

**ANTS AS INDICATORS OF BIODIVERSITY: A STUDY ON THE
ANT FAUNA OF COIMBATORE ZOOLOGICAL PARK AND
TAMIL NADU AGRICULTURAL UNIVERSITY CAMPUS**

Thesis submitted in part fulfillment of the requirements for the degree of

Master of Science in Environmental Sciences to the

Tamil Nadu Agricultural University,

Coimbatore - 641 003

By

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I.D. No.: 01-610-007

DEPARTMENT OF ENVIRONMENTAL SCIENCES
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMIL NADU AGRICULTURAL UNIVERSITY
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CERTIFICATE

This is to certify that the thesis entitled "**ANTS AS INDICATORS OF BIODIVERSITY: A STUDY ON THE ANT FAUNA OF COIMBATORE ZOOLOGICAL PARK AND TAMIL NADU AGRICULTURAL UNIVERSITY CAMPUS**" submitted in part fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE in ENVIRONMENTAL SCIENCES** to the Tamil Nadu Agricultural University, Coimbatore is a record of *bona fide* research work carried out by **Mr.P. JAWAHAR**, under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

ANTS AS INDICATORS OF BIODIVERSITY : A STUDY ON THE ANT FAUNA OF COIMBATORE ZOOLOGICAL PARK AND TAMIL NADU AGRICULTURAL UNIVERSITY CAMPUS

By

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2003

A study on the ant fauna of Coimbatore zoological park (CZP) and Tamil Nadu Agricultural University (TNAU) campus was carried out for six months from December to May, 2003 to assess the biodiversity of ant fauna of the two sites and to identify the indicator species for an ecosystem. Four sampling techniques were employed viz., pitfall trap, bait trap, winkler extraction and direct sampling so as to give a complete representation of the ant fauna in the study sites.

The survey revealed the presence of 37 species of ants in both sites as a whole under five sub families. About 23 species of ants belonging to five subfamilies were recorded at each site viz., CZP and TNAU campus. The two sites have nine species of ants in common under three subfamilies.

Various measures viz., diversity indices like Shannon Wiener index, Margalef D index, abundance indices like Species number, species richness estimator like Jack knife

estimator and similarity measure like Jaccard's index were computed for the CZP and TNAU campus. The species richness measure showed that CZP was richer than TNAU campus. The similarity measure showed that evergreen zone and moist deciduous zone were more similar in CZP and evergreen zone and semi-evergreen zone were more similar in TNAU campus. The Diversity measures showed that, in CZP and TNAU, evergreen zone was found to be more diverse.

In CZP, the ant species *Monomorium gracillimum* Smith was found associated with *Acacia horida*, a tree characteristic of shrub thorny forest. In TNAU campus, *Solenopsis geminata* Fabricius was found to indicate the disturbance due to agricultural operations in agro ecosystems. The potentiality of these two species as indicators of ecosystem is proposed and discussed.

LIST OF FIGURES

Figure No.	Title	Page No.
3.1.	Map showing the location of Coimbatore Zoological Park	
3.2.	Map showing the different zones of Coimbatore Zoological Park	
3.3.	Map showing location of TNAU campus	
3.4.	Layout of the study plot	
3.5.	Pitfall trap	
3.6.	Bait trap	
3.7.	Arrangement of Pitfall trap and Bait trap in the plot of 10 m x 10 m	
3.8.	Sifter	
3.9.	Winkler sack	
4.1.	Shannon wiener index during the sampling period in CZP.	
4.2.	Species number during the sampling period in CZP.	
4.3.	Margalef D index during the sampling period in CZP.	
4.4.	Shannon wiener index for different zones in CZP.	
4.5.	Species number in different zones of CZP.	
4.6.	Margalef D index in different zones of CZP.	
4.7.	Species accumulation curve for CZP.	
4.8.	Jack knife estimate of species richness in CZP.	
4.9.	Shannon wiener index during the sampling period in TNAU campus.	
4.10.	Species number during the sampling period in TNAU Campus.	
4.11.	Margalef D index during the sampling period in TNAU Campus.	
4.12.	Shannon wiener index for different zones of TNAU Campus.	
4.13.	Species number in different zones of TNAU Campus.	
4.14.	Margalef index in different zones of TNAU Campus.	
4.15.	Species accumulation curve for TNAU Campus.	
4.16.	Jack knife estimate of species richness in TNAU Campus.	

5.1	Rainfall pattern in CZP and TNAU campus	
5.2.	Distribution of the common ant species across different zones of CZP and TNAU Campus.	
5.3.	Composition of ant species in CZP.	
5.4.	Distribution of common ant species in CZP and TNAU Campus.	
5.5.	Composition of ant species in TNAU Campus.	
5.6.	Distribution of <i>Monomorium gracillimum</i> Smith during the sampling period in CZP.	
5.7.	Distribution of <i>Solenopsis geminata</i> Fabricius during the sampling period in TNAU Campus.	

LIST OF TABLES

Table No.	Title	Page No.
4.1.	Ant species in CZP and TNAU campus.	
4.2.	The presence or absence of ant species in CZP and TNAU campus.	
4.3.	Total number of ant individuals collected during the sampling period in CZP.	
4.4.	Total number of ant individuals collected in different zones of CZP.	
4.5.	Ant individuals collected by different sampling methods in CZP	
4.6.	Total number of ant individuals collected during the sampling period in TNAU campus.	
4.7.	Total number of ant individuals collected in different zones of TNAU campus.	
4.8.	Ant individuals collected by different sampling methods in TNAU campus	
4.9.	Class/ Order of invertebrates found in CZP and TNAU campus.	
4.10.	The various diversity estimates of ant species during the survey period in CZP and TNAU campus.	
4.11.	The various diversity estimates of ant species in different zones of CZP and TNAU campus.	
4.12.	The ant species accumulation in CZP and TNAU campus observed during the study period.	
4.13.	The Jack knife estimator of ant species richness estimator of ants in different zones of CZP and TNAU campus.	
4.14.	Jaccard's index (C_j) of similarity matrix for different zones in CZP.	
4.15.	Jaccard's index (C_j) of similarity matrix for different zones in TNAU campus.	

LIST OF PLATES

Plate No.	Title	Page No.
1.	Plantation zone - Coimbatore Zoological Park	
2.	Moist deciduous zone - Coimbatore Zoological Park	
3.	Evergreen zone - Coimbatore Zoological Park	
4.	Shrub thorny zone - Coimbatore Zoological Park	
5.	Shola grassland zone - Coimbatore Zoological Park	
6.	Agricultural zone - TNAU Campus	
7.	Semi evergreen zone - TNAU Campus	
8.	Evergreen zone - TNAU Campus	
9.	Grassland zone - TNAU Campus	
10.	Deciduous zone - TNAU Campus	
11.	<i>Camponotus compressus</i> Fabricius	
12.	<i>Camponotus sericeus</i> Fabricius	
13.	<i>Oecophylla smaragdina</i> Smith	
14.	<i>Paratrechina longicornis</i> Latreille	
15.	<i>Crematogaster</i> sp.	
16.	<i>Meranoplus bicolor</i> Guerin	
17.	<i>Monomorium gracillimum</i> Smith	
18.	<i>Solenopsis geminata</i> Fabricius	
19.	<i>Tetraponera aitkeni</i> Forel	

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
1.		
2.		
3.		
4.		
5.		
6.		

Chapter I

INTRODUCTION

Ants, owing to their altruistic behaviour are a source of inspiration for man. They are the second most abundant group of insects next only to beetles and numerically the most abundant of social insects. At any given moment, there are at least 10^{15} living ants on the earth (Wilson, 1971). The food specialization and preying habits of ants make them fascinating.

Ants also play an important role in any ecosystem as they carry out multiple functions as predators, folivores, frugivores, mutualists, phytophagons, scavengers and so on. Owing to their important role in an ecosystem they respond well to small changes happening in their habitats. The response being in the form of increase or decrease in abundance, alteration of nesting sites and density and appearance or disappearance of certain species thereby satisfying the important criteria to be a bioindicator. Hence the abundance and diversity of ants existing in an area is itself an indication of the well being of an ecosystem.

Areas of high biological diversity are identified by measuring the well-known taxonomic group such as ants as a surrogate for the number of species in sympatric, poorly known taxonomic groups (Beccaloni and Gaston, 1994). The use of biodiversity surrogates has particular implications for conservation issues relating to resource allocation and design, and ants have played a prominent role in these analyses (Oliver and Beattie, 1996a).

The topographically diverse Indian subcontinent contains endemic plant communities and diverse insect fauna including ants. As a group ants exhibit a remarkable diversity in size, shape, morphology and biology. In India, where biodiversity assessment is needed, evolving a suitable indicator approach serve to be efficient and cost effective. Ants are

such candidates to be bioindicators. Hence the study evolved with the following objectives:

- i. Collection, preservation and identification of ant species in Coimbatore Zoological Park (CZP) and Tamil Nadu Agricultural University (TNAU) Campus.
- ii. Working out zone wise ant diversity in CZP and TNAU Campus.
- iii. To assess the association of ants with plants and other invertebrates.
- iv. Finding out the possibility of using ants as indicators of ecosystem.

Chapter – II

REVIEW OF LITERATURE

In this chapter a review of systematic study and diversity of ants in the world and Indian context, bioindicator approach and association of ants with various organisms are briefed.

