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Seasonal patterns in ant (Hymenoptera: Formicidae) activity in a forest habitat of the West Khasi Hills, Meghalaya, India

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ABSTRACT. Seasonal variation in ant activity was studied in a subtropical humid forest of Meghalaya, northeast India, using pitfall traps as the sampling method. A total of 108,733 ant individuals were collected during sampling, consisting of 28 species in 18 genera. Subfamilies comprised Myrmicinae (12 species), Formicinae (eight), Ponerinae (five), Dorylinae, Cerapachyinae and Dolichoderinae (one species each). Number of species recorded was highest during spring and summer and lowest during winter. Number of individuals and species diversity per sample was lower during winter and higher during summer. Number of individuals, species richness and Shannon entropy per sample varied significantly among seasons.

Keywords: Ant, seasonal activity, forest habitat, Meghalaya, India.

INTRODUCTION

Among insects ants are considered important indicators in biodiversity evaluation and monitoring because of their numerical dominance (Folgarait 1998; Underwood & Fisher 2006). Also ants are sensitive to changes in the environment (Kaspari & Majer 2000; Andersen *et al.* 2002; Watt *et al.* 2002; Brühl *et al.* 2003).

In India, the earliest inventory of ants consisted of 621 species in 73 genera, classified under 12 subfamilies (Bingham 1903). The most recent species list includes approximately 660 species from 87 genera belonging to 12 subfamilies (Bharti 2012). From the state of Meghalaya 163 species of ants, in 52 genera, were reported by Mathew & Tiwari (2000). Estimates of local species richness of ant communities from the Indian subcontinent (Oriental region) are available for different localities including the North-Western Himalayas, Western Ghats and West Bengal (Basu 1997; Rastogi *et al.* 1997; Tiwari *et al.* 1998; Bharti 2002; Rajagopal *et al.* 2005; Sabu *et al.* 2008; Savitha *et al.* 2008; Bharti & Sharma 2009). While few have focused on seasonality, one study in the Punjab Shivaliks showed the number of active species to vary considerably between summer and winter (Bharti *et al.* 2009). Basu (1997), in a study of seasonality and spatial patterns of ground-foraging ants in the Western Ghats, found marked seasonality of all ant species, with fewer species and individuals sampled per plot during the wetter seasons.

The state of Meghalaya is in northeast India at border of the Indo-Burma and Eastern Himalayas Biodiversity Hotspots (Critical Ecosystem Partnership Fund 2012). The only studies of ants carried out in the state of Meghalaya have been inventories and distribution studies (Mathew & Tiwari 2000). To our knowledge no work on the seasonal pattern of ant activity has been conducted in this region. Therefore, the present work is aimed at understanding the seasonality of ants in terms of species diversity, foraging activity and species composition under the influence of various ecological factors associated with the annual seasonal cycle.

MATERIALS AND METHODS

Study area

The present study was carried out in a subtropical hilly forest habitat of the West Khasi Hills, Meghalaya (25°2′-26°7′N, 89°49′-92°50′E) in the northeastern part of India. The co-ordinates and altitude of the study site were measured with a Garmin GPS 12 XL receiver. The study site lies at an altitude of approximately 1484 m a.s.l. with coordinates 25°50′48″ N and 91°26′45″ E. The forest was dominated by the tree species *Quercus griffithii* Hook.f. & Thomson ex Miq., *Quercus glauca* Thunb., *Schima khasiana* Dyer, *Magnolia champaca* (L.) Baill. ex Pierre and *Castanopsis* sp. Meghalaya lies within the northeastern part of the Indian Himalayas. The topography of Meghalaya shows irregular terrain in the northern and the western part. The major feature of the region is the central upland plateau, with the southern part exhibiting steep slopes. The elevation of the plateau ranges between 150 m and 1961 m a.s.l. The major vegetation is broadleaf (tropical and subtropical evergreen and semi-evergreen forests along with moist deciduous forest), mixed broadleaf-pine, and pine forests; these cover about 48%, 4.5% and 7.1% of the total area of the state respectively. Pine forests are confined between 800 and 2000 m a.s.l. The annual rainfall ranges from 2000 to 5000 mm.

Study period

The study was conducted for a continuous period of two years. Each sampling site was sampled at monthly intervals from September 2007 to August 2009.

