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Worker ant community observed by repeated sampling and information on endemic *Aneuretus simoni* Emery in the Gilimale Forest Reserve in Sri Lanka

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ABSTRACT. The ant community of Gilimale Forest Reserve in Sri Lanka is of special interest as a habitat of the island-endemic *Aneuretus simoni*. Ant community composition and aspects of *A. simoni* ecology in this forest were investigated using multiple sampling methods simultaneously, on six visits to Gilimale from February to December 2004. Daytime sampling of ants was carried out along ten 100 m transects by honey and canned-fish baiting, leaf litter and soil sifting, hand collection, pitfall trapping and mini-Winkler extraction. Honey baits at 1 m height on trees, and honey-baited pitfall traps on the ground, were set overnight. Air and soil temperature, depth of leaf litter and soil moisture during sampling were recorded on each occasion. Fifty species, in 38 genera, were recorded. *Aneuretus simoni*, *Camponotus* sp. 1, *Carebara* sp., *Dolichoderus* sp. 1, *Leptogenys* sp., *Lophomyrmex quadrispinosus*, *Monomorium* sp., *Myrmicaria brunnea*, *Odontomachus simillimus*, *Paratrechina* (sensu lato) sp., *Pheidole* sp. 2, *Pheidole* sp. 7, *Pheidologeton* sp., *Polyrhachis* sp., *Solenopsis* sp., *Technomyrmex bicolor* and *Tetramorium bicarinatum* were common and detected on all occasions. Detectability of *A. simoni* was consistently high and the species comprised 3–6 percent of worker ants collected on each of the six occasions.

Keywords: *Aneuretus simoni* Emery, Gilimale Forest Reserve, species richness, rare ants, multiple methods, repeated sampling

INTRODUCTION

Since 1955, Gilimale Forest Reserve in Sri Lanka has been known as a habitat of the Sri Lanka-endemic ant, *Aneuretus simoni* Emery (Wilson *et al*. 1956; Jayasuriya & Traniello 1985), the sole extant representative of Subfamily Aneuretinae. Gilimale Forest Reserve (6º 47′ N and 80º 28′ E, average altitude 152 m) occupies approximately 1,147 ha and is situated in Ratnapura District, in Sabaragamuwa Province. This wet evergreen tropical forest receives on average 4,758 mm of rainfall annually and is characterised by highly dissected terrain with numerous streams draining into several rivers. The average slope ranges from 9º to 15º, but certain areas adjoining streams and rivers are extremely steep (Balasubramanium *et al.* 1991).

Eleven ant genera (*Aneuretus*, *Camponotus*, *Crematogaster*, *Euponera* (*Brachyponera*), *Euponera* (*Mesoponera*), *Myrmicaria*, *Paratrechina* (*Nylanderia*), *Pheidole*, *Ponera*, *Polyrhachis* and *Technomyrmex*) were recorded from the forest by Wilson *et al.* (1956), whereas ten genera (*Aneuretus*, *Camponotus*, *Crematogaster*, *Monomorium*, *Odontomachus*, *Pachycondyla*, *Paratrechina*, *Ponera*, *Solenopsis* and *Tetramorium*) were recorded by Jayasuriya & Traniello (1985). Our first survey of Gilimale Forest, in February 2004, revealed nine subfamilies (Aenictinae, Amblyoponinae, Aneuretinae, Dolichoderinae, Dorylinae, Formicinae, Leptanillinae, Myrmicinae and Ponerinae) and 37 species including *A. simoni* (Dias & Perera 2005a). Three visits in April, June and August 2004 collectively recorded nine subfamilies

(Pseudomyrmecinae added; Dorylinae not found) and 35 species from the ground and lower canopy of the forest (Dias & Perera 2005b). The survey was extended through October and December 2004 and the results of the six visits are combined here to characterise the community of ground-dwelling ants observed by simultaneous multiple sampling in Gilimale Forest throughout 2004. We also report on several ecological aspects of *A. simoni* workers in this forest.

