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Response of ants to disturbance gradients in and around Bangalore, India

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Abstract: There is an emphasis the world over to build back biodiversity even in human-dominated landscapes, such as cityscapes. Birds and butterflies that are highly vagile have been studied extensively, but less mobile taxa such as ants have been ignored, for this reason we chose them as the study taxa for this work. The distribution and abundance of ant species across a disturbance gradient in and around Bangalore city was studied. Five sites were sampled and these represented a gradient of urban land use that ranged from highly disturbed to comparatively less disturbed areas. A total of 51 species of ants belonging to seven subfamilies were recorded. Ant species richness and abundance was higher in the disturbed site. Species richness is significantly correlated with litter and canopy cover. Common species increased with disturbance. Disturbed sites supported rare species, suggesting that these habitats located in urban settings also require protection. The management implications of the results are discussed.

Resumen: Se ha puesto mucho énfasis en todo el mundo en la reconstrucción de la biodiversidad, incluso en paisajes antrópicos, por ejemplo los urbanos. Las aves y las mariposas, que son muy vágiles, han sido estudiados ampliamente, pero taxa menos móviles como las hormigas han sido ignorados; por esta razón éstas fueron seleccionadas como el taxón de estudio para este trabajo. Se estudiaron la distribución y la abundancia de las especies de hormiga a lo largo de un gradiente de perturbación en Bangalore y sus alrededores. Se muestrearon cinco sitios que representaron un gradiente de uso urbano del suelo que varió desde muy perturbado hasta áreas relativamente menos perturbadas. Se registró un total de 51 especies de hormigas pertenecientes a siete subfamilias. La riqueza y la abundancia de especies fueron mayores en el sitio perturbado. La riqueza estuvo correlacionada significativamente con el mantillo y la cobertura del dosel. Las especies comunes se incrementaron con la perturbación. Los sitios perturbados albergan especies raras, lo que sugiere que estos hábitats, localizados en contextos urbanos, también requieren protección. Se discuten las implicaciones de estos resultados para el manejo.

Resumo: No mundo há uma ênfase em reconstruir a biodiversidade mesmo em paisagens dominadas pelo homem, como sejam as paisagens citadinas. As aves e as borboletas que são fortemente móveis têm sido extensivamente estudadas, mas os taxa menos móveis, como sejam as formigas, têm sido ignorados e por isso foi o taxa escolhido para objecto deste estudo. Assim, a distribuição e abundância das espécies de formigas através de gradientes disturbados em e à volta da cidade de Bangalore foram estudadas. Foram amostrados cinco locais representando um gradiente de uso do solo urbano que variou entre o altamente disturbado a áreas

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comparativamente menos disturbadas. Na sua totalidade foram registadas 51 espécies de formigas pertencendo a sete sub-famílias. A riqueza específica e abundância foi mais elevada nos locais disturbados. A riqueza específica estava significativamente correlacionada com a folhada e a cobertura do copadado. As espécies comuns aumentaram nos locais disturbados. Os locais disturbados suportaram espécies raras, sugerindo que estes habitats localizados em zonas urbanas também requerem protecção. As implicações dos resultados para a gestão são discutidas.

Key words: Ants, biodiversity, disturbance gradient, indicators species, urbanization.

Introduction

Increasing urbanization and changes in land use patterns cause extensive disruption of natural ecosystems in biodiversity rich tropical countries (Sodhi & Lim 2003). Many species are not only capable of adapting to disturbed natural systems but could also proliferate and become invasive in relation to native species (Hobbs & Huenneke 1992). However, human induced disturbance, if not too drastic, could also maintain ecological communities and sustain rare species. Remnants of natural vegetation in urban settings could be important reservoirs of biodiversity and contribute to the improvement of quality of life in cities (Balram & Suzana 2005). However, due to ever increasing anthropogenic pressures, these remnant patches are vulnerable to further degradation. It is, therefore, necessary to inventory and monitor biodiversity in urban settings and formulate effective management plans towards their conservation.