Collection methods

Ant fauna were sampled using pitfall traps (Agosti & Alonso 2000; Bestelmeyer *et al.* 2000), with 11 pitfall traps placed at 10-m intervals along a line transect of 100 m. Five locations were selected, for similar vegetation types, good spatial separation (each about 3 km from the nearest) and where there was adequate soil for pitfall traps to be dug, and a permanent line transect was set up at each of these sites. The traps consisted of plastic vials of 6 cm diameter x 8 cm depth containing 70% alcohol (two-thirds filled) as a preservative. Each trap was inserted into the ground to a depth so that the upper rim of the vial was level with the soil surface. After 48 hours, each trap was removed from the soil and returned to the laboratory.

Relative humidity and air temperature was recorded with a digital handheld meter (Model Lutron LM 8000). Soil temperature was recorded with a digital thermometer having a long metallic probe which was inserted into the soil. A soil sample was taken from the site and brought to the lab for pH measurement by standard methods using a digital pH meter. Data were recorded monthly at noon time during the day while laying the traps. The parameters were averaged for each season.

Data analysis

All ants were manually sorted, preserved in 70% alcohol and dry-mounted (Lattke 2000). For each sampling station we counted the total number of species (S) and total number of individuals (N). Reproductives were excluded from the analyses following Longino *et al.* (2002). Specimens were identified using a single key to identify subfamilies, a series of keys to identify genera (Holldobler & Wilson 1990; Bolton 1994) and series of keys to identify species (Bingham 1903; Mathew & Tiwari 2000). Specimens were also sent to Prof. R. Gadagkar, Centre for Ecological

Sciences, Indian Institute of Science, Bangalore and Dr Himender Bharti, Department of Zoology, Punjabi University Patiala, Punjab, India for authentication. The morphospecies were indicated by numbering the genera.

The annual seasonal cycle was simplified as winter (December, January and February), spring (March, April and May), summer (June, July, August) and autumn (September, October and November). The total number of individuals of each species was pooled for the three months of a given season and diversity measure calculated was the exponent of Shannon index (*H'*). The Shannon Wiener diversity index is denoted by $\mathbf{H' = - \Sigma\ p_i \ln p_i}$; the proportion of *i* related to the total number of species (p_i) is calculated and multiplied by the natural logarithm of this proportion ($\ln p_i$) (Shannon & Weaver 1949).

Table 1: List of ant species from West Khasi Hills, Meghalaya

Subfamily	Species
Cerapachyinae	*Cerapachys sulcinodis* Emery, 1889
Dolichoderinae	*Tapinoma* sp. 1
Dorylinae	*Dorylus orientalis* Westwood, 1935
Formicinae	*Camponotus* sp. 1
	Camponotus sp. 2
	Camponotus sp. 3
	Camponotus sp. 4
	Nylanderia sp. 1
	Polyrhachis dives belli Forel, 1912
	Polyrhachis hippomanes ceylonensis Emery, 1893
	Polyrhachis sp. 3
Myrmicinae	*Aphaenogaster* sp. 1
	Cardiocondyla nuda nuda (Mayr, 1866)
	Carebara rectidorsa (Xu, 2003)
	Crematogaster sp. 1
	Crematogaster subnuda subnuda (Mayr, 1879)
	Kartidris nyos Bolton, 1991
	Myrmica sp. 1
	Pheidole roberti Forel, 1902
	Pheidole smythiesii Forel, 1902
	Temnothorax rothneyi rothneyi (Forel,1902)
	Tetramorium sp. 2
	Tetramorium urbanii Bolton, 1977
Ponerinae	*Leptogenys kitteli kitteli* (Mayr, 1870)
	Odontomachus monticola Emery, 1892
	Pachycondyla javana (Mayr, 1867)
	Pachycondyla sp. 2
	Pachycondyla sp. 3

Table 2: Midday ecological parameters recorded at the study sites from September 2007 – August 2009 (n=5, ±=SD)

