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RESEARCH ARTICLE

Ground-dwelling ant assemblages (Family: Formicidae) in six coconut (*Cocos nucifera* L. 1753) plantations in Sri Lanka

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Abstract: The contribution of six well-established coconut plantations to the conservation of biodiversity, specifically of ants, was investigated using soil sifting, timed hand collection and honey baiting along five, 100 m transects established in each plantation. Twenty honey-baited pitfall traps were set throughout each sampling area of each plantation. Collected worker ants were preserved in 70% ethanol and sorted and identified to the furthest possible taxonomic levels under a low-power stereo-microscope. The ant species observed at the five transects in each plantation were tabulated and species richness and proportional abundance of each species at each plantation were recorded. The Shannon-Wiener Diversity index for the ant assemblage at each plantation was calculated. Air and soil temperature, soil humidity and soil pH at each locality were also measured. A diverse ant assemblage occurred at each plantation, where between 19 and 29 species in 4 or 5 subfamilies were recorded; the Shannon-Wiener diversity index values were determined. Higher proportions of formicines and myrmicines than those of other subfamilies were observed. Two or more species in higher proportions than the rest of the ants occurred in each assemblage. Also, the six plantations shared three species and five plantations shared nine species in common. The considerable diversity of ants indicated a healthy environment and provided insight into the presence of other animals in the well-established coconut plantations.

Key words: Insect diversity, beneficial insects, Formicidae, coconut estates, community, Hymenoptera.

Introduction

Coconut farming is traditionally practiced around the world, especially in Asia and the coconut, an essential commodity of people, is also a main export product in Sri Lanka. Coconut is a major plantation crop covering approximately 395,000 ha of land, which accounts for 12% of all agricultural produce in the country. In addition to the nuts, most other parts of the coconut tree are used in many activities and as a source of income; the plant is even called “Tree of life” by Sri Lankans. Current annual production of coconut is not adequate to meet its per capita consumption and export targets so that more production in the country requires the extension of coconut farming to other lands in the future (EDB – Sri Lanka Export Development Board). Clearing of land for planting coconut initially and anthropogenic activities such as weeding, adding manure, pest control, cattle feeding, harvesting practices and collection of fallen coconut fronds regularly as firewood cause high disturbance in the coconut estates. However, surveys on the biodiversity of well-established coconut plantations are scarce in the region.

Ants (Hymenoptera: Formicidae) are a major component of biodiversity in the tropics (Hölldobler & Wilson 1990) and are appropriate for programs of inventory and biodiversity monitoring because most species have stationary, perennial nests with fairly restricted foraging ranges (Alonso 2000). They are therefore ideal organisms for the preparation of inventories in tropical agro-forestry ecosystems (Room 1971; Majer *et al*. 1984; Philpott & Armbrecht 2006; Hosoishi *et al*. 2013). The number and composition of ant species in an area indicate the health of an ecosystem and provide insight into the presence of other organisms, since many ants maintain obligate interactions with plants and other animals (Alonso & Agosti 2000). Relative proportions and diversity of ants evaluated by several sampling methods can be used to indicate different aspects of an ecosystem (Gerlach *et al*. 2013).

Habitat destruction and alteration are the major causes for the loss of biodiversity on earth (Ehrlich 1988) although such activities for some agricultural practices such as rubber plantations seem only to be destructive in the initial stages (Hosoishi *et al*. 2013). Hence, the contribution of well-established coconut plantations to the conservation of biodiversity, in terms of diversity and species composition of ants, in Sri Lanka, is of interest. We here report on the species richness, diversity and species composition of the ground-dwelling ant fauna observed by simultaneous soil sifting, timed hand collection, honey-baiting and pitfall trapping at five locations in each of six coconut plantations in Sri Lanka.