Insects are particularly useful in the evaluation of biodiversity and ants have been used extensively as indicators of disturbance (Andersen 1997; Holldobler & Wilson 1990; Kim 1993; Kremen 1993). Ants are diverse, abundant, easily found, and can be reliably sampled and monitored (Andersen 1997; Majer 1983). They are relatively sedentary, with restrictive ranges and are responsive to small-scale changes in both space and time (Andersen 1997; Holldobler & Wilson 1990; Kremen 1993; Majer 1983).

We looked at ant diversity and distribution across an urban gradient in Bangalore, one of the fastest growing cities in India, which has a population of about 7 million (Nayaka *et al.* 2003). Bangalore was historically known as the "Garden City" with extensive green areas, but increasing urbanization has resulted in the loss of green cover in recent times. Preliminary work has shown that Bangalore supports about 75 species of ants (Gadagkar 1997; Kumar *et al.* 1997). So far studies have been restricted to developing checklists and there has not been any study to understand the impact of increasing human induced disturbance on ants. Thus, this study fills the lacuna with the following objectives: (i) to assess ant diversity and distribution across sites with different degrees of anthropogenic disturbance in and around Bangalore, (ii) to identify the influence of ecological determinants such as canopy cover and litter on ant distribution, and (iii) to identify species that can be used as effective indicators of disturbance.

Materials and methods

Study area

Bangalore city is situated at 12º 57' N and 77º 35' E, in the state of Karnataka, India. The average elevation is 900 m asl. Bangalore receives rainfall both from the SW (June to September) and NE (Novermber and December) winds and the average rainfall is 800 mm (Nayaka *et al.* 2003). The vegetation in Bangalore is of the dry deciduous type.

The term *disturbance* in this paper refers to ecosystems that are physically as well as biologically modified by human interventions. Five sites were chosen across Bangalore city and their levels of disturbance were assessed by ranking commonly seen disturbances such as pedestrian pressure, littering, clearing leaf litter, exotic tree plantation and roads and buildings: Rank '5' is regarded as maximum disturbance, '4' high disturbance, '3' moderate disturbance, '2' less disturbance, '1' least disturbance and '0' ranked no disturbance. The urban sites comprised of (1) Cubbon Park (CP), with an area of 121.41 ha and (2) Lalbagh (Lb) an area of 97.12 ha. These sites are located in the centre of the city and have good tree cover, but pedestrian pressure and littering are the main sources of disturbance; (3) Gandhi Krishi Vighyan Kendra (GKVK-University of Agricultural Sciences Campus), about 1500 ha in area is situated in the suburban region covered with dry forest and a few orchards. These sites are considered moderately disturbed; (4) Bangalore University (BU) which is about 445.16 ha lies 20 km from the city has a relatively less disturbed dry thorny forest, and (5) the foothills of Nandi Hills (NH), which is more than 850 ha in area, lies about 60 km from the city and is covered with dry deciduous forest, are considered relatively less disturbed and are rural sites.

Sampling protocol

The study was carried out from February to April, 2002. Twelve sites were chosen randomly in each study area for sampling. A 10 x10 m quadrat was laid and four different methods were used to sample for ants in this quadrat. The number of quadrats to be laid in each study site and the time for individual ant sampling methods was standardized through a pilot study carried out in January of the same year. The sampling methods employed were:

a) Bait Trap: Four bait types- egg yolk, fried coconut, honey and dead insects were used and were placed in the corners of the quadrat. The baits were left undisturbed for fifteen minutes and later ants were collected for a period of five minutes from all the 4 baits.
b) Litter Collection: Litter was collected from four 1x1 m quadrats, which were placed randomly around the 10 x 10 m quadrat. The litter was collected and searched thoroughly for ants by spreading it on a plastic tray which was smeared with talcum powder so as to avoid ants from escaping.
c) Pitfall traps: Three pitfalls were placed randomly in the 10 x 10 m quadrat. Each pitfall contained 70% alcohol and a few drops of glycerin to reduce evaporation of alcohol. Collection was done 24 hrs after the traps were laid. The trapped ants were then transferred into vials containing 70% alcohol.
d) All-out search: Other than trapping ants by the methods described above, an intensive all-out search for fifteen minutes was carried out to collect representative individuals of all species seen in the quadrat. The search was carried out after laying the baits.

