forest	Specimens (per ha)		
	G	T	U	Type	winter	summer	rainy season
64. *Dilobocondyla* sp.2 of AMK		T	U	M		HC	
65. *Lophomyrmex birmanus* Emery, 1893	G		U	M	HC	HC	HC
66. *Meranoplus bicolor* (Guérin-Méneville, 1844)	G	T	U	D		HC	HC
67. *Meranoplus* sp.3 of AMK	G			D	125	125	125
68. *Monomorium chinense* Santschi, 1925	G	T		M, D	375	HC	HC
69. *Monomorium destructor* (Jerdon, 1851)	G	T		M, D	375	8,750	HC
70. *Monomorium floricola* (Jerdon, 1851)	G	T		D	HC	HC	HC
71. *Monomorium pharaonis* (Linnaeus, 1758)	G	T		M, D	14,500	125	4,000
72. *Monomorium sechellense* Emery, 1894	G	T		M, D	125	375	375
73. *Monomorium* sp.1 of AMK	G	T	U	M, D		875	875
74. *Myrmecina* sp.7 of AMK	G		U	M		125	125
75. *Oligomyrmex* sp.10 of AMK	G		U	M			875
76. *Pheidole capellinii* Emery, 1887	G		U	M			5,500
77. *Pheidole nodifera* (Smith, F., 1858)	G		U	M		125	
78. *Pheidole pieli* Santschi, 1925	G		U	M, D	125	375	1,500
79. *Pheidole planifronts* Santschi, 1920	G		U	M, D	1,625	3,500	500
80. *Pheidole rabo* Forel, 1913	G		U	M, D		HC	9,500
81. *Pheidole taivanensis* Forel, 1912	G		U	M, D	875	5,750	4,125
82. *Pheidole* sp.1 of CUMZ	G			D	HC		
83. *Pheidologeton affinis* (Jerdon, 1851)	G			M, D			HC
84. *Pheidologeton diversus* (Jerdon, 1851)	G		U	M, D	24,625	HC	125,625
85. *Recurvidris* sp.1 of AMK			U	M			375
86. *Smithistruma* sp.1 of CUMZ				M			125

TABLE 1. (continued)

Scientific Name	Site Found			Forest	Specimens (per ha)		
	G	T	U	Type	winter	summer	rainy season
87. *Solenopsis geminata* (Fabricius, 1804)	G		U	D	HC	HC	
88. *Tetramorium ciliatum* Bolton, 1977	G	T	U	M		HC	HC
89. *Tetramorium eleates* Forel, 1913	G		U	M		HC	
90. *Tetramorium insolens* (Smith, F., 1861)	G		U	M	125		
91. *Tetramorium nipponense* Wheeler, W.M., 1928	G			M	HC	HC	HC
92. *Tetramorium palaense* Bolton, 1979	G		U	M			HC
93. *Tetramorium simillimum* (Smith, F., 1851)	G		U	M		HC	
94. *Tetramorium smithi* Mayr, 1879	G		U	M, D	125		1,500
95. *Tetramorium walshi* (Forel, 1890)	G		U	M, D	HC		500
96. *Tetramorium* sp.2 of AMK	G		UU	M, D		3,625	2,000
97. *Tetramorium* sp.8 of AMK	G		U	M			125
98. *Vollenhovia* sp.2 of AMK				M			HC
Subfamily Ponerinae							
99. *Anochetus graeffei* Mayr, 1870	G			M, D			375
100. *Diacamma intricatum* (Smith, F., 1857)	G			M	HC	HC	HC
101. *Diacamma vargens* (Smith, F., 1860)	G			M, D	125	500	250
102. *Diacamma* sp.7 of AMK	G			M	HC	HC	
103. *Gnamptogenys bicolor* (Emery, 1889)	G			M	HC	HC	HC
104. *Gnamptogenys binghamii* (Forel, 1900)	G			M		125	
105. *Harpegnathos venator* (Smith, F., 1858)	G		U	M	HC		
106. *Hypoponera* sp.1 of AMK			U	M, D		125	750
107. *Hypoponera* sp.7 of AMK			U	D			250
108. *Leptogenys birmana* Forel, 1900	G			M		HC	HC

TABLE 1. (continued)