2.1. Ant Diversity

2.1.1. Ant diversity: Global scenario

There are 16 sub families, 296 genera and 11006 species of ants in the world existing as subsets of the total species in different bio-geographic zones. Ants are capable of adapting to all given possible habitats and are found in all terrestrial habitats from sub-arctic tundra to equatorial rain forest, from sea coast to great altitudes, from swamp to harsh desert and from deep in soil to the tip of the tallest trees. Moreover, they are highly varied in their morphology and biology; exhibiting a remarkable diversity (Musthak Ali and Chakravarthy, 2000).

Wilson (1988) showed the amazing diversity of ants as he identified 43 species in 26 genera on a single tree from Tambupata reserve in the Peruvian Amazon. In Western Amazon basin, Verhaagh collected 350 species belonging to 71 genera, which houses the richest ant fauna in the world (Holldobler and Wilson, 1990).

The study on diversity and abundance of ants in relation to forest disturbance and plantation establishment in Southern Cameroon showed that the deforestation can reduce arthropod species richness and reforestation methods (using a single tree species (*Terminalia ivorensis*), can have a marked effect on arthropod species richness and

composition. Specifically it revealed that species richness could be greater in plantations established after partial manual clearance of forest than completely cleared forest (Watt *et al.*, 2002).

The study on the effect of clearing of tropical rain forest in lowland site Panguana, Brazil showed that, prior to clearing a total ant fauna of 520 species in an area of 10 km² was recorded, which was considered to be the most diverse ant fauna ever recorded. The ant fauna was almost destroyed after the destruction of the forests for establishing plantations and pastures. The recolonization of these habitats depended upon the availability of nesting sites especially of arboreal ants and ground ants which nest on the rotten woods. But those habitats were dominated by ants such as *Solenopsis geminata* and *Brachymyrmex* sp which were not present in the habitat before clearance (Verhaagh, 1989).

2.1.2. Ant diversity: Indian scenario

Some of the major contributions on the description of Indian ants are those of Jerdon (1851), Forel (1901), Rothneyi (1889), Wheeler (1910), Usman and Putturudraiah (1955), Baroni urbani (1977), Bolton (1977), Reddy *et al* (1981), Musthak Ali (1981), Dutta and Raychaudhuri (1986), Kamtar (1983) and Devi *et al.* (1986).

Jerdon (1851) worked on Indian ants particularly from southern India and recorded 46 species under 8 genera from this region; of these, 39 species were new to science. Later on, Rothneyi (1889), Donisthorpe (1943) contributed much to the ant fauna of southern India. The pioneer work by Bingham (1903) on the Ant fauna of British India, including Burma and Ceylon serves as a good reference for Indian ants.

Among the 11000 described species of ants from all over the world, about 600 species are from the Indian sub continent, which includes 498 species reported by Bingham (1903) and the rest being the later additions (Veeresh and Musthak Ali, 1987).

The taxonomic study on ants of Southern India was quite recent and the study encompassed Tamil Nadu, a part of Kerala and Andhra Pradesh. The study recorded 219 species under 48 genera belonging to seven subfamilies. Out of 219 species, 22 species were reported for the first time from Southern India and two species were newly recorded from India (Tiwari, 1999).

The study on the abundance and diversity of ants in 12 selected localities of Western Ghats showed that the ants were comparable to other tropical habitats of the world. Ants accounted for 5.4 to 12.8% of the entire insect species caught in these localities and 5.1 to 43.2% of all insect numbers caught, which shows that ants constitute a significant proportion of insect fauna in Western Ghats. The disturbed localities in the forests showed lower richness and diversity in their ant fauna. The study yielded a statistically significant positive correlation between ant species diversity and plant species diversity (Gadagkar *et al.*, 1993).

The assessment of the insect species diversity in the Uttara Kannada district of Karnataka showed that the canopy cover index influence the number of species and diversity of insects. The diversity and number of species reached very high levels at intermediate levels of canopy cover (Gadagkar *et al.*, 1990). The ant fauna of Karnataka was composed of 125 species of ants coming under seven sub families viz., Dorylinae, Cerapachyinae, Ponerinae, Pseudomyrmicinae, Myrmicinae, Dolichoderinae and Formicinae (Musthak Ali, 1991). The study on the ant species richness at selected

localities of Bangalore recorded 75 ant species belonging to 33 genera and six subfamilies (Kumar *et al.*, 1997) whereas, the study on ant fauna of the Indian Institute of Science campus, Bangalore reported 70 species of ants belonging to 32 genera and six subfamilies (Rastogi *et al.*, 1997).

The study on ant species richness across the altitudinal gradient in the Western Ghats of Karnataka along a stretch of 70 km yielded 60 species of ants belonging to 31 genera and six subfamilies of Formicidae namely Ponerinae, Dorylinae, Pseudomyrmecinae, Myrmicinae, Dolichoderinae and Formicinae. Based on the range and distribution of ants in Karnataka, 16 species were found endemic to Western Ghats region and two separate species *Leptogenys dentilobis* and *Camponotus angusticollis* were identified as an indicator of cool moist, evergreen forest patch in Western Ghats (Rajagopal *et al.*, 1998).

2.2. Interaction of Ants with other Organisms

2.2.1. Ant – Plant interaction

The angiosperms and the ants have been closely associated throughout most of their respective histories. The ants increased in diversity and abundance at the end of cretaceous period and sized new roles as pollinators and seed dispersers, and appropriated the plants as domiciles. Complex symbioses have been fashioned among the thousands of species of ants and plants. Often these relationships are parasitic, with one exploiting the other and giving nothing in return. In other cases they are commensalistic, with one partner making use of other but, as in the case of ants occupying hollow stems, neither harming it nor helping it (*Camponotus* and *Crematosgaster* occupying the hollow stems of plants). Of maximum scientific interest, however, is the fact that some symbioses appear to be mutualistic. Ants use cavities supplied by the plants for nest sites, as well as

nectar and nutritive corpuscles given them as food. They also protect their plant hosts from herbivores, distribute their seeds, and literally pot their roots with soil and nutrients. There is abundant evidence that some pairwise combinations of ants and plants have co-evolved so that each was specialised to use other's services. The studies by Davidson (1988) also concluded that the ant-plant symbiotic relationship was truly mutualistic in which ants obtain shelter, nourishment or both and plants obtain protection against both arthropod and vertebrate herbivores. This mutualistic linkage has produced some of the most elaborate adaptations known in nature (Holldobler and Wilson, 1990).

Though ants are considered as carnivores by most of the myrmecologists, they have some direct or indirect relation with plants like especially *Acacia* and *Cecropia*, producing specialized food bodies such as Beltian bodies for attracting ants which in turn act as effective seed dispersers. Ants relying on homopterans for their honeydew also indirectly rely on the plants from which the homopterans suck the sap. Ants act as herbivores in certain Neotropics, as they harvest an estimated 15% of fresh vegetation. Jolivet (1996) added that ants participate in symbioses with over 465 plant species in over 52 families.

The ants, predominantly species of the genera *Camponotus*, *Crematogaster* and *Solenopsis* obtain nutrition from extrafloral nectaries, elaiosomes, and fruit sap; the plant gain protection from herbivores, including leaf cutting attines (Weber, 1943). A well-studied ant plant mutualism is between *Acacia* (Leguminasae) and ants, in which the ants gain the extra floral nectaries and Beltian bodies produced by acacia and acacia in turn gain protection from large browsing mammals. Also, the ants kill the other plants growing within a certain radius thereby preventing competition for acacia (Janzen 1966, 1967). Ants also help in germination of seeds by removing the fruit pulp in the case of the

tree *Hymenaea courbaril* (Caesalpiniaceae), thereby preventing fungal infection (Oliviera *et al.*, 1995).

The vegetation has a three-fold influence on the diversity (species richness) of ant communities through its effects on microclimate, carrying capacity and structural complexity of the habitat (Greenslade, 1971). The colony structure and species richness of ants altered with the disturbance in the vegetation cover as the density of species in the ground layer was low despite a high density of individuals and the time taken for the ground living ants to recover from disturbance was more (Greenslade and Greenslade, 1977).

In *Croton bonplandianum* a shrub, the total nectar production increases as the plant ages. Correspondingly, ant activity and ant mediated removal of seeds also increased and a further demonstration showed that seed removal was higher under croton plants supplemented with artificial nectar than under plants without nectar (Ganeshaiah and Umashaanker, 1988). The increased ant activity due to more nectar exudation protected the plants from defoliation by herbivores and increased dry weight (Bentley, 1976). The display of dispersed nectaries in croton plant is to encourage the randomly foraging ant species and to discourage trail formers because the seed dispersal is effectively done by these random foragers as the chance of encountering the seeds fallen around the plants is more (Veena *et al.*, 1989).

2.2.2. Ants -Faunal relation

Myrmecophily is almost exclusively an invertebrate phenomenon. A respectable list of vertebrate species, including frogs, lizards, snakes, birds, small and medium sized mammals and even primates occasionally live with social insects or prey upon them. But very few are specialized for such association. The vast majority of obligate invertebrate symbionts are moreover arthropods, and it is among these organisms that the most

striking adaptations for life with social insects have taken place. A number of these myrmecophiles make their homes in nests of the ants and enjoy all the social benefits of their hosts (Holldobler and Wilson, 1990).