METHODS

Field and laboratory methods

Ten locations of Gilimale Forest Reserve were surveyed for ants, using several sampling methods along a 100 m transect laid at each location, on 23–26 February, 15–18 April, 24–27 June, 24–27 August, 29–31 October and 17–19 December 2004. At each location we carried out extraction of ants by (a) mini-Winkler sacks, (b) soil sifting, (c) pitfall trapping, (d & e) honey and canned fish baiting, (f) litter sifting by hand and (g) timed hand collection. Within each transect:

(a) Five polythene bags were each filled with leaf litter from five different 1 m^2 areas, sampled at 20 m intervals along the transect, and the litter in each bag was transferred to a mini-Winkler sack kept in the laboratory. The worker ants emerging after 48 hours were preserved in 85% ethanol.

(b) Ten soil samples (each 20 x 20 wide x 10 cm deep), taken at 10 m intervals along a line which was parallel and 1 m left of the transect, were sifted through mesh into a white tray. All ants seen with the naked eye were collected into glass vials filled with 85% ethanol.

(c) Ten cups (volume: 110 cm^3), each half-filled with soap water, were set in the soil at 10 m intervals along a line parallel and 1 m right of the transect, with the mouth of the cups flush with the surface soil level.

(d, e) Twenty-five baits each of honey and canned fish (jack mackerel in natural juice with added salt), on a 5 x 5 cm piece of gauze, were placed alternately on the ground at 4 m intervals along the transect, and the pieces of gauze and attending ants were collected after one hour into a plastic bottle filled with 50% ethanol.

(f) Ten litter samples (each of one full sieve), taken at 10 m intervals along the transects, were sifted into a white tray and ants seen with the naked eye were collected into a vial filled with 85% ethanol.

(g) Hand collection was conducted for 10 minutes, around a point approximately 10 m apart from the next, with ten such points in each transect. At each point, ants crawling on the forest floor along a horizontal line which connects each point at 1 m left and 1 m right of the transect, were collected and ants were preserved in 85% ethanol.

Some of the locations were also sampled at night by different methods: (h) honey-baited pitfall traps on the ground and (i) honey-baited small plastic vials hung on trees.

(h) In three of the transects used during the daytime, ten plastic cups of 110 cm^3, each honey-baited and half-filled with 50% ethanol, were set in the evening in the soil along the 100 m transect.

(i) At the same three locations in February, and five locations on subsequent occasions, ten honey-baited small plastic vials were hung in the evenings (17:00–18:00 h) on ten trees, 10 m apart along the transects, and were collected at around 07:00 h the following morning.

Collected ants were preserved in 85% ethanol and the presence of *A. simoni* and other species was recorded. Ants were identified to the furthest possible taxonomic level using a low-power stereo-microscope at suitable magnifications with the assistance of Professor Seiki Yamane, Kagoshima University, Japan, and

by reference to Bolton (1994, 2003). Scientific names of the ants are given according to Bolton *et al*. (2006).

Measurement of environmental parameters during the sampling of ants

During each survey, air and soil temperature at the start, middle and end points of each transect were measured using a thermometer and the mean value per transect was recorded. Depth of the leaf litter layer was measured in the same manner using a ruler, and the mean depth (cm) per transect was recorded. Similarly, three subsamples of soil from each transect were brought to the laboratory and soil humidity (Brower *et al.* 1998) of each transect was recorded. The mean value of each parameter during the sampling period was calculated from the ten locations measured on each occasion.

RESULTS

Species richness and composition of worker ant community

Table 1 shows that worker ants belonging to 11 subfamilies, 38 genera and 50 species were recorded from the six visits to Gilimale Forest in 2004. The number of subfamilies observed on each occasion was 9, 8, 6, 9, 7 and 6, respectively. Seventeen species [*Aneuretus simoni* Emery, *Camponotus* sp. 1, *Carebara* sp., *Dolichoderus* sp. 1, *Lophomyrmex quadrispinosus* (Jerdon), *Leptogenys* sp., *Monomorium* sp., *Myrmicaria brunnea* Saunders, *Odontomachus simillimus* F. Smith, *Paratrechina* (sensu lato) sp., *Pheidole* sp. 2, *Pheidole* sp. 7, *Pheidologeton diversus* (Jerdon), *Polyrhachis* sp., *Solenopsis* sp., *Technomyrmex bicolor* Emery and *Tetramorium bicarinatum* (Nylander)] were common on all occasions and observed throughout the study period. In addition, *Acropyga acutiventris* Roger, *Cardiocondyla* sp., *Cerapachys* sp., *Dorylus* sp., *Pachycondyla* sp. 3, *Pheidole* sp. 8 and *Tetraponera allaborans* (Walker) were observed on two or more of the six visits. The highest species richness was recorded in February, whereas lowest species richness was observed in December (Fig.1).