Scientific Name	Site Found			Forest Type	Specimens (per ha)		
	G	T	U		winter	summer	rainy season
109. *Leptogenys diminuta* (Smith, F., 1857)	G			M, D	125	5,625	HC
110. *Leptogenys myops* (Emery, 1887)	G			D		2,250	
111. *Leptogenys* sp.5 of AMK	G			M		HC	
112. *Leptogenys* sp.6 of AMK	G			M	3,875		
113. *Leptogenys* sp.15 of AMK	G			M		125	HC
114. *Odontoponera denticulata* (Smith, F., 1858)	G			M, D	10,750	22,750	26,625
115. *Pachycondyla astuta* Smith, F., 1858	G			M	HC	HC	HC
116. *Pachycondyla luteipes* (Mayr, 1862)	G			M, D		1,000	375
117. *Pachycondyla rufipes* (Jerdon, 1851)	G			M, D	125		125
Subfamily Pseudomyrmecinae							
118. *Tetraponera allaborans* (Walker, 1859)	G	T		M, D	HC		HC
119. *Tetraponera attenuata* Smith, F., 1877	G	T		M		HC	
120. *Tetraponera difficilis* (Emery, 1900)	G	T		M, D	125	250	HC
121. *Tetraponera rufonigra* (Jerdon, 1851)	G	T		M, D	HC	HC	HC

Anoplolepis gracilipes and *Odontoponera denticulata* were found the most frequently in both forest areas, although *Odontoponera denticulata* has mean numbers of 0 in the dry dipterocarp forest in winter and rainy seasons and only 0.1 in summer. From the pitfall trap data, the density of *Anoplolepis gracilipes* was found to be significantly higher in the mixed deciduous forest than in the dry dipterocarp forest in the summer ($p \leq 0.05$), due to a marked decrease in the ant density in the dry dipterocarp forest. However, in the rainy season the reverse was true, it was found to be significantly higher in the dry dipterocarp forest than in the mixed deciduous forest ($p \leq 0.05$) due to both an increase and a decrease in the ant density in the dry dipterocarp and mixed deciduous forests, respectively (Table 3) (Fig. 2). The density of *Odontoponera denticulata* was significantly higher in the mixed deciduous forest than in the dry dipterocarp forest ($p \leq 0.05$) in all seasons (Table 3).

A comparison of the densities of *Anoplolepis gracilipes* and *Odontoponera denticulata* across the three seasons showed that the density of *Anoplolepis gracilipes* in mixed deciduous forest was significantly different among the three seasons ($p \leq 0.05$). In the winter the density of this species was not significantly different from the density

TABLE 2. Total mean numbers* (± SE) and medians of ecological indices of ant species caught using pitfall traps in a mixed deciduous and dry dipterocarp forests within Sri Nan National Park.

Forest type	Species diversity index						Index of dominance					
	Winter		Summer		Rainy season		Winter		Summer		Rainy season	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
mixed deciduous forest	1.58±0.19a	1.41	1.68±0.13a	1.55	0.71±0.18a	0.51	0.43±0.05a	0.4	0.45±0.04a	0.43	0.76±0.07a	0.86
dry dipterocarp forest	0.77±0.23b	0.6	0.79±0.25b	0.44	0.4±0.18a	0.0	0.73±0.09b	0.83	0.59±0.11a	0.56	0.84±0.07a	1.0

*: Means with a different letter in the same column are significantly different ($p \leq 0.05$; Mann-Whitney U test).

TABLE 3. Total mean numbers* (± SE) and medians of ant species (*Anoplolepis gracilipes* and *Odontoponera denticulata*) in mixed deciduous and dry dipterocarp forests using pitfall traps in Sri Nan National Park.

Forest type	*Anoplolepis gracilipes*						*Odontoponera denticulata*					
	Winter		Summer		Rainy season		Winter		Summer		Rainy season	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
mixed deciduous forest	4.2±1.18a	0.0	4.33±2.36a	0.0	0.6±0.31a	0.0	9.5±3.65a	2.0	17.5±7.5a	3.5	20.09±11.0a	2.0
dry dipterocarp forest	2.7±1.26a	0.0	0.9±0.79b	0.0	8.4±3.41b	1.0	0.0±0.0b	0.0	0.1±0.1b	0.0	0.0±0.0b	0.0

*: Means with a different letter in the same column are significantly different ($p \leq 0.05$; Mann-Whitney U test).

in the summer, but in the winter and summer *Anoplolepis gracilipes* densities were found to be significantly higher than that in the rainy season. In the dry dipterocarp forest, the density of *Anoplolepis gracilipes* was found to be significantly higher in the rainy season than in the summer ($p \leq 0.05$), but the densities of *Odontoponera denticulata* in mixed deciduous and in dry dipterocarp forests were not significantly different across the three seasons (Fig. 4).