Ants have significant interactions with other animals by playing a dual role as predators and prey. Ants belonging to a diverse group such as *Acanthostichus*, *Cylindromyrmex*, *Eurhopalothrix heliscata*, *Carebara*, *Carebarella*, *Erebomyrma*, *Liomyrmex*, *Paedalgus* and *Solenopsis* have specialized on termites as they build their nests near to termitaria and steal termite eggs and brood for food (Brown, 1975; Wilson and Brown 1984; Forel, 1901; Wheeler, 1914). Ants also specialize on other arthropod eggs, Collembola, Millepedes, Isopods, earwigs and other insects. They also predate on other ants (*Cerapachys* and *Neivamyrmex*) (Wheeler 1918; Rettenmeyer, 1963). Ants owing to their large numbers, trailing tendency, long-lived stationary nests, serve as a food source for other predators. The predators that efficiently overcome the defense mechanisms of ants include Assassin bugs (Reduviidae), ground beetle larvae (Carabidae), rove beetles (Staphylinidae), ant lions (Myrmeleontidae) and worm lions. Other Arthropods that predate on ants include Wind scorpions (on leaf cutting ant *Atta cephalotes*) and spiders (Evans, 1977; Bukowski, 1991). The vertebrate specialists of ants include ant eaters, toads, lizards, snakes and birds (Bequaert, 1922; Weber, 1972).

2.2.3. Symbioses of ants

Ants have significant symbioses with other fauna such as aphids, lycaenid butterfly caterpillars, acari, araneae, collembola, diplopoda, isopoda and other insects. In Insects the orders coleoptera, diptera, homoptera, hymenoptera, lepidoptera, neuroptera, orthoptera, psocoptera and thysanura are important (Holldobler and Wilson, 1990).

2.2.3.1. Ant - Homopteran association

Ants exhibit parallel behaviour as that of cattle rearing by humans, tends homopterans for their honeydew. The homopterans tending ants belong to the subfamilies dolichoderinae, formicinae and myrmicinae and the homopterans belong to the family aphidae, cercopidae, cicadellidae, coccidae, fulgoridae, membracidae, pseudococcidae and psyllidae (Schultz and McGlynn, 2000). The honeydew produced by the phloem feeding homopterans consists of the large portion of carbohydrates and amino acids which nourish the ants depending on them and Homopterans in turn gain protection from predators and parasitoids (Dixon, 1985). Ants have highly organised systems for harvesting honeydew from certain aphids. Aphids show a range of association with ants; obligate ant attendance (*Symydobius oblongus*), facultative myrmecophily (*Aphis fabae cirsiacanthoides*) and no attendance by ants. The ant attendance in aphids was studied in laboratory and field conditions by Stadler and Dixon (1999). They concluded that under field condition the ant-attended colonies achieved higher peaks. Most of the ant Homopteran associations are facultative mutualisms. The virgin queen of *Acrophyga* species carries a coccid symbiont in her mandibles during the nuptial flight to serve as a parthenogenetic progenitor of a future herd of coccids that will supply honey dew for the future colony (Buschinger *et al.*, 1987). The Malaysian ant *Hypoclinea cuspidatus* (Dolichoderinae) is an obligate symbiont of the mealy bug *Malaicoccus formicarii* (Pseudococcidae) and their colony keeps on moving with their symbionts as the old feeding sites are depleted and new ones required (Maschwitz and Hanel, 1985).

2.2.3.2. Ants -Fungi association

Most of the ants avoid fungi, though it is present in infrabuccal pockets but it is absent in the digestive tract. The digestive tract symbiotic fungus does exist in the myrmicine tribe Cephalotini, *Cephalotes atratus* and *Zacryptocerus clypeatus* (Caetano,

1989). Though there are fungivorous ants, fungus such as *Cladosporium myrmecophilum* are found growing in the cemented carton constructed by ants (Lagerheim, 1900). Some ants are said to consume the spores of the mycorrhizal fungi in the order Glomales, family Endogenaceae, as they are big size and rich in lipid (Janos, 1993). The study on the role of ant workers in maintaining the fungal garden revealed that the workers pruned the fungal mycelia to stimulate the growth of the fungi and nutrition for their ant colony (Bass and Cherrett, 1994).

The best example of ant – fungi obligatory symbiosis is the Attini (Myrmicinae), in which the fungus constitutes the sole source of food for larvae and adult (Quinlan and Cherrett, 1979). The less-derived attines (leaf cutting ants) cultivate their fungi on the bed prepared from insect frass, seeds and other organic detritus while, higher attines prepared beds from leaves and flowers specially cut for this purpose. The fungi belonging to the families agaricaceae, lepiotaceae are grown commonly by attini ants. Also some species within the genus *Apterostigma* cultivate distantly related fungi of genus *Gerronema* in the family tricholomataceae (Moncalvo *et al.*, 2000).

2.3. Bio-indicator approach

2.3.1. What is a Bio-indicator?

Indicator species is an organism whose characteristics (e.g., presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental condition of interest (Landres *et al.*, 1988).

Bioindicator is a species thought to be sensitive to environmental change and therefore to serve as an early warning indicator of environmental changes such as global warming (Parsons, 1991).

Indicator species is one that reflects the effects of a disturbance regime or the efficacy of efforts to mitigate disturbance effects (Milledge *et al.*, 1991).

An indicator species is meant as a species whose presence indicates the presence of a set of other species and whose absence indicates the lack of that entire set of species (Spellerberg, 1994).

Most of the bio-indicators are a dominant species that provides much of the biomass or number of individuals in an area (Lindenmayer *et al.*, 2000).

2.3.2. Criteria to be a bio-indicator

The areas rich in biological diversity are identified and their biological content are studied by means of taxonomically well known group called as surrogates. A good surrogate species or Bio-indicator species should satisfy four basic criteria. They should:

- i) Be easily sampled and monitored
- ii) Represent fairly diverse groups and/or groups of biological importance in the ecosystem under study,
- iii) Have known relationships to the diversity of other taxa, and
- iv) Respond to environmental change in ways similar to other taxa (Oliver and Beattie, 1996b).

Most groups selected as potential indicator taxa meet the first two criteria (Alonso, 2000). Many invertebrate groups have been considered as potential indicator taxa owing to their high diversity and ecological importance (Kremen, 1992).

Noss (1990) and Pearson and Cassola (1992) have given the logistical and biological criteria that are desirable to maximise the generality of indicator organisms. They include.

- i) Taxonomically well-known and stable so that populations can be reliably defined.
- ii) Biology and general life history well understood: limiting resources, enemies, physical tolerances, and all stages of the life cycle available to readily incorporate into hypothesis and experimental design.
- iii) Populations readily surveyed and manipulated such that tests are logistically simple and inexperienced students and non-professionals can be trained easily to conduct studies.
- iv) At higher taxonomic levels (order, family, tribe, genus), occurrence over a broad geographical range and breadth of habitat types so that results will be broadly applicable.
- v) At lower taxonomic levels (species, subspecies), specialisation of each population within a narrow habitat is likely to make them sensitive to habitat change.
- vi) Some evidence that patterns observed in the indicator taxon are reflected in other related and unrelated taxa; and
- vii) Potential economic importance of some populations so that scientists and politicians can be convinced that this taxon is worth dedicating local personnel and resources for studies.

The above criteria are not fixed and their priority varies with situation. All the biodiversity studies can be placed into one of two distinct but interrelated categories. These two categories differ in their objectives and thus in the general priority of the criteria applied to potential indicator taxa (Kremen *et al.*, 1994). First, monitoring studies evaluate changes in habitats or ecosystems over time, such as habitat degeneration (Noss, 1990). Here high priority for potential indicators is placed on sensitivity to environmental changes. Second, inventory studies record the distributional patterns of taxa or ecological units over geographical space, generally for establishing conservation areas. Here high priority for potential indicators is placed on strong phylogenetic and bio geographical history such as endemism, co-occurrence, and centers of evolution (Erwin, 1991). The present study is an approach to identify ants that are indicators of biodiversity and ecosystem condition.

2.3.3. Need for Bio-indicators

The increasing loss of habitats and biodiversity has created a situation to assess the existing diversity of organisms for conservation planning process. Since, time, money and limited available taxonomic expertise prohibit a complete survey of all taxonomic groups, several rapid strategies for measuring biodiversity have been developed and implemented (Schulenberg and Awbrey, 1997). Focussing on selected taxonomic groups referred to variously as Indicator taxa, Priority taxa, Surrogate taxa, Predictor sets, Focal groups or Target taxa and measuring the species richness or diversity of such indicator groups have been proposed as a representative measure of the species richness or diversity of other taxa, and therefore as an indicator of the overall diversity of an area. The bio-indicator approach enables the countries with limited financial commitment for bio-diversity assessment to assess their biodiversity.

2.3.4. Ants as bio-indicators

Ants appear to be an ideal candidate for use as an indicator group because they are diverse, found abundantly in almost every terrestrial habitat in the world, and easily collected (Majer, 1983). Ants are appropriate for biodiversity inventory and monitoring programs because most species have stationary, perennial nests with fairly restricted foraging ranges (ranging from less than a meter to few hundred meters). Ants are most constantly present at a site and can thus be more reliably sampled and monitored unlike other insects that move frequently between habitats in search of food, mates, or nesting sites (Alonso, 2000).