Effects of using several sampling methods and transects on recorded species richness

Employing a combination of several simultaneous sampling methods yielded more ant species than

Table 1: Worker ant species observed on each visit to Gilimale Forest and overall worker ant community recorded in 2004. Bold letters show the species observed on all occasions. Species numbers are according to the first author's collection kept at the Department of Zoology, University of Kelaniya, Sri Lanka. *sensu lato. p = present

Subfamily	Genus/ species		Visit						Overall
			1	2	3	4	5	6	
1. Aenictinae	*1)*	*Aenictus* sp.	p	p	-	p	-	-	P
2. Amblyoponinae	*2)*	*Amblyopone* sp.	p	p	-	p	-	p	P
3. Aneuretinae	***3)***	***Aneuretus simoni***	**p**	**p**	**p**	**p**	**p**	**p**	**P**
4. Cerapachyinae	*4)*	*Cerapachys* sp.	-	p	-	-	-	-	P
5. Dorylinae	*5)*	*Dorylus* sp.	p	-	-	-	-	-	P
6. Dolichoderinae	***6)***	***Dolichoderus* sp. 1**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	7)	*Tapinoma indicum*	p	-	-	p	-	-	P
	8)	*T. melanocephalum*	-	-	p	p	p	-	P
	9)	***Technomyrmex bicolor***	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	10)	*T. albipes*	p	-	p	p	p	p	P
7. Formicinae	*11)*	*Acropyga acutiventris*	-	-	-	-	-	p	P
	12)	*Anoplolepis gracilipes*	p	p	p	p	-	-	P

Table 1 (*continued*)

Subfamily	Genus/ species	Visit						Overall
	***13) Camponotus* sp. 1**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	14) C. sp. 2	p	p	p	p	-	-	P
	15) Lepisiota sp.	p	-	-	-	-	-	P
	16) Myrmoteras sp.	p	-	p	-	-	p	P
	***17) Paratrechina* sp.**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	18) P. longicornis	p	-	-	p	p	-	P
	***19) Polyrhachis* sp.**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	20) Pseudolasius sp.	-	-	p	p	p	-	P
8. Leptanillinae	*21) Leptanilla* sp.	p	-	p	p	p	-	P
9. Myrmicinae	*22) Calyptomyrmex* sp.	-	-	p	p	p	-	P
	23) Cardiocondyla sp.	p	-	-	-	-	-	P
	***24) Carebara* sp.**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	25) Cataulacus sp.	-	p	p	p	-	-	P
	26) Crematogaster sp. 1	p	p	p	p	p	-	P
	27) C. sp. 2	p	-	-	-	-	p	P
	28) C. sp. 3	p	-	-	-	-	p	P
	29) Lophomyrmex quadrispinosus	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	30) Meranoplus bicolor	-	-	p	p	p	-	P
	***31) Monomorium* sp.**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	32) Myrmicaria brunnea	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	***33) Pheidole* sp. 2**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	***34) P.* sp. 7**	**p**	**p**	**p**	**p**	**p**	**p**	**P**
	35) P. sp. 8	p	-	-	-	-	p	P
	***36) Pheidologeton* sp.**	**p**	**p**	**p**	**p**	**P**	**p**	**P**
	***37) Solenopsis* sp.**	**p**	**p**	**p**	**p**	**P**	**p**	**P**
	38) Strumigenys (Quadristruma) sp.	p	p	p	p	P	-	P
	39) Tetramorium sp.	p	p	p	-	P	p	P
	40) T. bicarinatum	**p**	**p**	**p**	**p**	**P**	**p**	**P**
10. Ponerinae	*41) Anochetus* sp.	p	p	-	p	P	p	P
	42) Centromyrmex feae	p	p	p	-	P	-	P
	43) Hypoponera sp.	p	p	p	p	P	-	p
	***44) Leptogenys* sp.**	**p**	**p**	**p**	**p**	**P**	**p**	**p**
	45) Odontomachus simillimus	**p**	**p**	**p**	**p**	**P**	**p**	**p**

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Table 1 (*continued*)

Subfamily	Genus/ species	Visit						Overall
	46) *Ponera* sp.	p	p	p	p	-	p	p
	47) Pachycondyla sp. 1	-	p	p	-	P	p	p
	48) P. sp. 2	-	p	-	-	P	-	p
	49) P. sp. 3	-	-	-	-	-	p	p
11. Pseudomyrmecinae	*50) Tetraponera allaborans*	-	-	-	p	P	-	p
	Total	**39**	**32**	**34**	**36**	**33**	**29**	**50**

using a single method on each occasion (Table 2). The cumulative number of species observed during this study increased with the number of transects (to ten) and visits (to six) (Fig. 1).