Habitat characterization

The canopy cover in each site was assessed by standing in 5 randomly chosen places within each quadrat. Canopy cover was ranked as '0' if there was no canopy directly overhead; as '1' if adjacent crowns barely met, as '2' when they overlapped but if the sky was visible and as '3' when the sky was no longer visible. This method has been used by several authors and found to be reliable (Aravind *et al.* 2001; Daniels 1991). The litter depth was ranked in terms of the number of overlapping leaves or the number of layers on the surface: 0-3 leaves ranked '0', 4-7 leaves ranked '1' and more than seven leaves, ranked '2'.

The Normalized Difference Vegetation Index (NDVI)

The NDVI provides an indication of the canopy cover. NDVI are sometimes referred to as "greenness maps" since they represent the vegetative dynamics. NDVI is calculated as (NIR-R)/(NIR+R), where NIR- near infra red band and R is a red band in satellite imagery. The latitude and longitude of all the sampling sites were obtained from 1:25,000 and 1:50,000 Survey of India (SoI) toposheets. These points were overlaid on the LANDSAT TM imagery for the year 2000 using ERDAS imagine. Each sampling point was marked on the satellite imagery around which an average of 9 pixels (pixel size of the imagery was 35 m) with a 100 m buffer was considered.

All ants collected were identified in the lab down to species level when possible. The unidentified species were assigned to Recognizable Taxonomic Units (RTU). The number of species in each site was computed and species diversity was calculated using the Shannon-Wiener Index (Magurran 1983). Cluster analysis using Euclidean Distance was performed to assess the similarity between the sites sampled. Correlation and Regression analysis were performed to assess the relation between diversity parameters and habitat characteristics. All analysis was done using Statistica software (ver 4.5; Statsoft inc).

Nestedness

Nestedness of ant species across the five habitats was calculated using NESTCALC (Atmar & Patterson 1993). Nestedness occurs when the species recorded found in a fragment is a subset of species found in a larger fragment. It is analyzed using a presence-absence matrix where species are organized in columns in descending order from those found in the largest number of sites to those occurring in the least number of sites. Sites are organized in rows from the site with the most species to the site with the least. If the matrix is packed in the upper left hand corner, it indicates that the distribution pattern is nested (see Atmar & Patterson 1993 for more information).

Common/rare/unique

The ant species were listed in descending order based on their mean abundance across sites. The relative abundance of each species was calculated and the per cent with respect to the total was estimated. Species that fell within the first quartile of the species abundance distribution were designated as rare and the rest as common (Davidar *et al.* 1996). Uniqueness of each site was expressed as a percentage of number of unique species of the total species present.

Results and discussion

Ant fauna of the five sites in and around Bangalore city consisted of seven subfamilies, 24 genera, 51 species (Appendix 1) and 1400 individuals. Cubbon Park (CP) had the highest number of species and the highest diversity (Table 1). A Kruskal-Wallis test showed that there are significant differences between sites in species richness (KW=11.482, n=5, p=0.022) but not with regard to species diversity (KW=7.647, n=5, p=0.105). CP, which had the highest ant diversity, is situated in the centre of the city and was found to have the highest level of disturbance when compared to all the sampling sites (Table 2). A study carried out by Kumar *et al.* (1997) also shows that ant species richness is relatively high in sites that were sampled within the city. The urban sites contribute to the highest percentage of unique species of ants across gradients of disturbance compared to the sub-urban and the rural sites (Fig. 1). This suggests that the generalists, which acclimatize to high levels of disturbance, could be contributing to the high diversity in the urban sites.