The patterns in the species richness and diversity of ants are correlated with patterns in taxa that have similar nesting or feeding needs, taxa that are affected by similar environmental factors, or taxa with which ants have significant interactions. Ants are regarded as generalist feeders and nesters but many species have very specific diets and microclimate needs. Similar patterns of species richness may also be found in ants and in particular plants, homopteran, and beetle species with which ants have obligate mutualistic interactions (Alonso, 2000).

Lawton *et al.*, (1998) found positive associations between the species richness of ants and that of plants, beetles, scorpions, termites, ground foraging invertebrates and low vegetation dwelling invertebrates that were collected from pitfall traps as that of ants.

The diverse community of ants requiring a variety of plants for nesting, food or to regulate the microclimate they needed enables to correlate the species richness of plants with that of ants (Alonso, 2000). The ant species richness was found to increase with the increasing plant species richness in the Eucalyptus woodlands (Abensperg - Traun *et al.* 1996) and other Natural Australian habitats (Cranston and Trueman, 1997) as the

microhabitats and microclimate became available for specialist species with specific requirements.

Ants have been successfully used as potential indicators in agro ecosystems of North Carolina and Virginia, USA and found that ant assemblages was related to management factors, soil variables and cropping practices (Peck *et al.*, 1998). They also suggested that, to use ants as an environmental indicator, species assemblages would have to be calibrated to known level of disturbances that can affect agro ecosystem conditions. The measurement and comparison of the species diversity of ants in the natural vs. agricultural habitats showed that ants can be used as potential environmental indicators of soil quality (Lobry-de-bruyn, 1999).

The response of the community structure and population size of ants to overgrazing is used as a successful environmental indicator in arid zone of Southern Australia. The abundance and diversity of ant communities altered in response to overgrazing and the indicator value of ants was proved (Read and Andersen, 2000). Ant communities are used as indicator organisms for studying the impact of logging in the Brazilian Amazon region. a two-fold reduction in the dominance of ants of the highly diverse genus *Pheidole* was found associated with forest alterations in high impact logging sites. Ants of the genus *Pheidole* are useful indicators for forest disturbances resulting from timber extraction (Kalif *et al.*, 2001).

A study on the change in the structure of arboreal tropical ant communities by anthropogenic disturbance showed that the diversity and complexity of ant communities increase at the alpha and beta diversity level with the increasing year of rehabilitation of anthropogenically disturbed forests in South East Asian lowland. It emphasized

autecological study of *Crematogaster*, *Camponotus* and *Tetraponera difficilis* as disturbance indicators. (Floren *et al.*, 2001).

The community structure and vertical distribution of ants, plants and butterflies are successfully used by Osborn *et al* (1999) to evaluate the biodiversity of land and fresh water zones in the Neotropical zones of South America.

A functional group model for community structure of ants was used to measure the habitat disturbance in the humid tropics of Australia and validation of ants as bio-indicators of habitat disturbance was emphasized (King *et al.*, 1998). Similarly the ant species *Wasmannia auropunctata* was used as environmental indicator of habitat disturbance in the Forest and Woodland of New Caledonia (Jourdan and Chazeau, 1999). The community survival relationship and the habitat change effects of ants was successfully used in Moscow, Russia and the role of ants as environmental indicator and biodiversity guide was studied (Zakharov and Sablin, 1998).

The recolonization of pattern of ants was used as indicator for restoration success in the rock phosphate mine site reclamation, Dehradun by re-vegetation with colonizing plant species. The vegetation density increased with the increasing ages of rehabilitation. Similarly, the diversity and density of ant fauna showed trends similar to that of the vegetation with increasing age of rehabilitation of the mine site. The increasing density of plant cover helps the ants by providing more sap, seeds and prey to feed on. The colonization pattern is in the order of ground nesting ants in the first year, ground foraging ants in the second year, wood nester ants in the successive years of rehabilitation as the tree canopy cover increased (Bhatt and Soni, 1992).

The study on long-term recolonization pattern of ants in Western Australian rehabilitated bauxite mines concluded that ants could be used as indicators of restoration success in an area, which was affected by mining. It showed an increase in ant recolonization in the affected area corresponding to increase in the tree canopy and rehabilitated tree cover (Majer and Nichols, 1998). The invertebrates especially ants proved to be cost effective to gather and potentially high in information content. They contributed to the data on physical factors and plant and vertebrate communities in rehabilitated mine site areas. The invertebrate data provided an indication of the degree of re-establishment of ecosystem functioning (Bisevac and Majer, 1999).

3.4. Sampling Ants

The ant fauna existing in an area has to be sampled by an integration of various collection techniques as each sampling method was aimed to collect ants from their respective habitats. However, choosing an appropriate technique decides the outcome of the study. Four sampling methods namely hand collecting, leaf litter sifting, soil core sampling and honey bait trapping were used to sample the ground and lower vegetation level ants in two different forest types in Sabah, Borneo (Hashimoto *et al.*, 2001). They further ranked each of the four methods with respect to the number of species collected, sampling efficiency and community characterization. They suggested a combination of methods to provide an adequate representation of the ant fauna. The use of pitfall trap in sampling the ground dwelling ants was most common and the catches obtained by pitfall traps were compared with those obtained by a complimentary suite of sampling procedures (Majer, 1997). He suggested a full sampling protocol, which adequately samples ants and other terrestrial invertebrates while censusing communities. A comparison of catches from pitfall traps and hand collection in Australian savannah showed that both procedures provided a similar representation of the epigeic ant

community (Andersen, 1991). He further suggested that pitfall traps might provide an inadequate census in less open habitats where litter impedes surface activity. Bestelmeyer *et al* (2000) suggested the mini-Winkler extractor as a standard sampling method for ant inventory. However, because this method collects only ground- dwelling ants, it provides an inadequate representation of the total ant fauna (Hashimoto *et al.*, 2001).

Chapter III

MATERIALS AND METHODS

In this chapter, the design of the study plot, description of the study area, various sampling methods practiced in the study, identification aspects of ants and various statistical indices with their formulae are briefed.

3.1 Background of the Study Area

3.1.1. Coimbatore Zoological Park

Coimbatore zoological Park (CZP) is a simulated zoo having forest types of Nilgiris (Ashraf, 2000), lies in the rain shadow part of the Nilgiri Biosphere Reserve (NBR) at an altitude of 600 m above Sea Level in Thuvaipathy village of Anaikatty (11°6'N 76°45'E) about 30 Km from Coimbatore, Tamil Nadu (Fig 3.1). The NBR lying next to the CZP that is situated on the eastern slopes of the Nilgiri hills was the theme for the CZP.

The CZP was considered a replica of the Nilgiri Biophere Reserve and it was focused on the conservation and education of its flora and fauna (Walker *et al.*, 1999). The area of the zoo is 250 acres, which constitute a part of the large two square kilometre catchment area. Two hill slopes northern and southern, also form a part of the Zoo (Ashraf, 2000). The hills elevate 80 to 120 m from the valleys.

The vegetation type in the adjoining reserve forest could be considered as an inter mix of thorny and dry deciduous forest species, which is typical of the forest in Nilgiri eastern slopes.

The ambient temperature at the site varies from 22°C to 35°C during the day. The site receives an annual rainfall of about 1,200 mm, much of which is received during the

Northeast monsoon (October to January). Daytime humidity levels vary from 40 to 55 per cent during the dry season (January to April) and from 60 to 100 per cent during the monsoons (August to November). The area is influenced by strong winds during June to September (Ashraf, 2000).

The site has been divided into eight thematic zones based on the established vegetation as dry deciduous zone, evergreen zone, moist deciduous zone, shola grassland zone, multiple use zone, rain shadow zone, semi evergreen zone and shrub thorny zone. Among these, five zones were chosen for the study. They are plantation zone, moist deciduous zone, evergreen zone, shrub thorny zone and shola grassland zone (Plate 1,2,3,4 and 5)(Fig 3.2). These zones are well developed according to the plans of the zoo authorities.

The major plant species existing in plantation zone were *Cocos nucifera*, *Psidium gujava*, *Terminalia catapa* and *Citrus* sp. The important plant species existing in moist deciduous zone are *Alstonia scholaris*, *Bombax ceiba*, *Bambusa bamboos*, *Grewia tiliifolia*, *Gmelina arborea*, *Terminalia paniculata*, *Tectona grandis* and *Xylia xylocarpa*. The shrub thorny zone consists of six important species namely *Acacia horida*, *Acacia mellifera*, *Acacia leucophloea*, *Bauhinia racemosa*, *Erythroxylon monogynum* and *Zizyphus mauritiana*. Similarly, there were six plant species existing in Shola grassland zone namely *Artabotrys odoratissimus*, *calophyllum inophyllum*, *Ficus retusa*, *Ficus benjamina*, *Harpulia cuppanoides* and *Schefflera actinophylla*.. The zoo is the home to birds and animals like wild boars, black napped hares (*Lepus nigricollis nigricollis*) and Elephants (as CZP is a part of the corridor linking the Mudumalai and Siruvani forests).

3.1.2. Tamil Nadu Agricultural University Campus

Tamil Nadu Agricultural University Campus (TNAU) campus is a man engineered ecosystem characterised by agricultural habitats including wetlands, drylands and gardenlands, botanical garden having different types of trees viz. evergreen trees, semi evergreen trees and deciduous trees, different garden types and grasslands (frequently mowed) (Plate 6,7,8,9 and 10)(Fig 3.3).

