

## Ant diversity in rubber plantations (*Hevea brasiliensis*) of Cambodia

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**ABSTRACT.** We investigated the arboreal and ground ant fauna in rubber plantations (*Hevea brasiliensis*) in Kampong Cham Province, Cambodia. A total of 41 species of Formicidae, belonging to 28 genera in seven subfamilies, were collected. In three types of rubber plantations examined 25, 23 and 27 species of ants were found in a six-year-old, a nine-year-old and an old (>50-year) plantation, respectively. Total species richness of ants did not differ significantly among the three types of plantations. The most common ant species were the native *Oecophylla smaragdina*, which occurred in 50% of the samples, and the exotic invaders *Tapinoma melanocephalum* and *Anoplolepis gracilipes* which were in 27 % and 13 % of samples respectively. The older plantation, especially, had abundant leaf litter and fertile soil, and some rarer more cryptic ant genera, e.g. *Calyptomyrmex*, *Pyramica* and *Discothyrea*, were found in the leaf litter.

**Keywords:** Cambodia, ants, rubber plantation, biodiversity, time unit sampling, Winkler extraction.

### INTRODUCTION

Ants are ideal organisms for use in biodiversity inventory because they are one of the major components of biodiversity in the tropics (Hölldobler & Wilson 1990). Moreover, ants are a dominant element in tropical agroforestry ecosystems (Room 1971; Majer et al. 1994; Philpott & Armbrecht 2006). Primary and logged forests have been rapidly converted to monoculture plantations (rubber, oil palm, timber) in Southeast Asia (Clay 2004). The changes in these habitats have resulted in a decline in biodiversity. Studies on such changes in oil palm (*Elaeis guineensis* Jacq.) plantations have focused on ants (Pfeiffer et al. 2008; Brühl & Eltz 2010; Fayle et al. 2010), butterflies (Koh 2008) and birds (Aratrakorn et al. 2006; Koh 2008). Similar studies in the case of rubber plantations (*Hevea brasiliensis* (Willd. ex.

A.Juss.) Mull.Arg.) have focused on, for example, plants and birds in Sumatra (Beukema et al. 2007), however few studies have considered ant species composition (but see Bickel & Watanasit 2005). Although rubber plantations have become more extensively planted recently, the ant fauna of these habitats is poorly investigated. In order to assess the contribution of rubber plantations as a land-use type to the conservation of biodiversity, the community patterns of the ant fauna need to be assessed.

Generally, rubber plantations go through several developmental stages according to age. Younger and older plantations are often covered with weeds and shrubs, and are not often used for collecting rubber sap, while the ground of intensive plantations has few weeds. Although the ant community may be expected to change during succession even in plantations, few studies

have described such changes in young vs. old plantations; exceptions are in oil palm by Brühl & Eltz (2010) and in citrus orchards by Cerdá et al. (2009). The aim of the present study is to analyse ant communities in rubber plantations of three different ages based on a preliminary survey using arboreal and terrestrial samples.