	First annual cycle				Second annual cycle			
Ecological parameter	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Air temperature (ºC)	19.5 ± 0.6	16.7 ± 0.6	24.7 ± 1.1	23.7 ± 0.9	20.2 ± 0.5	16.9 ± 0.6	23.8 ± 1.3	23.8 ± 0.7
Soil temperature (ºC)	15.6 ± 0.3	12.1 ± 0.5	18.8 ± 0.5	20.1 ± 0.7	15.3 ± 0.5	11.4 ± 0.7	16.5 ± 0.4	19.5 ± 0.2
Relative humidity (%)	80.4 ± 0.8	63.7 ± 1.7	60.7 ± 1.0	83.0 ± 1.0	78.8 ± 0.9	58.2 ± 5.9	62.7 ± 2.8	81.9 ± 1.4
Soil moisture (%)	30.1 ± 1.2	19.8 ± 2.1	22.8 ± 2.2	47.1 ± 7.0	41.0 ± 3.8	25.9 ± 6.5	27.0 ± 0.3	38.4 ± 3.3
Soil pH	5.99 ± 0.32	5.95 ± 0.10	5.95 ± 0.25	6.11 ± 0.35	6.30 ± 0.49	6.14 ± 0.12	6.11 ± 0.14	6.38 ± 0.12

Table 3: Results of Pearson correlation analyses for seasonal ant abundance, species richness and Shannon Index with soil moisture, soil temperature, air temperature, relative humidity and soil pH (n=40).

Ecological parameter	Degrees of freedom	Number of individuals	Species richness	Shannon Index
Soil moisture	38	0.530**	0.487**	0.391*
Relative humidity	38	0.722**	0.528**	0.415**
Soil temperature	38	0.693**	0.680**	0.674**
Air temperature	38	0.355*	0.503**	0.584**
Soil pH	38	0.062	0.185	0.123

** Correlation is significant at $P < 0.01$
* Correlation is significant at $P < 0.05$.

Table 4: Diversity indices pooled seasonally for both years, from pitfall traps.

	Sampling sites	Total number of individuals	Species richness	Exponent of Shannon index (H')	Evenness index	Dominance index
Autumn						
First year	Transect 1	3122	12	3.90	0.53	0.53
	Transect 2	4135	14	2.04	0.27	0.77
	Transect 3	4015	10	2.68	0.43	0.65
	Transect 4	4517	13	3.10	0.44	0.63
	Transect 5	1955	12	1.73	0.22	0.89
Second year	Transect 1	3085	14	3.22	0.44	0.69
	Transect 2	4461	12	3.00	0.44	0.65
	Transect 3	3363	14	2.51	0.35	0.74
	Transect 4	4534	13	3.17	0.45	0.58
	Transect 5	4332	15	3.65	0.48	0.59

Mean±SD		2886±1802	12.9±1.5	2.9±0.67	0.41±0.09	0.67±0.10
Winter						
First Year	Transect 1	1036	8	1.72	0.26	0.89
	Transect 2	1112	11	3.78	0.55	0.35
	Transect 3	1037	6	2.40	0.49	0.75
	Transect 4	870	8	2.86	0.51	0.65
	Transect 5	752	8	1.88	0.30	0.85
Second year	Transect 1	914	11	2.49	0.38	0.78
	Transect 2	953	10	3.34	0.52	0.55
	Transect 3	635	8	1.52	0.20	0.90
	Transect 4	763	7	1.97	0.35	0.82
	Transect 5	690	7	1.50	0.21	0.91
Mean±SD		876±162	8.4±1.7	2.38±0.78	0.37±0.13	0.74±0.18
Spring						
First Year	Transect 1	3516	12	4.22	0.58	0.55
	Transect 2	3236	14	3.10	0.43	0.72
	Transect 3	2811	17	3.39	0.43	0.57
	Transect 4	2791	11	2.74	0.42	0.71
	Transect 5	3629	13	3.35	0.47	0.67
Second year	Transect 1	3039	12	3.21	0.47	0.55
	Transect 2	1590	9	3.51	0.57	0.39
	Transect 3	1994	13	4.30	0.57	0.53
	Transect 4	2926	16	3.46	0.45	0.60
	Transect 5	3191	11	3.78	0.55	0.43
Mean±SD		2872±639	12.8±2.4	3.51±0.48	0.49±0.07	0.57±0.11
Summer						
First Year	Transect 1	3869	13	3.07	0.44	0.48
	Transect 2	2814	15	3.38	0.45	0.57
	Transect 3	2778	15	4.15	0.53	0.39
	Transect 4	4023	16	4.33	0.53	0.49
	Transect 5	3548	12	3.65	0.52	0.50
Second year	Transect 1	3361	12	4.33	0.59	0.48
	Transect 2	3477	12	4.20	0.58	0.52
	Transect 3	2935	12	4.46	0.60	0.38
	Transect 4	3359	12	4.97	0.65	0.42
	Transect 5	3578	13	3.66	0.51	0.58
Mean±SD		3374±423	13.2±1.6	4.02±0.58	0.53±0.07	0.48±0.07

A rank abundance curve was plotted showing the abundance of each species against the rank (Longino *et al*. 2002). This was to show changes in the numerical dominance of species in the community over seasons. Abundance was log(x+1)-transformed to plot the rank-abundance curve.