Species such as *Acantholepis opaca*, *Oecophylla smaragdina*, *Paratrechina longicornis* and *Solenopsis geminate* were commonly found in all the sites and they all belong to the subfamily Formicinae. Considering the total number of individuals across all the sites and sampling methods, it is evident that *Solenopsis geminate* is highly abundant followed by *Monomorium indicum*. This shows that *Solenopsis geminate* particularly, is competent and can adapt to the changing conditions. This species is omnivorous in diet and studies carried out by Risch & Caroll (1982) have shown that they are abundantly found in disturbed ecosystems. Moreover, it was found to frequently reside in human structures, which substantiates its presence in most sites. The two abundantly found species clearly show two distinct trends: abundance of *Solenopsis geminate* increases with increase in disturbance while that of *Monomorium indicum* increases in less-disturbed areas across the sites (Fig. 2). Thus, *Solenopsis geminate* could be used as an indicator for disturbed sites and *Monomorium indicum* an indicator for relatively less disturbed sites. The abundance plot shows that CP, BU and NH have few species that dominate the community, thus fall into the higher abundance region and the species that contribute to it is *Solenopsis geminate* in CP and *Monomorium indicum* in BU and NH. Overall, the abundance plot shows uneven distribution across all the sites (Fig. 3).

Table 1. Species richness, Shannon's Diversity index and abundance of ants across sites.

Sites	Species Richness	Species Diversity	Number of Individuals
Cubbon Park	28	2.37	426
Lalbagh	22	2.07	226
GKVK	23	2.21	241
Bangalore Univ	13	1.73	232
Nandi Hills	28	2.18	275

Table 2. Types of disturbances recorded across all sites.

Study site	Pedestrian pressure	Littering	Clearing leaf litter	Exotic plantation	Roads and buildings	Mean
Cubbon Park	5	5	5	4	0	3.8
Lalbagh	5	5	2	2	0	2.8
GKVK	3	3	2	0	3	2.2
Bangalore Univ	2	2	3	0	2	1.8
Nandi Hills	1	1	1	0	3	1.2

Rank '5' is regarded as maximum disturbance, '4' high disturbance, '3' moderate disturbance, '2' less disturbance, '1' least disturbance and '0' ranked no disturbance

Ant species belonging to the subfamily Myrmicinae were well represented across the varied disturbance regimes, suggesting that they are capable of adapting to the changing environmental conditions. Their omnipresence categorizes them as generalists. In contrast, the presence of Dolichoderines and Ponerines were restricted only to certain sites. Anderson (1995) mentions that the Dolichoderines are open habitat species, highly active and aggressive and exert a major competitive influence on other ants, and thus explain their restrictive distribution i.e., NH and GKVK (Table 3). On the other hand, Ponerines are habitat specialists and they specifically forage only on other arthropods (Andersen 1995). They were found in relatively large numbers in NH and CP (Table 3). They are mostly ground-dwelling ants that nest and forage exclusively within the soil and litter (Ajay & Sunil 2006; Andersen 1997). Thus, abundant leaf litter could signify presence of arthropods directly indicating the presence of Ponerines. All this shows that microhabitat conditions play a major role in determining the presence/absence of a particular family of ants.

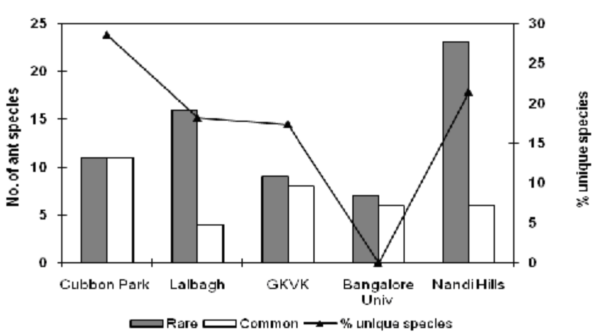

Fig. 1. Urban sites contribute to the highest percentage of unique species of ants and the number of Common species, but the number of Rare species is highest in peri- urban sites.

