Chapter 4

Ant Community Structure and Composition

Monomorium minimum feasting on watermelon

Introduction

India is an agricultural country with 60% of the land area under agriculture.

Vadodara is characteristically surrounded by agricultural fields. The major crop plants grown in the agricultural fields of Vadodara are :Spinach (*Spinacia olerecea*), Cabbage (*Brassica olerasea var.campestris*), Raddish (*Raphanus sativus*), Paddy (*Oryza sativa*), Pigeon pea (*Cajanus cajan*), Maize (*Zea maize*), Wheat (*Triticum aestivum*), Brinjal (*Solanum melongena*), Sugarcane (*Saccharum officinarum*), Paddy (*Oryza sativa*), Castor (*Ricinus communis*), Cotton (*Gossypium* sp.) etc.

Varying farming traditions, combined with specific soil and climate conditions, have resulted in diverse and highly characteristic agricultural landscapes. The increasing use of pesticides have left these landscapes with little diversity ,especially of insects. Ants, being largely soil-dwellers are highly affected by the application of pesticides.

Urban regions are conceived as land and water embedded within and surrounding areas of intense urban land use. These lands include fragments of un-built land within urban districts as well as remnant patches of natural habitats and agricultural lands which are not yet converted to urban land uses, including parks and natural areas within or in the periphery of urban lands. We include this variety of land within our concept of an urban region since these lands and the biota they harbour are likely to be affected by activities associated with the nearby urban lands.

Urbanisation is spreading in Vadodara at a fast pace. The cosmopolitan culture makes this city invite more diversified cultures for settlement. The sudden boom of malls and multiplexes, apartments and commercial complexes has made Vadodara a concrete jungle.

The only green spaces are the community gardens made for recreational purposes and the small residential gardens that people maintain in front of their houses. Trees lining the roadside also suffer damage due to the never ending digging and reconstruction of roads. The pollution levels of Vadodara are high due to the industries present here.

This study has been conducted with the purpose of exploring the impact of agricultural practices and urbanisation on ant diversity. The common objectives of this chapter are:

(i) To examine the capacity of habitats to support ant diversity by determining the ant community composition in urban and agricultural habitats

(ii) To determine the principle ecological factors affecting ant diversity in urban and agricultural ecosystems.

(iii) To provide important information regarding effective management of habitats for ecological processes.

Materials And Methods

Sampling Techniques

The methods used for sampling ant species in this study were

- Pitfall trap Method
- Baiting
- Hand Collection

The details of these methods have been described in the Chapter 2 General Materials and Methods.

A combination of different methods was used for sampling in Urban and Agricultural ecosystems.

Sampling Techniques for Urban Ecosystems

The urban ecosystems studied were varied with respect to their area, vegetation, surrounding and also the type of physical conditions hence the sampling techniques had to be decided on the basis of the habitat features.

Sampling Techniques for Urban Community gardens (USites) and Fragmented Areas (UFSites): Two sampling methods- Pitfall traps and Hand collection were used to sample ants of community gardens and fragmented areas.

Pitfall traps were placed in the major areas in the gardens; the lawns, the margins of flower beds and the edges of the joggers' paths. The rest of the places like the concrete structures, tree trunks, flower pots etc were searched manually for 2 hrs from 08:00h to 10.00 h and subsequently from 18:00h to 20:00 h on the same day the pitfalls were placed in the gardens.

Sampling Techniques for Residential areas (URSites): The methods of collection were baiting and hand collection. The collections were conducted every month for a period of two hrs 08:00h to 10.00 h and subsequently from 18:00h to 20:00 h on the same day always in the same houses. Baits made from sugar, honey and peanut butter were placed inside every possible place. The baits were placed on paper platforms and beverage straws 0.5 cm in diameter and 2 cm long.

This included In the interiors of the houses baits were placed in the kitchen, in the bathroom, and in the wash area. The baits were removed after 24 hours and placed in plastic bags. Manual collections were also conducted around the outside of the houses (walls, gardens, garage, and yard).

All other methods like sweep net were used for collecting ant species for taxonomic purposes.

Sampling Techniques for Agricultural Fields (ASites)

Pitfall traps and Hand collection were used to sample ants of agricultural fields.

Pitfall traps were placed in transects at least 2 m apart in agricultural fields. Pitfalls were also placed in field margins along the same transect lines. The pitfalls were left in place for a 24 hr. Period. There was also a manual search carried out for 2 hrs from 08:00h to 10.00 h and subsequently from 18:00h to 20:00 h on the same day the pitfalls were placed in the fields.

Sampling Period

The sampling period of four years (2005-2008) was divided into two phases per year. Each phase comprised of 4 months: Phase I (January to April) and Phase 2 (September to December) (Table 1) making the total number of sampling periods to 32.

A sampling period was taken as all ant occurrences in one sampling period (a month) using all methods applicable to that site. Therefore there were 32 samples per site in this study period (Table 8)

The months of May and June were omitted from sampling as these months face intense heat in Vadodara while there is heavy rainfall in the months of July and August as these are monsoon months. Field work was difficult to carry out during this period. However, occasional visits to the field were conducted during this period to collect isolated samples for the purpose of taxonomical studies.

Table 8. Sampling Plan		
	From 2005 to 2008	
Sampling Period	Phase 1 (Jan - Apr.)	Phase 2 (Sept - Dec)
Sampling period 1	1 Jan - 31 Jan	1 Sept- 30 Sept
Sampling period 2	1 Feb - 28 Feb	1 Oct - 31 Oct
Sampling period 3	1 Mar- 31 Mar	1 Nov. - 30 Nov.
Sampling period 4	1 Apr - 30 Apr	1 Dec. - 31 Dec.

Statistical Analysis

Statistical analysis, in all cases was done using presence absence data i.e. species were recorded in a matrix on the basis of their presence (or absence) in a sample (Longino, 2000). Pseudoabundances (species occurrences within the single samples) were then calculated as abundance measurements-the summed presence of species in samples of habitats.

Urban Sites

Data collected from baiting and hand collection at each urban site over four years from 2005-2008 were used in the analysis of ant abundance and diversity at sites and analyses of ant community structure.

A total of 8 urban sites (4 residential areas and 4 community gardens were surveyed during these four years. Two fragmented habitats were also surveyed giving a total of 10 urban sites.

The total counts of each species of ants in all methods at a site were pooled, giving a single value of ant abundance partitioned by species for each site.

Ant species richness is given as the total number of species occurring at each site. Diversity was calculated from pseudo-abundance values .

Agricultural Sites

Data collected from pitfall traps and hand collection at each agricultural site over four years from 2005-2008 were used in the analysis of ant abundance and diversity at sites and analyses of ant community structure.

A total of 4 agricultural sites were surveyed during these four years. The total counts of each species of ants in all methods at a site were pooled, giving a single value of ant abundance partitioned by species for each site.

Ant species richness is given as the total number of species occurring at each site. Diversity was calculated from pseudo-abundance values

Data Entry

The presence and absence of ant species in the samples were arranged in a data matrix. The abundance data were not included as ants are social organisms and the presence of many individuals may be simply due to collecting a nest or a column of foragers (Chung and Maryati, 1996).

Many samples were collected to get an estimate of the relative abundance of a species and the presence in samples as an indication of abundance (= pseudo abundances) was used. The advantage of using presence absence data is that all individual workers in the sample do not have to be counted so large number of samples can be processed in less time.