TNAU campus is geographically located at 11°N latitude and 77°E longitude. It lies 426.7 meters above mean sea level and receives an annual rainfall of 644 mm (30 years average) received in 49.8 rainy days. The mean maximum and minimum temperature are 31.7°C and 21.3°C, respectively. The relative humidity ranged from 61 - 91% and 14 - 68% during forenoon and afternoon respectively. The mean bright sunshine hours/day is 7.4 hours and mean evaporation is 3.82 mm/day.

The important tree species that exist in TNAU campus are *Eucalyptus tereticornis*, *Azadirachta indica*, *Tamarindus indicus*, *Santalum album*, *Ficus bengalensis*, *Bambusa bamboos* and *Peltoforum ferrugineum*. Besides agricultural crops such as Bhendi (*Abelmoschus esculentus*), Jasmine (*Jasminum sambac* and *Jasminum auriculatum*), Groundnut (*Arachis hypogaea*), Maize (*Zea mays*) and Coconut (*Cocos nucifera*) are the important agricultural crops in TNAU campus.

3.2. Sampling Design

A total of 5 shifting plots were sampled at each survey in Coimbatore Zoological Park and 5 plots in Tamilnadu Agricultural university campus. Each plot had an area of 10 m x 10 m (100 m²). The plots were shifted from one place to another for each survey

within the respective habitat to make the sampling more representative for each zone in the Coimbatore zoological park and Tamil Nadu Agricultural University (Fig 3.4).

The plots were selected randomly as a representative of each zone away from the access pathway by 5-10 meters. Plots that are less prone to disturbance by humans and other external factors were chosen for sampling.

3.3. Sampling Methods

The methodologies for sampling the ants given by Bestelmeyer *et al* (2000) were followed in this study.

3.3.1. Pitfall trap method

Pitfall trapping is the placement of open containers containing killing agent in the ground surface to trap the surface-active animals that fall unwittingly into the container containing killing agent (Eg: Detergent Solution).

Materials

- Pitfall traps (Containers)
- Shovel
- Killing agent (Detergent)
- Tea Strainer

Method

Plastic containers of size 9.5 cm height and 7 cm diameter were used to sample ants (Fig 3.5). The traps were placed in such a way to minimize the disturbance of the ground surface. A hole was dug using a shovel that is slightly bigger than the trap. The killing agent is filled to 25% of the container's volume. The trapping container was left

for 24-48 hours and the ants collected in the pitfall trap were strained using a tea strainer and the specimens were stored in vials containing 75% alcohol for observation and counting. Pitfall traps can provide information on species richness, composition and relative abundance of ant foragers.

3.3.2. Baiting

Baiting employs food substances as attractants to points from where they may be collected and observed. Usually foods that were rich in carbohydrates were used as bait. Wheat bread soaked in thick Jaggery solution was used as a baiting material for the study (Fig 3.6). This technique provide data on species richness, composition, relative abundance of ant foragers at individual baits, frequency of occurrence at sets of baits, frequency and nature of behavioural interactions, timing and duration of forager activity, rate and distance of removal of food items.

Materials

- Bait substance
- Bait platforms (A plastic plate of 15 cm diameter)
- Ethanol (75%)
- Forceps
- Aspirator.

Method

The wheat bread, soaked in a thick consistency jaggery solution was placed in the centre of the plastic plate and kept at the centre of the four quadrates formed in a plot of 10 x 10 m². The sampling duration was 60-90 minutes after placing the bait (Fig 3.7).

3.3.3 Direct sampling

Direct sampling is a spatially extensive technique and it involves searching for and collecting ants in different microhabitats within an area. The number of species inhabiting an area was found out. The data produced by direct sampling include richness, composition and the frequency of occurrence of species in plots.

Materials:

- Vials
- 75% Ethanol
- Forceps
- Aspirator
- White cloth

Method

The direct sampling involved searching the several microhabitats of ants such as leaf litter, twigs and nuts, under and on shrubs and trees, at the base and in the roots of grass clumps, under stones and in decaying logs, under barks. Ants when discovered were collected using forceps or aspirator or both in a vial.

3.3.4 Winkler Extraction

In this technique, the collected leaf litter was sifted first to remove large leaves and twigs from the sample and the sifted litter was then placed in the Winkler sack to process. During this time the ants from within the leaf litter sample migrate out of the litter as a behavioural response to disturbance of their habitat and eventually fall into a container.

Materials

- Litter sifter
- Winkler sack
- Quadrant
- Ground cloth
- Large plastic sample bags
- Plastic cups
- Twirl bags/ polythene bags
- Vials
- Ethanol (75%)

Method

The leaf litter collected within the quadrat was sifted using a sifter. Sifter consisted of an open-ended sack with a metal ring and attached handle at the top end, a mesh screen and handle located at about one-third the length of the sack from the top and a bottom end that may be tied shut (Fig 3.8). The detritus and smaller invertebrates including ants were collected into the bottom of the sack while retaining coarse material above the mesh while sifting. The sifting process was repeated a number of times for a 1m² sample. After sifting, the contents of the sifter sack were transferred to a sample bag. The sample bag should be porous and made of synthetic material.

The sample bags were removed for processing in the Winkler sack. The Winkler sack consists of a metal box frame that supports a covering made of canvas or cotton (Fig 3.9). Litter from each sample bag was separated into one or more 4 mm mesh inlet sacks, which are suspended inside the Winkler sack. Ants in the litter migrate out of the inlet sacks and were collected in a receptacle tied at the bottom. The receptacle was usually a

test tube partially filled with 75% ethanol. The Winkler sack was usually hung in a nail in a wall in a protected site. The Winkler sack was allowed to run for at least 24-48 hours for effective sampling.

3.4. Identification of Ants

All ant specimens collected during the study were preserved in 70 % Ethanol and identified with the help of Dr. Musthak Ali, Professor of Entomology, University of Agricultural Sciences, Bangalore. The Taxonomic Keys were referred from the **Hymenoptera. Vol. II. Ants, Cuckoo-wasps** in the fauna of British India series provided by Bingham (1903). The reference samples were kept at Department of Environmental Sciences, Tamil Nadu Agricultural University.

3.5. Biodiversity indices

Measures of diversity are frequently seen as indicators of well being of an ecosystem. They also serve as a measure of the species diversity in the ecosystem.

3.5.1. Shannon Wiener Diversity Index

It is an information statistic index based on the proportional abundance of species. The Shannon wiener index assumes that individuals are randomly sampled from an indefinitely large population (Pielou, 1975). The index also assumes that all species are represented in the sample. It is moderately sensitive to sample size and places more weightage on richness. i.e., if there are rare species recorded, the index tends to give a higher value. It was calculated from the equation:

$$H' = -\sum P_i \ln P_i$$

Where, H' = diversity

Pi = proportion of individuals found in the ith species = (ni / N)

Variance in diversity was calculated using the equation of Whittaker (1972).

$$\text{Var H'} = \frac{\sum P_i (\ln P_i)^2 - (\sum P_i \ln P_i)^2}{N} - \frac{S - 1}{2N^2}$$

Where, Pi = the proportional abundance of ith species

S = number of species

N = total number of individuals

3.5.2. Species Number

This presents the total species number in each sample.

3.5.3. Margalef's D Index

Margalef's D has been a favourite index for many years. It is calculated as the species number minus 1 divided by the natural logarithm of the total number of individuals.

$$D = \frac{S - 1}{\ln N}$$

3.5.4. Species Richness Estimators

If the study area can be successfully delimited in space and time and the constituent species enumerated and identified, species richness provides a useful measure of diversity. The widely used species richness estimators were,

3.5.4.1. The Jack Knife Estimator

Heltse and Forrester (1983) and Burnham and Overton (1978) developed the first order Jack knife estimator.

$$S_{\max} = S_{\text{obs}} + a(n-1/n) \text{ where,}$$

N = the number of samples

A = the number of species found only in one sample

3.5.5. Abundance

If data sets contained information on number of species, then the following were the models used to find their relative abundances.

3.5.5.1. Species Accumulation Curves

The plot of the cumulative number of species, $S(n)$, collected against a measure of the sampling effort (n) is termed as the species accumulation curve.

3.5.6. Similarity Measures

Similarity measures look at the similarity of pairs of sites, either in terms of species, presences and absences or by taking species abundances into account (quantitative data). The adopted measure was the Jaccard's measure (Magurran, 1988).