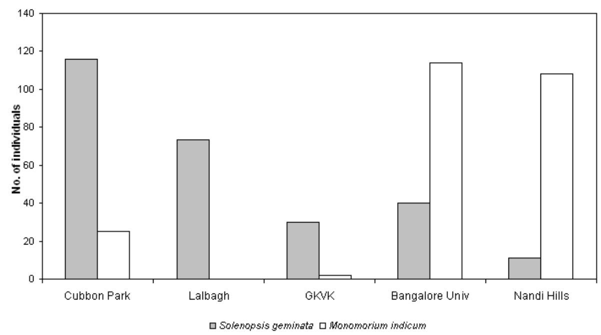

Fig. 2. Abundance graph across sites sampled indicates that *Solenopsis geminate* is abundant in disturbed sites and *Monomorium indicum* abundant in relatively less disturbed sites.

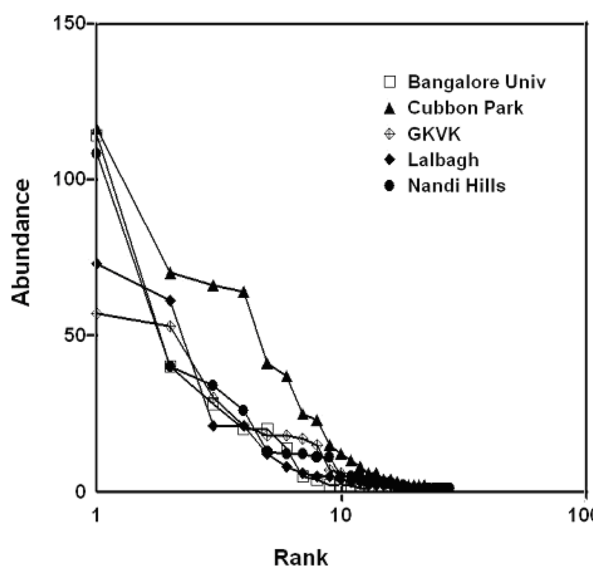

Fig. 3. Rank-Abundance plot of species recorded across sites shows an uneven distribution.

Table 3. Total number of species recorded in different subfamilies across sites.

Subfamily	Cubbon Park	Lalbagh	GKVK	Bangalore Univ	Nandi Hills
Pseudomyrmicinae	1	1	0	1	0
Ponerinae	5	1	3	1	6
Formicinae	7	7	9	5	7
Dolichoderinae	1	2	3	1	3
Myrmicinae	14	9	8	5	11
Dorylinae	0	1	0	0	1
Aenictinae	0	1	0	0	0
Total	28	22	23	13	28

Ant species representation is more or less similar across all the sampling methods that were used, which were; bait traps (egg, sugar and coconut), pitfall traps and all-out search. The bait trap showed the maximum ant species representation, which was 50 species followed by pitfall traps with 41 species. Though there is only a marginal difference in species representation across the different methods employed, a combination of all the three methods is recommended for ant sampling. This is because certain species were captured only in bait traps and visual search while a few others were collected only using the pitfalls. The litter collection method showed representation of 20 ant species across all the five sites that were sampled (Appendix Table 1). There were no ant species that was uniquely represented in the litter collection and this could be a result of clearing of litter and fire which were the two main litter management practices across the disturbed as well as the moderately disturbed sites. Here, we would like to emphasize that ants that are completely arboreal, those that live in the flakes of the bark, and many more that live in barely visible microhabitats could have been completely left out in the above sampling methods. Canopy baits, canopy pitfalls and intense visual search, could add many more species to the present checklist that we have provided (Appendix Table 1).

There is a positive relation between NDVI and three measures of diversity, however, this trend is not statistically significant (species richness: r=0.264, p=0.668; species diversity: r=0.43, p=0.470; abundance: r=0.625, p=0.259, n=5). Also, there is a significant correlation between species richness, canopy and litter depth (species richness and canopy: r=0.259, p=0.046; species richness and litter: r=0.295, p=0.022, n=59) suggesting that litter provides an ideal habitat and supports diverse ant families. Among different disturbance parameters, clearing litter has a negative impact on both species richness and abundance of ant fauna as shown by multivariate analysis (data not shown). However, the relation is not significant (r= 0.73, df=4, p>0.05).