Material and methods

Description of coconut plantations

Six plantations located at Namalwewa (C1) and Ihakuluwewa (C2) in North Central Province and Marawila (C3), Pallama (C4), Madurankuliya (C5) and Egodayagama (C6) in North Western Province were surveyed (Fig. 1). A tropical climate with monsoonal winds and rain prevailed in the regions but a prolonged arid period was noted in C4, C5 and C6 at the time of sampling. Generally, study areas in each plantation were covered with many weeds. Each plantation mainly consisted of tall coconut trees (5-7 m) that were at harvesting stage but few young trees were also present in Pallama and Madurankuliya estates.

Ant sampling and identification

Ant workers were sampled in five transects per plantation on the 1st July and 16th November in 2008, on the 23rd March, 26th May, 28th July in 2009, and on the 7th February in 2010 by (a) soil sifting, (b) timed hand collection and (c) honey-baiting simultaneously along a 100 m transect laid out in each plantation. Within each transect:

(a) Forty soil samples (each 5 cm x 5 cm and 5 cm deep) were taken at 2.5 m intervals along a line, which was parallel and 2 m to the left of transect. These were sifted through a mesh into a white tray. All ants seen with the naked eye were collected into glass vials filled with 85% ethanol.

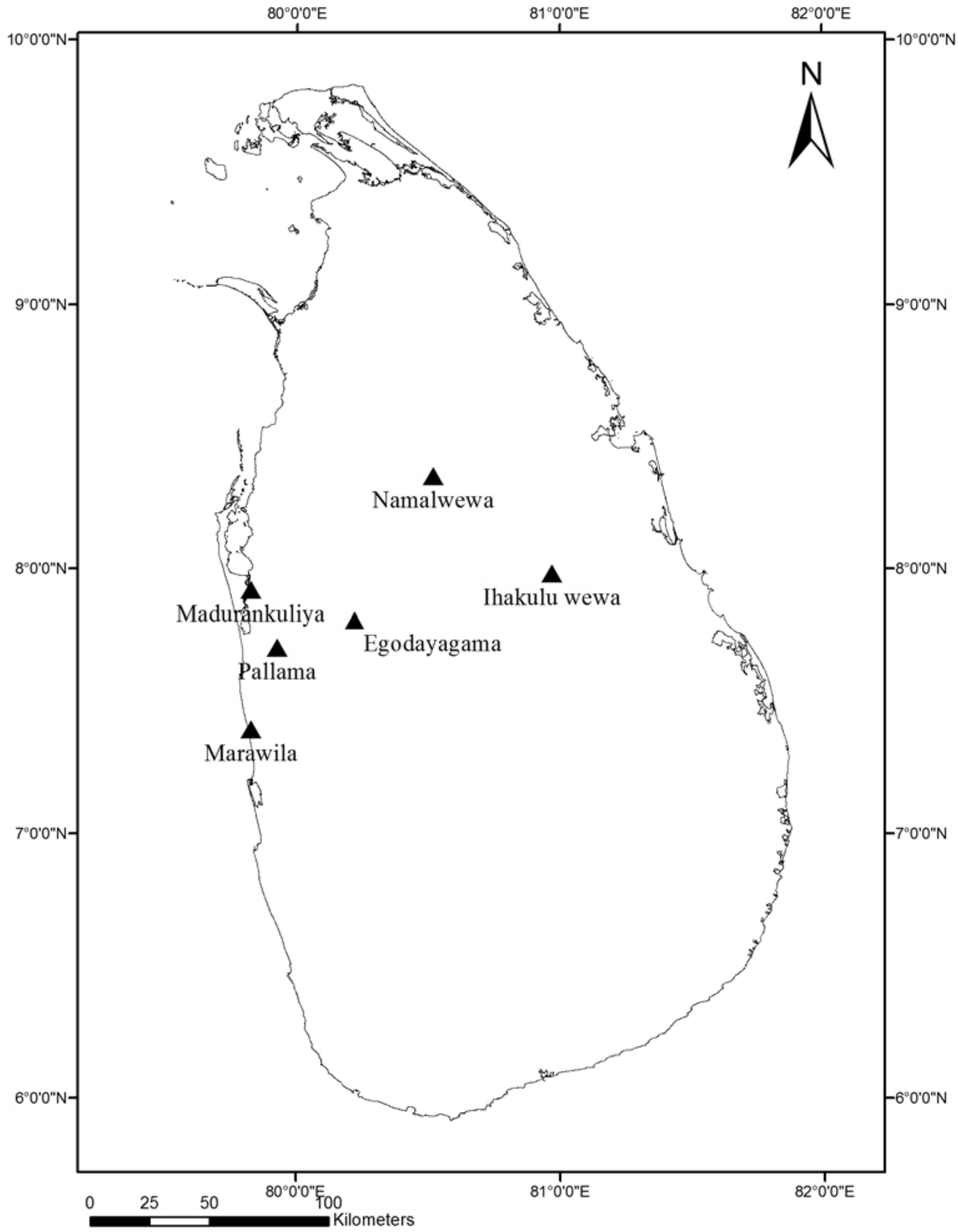

Figure 1. Map of Sri Lanka showing the location of each coconut plantation.

(b) Worker ants crawling on the ground within a radius of about 80 cm were hand collected into glass vials filled with 85% of ethanol over 5 minutes. These were taken around a point 2.5 m apart from the next, with forty such points in a line parallel and 1 m right of the transect.

(c) Forty pieces of gauze (each 2 cm x 2 cm), each with a drop of honey, were placed on the ground at 2.5 m intervals along the transect, and the pieces of gauze and attending ants were collected after one hour into a plastic bottle filled with 85% ethanol.

(d) Twenty honey-baited plastic cups (diameter: 7 cm) that were half-filled with 70% ethanol were set in the soil, with the mouth of the cup flush with the surface soil level, throughout each sampling area of each locality. The cups and the attending ants were collected after four hours and ants were preserved in 85% ethanol.