3.5.6.1. Jaccard's Measure

$$C_j = j / (a+b-j)$$

Where, j = the number of species common to both sites

a = the number of species in site A

b = the number of species in site B

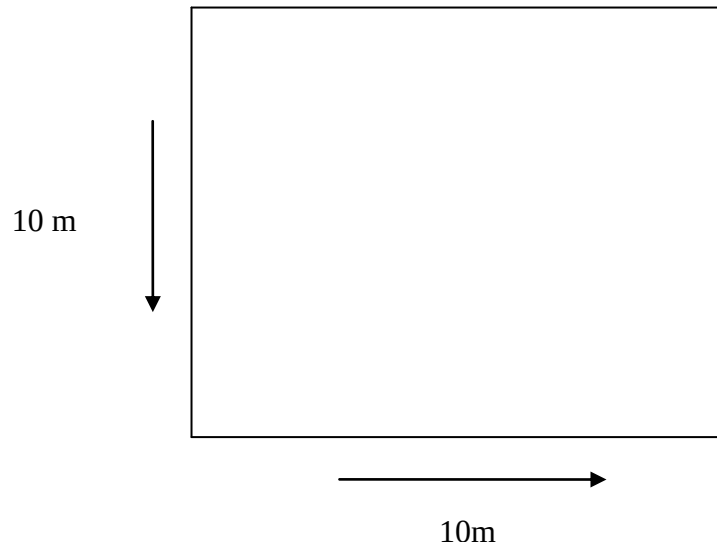


Fig 3.4. Layout of the Study Plot

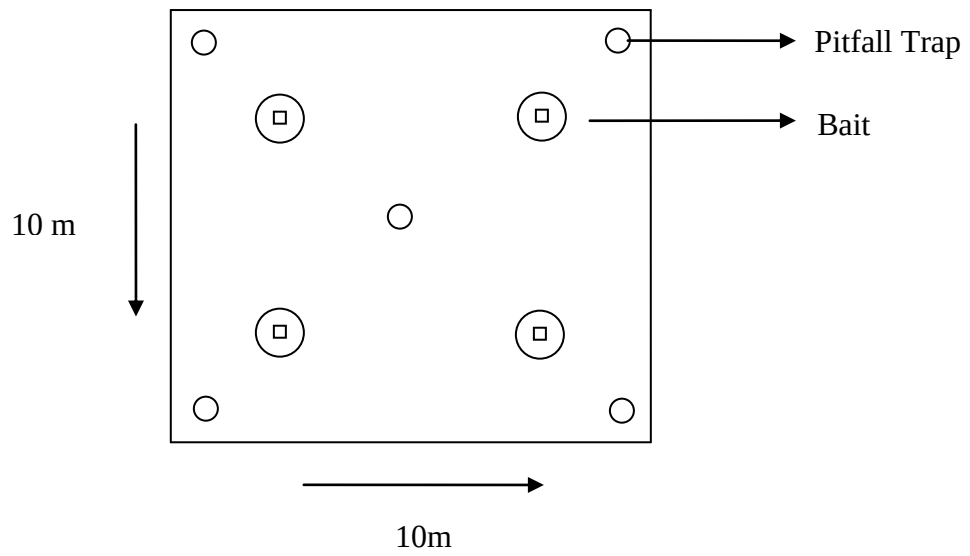


Fig 3.7. Arrangement of Pitfall trap and Bait trap in the Plot of 10m X 10m

Chapter IV

RESULTS

The results obtained during the study in Coimbatore Zoological Park (CZP) and Tamil Nadu Agricultural University (TNAU) Campus were given in this Chapter.

4.1. Ants observed in the study

4.1.1. Ants observed in Coimbatore zoological park

A five months study conducted in the five different zones of Coimbatore zoological park yielded ant species belonging to 18 genera under five subfamilies namely ponerinae, dolichoderinae, pseudomyrmecinae, myrmicinae and formicinae (Table 4.1). The presence and absence of the ant species found in the five different zones, of CZP namely plantation zone, moist deciduous zone, evergreen zone, shrub thorny zone and shola grassland zone were given in table 4.2. Among the five sub families of ants observed in Coimbatore Zoological park, formicinae was the biggest having ten species of ants namely *Camponotus compressus* Fabricius, *Camponotus sericeus* Fabricius, *Camponotus variegates* Smith, *Lepisiota simplex* Forel, *Paratrechina longicornis* Latreille, *Plagiolepis jerdoni* Forel, *Polyrhachis exercita* Walker, *Anaplolepis longipes* Jerdon, and *Oecophylla smaragdina* Smith (Table 4.1 and 4.2). The subfamily myrmicinae has eight species namely *Crematogaster rothneyi* Mayr, *Crematogaster* sp, *Meranoplus bicolor* Guerin, *Monomorium gracillimum* Smith, *Solenopsis geminata* Fabricius, *Pheidole* sp, *Aphaenogaster* sp and *Tetramorium* sp. In the sub-family ponerinae four species of ants namely *Diacamma rugosum* Le Guillou, *Pachycondyla tesserinoda* Emery, *Leptogenys chinensis* Walker and *Anochetus graeffei* Mayr were observed. The subfamily dolichoderinae and pseudomyrmecinae has one species each, namely *Tapinoma* sp and *Tetraponera aitkeni* Forel respectively.

Among the five zones, moist deciduous zone and evergreen zone was found to have more species of ants than other zones (Species number 17, Species number 17) respectively. The lowest richness of ant species was observed in plantation zone (Species number 7) (Table 4.9). The richness of ant species in shrub thorny zone and shola grassland zone were equal (Species number 13).

There were 14 ant species existing in Coimbatore Zoological park viz., *Plagiolepis jerdoni* Forel, *Anaplolepis longipes* Jerdon, *Camponotus variegates* Smith, *Polyrhachis exercita* Walker, *Lepisiota simplex* Forel, *Camponotus* sp, *Pheidole* sp, *Crematogaster rothneyi* Mayr, *Aphaenogaster* sp, *Diacamma rugosum* Le Guillou, *Leptogenys chinensis* Walker, *Anochetus graeffei* Mayr, *Pachycondyla tesserinoda* Emery and *Tapinoma* sp (Table 4.1 and 4.2). These ant species come under four sub species viz., formicinae, myrmicinae, ponerinae and dolichoderinae.

The ant species *Monomorium gracillimum* Smith was the most abundant ant species and it totaled to 2566 individuals (31.3 % of the total number of individuals) during the five months study duration (Table 4.3). The abundance was highest during January (1171) followed by February (692) and April (623). The abundance was very less during the months of December (59) and least in March (21) Table (4.3).

Aphaenogaster sp. was the second most abundant species and its abundance was highest during March (1060) followed by, February (310). The occurrence was nil during the months of December, January and April (Table 4.3).

The other abundant species were *Pheidole* sp (903), *Paratrechina longicornis* Latreille (681), *Meranoplus bicolor* Guerin (428), *Plagiolepis jerdoni* (299), *Anochetus*

graeffi Mayr (281), *Camponotus sericeus* Fabricius (275), *Oecophylla smaragdina* Smith (252), *Camponotus compressus* Fabricius (242) , *Diacamma rugosum* Le Guillou (210) and *Crematogaster* sp (210) (Table 4.3 and 4.4).

The least abundant species were *Leptogenys chinensis* Walker (2), *Tetraponera aitkeni* Forel (3), *Camponotus variegates* Smith (4), *Camponotus* sp (10), *Solenopsis geminate* Fabricius (12), *Tapinoma* sp (16), *Anaplolepis longipes* Jerdon (21), *Polyrhachis exercita* Walker (37), *Pachycondyla tesserinoda* Emery (46) and *Lepisiota simplex* Forel, (77) (Table 4.3).

Among the total individuals of 8181 observed during the entire study period (Table 4.4), the shrub thorny zone contributed 41% (Total number of individuals 3234) followed by moist deciduous zone (18.8%), shola grassland zone (13.5%), evergreen zone (11.9%) and plantation zone (8.7%) (Table 4.4).

The ant individuals sampled by different sampling methods were given in table 4.5. Among the sampling methods, bait trap was found to be more efficient in sampling ants in CZP as it contributed to 47 % of the total ant individuals, followed by pitfall trap (32 %) and direct observation (21 %).

4.1.2. Ants observed in Tamil Nadu Agricultural University Campus

The six months study in the five different plots of Tamil Nadu Agricultural University Campus yielded 23 species belonging to 13 genera and five subfamilies. The subfamilies of ants observed were ponerinae, pseudomyrmecinae, myrmicinae, formicinae and dolichoderinae (Table 4.1). The ant species under the subfamily ponerinae were *Pachycondyla rufipes* Jerdon, *Pachycondyla* sp and *Anochetus rudis* Emery. The ant

species in the sub-family pseudomyrmecinae were *Tetraponera rufonigra* Jerdon, *Tetraponera allaborans* Forel, and *Tetraponera aitkeni* Forel. The ants in the sub-family myrmicinae were *Monomorium pharaonis* Linnaeus, *Monomorium scabriceps* Mayr, *Monomorium floricola* Jerdon, *Monomorium gracillimum* Smith, *Paratrechina longicornis* Latreille and *Oecophylla smaragdina* Smith and in the sub-family dolichoderinae was *Tapinoma melanocephalum* Fabricius.

Among the five plots in different zones of Tamil Nadu Agricultural University, campus, viz., agricultural zone, semi evergreen zone, evergreen zone, grassland zone and deciduous zone, the richness of ants was found to be higher in evergreen zone (Species number 19) followed by semi-evergreen zone (Species number 17), deciduous zone (Species. number 15), grassland zone (Species number 11) and agricultural zone (Species number 10).

Among the subfamilies, myrmicinae had more number of ant species (Species number 10) followed by formicinae (Species number 6), ponerinae (Species number 3), pseudomyrmecinae (Species number 3) and dolichoderinae (Species number 1).