Environmental parameters

Slight differences in environmental conditions among sampling periods on the six occasions were noticeable (Table 3). The highest and lowest

Table 2: Species richness recorded by each sampling method and the overall methods on each visit to Gilimale Forest in 2004. Only daytime sampling methods used at all sites are shown.

Month	CB	HB	LS	SS	HC	CB+HB+LS+SS+HC
February	19	24	27	22	17	39
April	17	19	22	14	24	32
June	20	19	20	15	20	32
August	22	21	23	12	16	36
October	16	21	17	13	22	32
December	11	13	15	11	14	29
Total	**27**	**30**	**37**	**34**	**31**	**50**

CB = Canned-fish Bait, HB = Honey Bait, LS = Litter Sieving, SS = Soil Sieving, HC = Hand Collection.

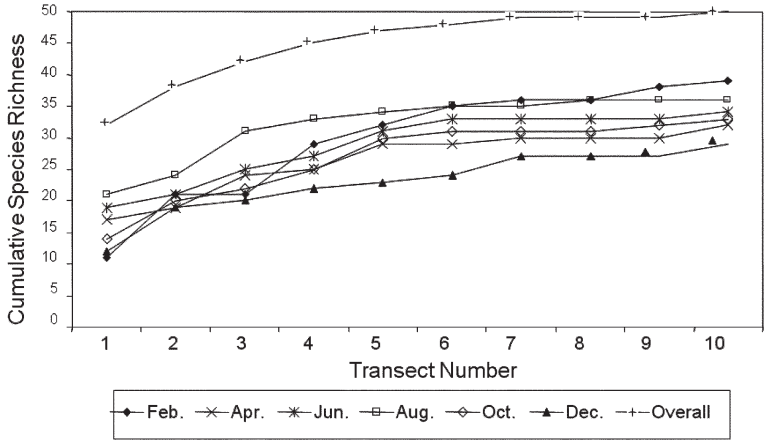

Fig.1. Species accumulation curves for ten transects on each visit, and overall cumulative number of species recorded, from Gilimale Forest. (Night time baits were unsuccessful and did not collect ants on all occasions)

soil relative humidity were recorded on February and June visits, respectively.

Table 3: Environmental parameters of Gilimale Forest recorded on each occasion in 2004 (mean of ten measurements ± SD)

Parameter	Feb	Apr	Jun	Aug	Oct	Dec
Air temperature (°C)	27.0 ± 2.8	29.1 ± 1.2	26.0 ± 1.3	28.5 ± 2.0	27.6 ± 1.7	27.5 ± 2.5
Soil temperature (°C)	24.6 ± 1.3	26.5 ± 0.53	24.4 ± 0.53	26.0 ± 1.7	26.3 ± 1.8	25.3 ± 2.1
Mean litter depth (cm)	2.3 ± 0.89	4.7 ± 1.7	5.3 ± 0.44	3.9 ± 0.2	4.6 ± 1.0	2.6 ± 1.1
Soil humidity (%)	35.7 ± 2.2	32.1 ± 1.4	19.6 ± 0.19	23.3 ± 4.6	28.0 ± 2.1	33.0 ± 4.1

Aspects of the ecology of *A. Simoni*

The sampling methods varied in effectiveness in catching *A. simoni* workers, between transects and between times of year (Table 4). No sampling method was effective in attracting these workers on all occasions. The species was recorded in all months at Transects 2, 3, 4, 5 and 7, and in all, except December, at Transects 1, 6 and 9. Percentage frequency of occurrence [(Number of transects positive for *A. simoni* / 10) x 100] of this species in Gilimale Forest ranged from 80% to 90% on the six occasions. The relative abundance of workers ranged from 3% to 6% of all collected specimens, with the highest proportion in February (Table 4). Table 5 shows that all methods except the tree traps were effective for detecting this species on each occasion.