The abundance data was used for cluster analysis and the results show that sites within the city and sites on the outskirts form separate groups showing high species turnover from urban to rural gradient (Fig. 4). A similar trend is also seen when the levels of disturbance across all sites was considered (Table 2). In a growing city like Bangalore, several small parks have been developed, which are either completely manicured or have only exotic trees. Thus, in order to make these green spaces friendly a mix of native vegetation could promote biodiversity conservation. This could add to the green cover as

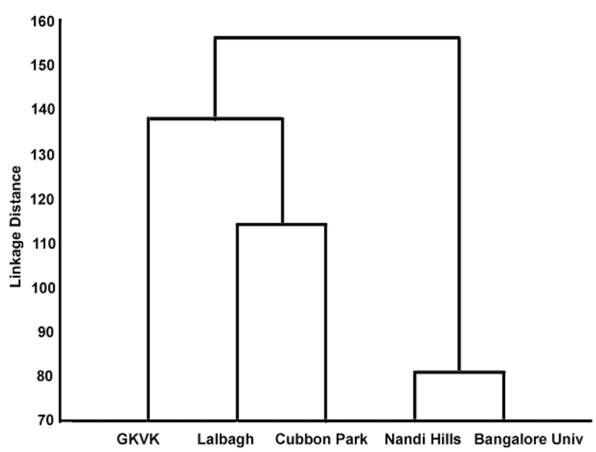

Fig. 4. Dendrogram shows that the ant composition is similar among disturbed and relatively less disturbed sites and unique in the moderately disturbed site.

well as provide suitable habitats to revive ant communities, a step towards conservation (Ajay & Sunil 2006).

The ant fauna was significantly nested ([P (T 39.17) = 2.24 x10^{-1}] with a fill of 44.8%) indicating that species in the smaller sites within the city are a subset of species in the less disturbed and larger peri-urban areas. Although the urban sites are subset of the other sites that were sampled, more rare species were encountered within disturbed sites. A detailed habitat characterization along with behavioral studies on these rare species might throw light on their presence in urban sites.

Common species such as *Solenopsis geminate*, *Camponotus sericeus*, *Monomorium* sp. increased with disturbance (Fig. 2), and rare species were abundantly found in disturbed and in the relatively less-disturbed sites. Presence of species such as *Acropyga acutiventris* and *Aenictus aitkeni*, was recorded in Lb indicating that rare species are able to survive amidst human disturbances only due to the availability of specialized microhabitats. Other rare species such as *Meranoplus bicolor* and *Techomyrmex albipes* were found to be present in NH, a relatively less-disturbed site. Kumar *et al.* (1997) and Pachpor & Ghodke (2000-2001) have mentioned that habitats with abundant trees support high diversity of ants. Thus, habitat variables such as canopy and litter can provide an ideal habitat for ants.

Conclusions

Urban biodiversity is a neglected field and few studies have been conducted on the species that survive and thrive in urban landscapes. A study on lichens in Bangalore and Kolkata has shown that due to the rapid increase in urbanization and air pollution over the past 18 years, lichen species sensitive to atmospheric pollution have been replaced by tolerant species (Nayaka *et al.* 2003). Related studies on ants, birds and butterflies have shown that species richness and diversity decreases with increase in disturbance (Andersen 1995; Blair 1996; Ingalhallikar *et al.* 2000-2001; Kunte 2000-2001; Pachpor & Ghodke 2000-2001). Other studies have indicated that while insectivorous birds and raptors decrease, granivores increase with increase in garbage (Blair 1999). Thus urbanization has differential effects on various taxa depending on their dispersability and adaptability to human settings. Many species also depend on food and nesting sites available in urban landscapes and are thus able to proliferate. Urban sites, especially if they have remnant vegetation, are important reservoirs of biodiversity. Existing green areas must be protected on a priority basis and more sites must be developed with native vegetation and maintained for enhancing biodiversity. Removal of dead trees and litter must be avoided and garbage dumping should be prohibited. Strict management policies and local stewardship associations must be put into place in order to conserve and protect the remaining green spaces within the city. Also, with the city growing, there is a surge in housing complexes in the campus with large expanse of greeneries, which may not actually support any biodiversity as they largely comprise of manicured lawns. With large scale awareness programs, local green groups can be formed and even these small green spaces can be converted into biodiversity friendly patches. In the long term, these could serve as a green corridor connecting larger patches in and around the city.