Collected worker ants were preserved in 70% ethanol with appropriate labels and were sorted and identified to the furthest possible taxonomic levels under a low power stereo-microscope at suitable magnifications with reference to Bingham (1903), Bolton (1994), the reference collection at the Department of Zoology and Environmental Management, University of Kelaniya and AntWeb (2014). Ant species observed at the five localities in each plantation were listed and species richness was recorded. Each ant species observed at a plantation was enumerated and the proportional abundance of each species (= Total number of i^{th} species/ Total number of all species) was calculated for each plantation. Shannon-Wiener Diversity Index values, $H' = \sum (p_i) (\ln p_i)$ where p_i = proportion of total sample belonging to i^{th} species (Krebs 1999) for the ant community observed at each plantation were calculated. Percentage frequency of occurrence of each ant species (= No. of plantations with i^{th} species/ Total No. of plantations surveyed (= 6) x 100) was also estimated.

Measurement of environmental parameters

During each survey, air and soil temperature at three representative points of each transect were measured using a thermometer and the mean value per plantation was calculated. Three soil samples from each transect were brought to the laboratory and soil humidity (Brower *et al*. 1998) of each plantation was recorded from five mean values. Soil pH (Soil pH meter, Spectrum Technologies) at a representative point was recorded and mean soil pH for each plantation was also calculated. One-way Analysis of Variance was used to test for any significant difference among the mean values of each parameter.

Results

Diversity and species composition of worker ants

Table 1 shows that a diverse ant assemblage occurred at each plantation. Twenty six, 27, 22 and 27 species in four subfamilies, Dolichoderinae, Formicinae, Myrmicinae and Ponerinae were observed at Namalweva (C1), Marawila (C3), Pallama (C4) and Madurankuliya (C5), whereas 29 and 19 species in five subfamilies including Cerapachyinae occurred at Ihakuluweva (C2) and Egodayagama (C6) plantations. Generally, higher percentages of formicines (32.1% - 44.4%) and myrmicines (44% - 47.3%) were observed at each plantation. Shannon-Wiener Diversity Index ranged from 1.4 to 3.0, which indicated a considerable ant diversity at each plantation. Forty eight species from 27 genera in five subfamilies (4.2% of cerapachyines, 8.4% of dolichoderines, 35.4% of formicines, 41.7% of myrmicines and 10.4% of ponerines) were recorded from the six plantations.