Data Analysis

The raw data of all the sampled sites of the study period were transferred in an electronic format in spreadsheet layout (Microsoft excel) and was analyzed to calculate important value indices from all the sampling sites.The data was then subjected to calculations of various diversity indices using computer software Species diversity and richness-version 2.6.

Alpha-diversity indices

Alpha-diversity describes the variety of organisms occurring in a particular place or habitat and is therefore often called local diversity (Swingland, 2001). To compare community diversities different α-diversity indices calculated based on the pseudo abundances (occurrence in number of samples) of all present species at a site. Magurran (1988) gives a detailed account of the terminology, calculations and limitations of the different indices. Some of the most common diversity indices-the Shannon-Wiener H', Simpson's D and Berger parker index were used.

All these indices have their advantages and disadvantages often show a lack of consistency (Roth *et al.,* 1994). No single index includes all of the characteristics of an ideal index with high discriminant ability, low sensitivity to sample size, and ease of calculation; therefore, it is best to use a combination of them (Roth *et al.,* 1994). The indices used here are the ones that are widely used and especially practical for a comparison with other ant community studies (e.g. Andersen, 1993; Chung and Maryati, 1996).

Species richness estimators

To obtain a reliable estimate of species richness is an important goal as it is among the most important criteria used to determine the conservation value of an ecosystem (Kremen *et al.*, 1993).

The total number of times a species was collected was used as a measure of abundance.

Species richness was used as a measure of diversity. Shannon Weiner and Simpsons' indices of diversity were calculated to account for varying species abundances. Berger Parker Index and Equitabilty Index (J) have also been calculated .The Shannon index was selected because it has good discriminatory ability between similar sites, only moderately influenced by sample size, sensitive to changes in species richness rather than dominance, simple to calculate, and is widely used (Magurran 1988)

Ecological diversity indices such as the Shannon-Wiener diversity index and the Simpson index summarize the information about the relative abundances of taxa within a sample or community . These are examples of heterogeneity indices.

Shannon – Weiner (Shannon –Weaver Index)

The most commonly used is the Shannon-Wiener diversity index (H'),

$$H' = -\Sigma(Pi\ \log_e(Pi))$$

Pi is the proportion of the i^{th} species in the total sample Thus number of species in the community and their evenness in abundance are the two parameters that define H'.

The higher value of H' ,greater is the uncertainity and this implies higher diversity and evenness of the community .for biological community value of H' does not exceed 5.

The Shannon-Wiener diversity index is sensitive to both species richness and evenness and is the best measure of their joint influence and also is not strongly affected by rare species It is also sensitive to changes in the rare species .

Simpsons index (D)

Simpson's index was the first of the heterogeneity indices used in ecology (Peet, 1974). The index measures the probability that two individuals selected at random from a sample will belong to the same species (Peet, 1974).

It is calculated as

$$D=\sum_{i=1}^{s} n_i(n_i-1)/N(N-1)$$

Where S is the number of species, N is the total number of individuals in the sample and n_i is the number of individuals of i^{th} species

For different community comparison, the lower the value of D, higher is the species diversity of the community.

Berger –Parker index

It is simple measure of the numerical importance of the most abundant species. The Berger-Parker Index accounts for both richness and relative abundance, presents the proportional importance of the most dominant species, and is simple and easy to calculate

Let,

$$d = N_{max}/N$$

where, Nmax is the number of individuals in the most abundant species and N is the total number of individuals in the sample.

The Berger-Parker index is then simply 1/d so that increases in the index value follow an increase in species diversity or a decrease in dominance.

Renyi's Diversity Ordering

Another method for the ranking of α-diversities is presented by the Renyi family of diversity ordering. By varying the scale parameter α we generate a range of diversity measures (for calculation of the Renyi index H(α) see Appendix), including H' and D. If a community displays higher values over the whole range it is more diverse, if two communities cross they are non-comparable.

To rank the alpha diversity measurements of the communities the renyi index H (alpha) was calculated for a range of diversity measurements (including Shannon Weiner's and Simpson's D diversity indices)of the scale parameter alpha (Legendre and Legendre, 1998). The H (alpha) diversity was plotted against the scale parameter and the resulting curves were compared . If H (alpha) values are higher over the full range of (alpha) and curves do not cross a community is ranked as more diverse. Species diversity within a region resulting from species turnover between habitats is termed beta diversity. To account for differences in the overall species abundance between the habitats, abundances were divided by the maximum abundance value reached for that species in any one of the habitats prior to any further analysis. The Renyi series was calculated using Species Diversity & Richness 2.3 (Henderson & Seaby, 1998).

Results

Ant community structure in Urban Ecosystem

Sampling techniques used for 8 urban sites over four years recorded 2867 species occurrences of 28 species in 17 genera and 6 subfamilies (Table 9).

24 species in 15 genera were found only in Community Gardens (USites) ,13 species in 10 genera were found in Residential areas (URSites). The Fragmented sites (UFsites) contained 28 species from 17 genera and 6 subfamilies.(Figure 27)

Of all the 28 species found at all urban sites 15 were absent from residential areas (URSites), 13 species were found in all sites whereas two species *Camponotus sericeus* and *Crematogaster soror* were collected from urban fragmented habitats (UFSites) (Table 10).

The subfamilies Myrmicinae and Formicinae were the most species rich being represented in urban ecosystem sites with 12 and 9 species respectively. The most abundant subfamily was Myrmicinae comprising 48 % of all ants trapped followed by Formicinae (32%). Pseudomyrmecinae (8%), Ponerinae (6%), Dolichoderinae (4%) and Dorylinae (2%) showed minimum representation (Figure 26)

Ant species richness varied from 26 in Urban sites (USites) to 13 in Urban Residential Sites (URSites), while Fragmented habitats (UFSites) recorded presence of all 28 species found in this study.

Alpha Diversity

Shannon Weiner index showed highest values for Urban fragmented sites, UFSite1(3.26) and UFSite2 (3.23) indicating maximum species diversity followed by Urban Community gardens (USites) the values ranging from 3.08 to 3.11.The minimum diversity was shown by Urban Residential sites (URSites) with Shannon Weiner index values reaching 2.4 (Table 11).

Table 9. Pseudoabundances of Ant Subfamilies in Urban Ecosystem

Site	Myrmicinae	Formicinae	Ponerinae	Pseudo - myrmecinae	Dolicho - derinae	Dorylinae
USite 1	218	142	31	46	24	12
USite 2	210	138	32	45	22	14
USite 3	215	145	38	46	23	21
USite 4	221	148	36	41	20	21
URSite1	131	99	0	0	14	0
URSite2	114	88	0	19	12	0
URSite3	123	98	0	10	11	0
URSite4	113	95	0	19	12	0
UFSite1	288	161	52	51	24	10
UFSite2	272	178	47	49	12	0