Table 4: Sampling methods that caught *A. simoni* workers in each transect laid, percentage frequency of occurrence in transects, and relative abundance of this ant species in Gilimale Forest. Numbers in parentheses indicate the total number of ants encountered on each occasion.

Year 2004	Transect number										Frequency of occurrence (% of transects)	Relative abundance (% of individuals collected)
	1	2	3	4	5	6	7	8	9	10		
Feb	CB HB LS	LS PT	HB LS	CB SS	SS	HB	HB LS WM		HB		80	6 (2482)
Apr	HB LS PT	CB HB LS PT	HB LS HC	LS HC	CB HB PT	CB HB	CB LS		LS HC	LS	90	5 (3227)
Jun	HB	SS PT	HB LS	CB HB LS PT	CB HB	CB SS HB	LS SS HB		HB	LS	80	5 (2659)
Aug	WM	HB LS PT	HB LS PT	HB LS PT	CB	HB LS	CB HB PT		HB	CB HB	90	5 (3458)
Oct	LS HC PT	HB LS PT	HB LS HC	HB LS PT	HB CB HC	CB HB SS	CB HB LS		LS	LS	90	3.5 (2311)
Dec		LS SS	HB LS HC	SS	LS		LS	LS			90	3 (2509)

CB = Canned-fish Bait, HB = Honey Bait, HC = Hand Collection, LS = Litter Sieving, PT = Pitfall Trapping, SS = Soil Sieving, WM = Mini-Winkler extraction

Table 5: Effective sampling method/s for each species. *sensu lato

Ant species	Effective methods
Aenictus sp.	LS, SS, HC
Amblyopone sp.	LS, SS
Aneuretus simoni	CB, HB, LS, SS, HC, WM, PT
Cerapachys sp.	SS
Dorylus sp.	CB, SS, HC
Dolichoderus sp. 1	CB, HB, LS, HC, PT, TT
Tapinoma indicum	CB, HB, LS, SS, HC, PT
T. melanocephalum	CB, HB, SS, TT
Technomyrmex bicolor	CB, HB, LS, SS, HC, WM, PT, TT
T. albipes	CB, HB, LS, SS, HC, PT, TT
Acropyga acutiventris	SS
Anoplolepis gracilipes	CB, HB
Camponotus sp. 1	CB, HB, LS, HC, WM, PT, TT
C. sp. 2	CB, HB, LS, HC, WM, PT, TT
Lepisiota sp.	LS, SS
Myrmoteras sp.	LS, SS
*Paratrechina** sp.	CB, HB, LS, HC, WM, PT, TT
P. longicornis	LS, SS
Polyrhachis sp.	CB, HB, SS, HC
Pseudolasius sp.	SS
Leptanilla sp.	LS, SS
Calyptomyrmex sp.	SS, PT
Cardiocondyla sp.	SS
Carebara sp.	CB, HB, LS, SS, HC, WM
Cataulacus sp.	HC
Crematogaster sp. 1	CB, HB, LS, HC, PT, TT
C. sp. 2	CB, HB, LS, HC
C. sp. 3	CB, HB
Lophomyrmex quadrispinosus	CB, HB, LS, HC
Meranoplus bicolor	HB, LS, PT
Monomorium sp.	HB, LS, WM
Myrmicaria brunnea	CB, HB, LS, SS, HC, WM, PT, TT
Pheidole sp. 2	CB, HB, LS, SS, HC, WM, PT
P. sp. 7	CB, HB, LS, SS, HC, WM, PT
P. sp. 8	CB, HB, LS, SS, HC, WM, PT
Pheidologeton sp.	CB, HB, LS, SS, WM, PT
Solenopsis sp.	CB, HB, LS, SS, HC, WM, PT

Table 5 (*continued*)

Ant species	Effective methods
Strumigenys (Quadristruma) sp.	LS, HC, WM
Tetramorium sp.	CB, HB, LS, HC, PT
T. bicarinatum	CB, HB, LS, SS, HC, WM, PT
Anochetus sp.	HB, LS, SS, HC
Centromyrmex feae	LS, SS
Hypoponera sp.	LS, SS
Leptogenys sp.	HB, LS, SS, HC, PT
Odontomachus simillimus	CB, HB, LS, SS, HC, PT
Ponera sp.	CB, HB, LS, SS, HC, PT
Pachycondyla sp. 1	LS
P. sp. 2	HC
P. sp. 3	LS, SS
Tetraponera allaborans	LS, HC