Moreover, in our study areas, there were some infrequent ant species which were found only once either pitfall traps or by leaf litter sifting. *Tapinoma indicum*, *Paratrechina* sp.8 of AMK, *Cardiocondyla emeryi*, *Leptogenys diminuta* and *Pachycondyla rufipes* were caught by the both methods. Nine species were recorded only in pitfall traps.- *Technomyrmex kraepelini*, *Camponotus* sp.3 of CUMZ, *Cardiocondyla nuda*, *Crematogaster rogenhoferi*, *Crematogaster* sp.5 of AMK, *Pheidole pieli*, *Tetramorium insolens*, *Tetramorium smithi*, and *Leptogenys* sp.15 of AMK. Twelve species were recorded only by leaf litter sifting.- *Paratrechina* sp.4 of AMK, *Plagiolepis* sp.1 of AMK, *Meranoplus* sp.3 of AMK, *Monomorium destructor*, *Oligomyrmex* sp.10 of AMK, *Pheidole nodifera*, *Smithistruma* sp.1 of CUMZ, *Tetramorium* sp.8 of AMK, *Gnamptogenys binghamii*, *Hypoponera* sp.7 of AMK, *Leptogenys myops*, and *Leptogenys* sp.6 of AMK (Fig. 2).

DISCUSSION

Altogether 121 species belonging to 41 genera in 7 subfamilies were caught from mixed deciduous and dry dipterocarp forests within the Sri Nan National Park. The species richness found in this research, conducted in the Oriental Realm, was less than that found in the hill dipterocarp forest in northern Peninsular Malaysia (211 spp.) (Mustafa et al., 2011).

The most abundant ants in this study belonged to the following genera.- *Camponotus*, *Polyrhachis*, *Tetramorium*,

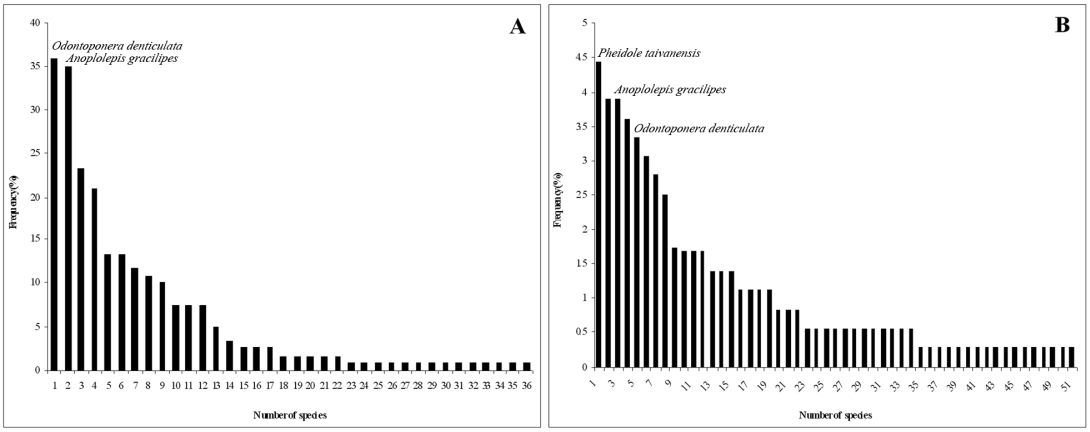
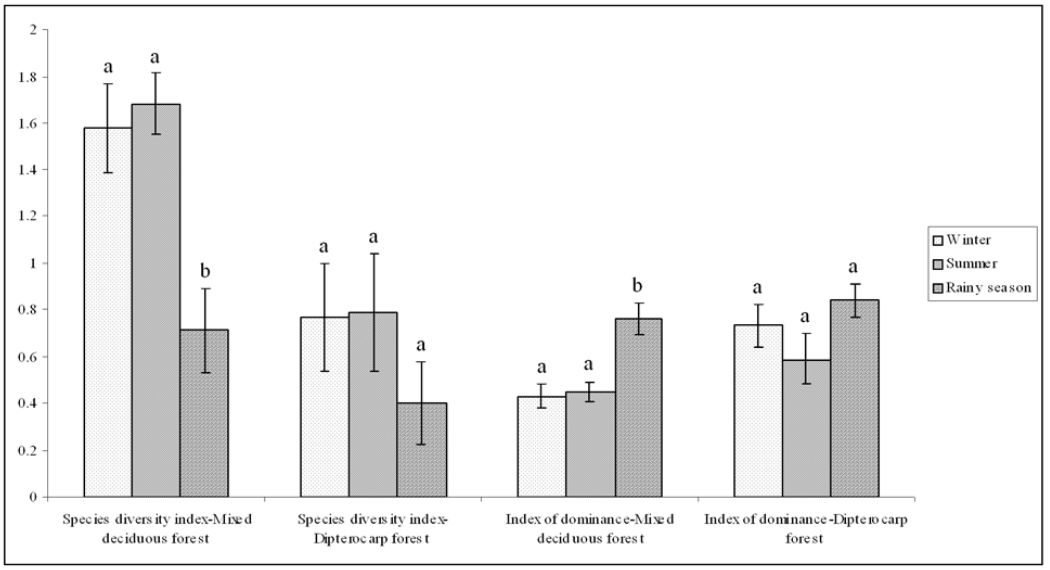