Data between the two years was compared using 'Mann Whitney U' tests (using SPSS Version 11.5) to check if the number of individuals and the measure of species diversity per sample unit in a given season differed significantly. Variation in the number of species, Shannon index and total number of individuals from each sampling unit (pooled seasonally for both years) over four seasons was analysed using a one-way ANOVA.

The association between relative humidity, air temperature, soil temperature, soil moisture and soil pH with total number of individuals, species richness and diversity index measure was calculated statistically by Pearson Correlation using SPSS (Version 11.5). Ecological factors were treated as the independent variables, and diversity measures as dependent variables.

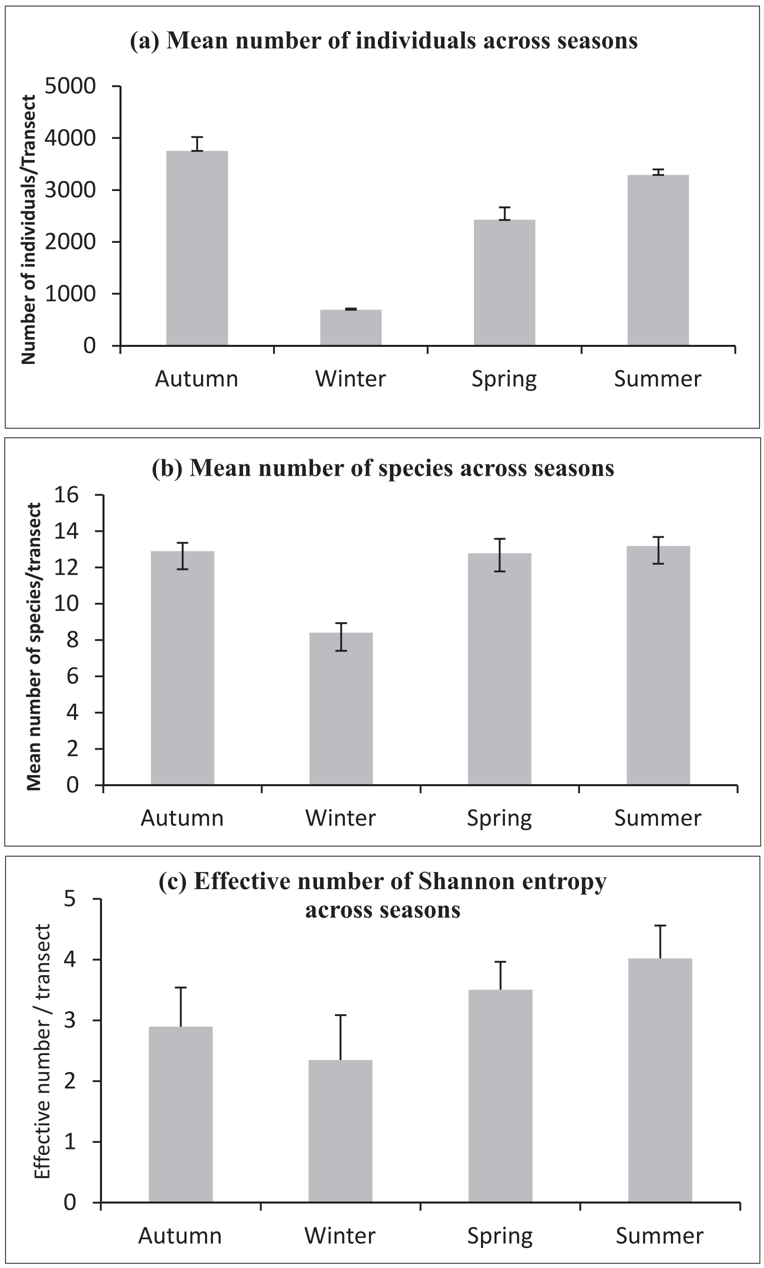

Fig. 1. Seasonal fluctuation in (a) number of individuals, (b) number of species and (c) Shannon entropy (± SD) per 100m per sampling effort (n=10). Pooled for two years.