## MATERIALS AND METHODS

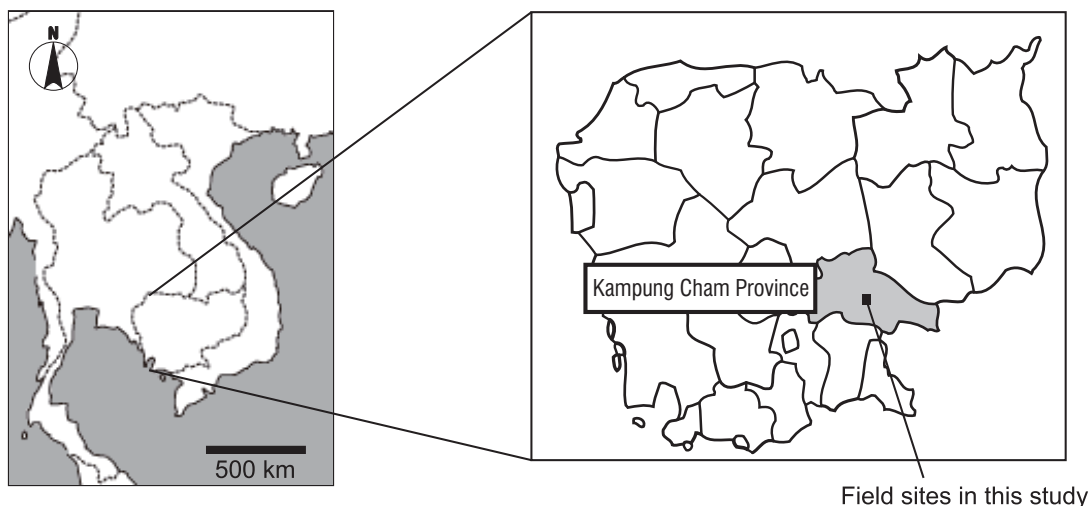
### *Study sites*

The study was carried out in the Cambodian Rubber Research Institute (CRRRI) field site (11°55' N and 105°34' E) in Kampong Cham Province, Cambodia (Fig. 1). The climate is tropical with a bi-annual alternation of monsoonal wind systems. The rainy season extends from May to October and the dry season from November to April. The average annual precipitation and temperature are 1,700 mm and 28°C, respectively (Khun et al. 2008).

The collecting sites included rubber plantation of three ages: (1) six years; (2) nine years; and (3) more than 50 years (Fig. 2). The forest floor was covered with many shrubs (1-2 m high) in the six-year-old plantation, and weeds in all three plantations. The weeds were cut regularly, but sprayed with very little herbicide. The study sites were at least 150 m from the forest edge, and the rubber plantations were surrounded by paddy-fields.

### *Ant sampling*

From the end of April to the beginning of May 2010, we sampled ants at points along three transects. Each transect had eight sampling points with 10 m spacing. Our study sites were composed of one plantation in each plantation type, and one transect in each plantation. All transects were situated at least 50 m from the plantation edge to reduce edge effects. The study focused on both the ground-dwelling and arboreal ant community and employed two kinds of sampling methods. Ants were sampled using time unit sampling only (modified from Ogata 2001) for arboreal ants, and Winkler extraction for ground-dwelling and cryptic ants. The hand sampling for arboreal ants was carried out starting 0.50 m above the ground surface and going up to a height of 2.00 m and was conducted for 15 minutes each sample. Arboreal ants were collected with forceps and aspirator into alcohol vials. Winkler samples in each plantation type were collected as 8 x 0.25 m<sup>2</sup> (0.5 m x 0.5 m) samples of leaf litter, situated at least 10 m apart from each other. The litter of each sample was sifted using a sieve with 6 x 6 mm mesh and left for extraction in a mini Winkler apparatus for two days. In total, we collected 24 arboreal ant samples and 24 leaf litter ant samples from the three transects. All specimens were sorted to genus using a key (Bolton 1994), then identified to species using review papers (e. g. Bolton 2000) where possible. Unidentified



**Fig. 1.** Our study sites in Cambodia's Kampong Cham Province.



(2a)



(2b)



(2c)

**Fig. 2.** Surveyed rubber plantations. (2a) six-year-old plantation; (2b) nine-year-old plantation; (2c) more than 50-year-old plantation. Note the differing plant cover on the ground.

specimens were given number codes (sp. 1, etc.), or species codes (sp. 2 of SKY, etc.) based on Seiki Yamane's collection. Fernandez (2004)

synonymised the genus *Oligomyrmex* under the genus *Carebara*, but Eguchi et al. (2011) regarded *Oligomyrmex* as a separate genus; the taxonomic status needs further study in the future, but we tentatively follow the system of Fernandez in this paper. Voucher specimens are preserved in the Institute of Tropical Agriculture, Kyushu University, Japan.

### Analysis

In order to assess the completeness of our survey for the sites sampled, we plotted a species accumulation curve for each site. To estimate the total number of species expected in each plantation, we used a sample-based randomisation procedure from software EstimateS (Colwell, 2006). The indices used to examine community structure of the different plantations were S (species richness),  $H'$  (Shannon's diversity index),  $H$  (Shannon's true diversity according to Jost, 2006) and  $D$  (Simpson's diversity index). Shannon's diversity index ( $H'$ ) was assessed as  $H' = -\sum (p_i \ln p_i)$ , where  $p_i$  is the proportion of samples of the  $i$ -th species in all eight samples and  $\sum$  is the sum of the terms for all species. Shannon's true diversity ( $H$ ) was then calculated as  $H = \exp(-\sum (p_i \ln p_i))$ . Simpson's diversity ( $D$ ) was calculated as  $D = 1/\sum p_j^2$ , where  $p_j$  is the proportion of samples of the  $j$ -th species in all of the samples and  $\sum$  is the sum of the terms for all species. Shannon's true diversity ( $H$ ) and Simpson's diversity ( $D$ ) were used to compare each site directly.