Three ant species, *Nylanderia yerburyi*, *Oecophylla smaragdina* and *Pheidole* sp. 4, were common at the six plantations (Relative Frequency of Occurrence (FO%) = 100). Ant species that were common at five of the plantations (FO% = 83.3) were *Camponotus compressus*, *Lepisiota capensis*, *Paratrechina longicornis*, *Lophomyrmex quadrispinosus*, *Meranoplus bicolor*, *Monomorium destructor*, *Pheidole* sp. 3, *Tetramorium bicarinatum* and *Pachycondyla tesseronoda*. Another thirteen species were restricted (FO% = 16.7) to a single plantation (Table 1). The rest of the species occurred at FO's from 16.7% to 50% among the six plantations.

Table 1 also shows that certain ant species were caught by a single method, two methods or more methods; e.g. *Cerapachys* spp., *Acropyga acutiventris*, *Prenolepis naoraoji* and *Centromyrmex feae* - soil sampling only; *Plagiolepis exigua* - honey baiting only; *Pheidole* sp. 11 - honey baiting and pitfall trapping only. All the other species were present in samples collected by the four methods.

Table 1. The ant species, the sampling method/s that caught each of them, their proportional abundance and the frequency of occurrence (land-wise and %) of each species in each coconut plantation (Species numbers are according to the first author's repository at the Department of Zoology and Environmental Management, University of Kelaniya, Sri Lanka) B – Honey baiting; H – Hand collecting; P – Pitfall trapping; S – Soil sifting; FO – Relative (%) Frequency of occurrence (out of six lands in brackets)

Subfamily	Species	Method	C1	C2	C3	C4	C5	C6	FO
Cerapachyinae	*Cerapachys aitkinii* Forel, 1900	S	-	-	-	-	-	0.002	**(1/6) 16.7**
	Cerapachys typhlus (Roger, 1861)	S	-	0.001	-	-	-	-	**(1/6) 16.7**
Dolichoderinae	*Tapinoma melanocephalum* (Fabricius, 1793)	S,H,B,P	-	0.008	-	-	-	-	**(1/6) 16.7**
	Tapinoma sp. 1	S,H,B,P	0.06	-	0.001	0.001	0.01	-	**(4/6) 66.7**
	Technomyrmex albipes (Smith F., 1861)	S,H,B,P	-	0.3	-	0.002	0.02	-	**(3/6) 50**
	Technomyrmex bicolor Forel, 1909	S,H,B	-	0.008	-	0.008	-	0.003	**(3/6) 50**
Formicinae	*Acropyga acutiventris* Roger, 1862	S	-	0.008	-	-	-	-	**(1/6) 16.7**
	Anoplolepis gracilipes (Smith F., 1857)	S,H,B,P	0.06	0.3	-	-	0.1	0.3	**(4/6) 66.7**
	Camponotus compressus Fabricius, 1787	S,H,B,P	0.002	0.005	0.001	0.007	0.03	-	**(5/6) 83.3**
	Camponotus irritans (Smith F., 1857)	S,H,B,P	-	0.005	0.006	-	0.1	0.006	**(4/6) 66.7**
	Camponotus oblongus Forel, 1916	H,P	-	-	0.001	-	-	-	**(1/6) 16.7**
	Camponotus reticulatus Roger, 1863	S,H,B,P	0.001	-	0.001	-	0.03	-	**(3/6) 50**
	Camponotus *rufoglaucus* (Jerdon, 1851)	S,H,B,P	-	0.01	0.001	-	0.03	-	**(3/6) 50**
	Camponotus sericeus (Fabricius, 1798)	S,H,B,P	0.009	-	0.04	0.002	0.02	-	**(4/6) 66.7**
	Lepisiota capensis (Mayr, 1862)	S,H,B,P	0.001	0.001	0.008	0.002	-	0.003	**(5/6) 83.3**
	Lepisiota fergusoni (Forel, 1895)	S,H,B,P	0.001	-	0.006	-	0.02	-	**(3/6) 50**
	Nylanderia yerburyi (Forel, 1894)	S,H,B,P	0.1	0.006	0.01	0.006	0.02	0.002	**(6/6) 100**
	Oecophylla smaragdina (Fabricius, 1775)	S,H,B,P	0.002	0.005	0.03	0.02	0.02	0.005	**(6/6) 100**
	Paratrechina longicornis (Latrielle, 1802)	S,H,B,P	0.05	0.04	0.2	0.02	0.05	-	**(5/6) 83.3**
	Plagiolepis exigua Forel, 1894	B	0.001	-	-	-	-	-	**(1/6) 16.7**
	Plagiolepis jerdonii Forel, 1894	S,H,B,P	-	-	0.08	0.004	0.01	-	**(3/6) 50**
	Polyrhachis punctillata Roger, 1863	S,H,B,P	0.002	-	-	-	-	0.002	**(2/6) 33.3**
	Prenolepis naorojii Forel,	S	-	-	-	-	-	0.002	**(1/6)**