FIGURE 2. Frequency (%) of ant species collected in the mixed deciduous and dry dipterocarp forests, within Sri Nan National Park, using pitfall traps (A) and leaf litter sifting (B).

Crematogaster, and *Pheidole* and were similar to the results previously reported by Bolton (1995b). Greatest numbers of ant species were found by the hand collecting method. Most of these species (106; 87.6%) were found in the mixed deciduous forest whilst only 56 species (46.3% total) were found in the dry dipterocarp forest. However, there was some segregation as only 42 species (34.7%) were common to both forests with 64 species belonging to 28 genera in 7 subfamilies, being recorded only from the mixed deciduous forest, and 15 species, belonging to 12 genera in 4 subfamilies, being recorded only from the dry dipterocarp forest. In mixed deciduous forest, most ant species caught were *Polyrhachis* spp. that maybe because of their arboreal behavior: living and building nests on trees, tree hollows, termite nests in dead logs, under the roots of epiphytes, on the underside of plant leaves or between leaves (Jaitrong et al., 2007; Noon-anant et al., 2009). This group of ants could be found in dense forest and they mostly lived in high moisture habitats. Most ant species in dry dipterocarp forest were found under soil, leaf litter, dead logs, and rocks. Some ant species were adapted to building nests in open areas and could withstand drought such as *Meranoplus* spp. (Hölldobler and Wilson, 1990; Jaitrong and Ting-nga, 2005; Torchote et al., 2010).

Taxonomic information of the family Formicidae in Thailand is limited, although they have been studied extensively in other countries. As a consequence, just over 1/3 of all samples (48 morphospecies; 39.7% total) could not be identified to species level, although how many of these are new species