To test the hypothesis that the species composition between six-year, nine-year and 50-year plantations varied, we calculated the Jaccard similarity index between them.

The statistical significance of differences between the three plantations was tested using analysis of variance (ANOVA).

## RESULTS

A total of 41 species in 28 genera were found (Table 1): 25 species in the six-year-old plantation, 23 species in the nine-year-old one and 27 species in the 50-year-old one. Among terrestrial samples for ground ants, 17 species occurred in the six-year, 17 species in the nine-year and 19 species in the 50-year plantations.

**Table 1:** Frequency of occurrence (0 to 1, n = 8) of ant species in three types of rubber plantations (six-year, nine-year, 50-year) of Kampong Cham Province, Cambodia. “ar” indicates arboreal sample, “gr” ground sample. Species richness (S), Shannon’s diversity index (H’), Shannon’s true diversity (H) according to Jost (2006) and Simpson’s diversity index (D) are shown at the end of the table.

Species	6yrs-ar	6yrs-gr	9yrs-ar	9yrs-gr	50yrs-ar	50yrs-gr
<b>AENICTINAE</b>						
<i>Aenictus changmaianus</i> Terayama & Kubota	0	0.125	0	0	0	0
<b>DOLICHODERINAE</b>						
<i>Tapinoma melanocephalum</i> (Fabricius)	0.375	0	0.5	0	0.75	0
<i>Technomyrmex elatior</i> Forel	0	0	0	0	0.75	0
<i>Technomyrmex horni</i> Forel	0	0.125	0	0	0	0.125
<i>Technomyrmex</i> sp. 7 of SKY	0.125	0	0.25	0	0	0
<b>FORMICINAE</b>						
<i>Anoplolepis gracilipes</i> (F. Smith)	0.125	0	0.5	0.125	0	0
<i>Camponotus rufoglaucus</i> (Jerdon)	0.125	0	0.375	0.25	0.5	0
<i>Nylanderia</i> sp. 17 of SKY	0.25	0.125	0	0.125	0	0.375
<i>Nylanderia</i> sp. 24 of SKY	0.875	0.25	0.125	0	0	0
<i>Oecophylla smaragdina</i> (Fabricius)	1	0	1	0	0.875	0.125
<i>Paraparatrechina</i> sp. 8 of SKY	0.5	0	0	0	0	0
<i>Paratrechina longicornis</i> (Latreille)	0	0	0	0	0.25	0
<i>Plagiolepis</i> sp. 1 of SKY	0	0.125	0	0.25	0	0.25
<b>MYRMICINAE</b>						
<i>Calyptomyrmex</i> sp. 6 of SKY	0	0.125	0	0.125	0	0
<i>Cardiocondyla wroughtonii</i> (Forel)	0	0	0	0	0	0.125
<i>Carebara</i> sp. 1	0	0	0	0.25	0	0
<i>Carebara</i> sp. 2	0	0	0	0	0	0.625
<i>Carebara</i> sp. 3	0	0	0	0.25	0	0.25
<i>Crematogaster ferrarii</i> Emery	0	0	0	0	0.5	0
<i>Crematogaster</i> aff. <i>jacobsoni</i> Forel	0.875	0.125	0	0	0	0.125
<i>Crematogaster treubi</i> Emery	0	0	0	0	0.25	0
<i>Monomorium</i> cf. <i>floricola</i> (Jerdon)	0.25	0	0	0	0.125	0
<i>Monomorium pharaonis</i> (Linnaeus)	0	0.25	0.25	0	0	0
<i>Monomorium sechellense</i> Emery	0	0.125	0	0	0	0
<i>Monomorium</i> sp. 1 of SKY	0	0	0	0.25	0	0
<i>Pheidole tjobodana</i> Forel	0	0	0	0	0	0.125
<i>Pheidole</i> cf. sp. eg-111	0	0.375	0	0.125	0	0.125
<i>Pheidologeton diversus</i> (Jerdon)	0	0.125	0	0	0	0.5
<i>Pyramica</i> sp.	0	0	0	0.125	0	0.25
<i>Strumigenys feae</i> Emery	0	0.125	0	0	0	0
<i>Tetramorium</i> sp. 63 of SKY	0	0	0	0.125	0	0.25
<i>Tetramorium</i> sp.	0	0.375	0	0.25	0	0
<b>PONERINAE</b>						
<i>Anochetus graeffei</i> Mayr complex	0	0.125	0	0.125	0	0
<i>Centromyrmex feae</i> (Emery)	0	0	0	0	0	0.125
<i>Hypoponera</i> sp. 2 of SKY	0	0.625	0	0.25	0	0.375
<i>Leptogenys</i> sp.	0	0	0	0.375	0	0.125
<i>Odontoponera denticulata</i> (F. Smith)	0	0	0	0	0	0.125
<i>Pachycondyla chinensis</i> (Emery) complex	0	0.125	0	0.5	0	0
<i>Pachycondyla</i> sp. 24 of SKY	0	0.125	0	0	0.125	0.125