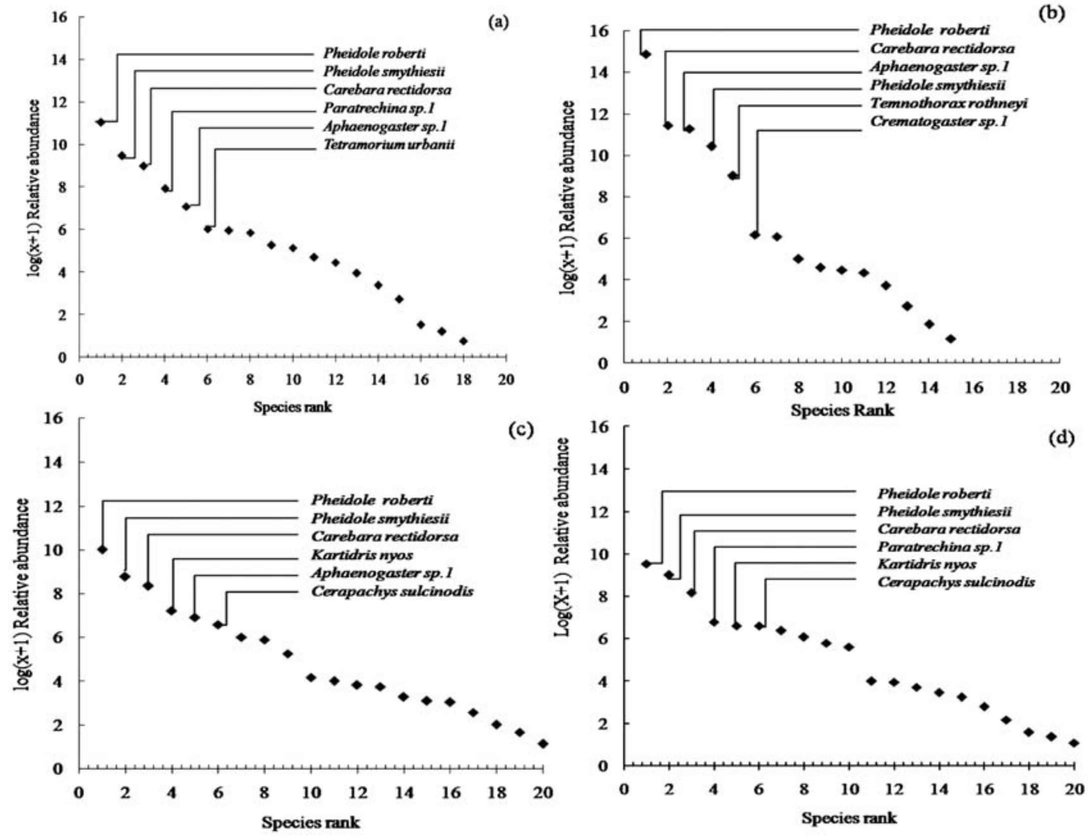

Fig. 2. Species rank-abundance curve for different seasons in a forest habitat of the study site. (Data pooled from all sampling units at a given season.) Relative abundance shown in the plot is log(x+1)-transformed. (a) Autumn, (b) Winter, (c) Spring, and (d) Summer.

RESULTS

We found a total of 28 species belonging to 17 genera. Subfamilies comprised Myrmicinae (12 species), Formicinae (eight), Ponerinae (five), Dorylinae, Cerapachyinae and Dolichoderinae (one species each) (Table 1).

The total number of species trapped showed changes with season. The number of species sampled during the studied years was highest in spring (23 species), summer (22 species) and autumn (21) and lower (16 species) during winter. Recorded taxa in the subfamily Myrmicinae were found in all the seasons, except for *Myrmica* sp. 1 which was recorded only during winter. Species of the subfamily Formicinae were most strongly represented during spring, when all eight species belonging to the genera *Nylanderia*, *Camponotus* and *Polyrhachis* were trapped. Six species were found in autumn, three in summer and three in winter; only one formicine species, *Nylanderia* sp. 1, was represented in all four seasons. All the reported species of Ponerinae were found in summer, whereas *Pachycondyla javana* was the only species found in winter and was recorded in all the seasons of the year. *Dorylus orientalis*, belonging to the subfamily Dorylinae, was recorded during autumn and summer only. Dolichoderinae was represented by *Tapinoma* sp. 1 only, found during the spring. Cerapachyinae, represented by *Cerapachys sulcinodis*, was not detected during winter.