CB = Canned-fish Bait, HB = Honey Bait, HC = Hand Collection, LS = Litter Sieving, PT = Pitfall Trapping, SS = Soil Sieving, WM = Mini-Winkler extraction, TT = Tree traps

DISCUSSION

Twelve subfamilies of ants have been recorded from Sri Lanka (Bolton 1995, 2003) and all but Ectatomminae were observed during this survey. Aneuretinae, Dolichoderinae, Formicinae, Myrmicinae and Ponerinae were observed throughout the study period. Two subfamilies more rarely encountered in Sri Lanka, Cerapachyinae (detected only from soil sifting, Table 5) and Dorylinae (detected only from canned fish baits, soil sifting and hand collection, Table 5), were detected on single occasions, and Aenictinae, Amblyoponinae and Leptanillinae were observed on three to four visits (Table 1), probably due to their cryptic habit and lower effectiveness of these methods. All five ant subfamilies recorded from this forest by Wilson *et al*. (1956) and Jayasuriya & Traniello (1985), Aneuretinae, Dolichoderinae, Formicinae, Myrmicinae and Ponerinae (according to current classification), were recorded during the present survey.

Sixty-two genera of ants (Bolton 1995; Dias 2006, 2008) have been recorded from Sri Lanka and 38 of those were recorded from Gilimale Forest in 2004, indicating a high diversity of ants in this wet zone forest. This is the only survey of ants that has been conducted in Gilimale Forest recently using several sampling methods simultaneously and also with repeated sampling. Higher species richness was revealed by the simultaneous application of several sampling methods, as observed in other ant research conducted in Sri Lanka (Dias & Gunathilake 2007a, b) and elsewhere.

All ant genera reported previously at Gilimale by Wilson *et al*. (1956) were collected during this survey. In addition to the 11 ant genera reported by Wilson *et al*. (1956), this study recorded 26 additional genera from the Gilimale Forest. *Pheidole*, *Monomorium*, *Tetramorium* and *Paratrechina* were reported from this forest in 1979 by Jayasuriya & Traniello (1985) and were also observed in 2004 (Table 1). Other ant genera associated with *A. simoni* in "Pompekelle," Ratnapura (another habitat of this species) in May 2001, *Anoplolepis*, *Cataulacus*, *Crematogaster*, *Pachycondyla*, *Pheidole*, *Pheidologeton*, *Solenopsis* and *Tetramorium* (Dias 2004), were also observed in the present collection. The results of the present survey suggest this forest reserve has continuously been a habitat of *A. simoni* from 1955 (Wilson *et al*. 1956) to 2004. It appears that environmental conditions such as soil temperature (24ºC to 28ºC in 2004) and soil humidity (19.6% to 35.7% in 2004) (Table 2) are favourable for this

rare and endemic ant species when compared with those at a dry-zone forest (soil temperature: 30.6ºC to 31.1ºC; soil humidity 4.8% to 6.4%) where this ant was absent (Kosgamage & Dias, 2009).

Table 4 summarises the sampling methods that caught *A. simoni* workers along each transect laid on each occasion in 2004. The use of honey baits in daytime and leaf-litter sifting resulted in finding the workers of this species more often than the other methods. Although overall relative abundance seemed to be low (Table 4), this species made up a considerable proportion of individuals of this ant community. However, this compound measure of abundance is influenced by the effectiveness of each method in detecting each species, and gives only an indication of actual relative abundance. Table 4 shows there is a high probability of detecting the species using these methods.

The species recorded in Table 1 can be considered a preliminary inventory of the ants of Gilimale Forest Reserve, and the list can doubtless be extended. But it serves as a reference for ant researchers and ecologists. Clearing of this forest for cultivation or development should be prohibited; as such actions may affect the existing favourable conditions for this evolutionarily-important ant species as well as for other rare ant species such as *Aenictus* sp., *Amblyopone* sp., *Cerapachys* sp., *Dorylus* sp., *Leptanilla* sp. and *Cardiocondyla* sp. Further ant surveys are recommended to improve the current inventory and to investigate the nesting ecology of *A. simoni*.

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