PROCERATIINAE						
<i>Discothyrea</i> sp. 3 of SKY	0	0	0	0.25	0	0.125
PSEUDOMYRMECINAE						
<i>Tetraponera attenuata</i> F. Smith	0.125	0	0.75	0	0.375	0
S	11	17	8	17	10	19
H'	2.11	2.65	1.92	2.74	2.13	2.77
H	8.24	14.15	6.82	15.49	8.41	15.96
D	9.09	25.0	11.11	25.0	10.0	20.0

As for arboreal ant samples, 11 species occurred in the six-year, eight species in the nine-year and ten species in the 50-year plantations. Combining all samples, *Oecophylla smaragdina* (Fabricius) and *Tapinoma melanocephalum* (Fabricius) were found in 50 and 27 % of all samples (24 ground + 24 arboreal = 48 samples), respectively. *Aenictus changmaianus* Terayama & Kubota, *Cardiocondyla wroughtonii* (Forel), *Monomorium sechellense* Emery, *Pheidole tjobodana* Forel, *Strumigenys feae* Emery, *Centromyrmex feae* (Emery) and *Odontoponera denticulata* (F. Smith) were found only in one sample each.

Among arboreal ant samples, the species accumulation curves for the nine-year and 50-year plantations reached an asymptote, indicating that sampling was quite complete, especially in the nine-year plantation (Fig. 3a). As a result the curve of the Jackknife 2 species estimator for the nine-year plantation declined after inclusion of more than four samples and converged with the observed species accumulation curve (Fig. 3a). On the other hand the species accumulation curve did not flatten off in the case of the six-year plantation, suggesting that sampling was incomplete. In the terrestrial sampling, too, species richness reached a plateau at the end of the sampling in the nine-year plantation, but it did not in the six-year or 50-year ones (Fig. 3b). This is reflected in the species estimations, which decreased only for the nine-year plantation. The jackknife method estimated the number of ant species (Jackknife 2) to be 16.21 (arboreal) and 35.21 (ground) in the six-year plantation, 8.34 (arboreal) and 23.2 (ground) in the nine-year, and 11.96 (arboreal) and 34.3 (ground) in the 50-year, based on eight samples in each case.