Table 10. Pseudoabundances of Ant Species in Urban Ecosystems

Species	USite1	USite2	USite3	USite4	URSite1	URSite2	URSite3	URSite4	UFSite1	UFSite2
Tapinoma melanocephalum	24	22	23	20	14	12	11	12	24	27
Dorylus labiatus	12	14	12	21	0	0	0	0	10	0
Camponotus compressus	32	29	32	30	30	32	31	28	32	32
Camponotus irritans	13	15	13	17	0	0	0	0	8	11
Camponotus sericeus	0	0	0	0	0	0	0	0	15	20
Formica rufa	28	25	28	25	18	19	25	12	26	22
Lasius sp.	16	15	16	18	20	11	15	16	15	16
Oecophylla smaragdina	10	14	10	13	0	0	0	0	13	22
Paratrechina longicornis	25	22	26	29	20	18	25	27	16	21
Polyrhachis lacteipennis	0	0	0	0	0	0	0	0	15	9
Prenolepis sp.	18	18	20	16	11	8	2	12	21	25
Crematogaster soror	0	0	0	0	0	0	0	0	20	21
Crematogaster subnuda	25	20	23	24	7	12	15	8	30	28
Meranoplus bicolor	11	11	12	13	0	0	0	0	22	16
Monomorium minimum	30	29	30	31	30	27	23	28	32	30
Monomorium pharaonis	29	27	27	26	15	18	17	18	31	28
Pheidole megacephala	27	24	26	25	32	26	28	23	32	29
Pheidole watsoni	31	31	27	29	32	16	21	25	30	32
Pheidole sp.1	14	16	17	16	15	15	19	11	21	18
Pheidole sp.2	11	12	11	15	0	0	0	0	15	18
Solenopsis geminata	24	21	25	22	0	0	0	0	29	27
Solenopsis invicta	0	0	0	0	0	0	0	0	15	16
Solenopsis sp2	16	19	17	20	0	0	0	0	11	9
Diacamma ceylonense	16	15	18	18	0	0	0	0	21	18
Diacamma rugosum	2	4	5	2	0	0	0	0	9	11
Leptogenys chinensis	13	13	15	16	0	0	0	0	22	18
Tetraponera allaborans	15	16	17	15	0	0	0	0	19	17
Tetraponera rufonigra	31	29	29	26	0	19	10	19	32	32

The measured diversity from maximum to minimum was:

UFSites > USites > URSites

The other diversity index computed was Simpson's Diversity Index. This showed the same trend with maximum values of 25.7 and 25.4 obtained from Urban fragmented sites and the minimum (10.6 to 11.9) from Urban Residential sites. Urban community gardens showed values falling between the fragmented and residential sites (21.3 to 22.6) showing moderate diversity (Table 5).

The measured diversity from maximum to minimum was:

UFSites > USites > URSites

Berger Parker Dominance index showed minimum values for Urban Fragmented sites (.05) and Urban Community garden sites(.06) while Urban residential sites showed maximum values (0.1) (Table 5). This indicates that species are more evenly distributed in the fragmented and community Garden sites without any specific dominant species. The Urban Residential sites on the other hand have certain species such as *Pheidole* spp. and *Camponotus* spp. which are more dominant than the others.

The Renyi's Diversity Ordering graphs of Urban habitats show Urban Fragmented sites (UFSites) at the highest implying highest diversity in these sites with Urban Community Parks (USites) ranking second and Urban Residential areas the third with the lowest diversity. Renyi Graphs of the Usites, URsites and UFSites show overlapping hence are not comparable, an indication of similar diversities within these habitats (Figure 28).

Table 11. Alpha Diversity Indices for Urban Ecosystem

Sample	Species No.	Shannon Weiner Index H	Simpsons' Index D	Berger Parker Index
USite1	24	3.0817	21.323	0.067653
USite2	24	3.1127	22.379	0.067245
USite3	24	3.1073	22.148	0.066806
USite4	24	3.1147	22.636	0.063655
URSite1	12	2.3991	10.695	0.13115
URSite2	12	2.4116	11.959	0.13734
URSite3	13	2.4605	11.553	0.1281
URSite4	13	2.4933	11.925	0.11715
UFSite1	28	3.2623	25.713	0.054608
UFSite2	27	3.2394	25.411	0.055846

Urban Residential Sites (URSites)

A total number of species occurrences in these areas was 958 (Table 10).

Comparing the internal (bathrooms, kitchens and wash areas) and external areas (walls, gardens, garage and yard and neighbourhood) of the residences, lower species richness (12 species) in the inside the homes of residential areas while higher species richness (13 species) were found on the outside of these areas. The locales that contributed with the greater number of ants were the wash area and kitchen and the species that showed greatest occurrences was *Pheidole* spp. inside houses whereas *Camponotus compressus* was found the most outside homes.

The inverse was found in the external areas of the houses, 13 species were recorded of which maximum were collected foraging in the soil and/or vegetation of the gardens and backyards of the residences (Figure 29).

The residential sites URSite2 and URSite 4 showed the minimum species occurrences (233 and 239) because of their proximity to construction sites. These areas are the upcoming and happening areas in terms of property and construction.

Urban Community Gardens Sites (USites)

The total number of species occurrences in the urban community garden sites was 1900; 24 species belonging to 15 genera and 6 subfamilies (Table 10).

9 species were collected only by pitfall traps and 5 species were collected only manually while the rest of the 10 species were collected by both methods.

Two types of assemblages were observed: arboreal and ground dwelling.The arboreal species were: *Oecophylla smaragdina, Tetraponera* spp., *Crematogaster* spp. etc. while ground dwelling species were Pheidole spp.,*Camponotus* spp., *Solenopsis* spp.,*Tapinoma melanocephalum*, *Dorylus labiatus,* etc.

Urban Fragmented Sites (UFSites)

Fragmented sites the offer the most diverse habitats to ant species. When compared with forest habitats fragmented habitats represent disturbed regions and hence show decreased diversity of ants (Suarez *et al.*, 1998). But when compared with other urban habitats, like in this study, they house the maximum diversity of ants. The reason is presence of undisturbed patches of land interspersed with manmade structures. The total species occurrence from the two Urban Fragmented areas was 1159 (Table 10).

Ecological remarks (observations of the species made during this research have been described for each species in Chapter 3 (Species Inventory) and their nesting and foraging patterns are dealt with in Chapter 6 (Nesting and Foraging Ecology of ant species).

Comparison of Sampling Methods

Three sampling methods were used for collection of ants in urban ecosystems: pitfall trapping (in USites and UFSites), baiting (in URSites) and hand collection at all sites.

A total of 25 ant species were trapped in pitfalls, 17 in baits and 24 by hand collection (Table 12).

Baiting was the more useful method of collecting arboreal ants like *Tetraponera* spp., *Crematogaster* spp.,and *Monomorium* spp., whereas pitfalls targeted the subterranean ones like *Polyrhachis lacteipennis*, *Solenopsis* spp.. 4 species were collected exclusively by pitfalls, while 14 species were collected by all methods.

Table 12. Ant Species Vs. different sampling methods

Species	Pitfall Trapping	Baiting	Hand Collection
Tapinoma melanocephalum	√	√	√
Dorylus labiatus	√	×	×
Camponotus compressus	√	√	√
Camponotus irritans	√	√	√
Camponotus sericeus	√	×	√
Formica rufa	√	√	√
Lasius sp.	√	√	√
Oecophylla smaragdina	√	√	√
Paratrechina longicornis	√	√	√
Polyrhachis lacteipennis	√	×	√
Prenolepis sp.	√	√	√
Crematogaster soror	√	×	√
Crematogaster subnuda	×	√	√
Meranoplus bicolor	√	×	×
Monomorium minimum	√	√	√
Monomorium pharaonis	√	√	√
Pheidole megacephala	√	√	√
Pheidole watsoni	√	√	√
Pheidole sp.1	√	×	√
Pheidole sp.2	√	×	√
Solenopsis geminata	√	√	√
Solenopsis invicta	√	√	√
Solenopsis sp2	√	×	√
Diacamma ceylonense	√	×	×
Diacamma rugosum	√	×	×
Leptogenys chinensis	√	×	√
Tetraponera allaborans	×	√	√
Tetraponera rufonigra	×	√	√

Ant community structure in Agricultural Ecosystem

Sampling techniques used for 4 agricultural sites over four years showed 1581 species occurrences of 25 species in 16 genera and 6 subfamilies (Table 13).