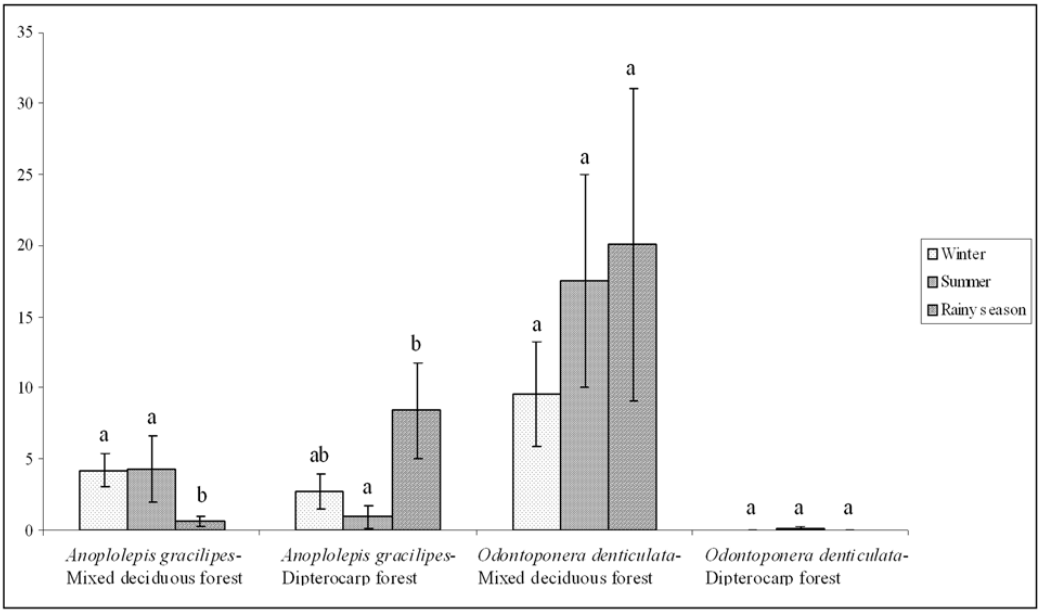
*: Means with a different letter in among the winter, summer, and rainy seasons are significantly different ($p \leq 0.05$; Kruskal-Wallis H and Mann-Whitney U test).

FIGURE 3. Total mean numbers* of ecological indices of ant species caught using pitfall traps among the winter, summer, and rainy seasons in a mixed deciduous and dry dipterocarp forests within Sri Nan National Park.

as opposed to variants of existing species is unresolved. Certainly, the morphospecies in the reference collection of ant specimens in the Chulalongkorn University Natural History Museum are suspected to be new species, although they have not yet been taxonomically described and published as such. Nevertheless, if they are indeed new species, then this implies at least nine new ant species were found in this study, representing 7.4% of the sampled species. However, this conjecture cannot be used to refute the current estimates of the ant biodiversity in Thailand as this study sampled only from disturbed sites that are close to the open road and from regenerating secondary forests. It is likely that other species would occur in less disturbed and especially primary forest regions.

Camponotus nicobarensis was frequently caught in this study in the mixed deciduous forest. This ant species is considered as an important forest pest because of their tree trunk dwelling behavior, where they live and make galleries inside the tree, but do not feed on the wood. Tree hollows, holes and dead branches are their most common nesting sites. Therefore, an improved awareness of dispersal in this ant species is required. Any reforestation and building construction project in Sri Nan National Park should have a pest management plan for controlling these ants.

Anoplolepis gracilipes is an exotic species in Thailand; it might be native to tropical Africa. Its distribution has clearly expanded by human agency, so that it is now widespread in tropical and subtropical



*: Means with a different letter in among the winter, summer, and rainy seasons are significantly different ($p \leq 0.05$; Kruskal-Wallis H and Mann-Whitney U test).

FIGURE 4. Total mean numbers* of ant species (*Anoplolepis gracilipes* and *Odontoponera denticulata*) among the winter, summer, and rainy seasons in mixed deciduous and dry dipterocarp forests using pitfall traps in Sri Nan National Park.

regions of the globe (Wilson and Taylor, 1967). In our study sites, we found that *Anoplolepis gracilipes* was the dominant species in both the mixed deciduous and the dry dipterocarp forests. These two forest zones are situated in the middle of Sri Nan National Park and were formally deforested and abandoned for a period of time. Our result is similar to that reported by Wiwatwitaya (2003), who suggested that *Anoplolepis gracilipes* could adapt to survive in dry habitats or low humidity areas, and so they preferred to inhabit, or are not outcompeted in, open areas or degraded forests.

Odontoponera denticulata was the dominant species in both mixed deciduous and the dry dipterocarp forests. It is widely distributed in many localities in South East Asia, including urban areas, agricultural areas, and natural forest (Yamane, 2009), and it is now common and widespread throughout Thailand (Jaitrong and Nabhitabhata, 2005), possibly due to its aggressiveness, carnivorous and scavengerous habits.

Species diversity indices were compared between the two forest types. Using the data from pitfall traps, the means of ant species diversity in the mixed deciduous forest were significantly higher than in the dry dipterocarp forest in both the winter and summer. This might be because the variety of plants, microhabitat types and food sources in the mixed deciduous forest were more abundant than in the dry dipterocarp forest in both seasons (Table 2). However, in the rainy season, the mean ant species diversity indices were not statistically different between the two forests, the number of species in the mixed deciduous forest (82) was higher than in the dry dipterocarp forest (50).