	1902								**16.7**
Myrmicinae	*Crematogaster dohrni* Mayr, 1879	S,H,B,P	0.04	-	0.2	0.06	0.08	-	**(4/6) 66.7**
	Crematogaster rothneyi Forel, 1913	S,H,B,P	0.25	0.08	-	-	-	0.2	**(3/6) 50**
	Lophomyrmex quadrispinosus (Jerdon, 1851)	S,H,B,P	0.2	0.03	0.1	0.7	0.07	-	**(5/6) 83.3**
	Meranoplus bicolor (Guerin-Meneville, 1844)	S,H,B,P	-	0.07	0.02	0.002	0.1	0.4	**(5/6) 83.3**
	Monomorium destructor (Jerdon, 1851)	S,H,B,P	0.01	0.003	0.001	-	0.03	0.003	**(5/6) 83.3**
	Monomorium floricola (Jerdon, 1851)	S,H,B,P	0.01	0.007	-	-	-	0.002	**(3/6) 50**
	Monomorium pharaonis (L., 1758)	S,H,B,P	0.05	0.001	0.01	-	0.008	-	**(4/6) 66.7**
	Monomorium sp. 4	S,H,B	0.003	-	-	-	-	0.003	**(2/6) 33.3**
	Pheidole sp. 1	S,H,B,P	0.001	0.002	0.01	-	0.03	-	**(4/6) 66.7**
	Pheidole sp. 2	S,H,B,P	-	-	0.04	0.014	0.02	-	**(3/6) 50**
	Pheidole sp. 3	S,H,B,P	-	0.006	0.04	0.06	0.12	0.03	**(5/6) 83.3**
	Pheidole sp. 4	S,H,B,P	0.003	0.04	0.04	0.1	0.03	0.01	**(6/6) 100**
	Pheidole sp. 7	S,H,B,P	-	0.001	-	-	-	-	**(1/6) 16.7**
	Pheidole sp. 9	S,B,P	0.001	-	-	-	-	-	**(1/6) 16.7**
	Pheidole sp. 11	B,P	-	-	0.001	0.007	-	-	**(2/6) 33.3**
	Solenopsis geminata (Fabricius, 1804)	S,H,B,P	0.01	-	0.001	0.006	0.03	-	**(4/6) 66.7**
	Tetramorium bicarinatum (Nylander, 1846)	S,H,B,P	0.2	0.003	-	0.002	0.02	0.005	**(5/6) 83.3**
	Tetramorium smithi Mayr, 1879	S,H,B,P	-	0.002	-	0.001	0.04	0.006	**(4/6) 66.7**
	Tetramorium tortuosum Roger, 1863	S,B,P	-	0.05	-	-	-	-	**(1/6) 16.7**
	Tetramorium walshi (Forel, 1890)	S,H,B,P	-	-	0.001	-	0.03	-	**(2/6) 33.3**
Ponerinae	*Anochetus graeffei* Mayr, 1870	S,H	-	-	-	-	-	0.002	**(1/6) 16.7**
	Centromyrmex feae (Emery, 1889)	S	-	0.001	-	-	-	-	**(1/6) 16.7**
	Diacamma ceylonense Emery, 1897	S,H,B,P	-	-	0.2	0.03	-	-	**(2/6) 33.3**
	Leptogenys processionalis (Jerdon, 1851)	S,H,B,P	0.003	-	-	-	-	-	**(1/6) 16.7**
	Pachycondyla tesseronoda (Emery, 1877)	S,H,B,P	0.003	0.007	0.002	0.004	0.02	-	**(5/6) 83.3**
		Total No. (N)	1453	884	848	855	590	623	
		Species richness	26	28	27	22	27	19	
		Shannon-Wiener diversity index	**2.19**	**2.0**	**2.4**	**1.40**	**3.0**	**2.10**	