The maximum number of species, 23 species were found in Padra (ASite4), Savli (ASite2) recorded 21 species while 20 species were collected from Timbi (ASite1) and Waghodia (ASite3).

In terms of species occurrences, Padra (ASite4) showed the maximum (434) followed by Timbi (423) and Savli (370). The minimum number of species occurrences was reported from Waghodia (354).

Agricultural ecosystems of Vadodara significantly showed absence 3 species of ants that were found in Urban Habitats .They are *Crematogaster subnuda* , *Leptogenys chinensis* and *Tetraponera rufonigra*. The subfamilies Myrmicinae and Formicinae were the most species rich being represented in agro ecosystem sites with 11 and 9 species respectively.

The most abundant subfamily was Myrmicinae comprising 47 % of all ants trapped followed by Formicinae (43%). Pseudomyrmecinae (1%), Ponerinae (2%), Dolichoderinae (4%) and Dorylinae(3%) showed minimum representation (Figure 30).

Alpha diversity

The Shannon Weiner index shows maximum diversity (3.0) for Padra (ASite4) , Savli (ASite 1) and Timbi (ASite2) show the values of 2.9 while the lowest diversity(2.8) is indicated in Waghodia (ASite3).(Table 8)

The measured diversity from maximum to minimum was:

ASite4 > ASite1 and ASite2 > ASite3

Simpsons' Diversity values also highest diversity in ASite4 with the index being the maximum (20.9).The lowest diversity however is shown by ASite 3 where the index shows minimum value (16.6). ASite1 and ASite 2 show similar diversity with values of 18.8 and 19.7 (Table 8)

Berger Parker Dominance Index (J) index showed minimum values for ASite4 (.073) and while ASite3 showed maximum values (0.90).This indicates that species are more evenly distributed in the ASite4 without any specific dominant species (Table 14)

Renyi's diversity ordering graph shows intersecting lines hence indicating towards non comparability between Agricultural sites ASite1, Asite2 and ASite4. However, ASite 3 shows low diversity as compared to all other sites (Figure 31).

The species occurrences seen in cultivated areas and field margins shows considerable difference in numbers (Table).Most of the species (23 out of 25 species) were trapped or collected from field margins (Figure 32).

Species such as *Camponotus compressus*, *Paratrechina longicornis* and *Solenopsis geminata*, belonging to the subfamily Formicinae, were commonly found in all the sites. Considering the total number of individuals across all the sites and sampling methods, it is evident that *Camponotus compressus* is highly abundant followed by *Monomorium minimum* in urban sites and *Pheidole watsoni* in agricultural sites. This shows that *Camponotus compressus* particularly, is competent and can adapt to the changing conditions. Studies carried out by Risch and Carroll (1982) have shown that omnivorous species like *Solenopsis geminata* are found in disturbed ecosystems, which in our study have also been found abundantly in all sites. Moreover, it was found to frequently reside in human structures, which substantiates its presence in most sites.

The species occurrences seen in cultivated areas and field margins shows considerable difference in numbers (Table 15).Most of the species (23 out of 25 species) were trapped or collected from field margins (Figure 32).

Table 13. Pseudoabundances of Ant Species in Agricultural Ecosystems

Species	ASite1	ASite2	ASite3	ASite4
Tapinoma melanocephalum	14	18	13	12
Dorylus labiatus	16	13	0	19
Camponotus compressus	32	29	32	32
Camponotus irritans	30	20	25	18
Camponotus sericeus	32	32	32	32
Formica rufa	12	13	8	17
Lasius sp.	15	8	4	6
Oecophylla smaragdina	0	0	20	15
Paratrechina longicornis	18	14	16	14
Polyrhachis lacteipennis	25	20	19	26
Prenolepis sp.	18	14	12	13
Crematogaster subnuda	25	20	16	21
Meranoplus bicolor	15	0	0	14
Monomorium minimum	15	9	4	18
Monomorium pharaonis	16	16	17	12
Pheidole megacephala	25	16	21	30
Pheidole watsoni	28	27	30	32
Pheidole sp.1	25	23	20	26
Pheidole sp.2	15	0	0	18
Solenopsis geminata	32	19	32	14
Solenopsis invicta	15	16	18	20
Solenopsis sp2	0	17	0	15
Diacamma ceylonense	0	16	5	0
Diacamma rugosum	0	0	0	10
Tetraponera allaborans	0	10	10	0

Table 14. Alpha Diversity Indices for Agricultural Ecosystem

Sample	Species No.	Shannon Weiner Index H	Simpsons' Index D	Berger Parker Index
ASite1	20	2.9443	18.874	0.07565
ASite2	21	2.9865	19.713	0.086486
ASite3	20	2.8586	16.653	0.090395
ASite4	23	3.0614	20.917	0.073733

Table 15. Ant Species occurrences within different areas of Agricultural Ecosystem		
Species	Within cultivated portions	Within field margins
Tapinoma melanocephalum	23	34
Dorylus labiatus	8	40
Camponotus compressus	60	65
Camponotus irritans	43	50
Camponotus sericeus	74	54
Formica rufa	21	29
Lasius sp.	18	15
Oecophylla smaragdina	10	25
Paratrechina longicornis	17	18
Polyrhachis lacteipennis	37	53
Prenolepis sp.	34	23
Crematogaster subnuda	33	49
Meranoplus bicolor	8	21
Monomorium minimum	20	26
Monomorium pharaonis	29	32
Pheidole megacephala	43	49
Pheidole watsoni	50	77
Pheidole sp.1	40	44
Pheidole sp.2	9	24
Solenopsis geminata	42	55
Solenopsis invicta	24	45
Solenopsis sp2	20	12
Diacamma ceylonense	9	12
Diacamma rugosum	3	7
Tetraponera allaborans	5	15