In mixed deciduous forest, species diversity indices were compared across the three seasons. Using the data from pitfall traps, the mean ant species diversity index in the rainy season was the lowest ($p \leq 0.05$). This might be due to abiotic factors, especially relative humidity and soil moisture during winter and summer which were clearly different from the rainy season. Our result is similar to the reports of Hölldobler and Wilson (1990) and Agosti et al. (2000), who suggested that temperature and effect of rainfall on quantity, population stability in the ecosystem, and the foraging behavior of ant workers in each species was different. They showed that some species were found in specific ranges of temperature, soil moisture, and rainfall. Additionally, the mean of number of rainy days during the rainy season was seventeen days per month. Moreover, Agosti et al. (2000) reported that the high levels of soil moisture had an effect on the foraging behavior and correlated with decreases in many activities, as after rainy periods, the foraging rate was lower that during dryer conditions because the rainfall or dew had an effect on chemical communication within the colony. Eguchi (2001) stated that quantity of rainfall was a limiting factor determining foraging ranges and the dispersion of genus *Pheidole*. In our study, *Pheidole* was the most species-rich genus and decreased activity of *Pheidole* species during wet conditions might explain our results. In the dry dipterocarp forest, the means of diversity were not significantly different across the three seasons because of many plant communities with poor water retentive properties, open canopies, and the intense sunlight. Although there was high rainfall in the rainy season, the sunlight caused a high rate of evaporation of ground

water, so the soil moistures were not different statistically in different seasons.

The mean dominance indices of ants caught by pitfall traps were not significantly different between mixed deciduous and dry dipterocarp forests in the summer and rainy seasons. In contrast, the mean dominance indices in dry dipterocarp forest in winter were significantly higher than in the mixed deciduous forest. This might be because the soil in the dry dipterocarp forest was of very low moisture content in winter. Only some kinds of ants such as *Anoplolepis gracilpes* and *Pheidologeton diversus* that can adapt and survive in dry and low humidity habitats were found (Hölldobler and Wilson,