Among the total number of 23 species observed in TNAU campus, 14 ant species were found to be uncommon to CZP and TNAU campus viz., *Camponotus rufoglaucus* Jerdon, *Polyrhachis aculeata* Mayr, *Pheidole sharpi* Forel, *Pheidole spathifera* Forel, *Monomorium pharaonis* Linnaeus, *Monomorium floricola* Jerdon, *Monomorium scabriceps* Mayr, *Pachycondyla rufipes* Jerdon, *Pachycondyla* sp, *Tapinoma melanocephalum* Fabricius, *Tetramorium walshi* Forel, *Anochetus rudis* Emery, *Tetraponera rufonigra* Jerdon and *Tetraponera allaborans* Forel (Table 4.1 and 4.2).

Solenopsis geminata Fabricius was the most abundant species in Tamil Nadu Agricultural University Campus (4116) contributing to 53.2% of the total individuals observed during the study (Table 4.6 and 4.7). The other abundant ant species were *Pheidole sharpi* Forel (771), *Camponotus compressus* Fabricius (536), *Tapinoma melanocephalum* Fabricius, (530), *Paratrechina longicornis* Latreille (409) and *Meranoplus bicolor* (404).

The least abundant ant species were *Pachycondyla rufipes* Jerdon, *Pachycondyla* sp., *Anochetus rudis* Emery, *Tetraponera aitkeni* Forel, *Polyrhachis aculeata* Mayr, *Tetraponera allaborans* Forel, *Camponotus rufoglaucus* Jerdon, *Tetramorium walshi* Forel, *Crematogaster* sp, *Monomorium floricola* Jerdon and *Monomorium gracillimum* Smith.

Among the different zones studied in Tamil Nadu Agricultural University campus, agriculture zone had more ant abundance contributing to 58.8% of the total ants observed in the TNAU campus followed by evergreen zone (15.7%), semi evergreen zone (13.05%) and grassland zone (6.5%). The ant abundance was less in deciduous zone (5.9%) (Table 4.7).

The ant individuals collected in TNAU campus by different sampling techniques were tabulated in table 4.8. Pitfall trap was found to be the efficient collection technique in TNAU campus contributing to 62 % of the total ant individuals caught, followed by bait trap (27 %) and direct observation (11 %).

4.1.3. Ant fauna common to Coimbatore zoological park and Tamil Nadu Agricultural University Campus

The ant species that were common to CZP and TNAU were marked in tables 4.1 and 4.2. They belonged to three sub families namely formicinae, myrmicinae and

pseudomyrmecinae. There were nine ant species commonly existing in CZP and TNAU viz., *Camponotus compressus* Fabricius, *Camponotus sericeus* Fabricius, *Oecophylla smaragdina* smith, *Paratrechina longicornis* Latreille, *Meranoplus bicolor* Guerin, *Monomorium gracillimum* Smith, *Solenopsis geminata* Fabricius, *Crematogaster* sp. and *Tetraponera aitkeni* Forel (Plate 11,12,13,14,15,16,17,18 and 19). The presence and absence of ant species in different zones of CZP and TNAU were tabulated (Table 4.2).

4.2. Invertebrates of the Study Area

4.2.1. Invertebrates of Coimbatore zoological park

The invertebrates of Coimbatore zoological park other than the family formicidae belonged to four classes and 12 orders (Table 4.9). The four classes were insecta, arachnida, diplopoda and chilopoda, of which the class insecta was having nine orders viz., orthoptera, hemiptera, diptera, lepidoptera, coleoptera, hymenoptera, dictyoptera, isoptera and homoptera. The class Arachnida had two orders namely Araneae and Scorpionida.

Among the different zones of Coimbatore zoological park, evergreen zone had nine orders of insects which was the highest followed by moist deciduous zone (6 orders), shrub thorny zone (6 orders), shola grass land zone (6 orders) and plantation zone (2 orders) (Table 4.9).

4.2.2. Invertebrates of Tamil Nadu Agricultural University Campus

The invertebrates encountered in different zones of Tamil Nadu Agricultural University Campus was categorised into class, order and family (Table 4.9). There were three classes and 12 orders of invertebrates in TNAU campus. Among the three classes insecta was the biggest, followed by gastropoda and arachnida. The class insecta had 12

orders viz., orthoptera, hemiptera, diptera, lepidoptera, isoptera, coleoptera, dermaptera, dictyoptera, neuroptera, homoptera, hymenoptera and thysanura. The class arachnida had only one order namely araneae and the class gastropoda was not further classified to family level.

Among the different zones, grassland zone had eight orders of insects, followed by deciduous zone (7 orders), semi evergreen zone (6 orders), agricultural zone (6 orders) and evergreen zone (3 orders) (Table 4.9).

4.3. Ant diversity and richness in the study areas

4.3.1. Coimbatore zoological park

The estimated diversity of ant species in Coimbatore zoological park was provided (Table 4.10 and 4.11). The diversity of ant species was calculated with respect to each survey (monthwise) (Table 4.10) and zones studied (Table 4.11).

The Shannon wiener index ranged between 1.30 and 2.13, Species number between 12 and 17 and Margalef D index between 1.53 and 2.24. The diversity of ant species was high during the month of December (H 2.13, Margalef D 2.24) and low in April (H 1.79, Margalef D 1.53) (Table 4.10) (Fig. 4.1, 4.2 and 4.3).

With respect to each zones studied, the Shannon Wiener Index ranged between 1.04 and 2.08, Species number between 13 and 17 and Margalef D index between 0.91 and 2.32 (Table 4.11). The evergreen zone had highly diverse ant species (H 2.08, Species number 17, Margalef D 2.32) and very least ant diversity was found in plantation zone (H 1.38, Species number 7, Margalef D 0.912). (Fig. 4.4, 4.5 and 4.6).

The species accumulation and richness of ants during the period of study and in different zones were furnished in table 4.12 and 4.13 and in figure 4.7 and 4.8. The species accumulation showed an increasing trend in CZP.

The Jaccard's Index (C_j) of similarity for the different zones of CZP was tabulated (Table 4.14). The Jaccard's Index value ranged from 0.18 to 0.62. Among the zones the moist deciduous zone and evergreen zone were more similar with respect to ant species (C_j 0.62) and plantation zone and shrub thorny zone were more dissimilar (C_j 0.18).

4.4.2. Tamil Nadu Agricultural University Campus

The diversity of ant species affected during the survey period (Monthly) and in different zones of TNAU campus were given in table 4.10 and 4.11. Shannon Wiener Index (H), Species number and Margalef D were used as diversity estimators.

During the period of survey the Shannon Wiener Index ranged between 0.37 and 2.07, Species number between 4 and 14 and Margalef D between 0.43 and 1.83 Table 4.10. The diversity of ants was high during the month of February (H 2.07, Species number 14 and Margalef D 1.83) and very less during the month of April (H 0.37, Species number 4, Margalef D 0.43) (Table 4.10)(Fig. 4.9, 4.10 and 4.11).

Among the different zones studied, the Shannon Wiener Index ranged between 1.10 and 2.00, Species number between 9 and 18 and Margalef D between 0.95 and 2.39 (Table 4.11). The ant diversity was found to be high in evergreen zone (H 1.54, Species number 18, Margalef D 2.39) and very low in agricultural zone (H 1.10, Species number 9, Margalef D 0.95) (Fig. 4.12, 4.13 and 4.14.).

The species accumulation and richness of ants assessed during the study period (monthwise) and in different zones were given in tables 4.12 and 4.13 (Fig. 4.15 and 4.16). The species richness was higher in CZP (23.24) compared to TNAU campus (21.75). The species accumulation curve reached a plateau in TNAU campus.

The Jaccard's Index (C_j) of similarity for the different zones of TNAU campus ranged from 0.25 to 0.65 (Table 4.15). Among the different zone the semi evergreen zone and evergreen zones were highly similar (C_j 0.65) and agriculture zone and grassland zone were highly dissimilar (C_j 0.25).

Chapter V

DISCUSSION

The survival of an organism depends on better environment. The stress conditions lead to various adaptations by the organisms for its growth and reproduction and thus leading to speciation. Ultimately more richness of a species in a particular environment indicates the suitability of the environment; thereby that organism can be considered as an indicator organism for that environment. Ants having a remarkable diversity of ecological and social adaptations comprise of greater number of known genera and species than all other eusocial groups combined. They were numerically the most abundant of social insects.

In this study, the association of ants with ecosystem was assessed by various sampling methods and various indices and suitability of ant as bioindicator for different ecosystem were critically analysed.

5.1. Sampling Methods

Among the four different sampling techniques employed for the study pitfall trap, bait trap and direct observation were more efficient in sampling the ground foraging ants and tree dwelling ants respectively. The Winkler extractor failed to give a good sample, as there was no moisture in the leaf litter and the litter composition of the different zones of two sites were less. The leaf litter moisture is an important criteria deciding the efficiency of Winkler extractor, during the dry spells when the leaf litter is dry, ants move their nests deep into the soil or up into the vegetation (Bestelmeyer *et al.*, 2000). The bait trap yielded high abundance of the dominant species existing in an area. However ants with specialized food habits did not visit the bait, as they might have required specialized

bait (Eg: Grass seeds for sampling desert harvester ants) (Davidson, 1977). This indicated that bait trap could be effectively used to sample the dominant ant species which were dietary generalists. Bait trap was found to be efficient sampling technique in CZP contributing to 47 % of the total individuals sampled, as *Monomorium gracillimum* Smith, the most abundant species in CZP was attracted more to jaggery bait (Table 4.5). On the other hand, Pitfall trap was the efficient sampling technique in TNAU campus contributing to 62 % of the total individuals sampled (Table 4.8). This was attributed to the abundance of *Solenopsis geminata* Fabricius in TNAU campus, which is a ground foraging ant and hence, caught more in pitfall trap compared to other traps.