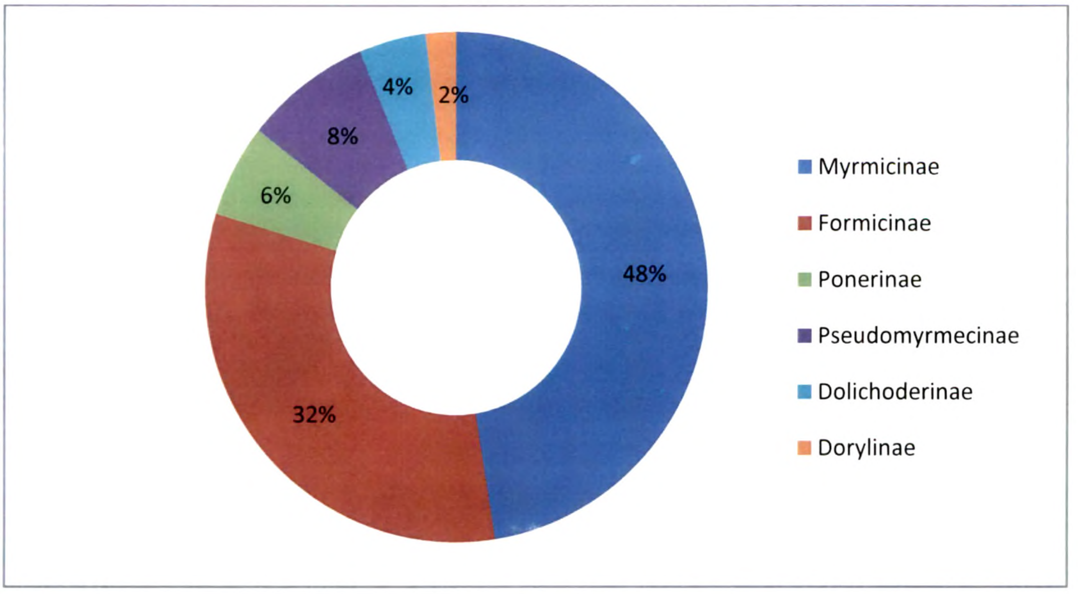

Figure 26. Percentage Composition of Ant Subfamilies in Urban Ecosystem

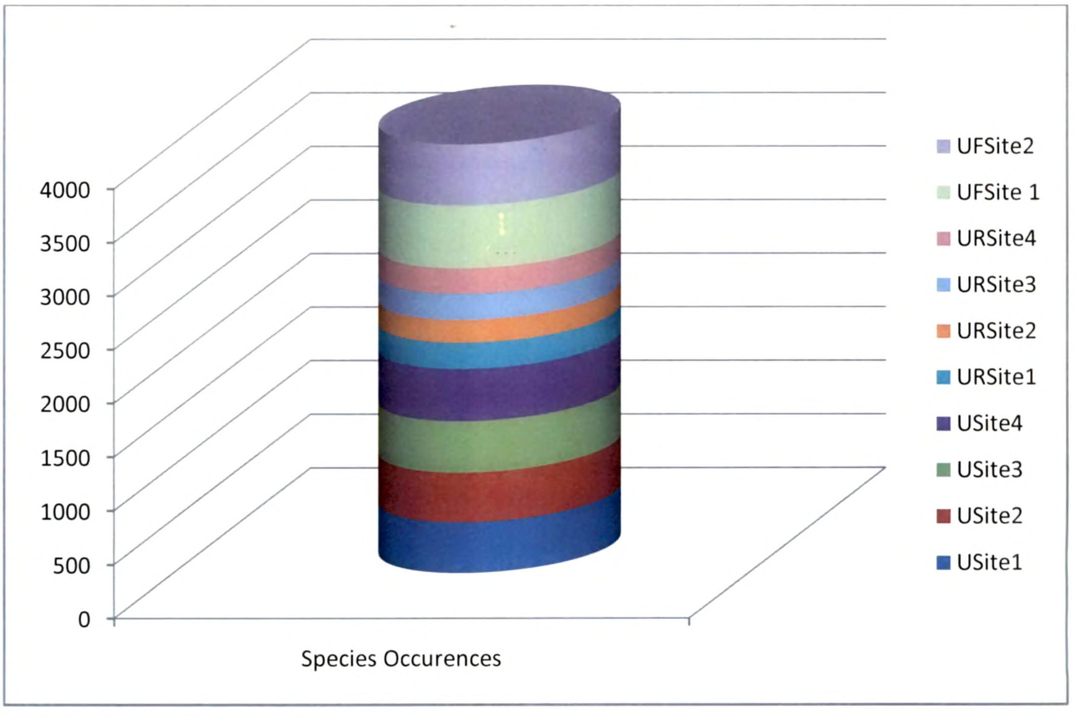

Figure 27. Ant Species Occurrences in Urban Ecosystem

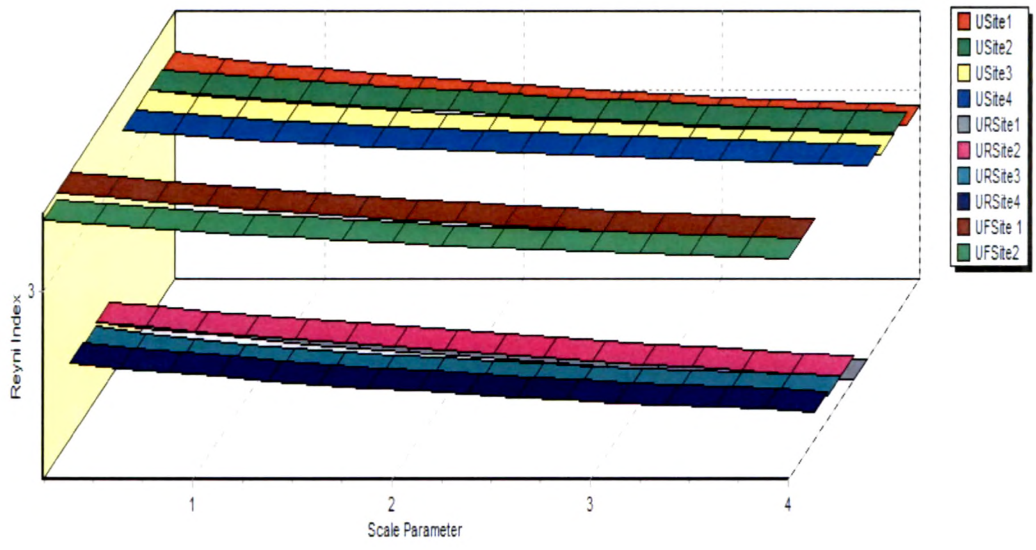

Figure 28. Renyi's Diversity Ordering Graph for Urban Ecosystems

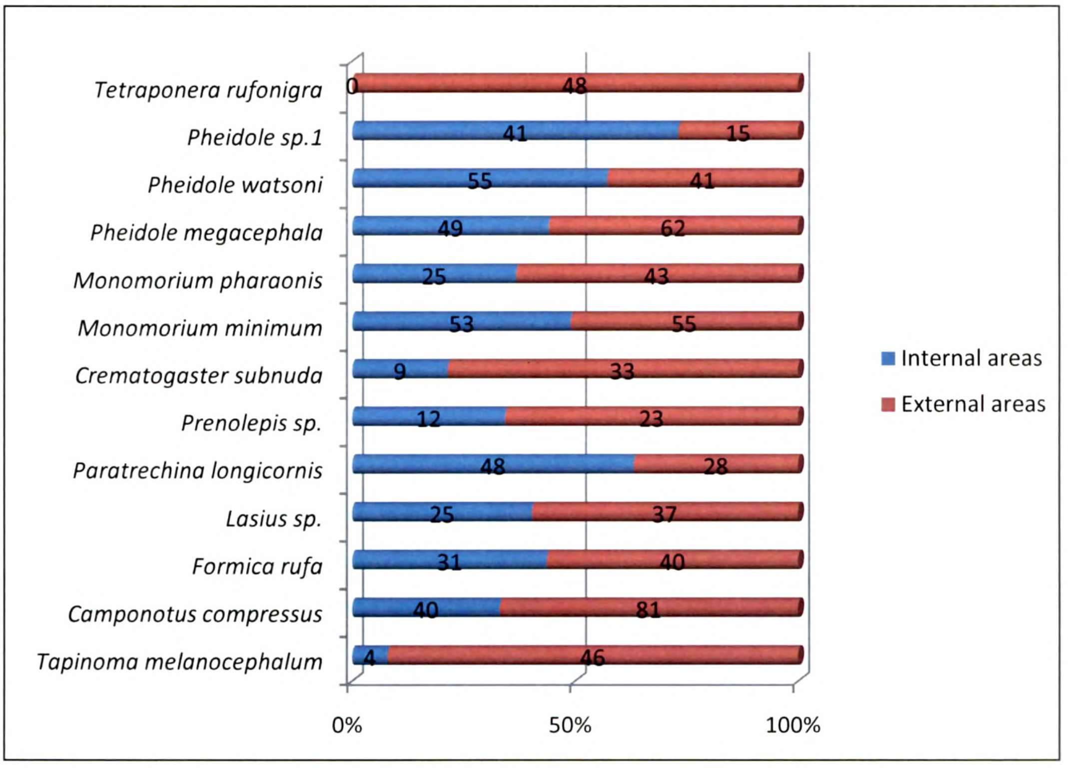

Figure 29. Distribution of ants in Different Areas of Urban Residential Sites

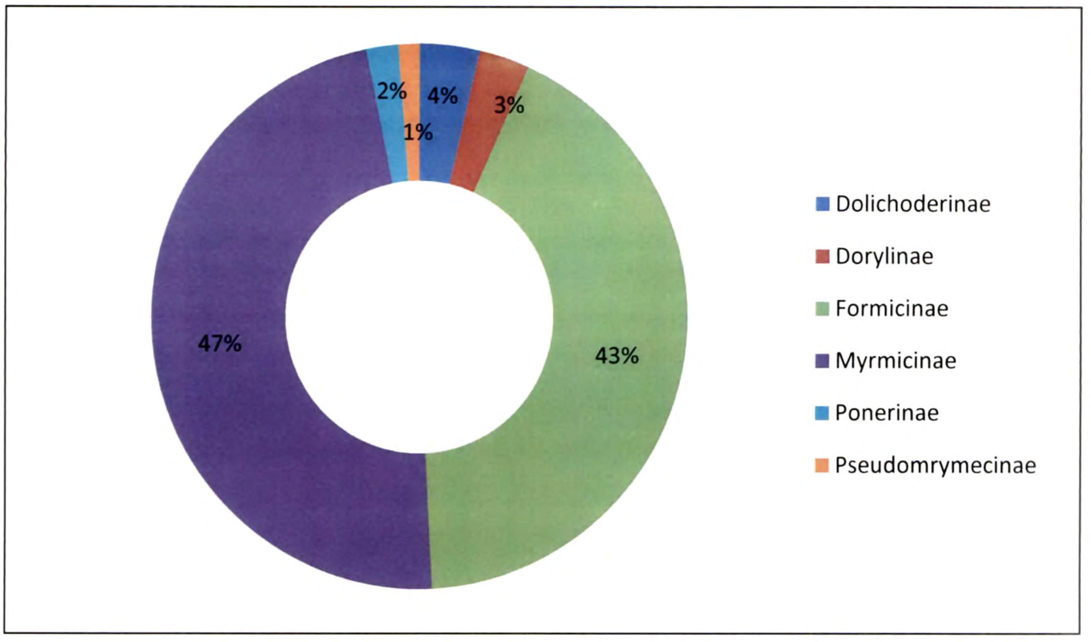