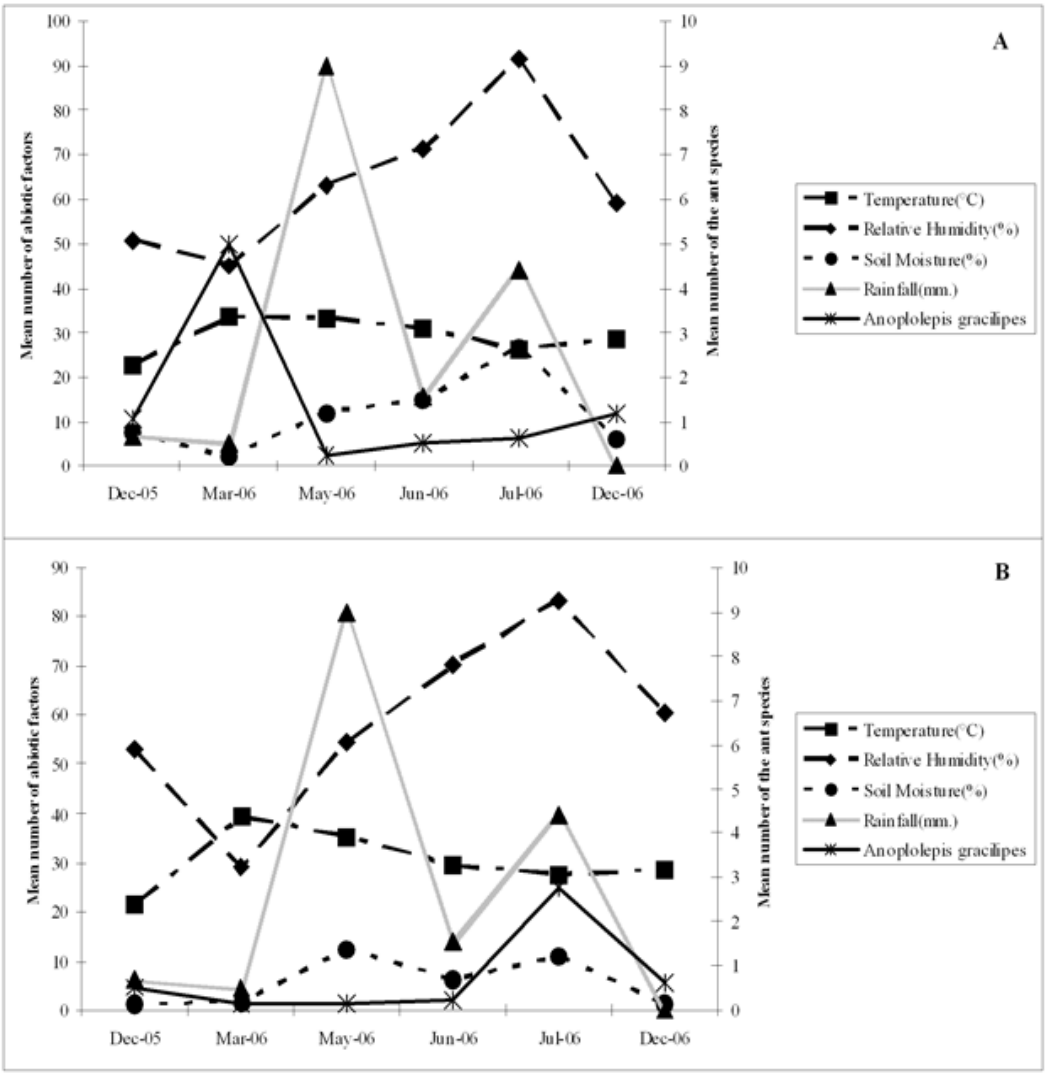


FIGURE 5. Mean numbers of *Anoplolepis gracilipes* and abiotic factors such as temperature, relative humidity, soil moisture, and rainfall in A: mixed deciduous forest and B: dry dipterocarp forest in Sri Nan National Park.

1990). In the summer and rainy seasons, there was a high dominance of ant species with no statistical difference between the two forest types (Table 2). *Anoplolepis gracilpes*, *Odontoponera denticulata*, *Pheidologeton diversus*, *Monomorium pharaonis*, and *Paratrechina longicornis* might disperse into the mixed deciduous and dry dipterocarp forests and, consequently, the mean dominance indices were not significantly different.

From summer pitfall trap data, the mean density of *Anoplolepis gracilipes* in the mixed deciduous forest was found to be significantly higher than in the dry dipterocarp forest (Table 3). Abiotic factors such as relative humidity and soil moisture in the summer of the mixed deciduous forest