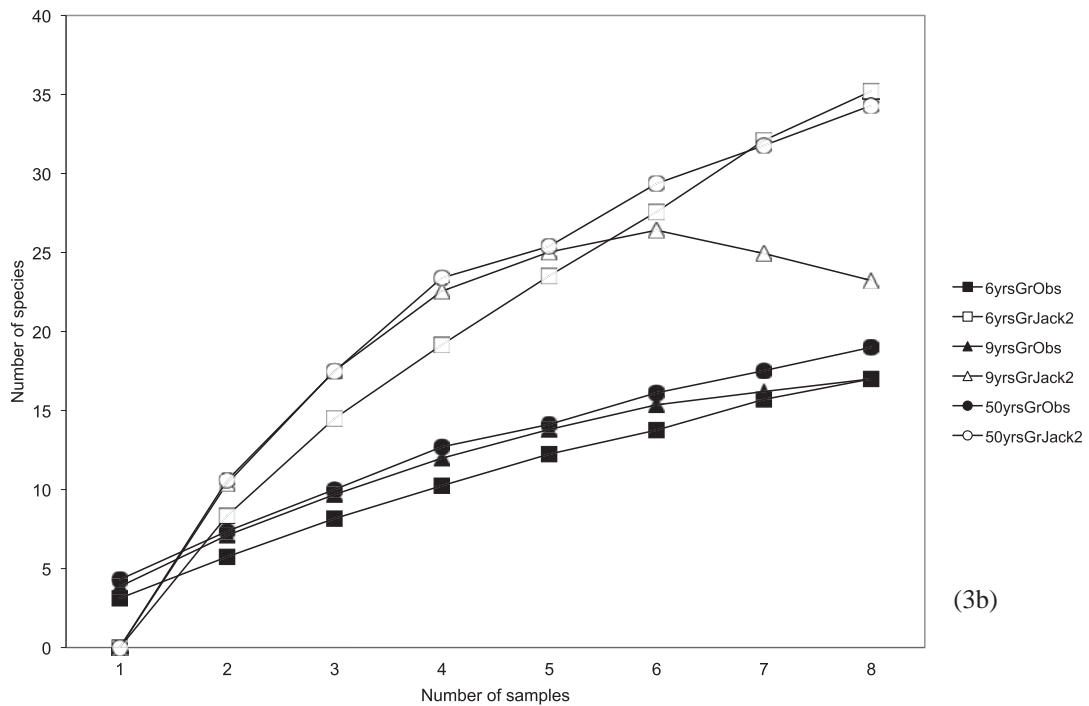
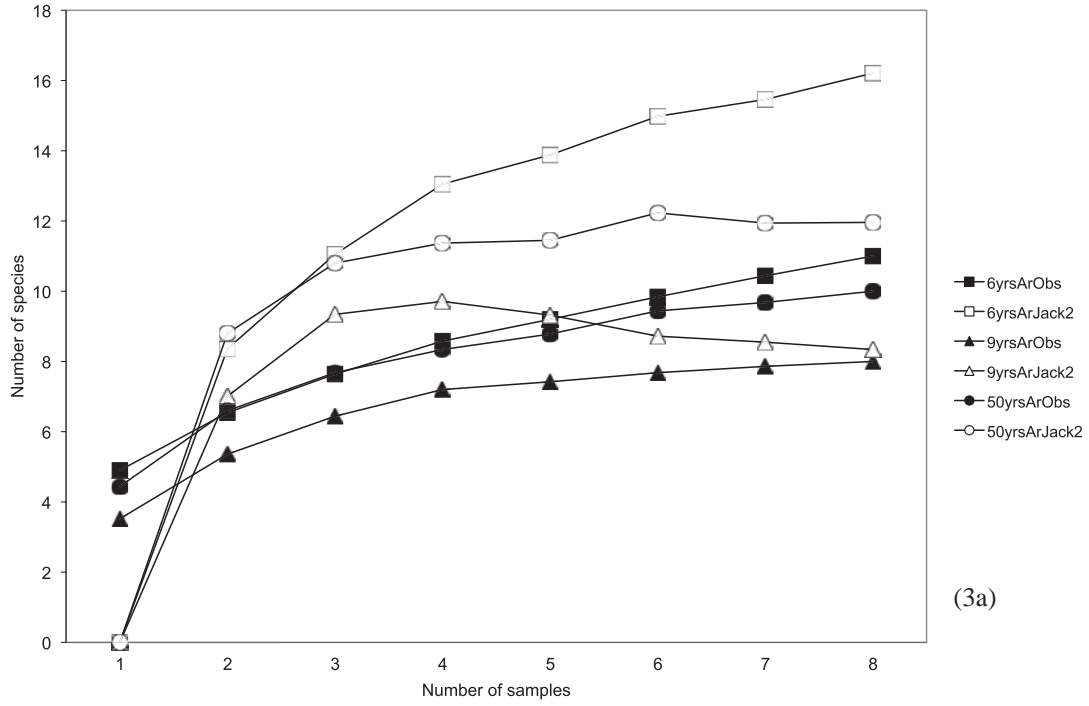
The total species richness of the ants in rubber plantations, including both arboreal and ground ants, was estimated to be around 46 species: 15 species in trees plus 40 species on the

ground (Fig. 4), with an estimated nine species common to both (16.3% of the combined total, based on the observed figures). The subfamily Myrmicinae was the richest in species (46% of the total species collected), followed by the subfamilies Formicinae (20%) and Ponerinae (17%). Species richness was not significantly different between the three plantation types (ANOVA, d.f. = 2, 21;  $F = 0.74$ ,  $P = 0.49$ ).