Figure 30. Percentage Composition of Ant Subfamilies in Agricultural Ecosystem

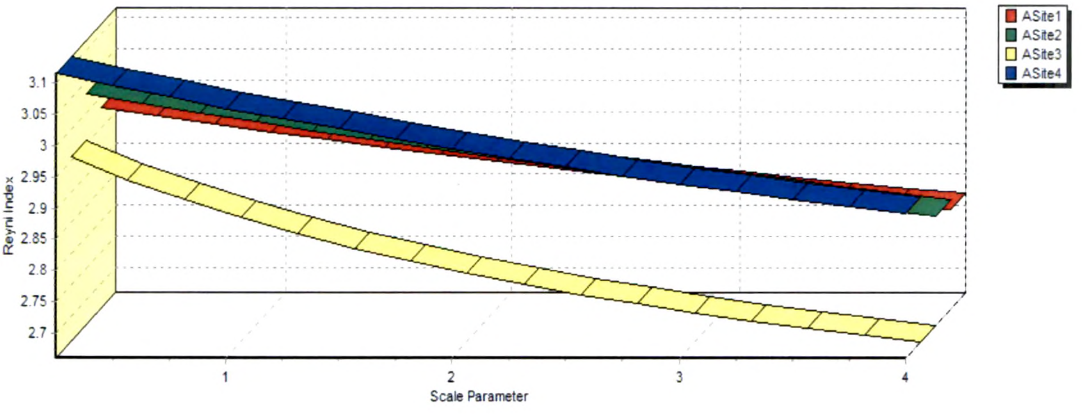

Figure 31. Renyi's Diversity Ordering Graph for Agricultural Ecosystems

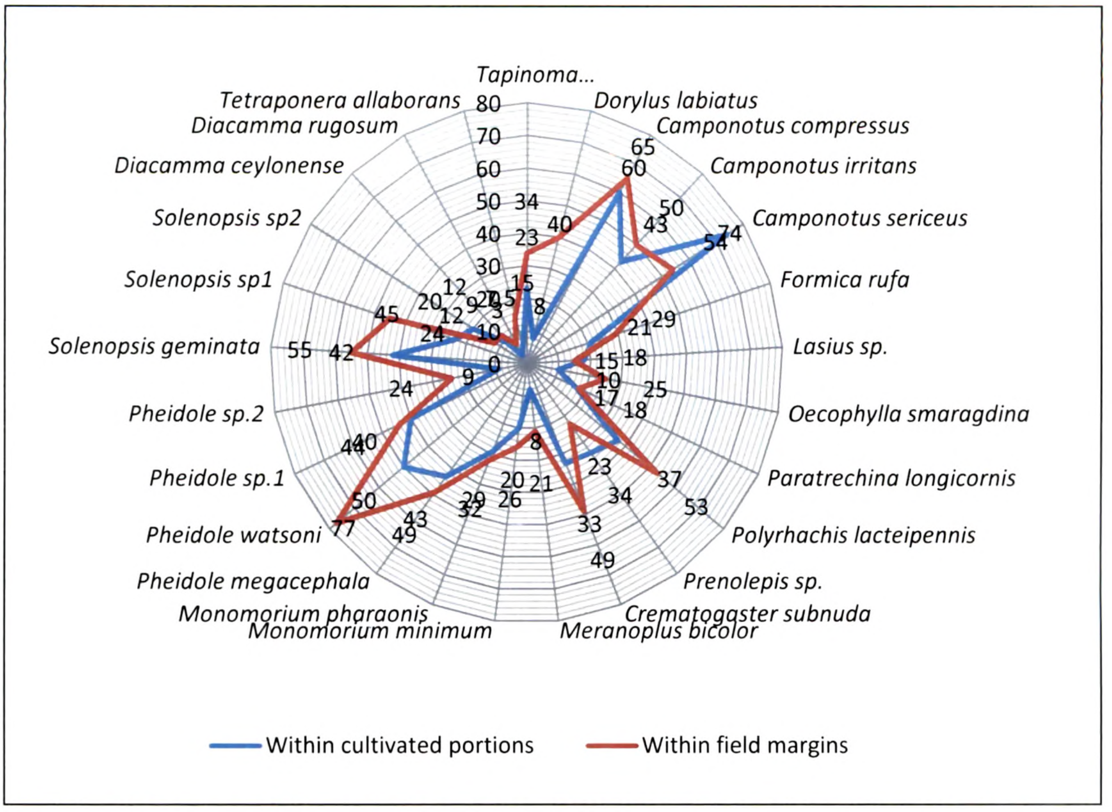

Figure 32. Ant Species vs different areas of Agricultural Fields

Discussion

Ants in Urban Ecosystems

The results of this study indicate, among the urban sites, presence of maximum diversity of ants in the urban Fragmented habitats with comparable number of species in Community gardens and the least in Residential sites.