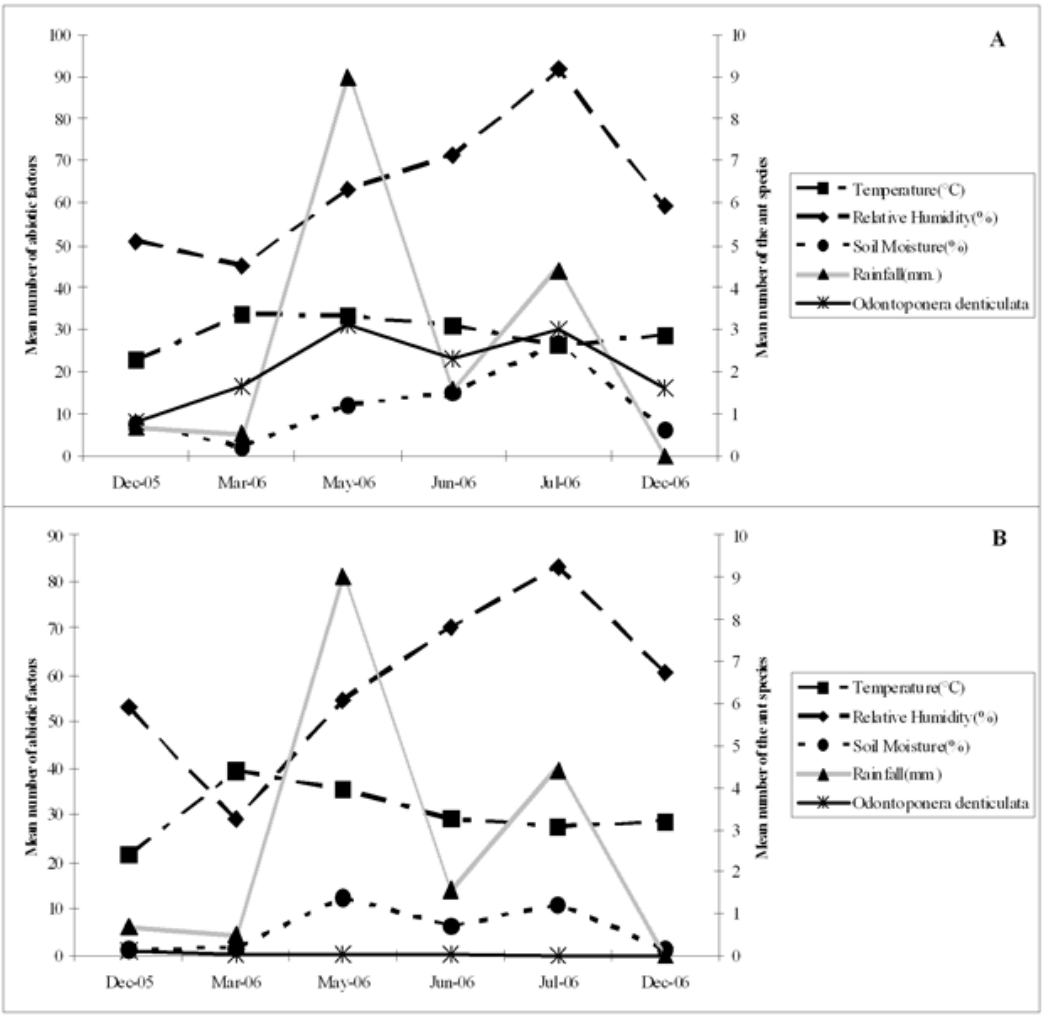


FIGURE 6. Mean numbers of *Odontoponera denticulata* and abiotic factors such as temperature, relative humidity, soil moisture, and rainfall in A: mixed deciduous forest and B: dry dipterocarp forest in Sri Nan National Park.

might be more suitable for *Anoplolepis gracilipes*. The relative humidity and soil moisture of dry dipterocarp forest was lower than in mixed deciduous forest. In the rainy season, with a lot of rain and high humid in the air, the mixed deciduous forest had a high relative humidity and soil moisture. Moreover, the low density canopy in dry dipterocarp forest allowed sunshine penetration to the ground and leaf litter causing low moisture humidity in soil and dry leaf litter, resulting in suitable habitat for *Anoplolepis gracilpes* (Fig. 5).

Using the data from pitfall traps, the density of *Anoplolepis gracilipes* in the mixed deciduous forest was the significantly lowest value in the rainy season. *Anoplolepis gracilipes* decreased its activities, because of the rainfall, relative humidity and soil moisture (Fig. 5). Normally, this species preferred the dry habitats, presumably because it uses dry litter and decayed wood in nest construction.

In addition, from the pitfall trap data, the mean density of *Odontoponera denticulata* was found to be significantly higher in the mixed deciduous forest than in the dry dipterocarp forest in all three seasons (Table 3). Although the main soil type in both forest types was loamy sand, the soil moisture in mixed deciduous forest was higher than that in dry dipterocarp forest. The higher soil moisture (Fig. 6) probably makes it easier for the ants to build their nest.. The greater variety of plants present in mixed deciduous forest probably resulted in a larger variety of leaf litter than in dry dipterocarp forest; and the food sources (such as small insects and small invertebrates) of *Odontoponera denticulata* were also increased. Hence, this predator of other ant species (Agosti *et al*., 2000; Sitthicharoenchai and Chantarasawat, 2006) generally can be found at higher density in the mixed deciduous forest than in the dry dipterocarp forest.

Furthermore, almost all the less frequent ant species reported in this study can be commonly collected using other methods. For example, *Crematogaster* spp. can be found by hand collection and visual inspection in the study areas as well as at Lai Nan Sub district study site as reported by Sitthicharoenchai and Chantarasawat (2006). However, one of the infrequent ant species, *Tetramorium insolens*, is a rare species in Thailand (Jaitrong and Nabhitabhata, 2005).and is a new record for the north of Thailand.

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