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Appendix Table 1.

Species	Family	Cubbon Park	Lalbagh	GKVK	Bangalore Univ	Nandi Hills
Acantolepis opaca	Formicinae	v	v	v	pl	v
Acropyga acutiventris	Formicinae		p			
Aenictus aitkeni	Dorylinae		p			
Aphaenogaster beccarii	Myrmicinae	epv				
Camponotus compresses	Formicinae	spv	ev	epvl		v
Camponotus rufoglaucus	Formicinae			epvl		
Camponotus sericeus	Formicinae	spv	espv	epvl		escv
Camponotus sp	Formicinae	p				
Crematogaster sp	Myrmicinae			escpv	ep	spl
Crematogaster sp1	Myrmicinae					v
Crematogaster sp2	Myrmicinae	e				p
Crematogaster sp3	Myrmicinae					c
Diacamma rugosum	Ponerinae	p	cpv			
Dolichoderus sp	Dolichoderinae			v		p
Dorylus sp	Dolichoderinae					v

Contd…

Appendix Table 1. Continued

Species	Family	Cubbon Park	Lalbagh	GKVK	Bangalore Univ	Nandi Hills
Leptogenys chinensis	Ponerinae	p		v		
Leptogenys diminuta	Ponerinae	ep				
Leptogenys processionalis	Ponerinae	ev		v		p
Leptogenys sp1	Ponerinae					p
Lophomyrmex quadrispinosus	Myrmicinae					epv
Meranoplus bicolor	Myrmicinae					p
Monomorium indicum	Myrmicinae	espv		es	spv	escpvl
Monomorium pharaonis	Myrmicinae			v		
Monomorium scabriceps	Myrmicinae	sv				
Monomorium sp	Myrmicinae	ecpvl		espvl	pv	c
Monomorium sp1	Myrmicinae	ecpv	ecvl			escpvl
Monomorium sp2	Myrmicinae	p	evl			p
Monomorium sp3	Myrmicinae		p			
Myrmicaria brunnea	Myrmicinae	escpv	c	v		
Oecophylla smaragdina	Formicinae	pv	v	epvl	epv	v
Pachycondyla luteipis	Ponerinae	pvl			pl	
Paratrechina longicornis	Formicinae	pv	cpv	p	p	spl
Pheidole sp1	Myrmicinae		pv		pv	p
Pheidole sp2	Myrmicinae	escpv	espvl		pv	sp
Pheidole sp3	Myrmicinae		p	esp		s
Pheidole spathifera	Myrmicinae	cpvl				
Pheidole woodmasoni	Myrmicinae			pl		
Polyrhachis rastelata	Formicinae			pv	pl	
Prenolepis sp	Dolichoderinae			c		
Solenopsis geminata	Formicinae	escpvl	escpv	espv	spv	spl
Tapinoma melanocephalum	Dolichoderinae		ev	c		scpl
Tapinoma sp	Dolichoderinae		p			
Technomymex albipes	Dolichoderinae	spv		epv	p	p
Tetramorium aitkeni	Myrmicinae	v				
Tetramorium lutipis	Myrmicinae	v				
Tetramorium sp	Myrmicinae	v		pl		
Tetramorium sp1	Myrmicinae		p			pv
Tetramorium sp2	Myrmicinae	pl	p	p		p
Tetramorium sp3	Myrmicinae		p			p
Tetraponera aitkeni	Pseudomyrmecinae	p				
Tetraponera rufonigra	Pseudomyrmicinae		c		epv	

e-egg, s-sugar, c-coconut, p-pitfall, v-visual search and l-litter