Although studies have proved that fragmentation reduces species richness (Suarez *et al.*,1998), this study indicates that in the face of compulsory urbanisation these are the best places to maintain diversity. This may be because Fragmented sites like the University Campus and Laxmivilas Palace Compound offer habitat heterogeneity which favors generalist species like *Camponotus* spp,, *Monomorium* spp..There are undisturbed patches of land interspersed by human managed plots .These contributed to the total species richness of fragmented sites.

Previous studies have also recognized that urban landscapes like Community Gardens present considerable opportunities to conserve existing biodiversity that might otherwise be lost (Clark *et al.*, 2008)

Ant species richness was noticeably lower in Urban Residential Sites. Only 13 species of ants out of the reported 28 ant species have been found in these sites. Residential areas represent the 'Urban Core' and are hence more affected by urbanization. This is mainly due the loss in vegetation cover. Moreover, roads, pavements, and buildings leave very little green space for many ant species specially the arboreal ants like *Tetraponera* spp., *Crematogaster* spp., *Oecophylla smaragdina* to survive. Gardens in houses have more exotic plants and are subjected to continuous use of insecticides for control of insect pests. This could be another reason for low species richness in urban residential habitats (Savitha *et al.*,2005).

Among residential sites, more ant species found outside homes than inside as also reported by Kamura *et al.* (2007) in a study on urban ant communities of Brazil, because most urban ants like *Pheidole* spp, *Paratrechina longicornis*, *Prenolepis* sp. require moist nesting substrates which are found primarily outdoors.

Further, urban ant species are omnivorous. They opportunistically consume live and dead animals and harvest carbohydrate-rich plant and insect exudates like Homopteran honeydew. This source of food colony growth and high worker numbers, may contribute to their local dominance. Omnivory and opportunistic foraging also bring these ants into human dwellings where a variety of foods may persist for varying periods. The reason for success of urban ants like *Pheidole* spp. and *Camponotus* spp.is that they have general and somewhat flexible nesting habits, which allows them to associate closely with humans . Their vagile behavior allows colonies to vacate an area in response to physical disturbance or insecticide applications, or to exploit favorable sites where food may be near at hand (Silverman, 2005).

Another interesting observation was that certain species like *Camponotus* spp. and *Lasius* sp. are able to resist colony extinction under unfavourable abiotic conditions, by constructing polydomous nests, where all nests function in an apparently cooperative fashion. This also allows the colony to secure and protect resources in a larger area (Traniello and Levings, 1986).

Ant species such as *Solenopsis invicta* and *Camponotus sericeus* were found only in Urban fragmented sites and not in any other urban site . This suggests that 'disturbance' caused due to urbanization has led to disappearance of the species from residential sites and community gardens.

Generalists like *Pheidole* spp. and *Camponotus* spp. feed on human leftovers, frequent the kitchen and garbage and are the dominant ants found there. Habitat specialists like *Polyrhachis lacteipennis* and *Leptogenys chinensis* are found more in fragmented habitats.

The capability of Fragmented habitats to show greater species richness compared to community gardens, as indicated by this study, can be attributed to, firstly, the presence of natural remnants within the disturbed patches that offer greater habitat variation for native species like *Camponotus spp., Pheidole watsoni, Tetraponera rufonigra, Crematogaster* spp. etc. Secondly, increased soil moisture in parks as compared to fragmented habitats reduces species richness.

Even though soil moisture is a favourable condition correlated to overall species richness in community gardens, very high levels of soil moisture may be unsuitable for ants because ant broods cannot grow in cold and wet environments. Prior studies have also found increased soil moisture to be associated with lower nest densities in urban areas (Thompson and McLachlan, 2007)

Although temperature was not explicitly examined in this study, it may also play a role in determining the observed distributions. Ants are primarily thermophilic and Andersen (1995) has suggested that low temperature is the principal stress affecting ant community structure, to the point of limiting taxa diversity. Remnants of forests in fragmented landscapes are distinctly cooler than other urban areas (Yilmaz *et al.*, 2007), mainly due to the shade provided by the canopy.

In general, larger natural fragments support a greater number of species while smaller fragments reduce population sizes and species richness (Suarez *et al.*, 1998; Bolger *et al.*, 2000; Yamaguchi, 2005).

One aspect that could possibly limit species numbers in urban areas is that urban species need to adapt to higher urban temperatures compared to rural areas (Angilletta *et al.*, 2007) and urban areas often have increased levels of pollution and soil compaction (Pyle *et al.*, 1981; Jim, 1998). Also, due to excessive watering of plants in community gardens may not permit these ants to forage adequately.

Our studies show that urban habitats, despite being degraded and challenged ecosystems, yield sizeable numbers of important species, especially in areas of high native diversity and endemism.

Ants in Agricultural ecosystems

Among agricultural sites ASite 3, Waghodia, shows minimum species occurrences .This can be attributed to the fact that this site is experiencing large scale construction in the past few years.

Our data shows that ant species richness was greater in field periphery (margins) than the cultivated portions. This could be due to excessive use of pesticides within the agricultural fields, and disturbed soils that had humidity or mineral concentration modified by cultivating. The way and intensity of soil use can change the richness and composition of the ant fauna making it different from undisturbed habitats with respect to ant species richness and composition (Majer, 1983; Andersen, 1997).

Agricultural practices have a strong effect on ant species composition and our observations agree with other studies that observed a change in ant species abundance, frequency and dominance after agriculture activities and different ant composition in natural and cultivated areas .Risch and Carroll (1982) and Nestel and Dickschen (1990) found that activity of a generalised predatory ant species, *Solenopsis geminata*, was increased with simplification of the agricultural system. Human and cattle activities within fields also act as deterrents in colony setup within the cropping areas.

It has also been shown in this study that isolated trees play an important role in ant biodiversity .Trees like *Ceasalpinia crista, Terminalia catappa* , *Casuarina tamarindus* etc. that are left on the periphery of fields in the urban areas help in increasing landscape heterogeneity and thereby can increase the conservation of ant species diversity in simplified landscapes (Gove *et al.*, 2005). In tropical environments, trees offer the only means of introducing some of the most active and aggressive ant species, such as *Crematogaster* spp, to agricultural landscapes (Peng and Christian, 2004; Philpott and Foster, 2005) as also proved by our studies. It has been suggested that these trees could act as a source of predatory ants, which may act as important agents in the biological control of agricultural pests (Majer and Delabie, 1999).Other suitable places for nest building and foraging for ants in agricultural ecosystems are hedgerows and non-tilled field-margins.