The Shannon true diversity (H) according to Jost (2006) could be directly compared and was much higher for terrestrial than arboreal ant communities in all three study sites. For example, the species richness and Shannon diversity H of ground ants were each more than double that of arboreal ants in the nine-year plantation (Table 1). Higher diversity of terrestrial communities was also indicated by higher values of the Simpson index (Table 1).

## DISCUSSION

To our knowledge, this is the first comprehensive report on the ant fauna of “real” rubber plantations, although similar work has been carried out in rubber plantations close to a reserve area, which may have acted as a source pool for many of the ant species recorded in that study (Bickel & Watanasit 2005). Bickel & Watanasit (2005) reported 16 ant species at tuna baits (20 traps) from nearby rubber plantations in Southern Thailand. Unlike our results, the most frequently observed species in their study were *Odontoponera denticulata* and *Camponotus* sp. It is likely this difference resulted from the sampling methods (their tuna baits vs. our Winkler extraction). It is sometimes difficult to collect such large and active ants as *Odontoponera* and *Camponotus* spp. by Winkler extraction. Bickel & Watanasit (2005) also referred to *Polyrhachis* sp., *Camponotus* sp. and *Cardiocondyla nuda* (Mayr) as plantation



**Fig. 3.** Species accumulation curves of the observed (continuous lines) and estimated (Jackknife 2, broken lines) species richness for each type of rubber plantation. Curves are plotted from the means of 50 randomisations of the sample accumulation order. 3a, arboreal ant samplings; 3b, ground ant samplings. (Note the estimated richness of zero at one sample is an artefact of the Jackknife method.)

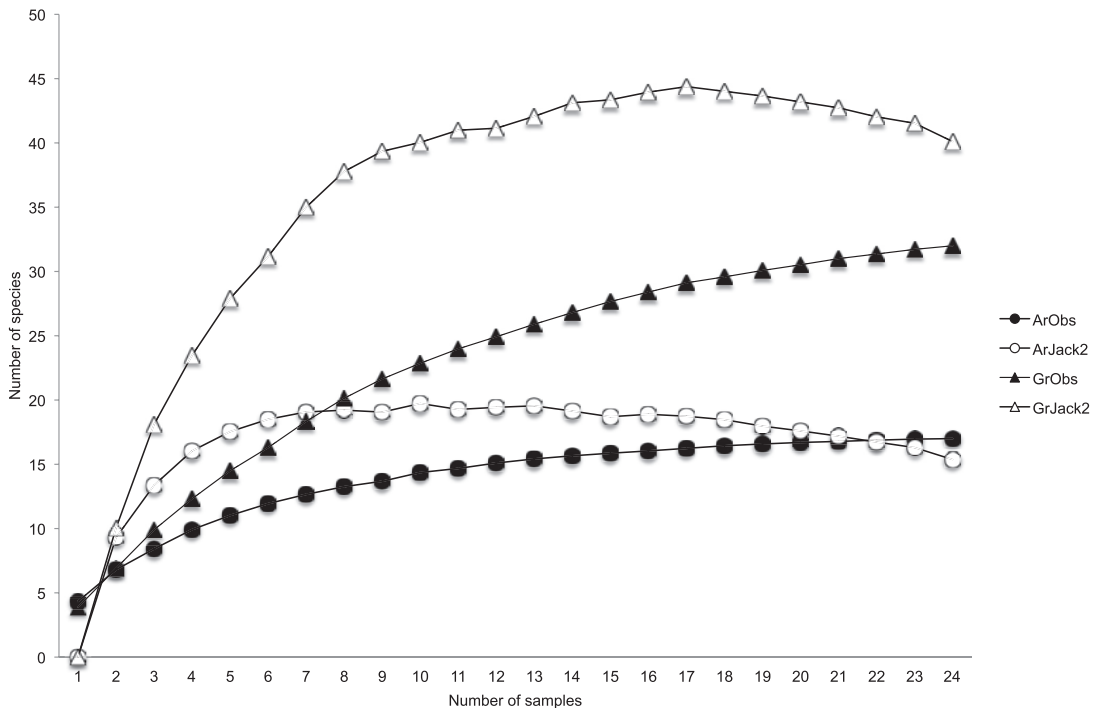
“specialists”, not found in other adjacent habitats. Similarly several *Polyrhachis* species were found common in oil palm plantations (Pfeiffer et al. 2008). However our collections did not include any *Polyrhachis* species, perhaps because our study sites are far from natural vegetation and rubber trees do not have the nesting spaces found in the larger leaves of oil palm trees. Among the species collected in this study *Tapinoma melanocephalum*, *Anoplolepis gracilipes* (F. Smith), *Paratrechina longicornis* (Latreille) and *Monomorium pharaonis* (Linnaeus) are invasive species according to McGlynn (1999). *Tapinoma melanocephalum* and *A. gracilipes* were found in 27 % and 13 % of the 48 samples, respectively.