Environmental parameters

Air and soil temperature, soil moisture % and soil pH observed at each plantation during the sampling varied with the location (Table 2). Comparable air and soil temperature values and slightly different soil pH values were observed at the six plantations ($p > 0.05$).

Although no significant difference was evident, considerable differences in soil humidity values were also evident among the six plantations.

Table 2. Mean soil and air temperature, soil humidity% and soil pH (± S.D.) observed at each coconut plantation.

Location	Temperature (ºC)		Soil humidity %	Soil pH
	Air	Soil		
Namalwewa (C1)	31.0	30.7 ± 0.4	5.1 ± 3.5	6.2 ± 0.2
Ihakuluwewa (C3)	30.0	28.4 ± 1.7	11.3 ± 1.8	6.9 ± 0.1
Marawila (C4)	33.0	33.8 ± 1.9	2.05 ± 1.2	5.2 ± 1.0
Pallama (C5)	30.0	29.0 ± 0.0	2.8 ± 1.5	5.4 ± 0.5
Madurankuliya (C6)	29.5	30.0 ± 0.0	2.9 ± 1.3	6.3 ± 0.2
Egodayagama (C7)	30.5	30.8 ± 0.46	9.4 ± 0.48	6.1 ± 0.31

Discussion

Ground ant diversity in coconut plantations was assessed for the first time in Sri Lanka. Species richness values recorded in the present study fall within the values observed by the four methods and leaf litter sifting at Kahalle Forest and Somawathiya Sanctuary in the dry zone (Dias & Kosgamage 2012). D'Cunha & Nair (2013) reported 17 species, a lower species richness than the current values, and four subfamilies similar to the current findings from a 2.5 ha coconut plantation in Karnataka, India. More diverse ant assemblages were recorded in the current survey but *C. compressus*, *C. oblongus*, *C. sericeus*, *O. smaragdina*, *P. longicornis*, *P. jerdonii*, *M. bicolor* and the genera, *Monomorium*, *Tetramorium*, *Anochetus*, *Diacamma*, *Crematogaster* and *Nylanderia* were common to the both surveys. Greenslade (1971) shared *O. smaragdina* in the Solomon Islands with the current survey. Twelve species of four subfamilies were recorded as the visitors of coconut flowers in Brazil (Conceição *et al.* 2014a) but *Camponotus* and the single species, *M. floricola* were only shared by the two studies. Four coconut plantations of the current survey had slightly higher species richness values than that reported from the oil palm plantations in Sabah, Malaysia (Bruhl & Eltz 2010). Gerlach *et al*. (2013) proposed that ants could be used as indicators in the ground layer but evaluation of the relative proportions and diversity of ants is required as they may be poor indicators of species richness. On the basis of the current findings, species richness, diversity and relative proportions of ants in the coconut plantations fulfilled the proposed requirements of Gerlach *et al*. (2013). It has been shown that agricultural practices such as fertilization, tillage and ploughing (anthropogenic activities) reduce ant diversity, biomass and colony densities. Hence, the surveying of the initial ant assemblages, subsequent ant assemblages and those in well-established plantations (e.g. in age sequences) are recommended to conclude if ants tolerate, recover or re-invade the same areas after the disturbance (Folgarait 1998; Conceição et al. 2014b) caused by the agricultural practices.