Total number of individuals per 100 m transect per month sampling effort (Table 4) varied significantly among seasons (ANOVA: $df = 39$; $f = 49.164$; $P < 0.001$). The total number of individuals trapped was highest during the summer seasons and lowest during winter (Fig.

1a). Species richness also varied significantly across seasons (*df* = 39; *f* = 15.927; *P* < 0.001). The number of species was highest during summer and lowest during winter (Fig. 1b). The Shannon entropy measure also varied significantly with season (*df* = 39; *f* = 12.297; *P* < 0.001) (Fig. 1 c), ranging from 2.34 ± 0.74 in winter to 4.02 ± 0.54 during summer. The variation in the number of individuals per sample followed the same pattern as the species richness and diversity index. The number of individuals was positively correlated with species richness (r = 0.701, *n* = 40, *P*<0.01) and with Shannon entropy (r = 0.517, *n* = 40, *P*<0.01).

Correlation of diversity measures with

Ecological factors

Ecological parameters were obtained at the spot during the study period. Parameters were averaged for their monthly value and were also averaged for each season as shown in Table 2. Measures of temperature, moisture and pH were all lowest in the cold and dry season and highest in wet and warmer season during the annual cycle.

Seasonal changes in ant individual numbers, species richness and Shannon-Wiener Index were significantly positively correlated with soil temperature, relative humidity, air temperature and soil moisture, but not significantly correlated with soil pH values (Table 3).

Seasonal changes in position of common species

The species rank-abundance curve indicates a change in the position of the common dominant species in the community (Fig. 2). There was a small change in some of the common dominant species in the annual cycle. *Pheidole roberti* was the most abundant species, and remained so in all the four seasons of the studied years. It comprised 66% of all sampled specimens (24,786 individuals) in autumn, a proportion which decreased sharply in winter to 15% (6,349 individuals), then increased rapidly to 58% (16,771 individuals) in spring and 47% (15,947 individuals) in summer. *Pheidole smythiesii* was the second-most abundant species during the summer at 27%, spring (18%) and autumn (16%), dropping in the winter (11%). Another interesting species was *Carebara rectidorsa*, which was the third-most abundant species in all three warmer seasons and took over as the second-most abundant in the winter. The relative abundance of the other species also showed a shift during different seasons.

DISCUSSION

Local diversity

Species recorded from the study site in the present investigation belonged to six subfamilies. The subfamilies Myrmicinae and Formicinae were the most diverse. The present investigation found only 17% of the total taxa recorded from the state of Meghalaya (Mathew & Tiwari 2000). Fifty-two species were observed from the Nongkhyllem Wildlife Sanctuary in the Ri-Bhoi district of Meghalaya (Mathew 2003). Compared to Nongkhyllem (altitude 416 m a.s.l) the number of taxa recorded in the present study site was found to be low. Besides sampling differences, this may be attributed to differences in the ecological and vegetation structure associated with the altitudinal difference between the study areas (Bharti 2008).

Seasonal pattern

The present study indicates that ants exhibit seasonal fluctuation in activity within the annual cycle. Total ant abundance, species richness and Shannon entropy varied significantly from winter to autumn. The abundance of ants was higher during the warmer season, i.e. from spring to autumn, than in the dry and cold winter season; this was similar to the findings of Bharti *et al*. (2009) and Suriyapong (2003). A rank-abundance curve, used to show the dominance patterns in the community, indicates the dominance of *Pheidole roberti* all year-round. Ant colonies are perennial and most of them have permanent nest sites (Wilson 1971). The areas in which a species nests are limited to those where it can survive throughout the year, but a colony can respond quickly to seasonal changes. Thus foragers may become active immediately when conditions are favourable (Levings 1983).

In the present study, during the wet season with high humidity and corresponding high soil moisture, the number of individuals recorded was high compared with the dry winter season. In temperate regions cold conditions inhibit ant activity which shows a distinct summer-winter activity cycle (Hölldobler & Wilson 1990). The results also suggest that soil moisture, soil temperature, relative humidity and air temperature are correlated with the quantitative variation of Formicidae in a seasonal cycle, while soil pH is not.

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