Interestingly some cryptic and rarer genera, e.g. *Calyptomyrmex*, *Pyramica* and *Discothyrea*, were found in the leaf litter. These genera are generally collected from good forests with abundant leaf litter (cf. Bolton 2000; Shattuck 2011). Although the fauna in the monoculture plantations is generally thought to

be a simple one, our study sites had abundant leaf litter and fertile soil, and could provide a favourable environment for these species.

Among the species collected in this study the genera *Crematogaster* and *Tetraponera* generally make their nests on trees. *Tetraponera attenuata* F. Smith was found in all three sites, whereas *Crematogaster ferrarii* Emery and *C. treubi* Emery were collected exclusively from the oldest site (Table 1). This result does not seem to be caused by incomplete sampling, but mainly because of the existence of the additional microhabitats found in the old plantation. The large rubber trees in old plantations can provide many hollows suitable for nesting.

The fauna in the plantations is generally thought to be low in number of species, but the terrestrial fauna differed from the arboreal one in our study sites (Fig. 3b, 4). A higher number of singleton species was collected in terrestrial samples (three species in the six-year, two in the nine-year and five in the 50-year) than in



**Fig. 4.** Comparison of the ant species richness between arboreal and terrestrial samples in the rubber plantation (all three sites pooled). Species accumulation curves are shown for the observed species richness (continuous lines) and estimated species richness (with species estimator Jackknife2, broken lines). (Note the estimated richness of zero at one sample is an artefact of the Jackknife method.)

arboreal samples (one, zero and three species respectively), suggesting that some ground ant species were not yet recorded from the soil fauna of these plantations (Figs. 3a, 3b, Table 1).

Pfeiffer et al. (2008) recorded 36 species in Tawau (Malay Peninsula) and 39 species in Banting (Borneo) in oil palm plantations by arboreal sampling. They found *Anoplolepis gracilipes*, *Oecophylla smaragdina* and *Technomyrmex albipes* the dominant species there. Our arboreal samples showed a similar pattern, with *Oecophylla smaragdina*, *Tapinoma melanocephalum* and *Anoplolepis gracilipes* present in the most samples (Table 1). Tramp or invasive species can easily be introduced to the plantations with imported seedlings. The high proportion of such species may have resulted in a lower diversity of the arboreal ant fauna than in natural forests, though comparative data are lacking from the study region.

Brühl & Eltz (2010) recorded 23 ant species by bait traps on the ground of oil palm plantations in Sabah, Malaysia (Borneo). In their study, the most common species was *Anoplolepis gracilipes*, followed by *Dolichoderus* sp., *Odontoponera denticulata*, *Technomyrmex* sp. and *Monomorium floricola*. Our terrestrial samples found *Hypoconerops* sp. 2 of SKY to be the most frequently collected species, followed by *Nylanderia* sp. 27 of SKY, *Carebara* sp. 2, *Pheidole* cf. sp. eg-111, *Pheidologeton diversus* (Jerdon), *Tetramorium* sp. 2 and *Pachycondyla (chinensis)* (Emery) complex sp. No invasive ant species (McGlynn 1999) were frequently collected in the ground ant fauna of our study sites. Unlike the sites in oil palm plantations (Brühl & Eltz 2010), our study sites had leaf litter and fertile soil in the ground. This difference may have an influence on the ground ant fauna.

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## ASIAN MYRMECOLOGY

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