Similar to the reports from other research on ants (Hosoishi *et al*. 2013), each coconut plantation had higher proportions of myrmicines and formicines than those of other three subfamilies. Each coconut plantation had higher proportions of two or several different ant species, such as *N. yerburyi*, *C. rothneyi*, *L. quadrispinosus* and *T. bicarinatum* at C1, and *T. albipes* and *A. gracilipes* at C2, and lower proportions of rest of the species, resulting in species composition of ground ants varying in the six plantations. The observed variability should be a reflection of environmental conditions (Table 2), food and nesting site availability (personal observation) and other fauna and flora occurred at each land. Species that were common at six and five plantations can be considered generalists (mostly tramp species) and indicator ant species of the coconut estates. Ant species restricted to a single plantation could be specialists adapted to form colonies only under the environmental conditions existed at that particular plantation. Soil nesting ants, such as *M. bicolor*, *S. geminata* and several ponerines observed in the present survey, belong to various trophic levels and can be considered as ecosystem engineers (Jones *et al*. 1994). Their effects on soil structure and processes directly and indirectly affect the flow of energy and material as well as the microhabitats of other species (Folgarait 1998). Hence, the presence of such soil nesting ant species, despite fertilization and other anthropogenic activities, is beneficial for the well-being of coconut plantations.

Nylanderia yerburyi, *O. smaragdina* and *Pheidole* sp. 4, the species common at the six plantations, together with *C. compressus*, *L. capensis*, *P. longicornis*, *L. quadrispinosus*, *M. bicolor*, *M. destructor*, *Pheidole* sp.3, *T. bicarinatum* and *P. tesseronoda*, the species that were common at five of the plantations only, can be considered the resident ant community of coconut plantations of Sri Lanka. Also, *A. gracilipes* (opportunist), *P. exigua* (cryptic species) and the tramp species, *M. destructor, M. pharaonis, T. melanocephalum, T. albipes* and *T. bicarinatum* observed at the coconut plantations are non-native species according to McGlynn (1999). Bingham (1903) indicated *Lepisiota* as an exotic species to Sri Lanka. Two invasive species (McGlynn 1999; Holway *et al.* 2002), *P. longicornis* and *S. geminata* were also observed in higher and lower proportions, respectively. *Anoplolepis gracilipes* was the most common species observed in oil palm plantations (Bruhl & Eltz 2010) and considerable proportions of *O. smaragdina*, *T. melanocephalum* and *A. gracilipes* were also reported from rubber plantations (Hosoishi *et al*. 2013). Lower proportions of arboreal *O. smaragdina* workers were observed in the present coconut plantations because few workers usually forage on the ground (personal observation). *Oecophylla* ants are the earliest recorded biological control agents (Huang & Yang 1987) and can be considered the most effective group of ants to control the pest species in tropical tree crops (Way & Khoo 1992; Peng & Christian 2004).

The ant list presented in Table 1 can be considered a preliminary inventory of ants in coconut plantations in Sri Lanka and represented a considerable contribution of well-established coconut plantations as a land use type to the biodiversity conservation. Further surveys that include sampling of night foragers, arboreal species and repeated sampling in the same plantations in the dry and rainy season are encouraged to improve the list.

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