Figure 33. Sayaji Baug

Figure 34. Sayaji Baug

Figure 35.
Sardar Baug

Figure 36.
Sardar Baug

Figure 37.
Lal Baug

Figure 38.
Lal Baug

Figure 39.
Akota Garden

Figure 40.
Akota Garden

Figure 41. Department of Zoology. The M.S University of Baroda

Figure 42. The M.S University of Baroda

Figure 43.
Bhookhi Nala,
The M.S
University of
Baroda

Figure 44.
Lawn in front
of Dept. of
Zoology. The
M.S University
of Baroda

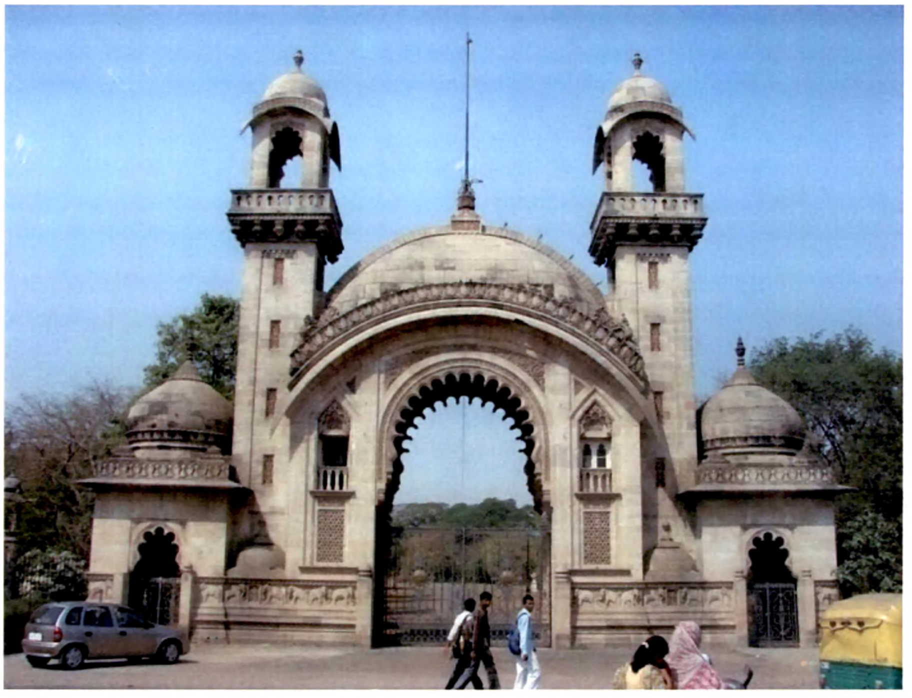

Figure 45.
Laxmi Vilas
Palace

Figure 46.
Laxmi Vilas
Palace

Figure 47.
Banyan tree
Laxmi Vilas
Palace

Figure 48.
Laxmi Vilas
Palace

Figure 49.
Pearl millet field Timbi

Figure 50
Paddy crop Timbi

Figure 51.
Mustard Field
Savli

Figure 52.
Crysanthemum
crop Savli

Figure 53.
Castor Field
Padra

Figure 54.
Fallow Field
Padra

Figure 55.
Cabbage
Crop Padra

Figure 56.
Paddy Crop
Padra

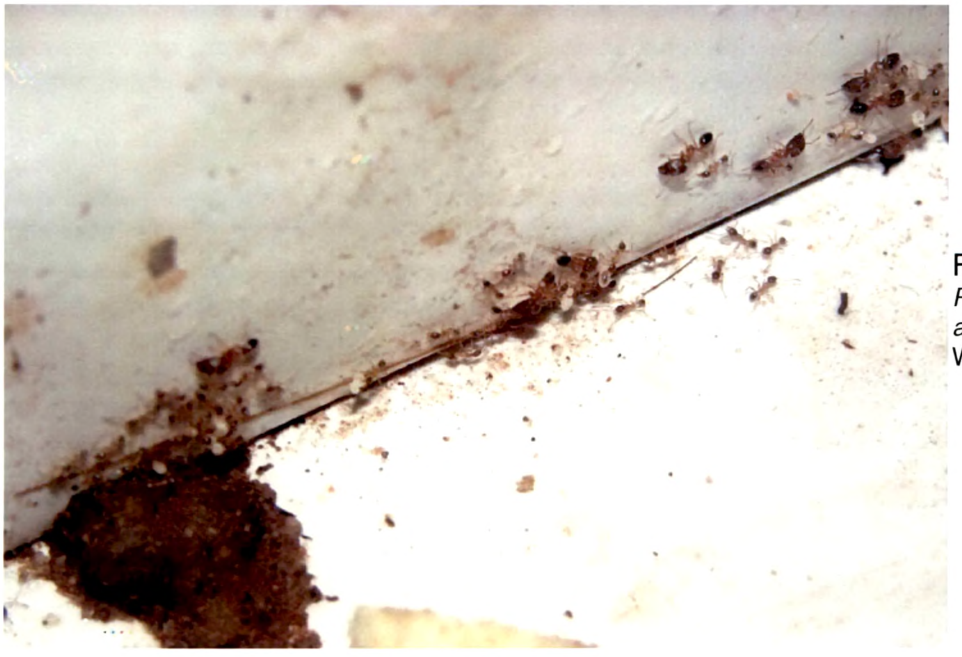

Figure 57. *Pheidole* *a*nts in Washroom

Figure 58. *Monomorium* Ants on Rooftop

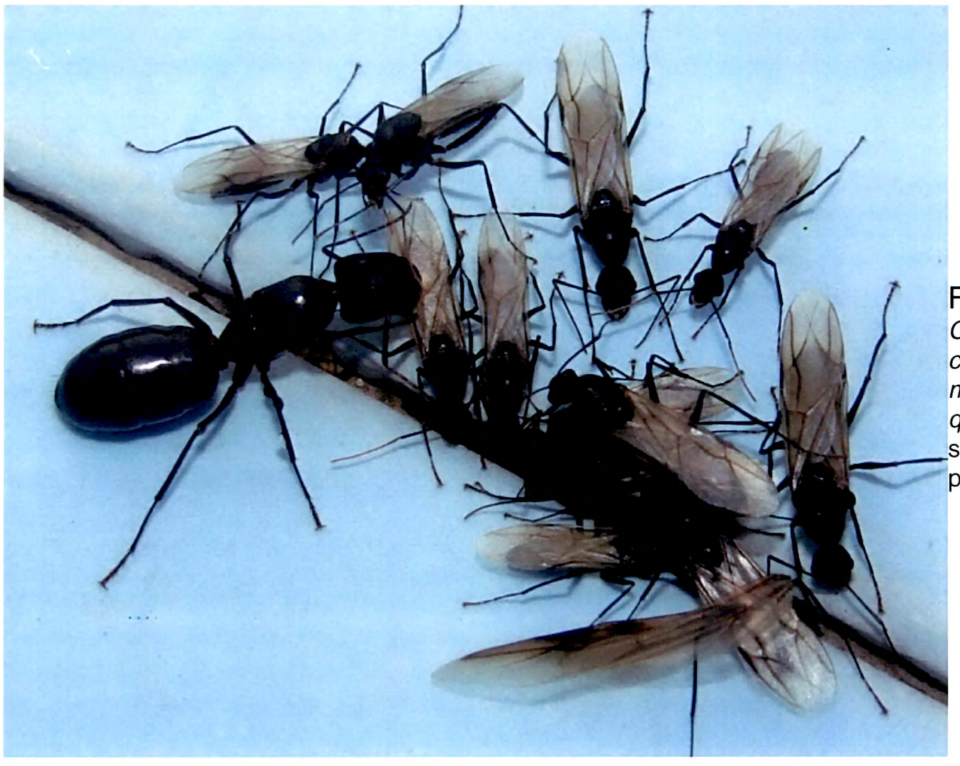

Figure 59. *Camponotus compressus males with queen n*ear swimming pool