5.2. Ant Diversity during Different Sampling Periods

In Coimbatore Zoological Park (CZP) 23 species of ants were recorded which falls under five sub families and 19 genera (Table 4.1 and 4.2). The diversity of ants was higher in the month of December (H 2.13, Margalef D 2.24 and Species number 16) (Table 4.10), which was similar to the assessment made during the month of March and less than the diversity observed during February. The Margalef D and Shannon Wiener index indicated that the month of December had higher diversity while the species number showed that the month of February was diverse (Species number 17) (Table 4.10). During the month of December, 150 mm of rainfall was received which was sufficient for plant regeneration and thereby satisfying the food needs of ants, that might have increased the diversity. However, though January month also a winter season, yet lack of rainfall might have led to low diversity (Fig 5.1). Similarly, New *et al* (1996) also reported a considerable decline in species diversity of ants in winter.

The species number was high during February (Species number 17) as the cold winter conditions had been reduced and the ant species might have started recovering

from winter cold. However due to the high rainfall coupled with high temperature, the ant species diversity had started declining in March (H 1.69, Margalef D 1.98 and Species number 16) and April (H 1.79, Margalef D 1.53 and Species number 12). The Shannon Wiener index and Margalef D index differed from each other for richness of ant species during the months of January, March and April. Shannon Wiener index is based on the information content of a sample and incorporates the observed distribution of individuals among species in their calculation. On the other hand Margalef D assumes the form of the distribution of individuals among species and utilizes the number of species and the number of individuals as inputs for calculation (Room, 1974) and hence, the differences do occur. However at higher index value, these two indices did not differ.

5.3. Ant diversity in different zones of CZP and TNAU campus

Among the five zones of CZP, the evergreen zone was found to have more diversity (H 2.08 and Margalef D 2.32) followed by moist deciduous zone, shola grassland zone, plantation zone and shrub thorny zone (Table 4.11). The evergreen zone was found to have more diversity than the other, as the canopy level was intermediate and also the plant species richness was more. Gadagkar *et al* (1990) suggested that both the number of species and diversity were more variable and can reach very high levels at intermediate levels of canopy cover, while relatively fewer species and lower diversity can be obtained at very high or very low value of canopy cover index. The less diversity of ant species in shrub thorny zone and shola grassland zone was attributed to the very low canopy cover and disturbance by human activities such as collection of fuel wood and cattle grazing. The undisturbed nature of evergreen zone and moist deciduous zone might have resulted in high ant diversity. The low ant diversity in plantation zone might be due to monoculture of coconut trees. The species number was found to be high in moist deciduous zone and evergreen zone (17) followed by shrub thorny zone and shola

grassland zone together (13) and plantation zone (7). As species number gives inference only on the number of species obtained and not on the number of individuals and its distribution, it resulted in a poor measure of diversity.

The species accumulation curve (Fig. 4.7) showed an increasing trend in CZP during the five sampling periods and it emphasized the need for further sampling and increasing inventory efficiency (Longino, 2000).

The similarity value inferred from Jaccard's index showed that the lowest similarity was between shrub thorny zone and plantation zone (C_j 0.18). As they have differential ant species representation and also plantation zone is characterised by coconut monoculture, which makes it different from shrub thorny zone which was characterised by diverse plant species to a great extent. The Jaccard's index value (C_j) of evergreen zone and moist deciduous zone was highest (C_j 0.62) which showed that they had similar ant species representation. The high similarity was attributed to their location, as these two zones were not far from each other and only nallah and few meters of open grasslands separated them. The similarity values as a whole ranged from 0.18 to 0.62. On the other hand, the mean similarity values ranged between 0.31 and 0.50. The lowest being the mean of plantation zone, owing to its monocultured coconut plantations and the highest being the evergreen zone due to its close location to moist deciduous zone, shola grassland zone and shrub thorny zone.

In Tamil Nadu Agricultural University (TNAU) Campus, 23 species of ants were recorded which falls under five sub families and 14 genera (Table 4.1 and 4.2). The ant species diversity found to be highest in the month of February (H 2.07, Species number 14 and Margalef D 1.83) and the least values were found in the month of April (H 0.37,

Species number 4 and Margalef D 0.43). The highest diversity in the month of February was attributed to moderate rainfall (25mm) (Fig 5.1) and high sunshine hours (8.7 hours). The ant species *Solenopsis geminata* Fabricius and *Pheidole sharpi* Forel were the dominant species in February. *Solenopsis geminata* Fabricius's dominancy can be attributed to its tolerance for stress to a greater extent, preference for dry condition and its ability to construct nests to a depth of even more than 10 cm and *Pheidole sharpi* Forel being a generalized forager (Greenslade and Greenslade, 1977) might have dominated other ant species in February.

Among the different zones existing in TNAU campus, the diversity estimators namely Shannon Wiener index, Species number and Margalef D index showed difference among different zones. Shannon Wiener index (H) ranked the diversity as deciduous zone (2.00) followed by grassland zone (1.93), semi-evergreen zone (1.70), evergreen zone (1.54) and agricultural zone (1.10).

While the Margalef D index value ranked the diversity of different zones in TNAU campus as evergreen zone (2.39) followed by semi evergreen zone (2.02), deciduous zone (1.65), grassland zone (1.60) and agricultural zone (0.95), the diversity rankings based on Margalef D and Species number were similar.

The evergreen zone was highly diverse (Margalef D 2.39, Species number 18) as it had more canopy cover, good plant growth and more leaf litter accumulation. It was in confirmation with the study of Gadagkar *et al* (1990), which revealed that the canopy cover index has a positive influence on the number of species and diversity of insects and Gadagkar *et al*, (1993) also found a statistically significant positive correlation between ants and plant species diversity. The next diverse zone was semi evergreen zone

(Margalef D 2.02, Species number 15) and the reasons attributed above hold good for its diversity as it was more similar to evergreen zone in ant composition. The agricultural zone was found to be less diverse (Margalef D 0.95, Species number 9) as the zone had a pedigree of monoculture during its past and present and the zone was frequently distributed by agricultural operations like spraying, ploughing and weeding that had led to the low diversity of ants.. This was in confirmation with the study of Floren *et al* (2001) who observed a complete destruction of the natural arthropod communities in an agricultural ecosystem while shifting it from natural forests to agro ecosystem.

The species accumulation curve showed that the TNAU campus has attained plateau at the end of the study in the Month of May (Fig. 4.15), which implied that five continuous sampling was sufficient to give account of ants in TNAU campus. As the TNAU campus was man engineered and the diversity of ants were comparatively lesser than CZP, it attained a plateau earlier than CZP.

The semi evergreen zone and the evergreen zone were found to be more similar (C_j 0.65) and agricultural zone and grassland zone were found to be less similar (C_j 0.25). The semi evergreen zone and evergreen zone share most of the ant species owing to its similarity in vegetation. On the other hand, the monocultural operations in agricultural zone and mowing operations in grasslands (Lawn) might have led to dissimilar ant assemblages. The mean value of Jaccard's Index (C_j) ranged between 0.36 and 0.57. The semi evergreen zone with mean C_j of 0.57 was more similar with the other four different zones and agricultural zone with mean C_j of 0.36 was more dissimilar with other zones owing to its monocultural cropping system and hence dissimilar ant assemblage.

The comparison of species richness between the two sites namely CZP and TNAU campus using the mean of Jack knife estimator showed that CZP (Mean estimate 23.24) was richer than TNAU campus (Mean estimate 21.75) as, the ant species richness tend to be low in areas of high disturbance (Gadagkar *et al.*, 1993). TNAU campus being a man engineered ecosystem and continuously disturbed for agricultural, educational, constructional and developmental purpose obviously had low species richness than relatively undisturbed area. The difference in species richness of ants in these two areas clearly reflected the impact of human interference.

The two sites namely CZP and TNAU campus shared nine species of ants in common contributing to 27 % of the total ant species (Table 4.1, 4.2, 4.3 and 4.7). Hence comparing the two sites with respect to the common ant species and their temporal distribution was justified. The distribution of the nine common ant species was found to vary with each zone (Fig. 5.2, 5.3). The abundance of the nine common ant species in CZP and TNAU campus also varied (Fig. 5.4.). Among the nine common ant species seven species were more abundant in CZP than TNAU campus except for *Camponotus compressus* Fabricius and *Solenopsis geminata* Fabricius which were more abundant in TNAU campus than CZP. The reason being that the ant diversity and abundance were generally high in undisturbed area than disturbed area. Disturbing processes will lead to adjustment in the ant community, which depends upon the rate of immigration and population growth (Greenslade and Greenslade, 1977). TNAU campus being a disturbed area due to agricultural operations and research activities had less abundant ant species compared to relatively undisturbed CZP. The high abundance of *Solenopsis geminata* Fabricius was due to their lack of ecological specialization (Room, 1974).

5.4. Ants as Bio indicators

The most abundant species in CZP was *Monomorium gracillimum* Smith and it was found to occur in abundant at shrub thorny zone (Total number of individuals 2384) and its abundance in TNAU campus was very less contributing only 0.57% of the total ant abundance (Fig 5.5). On the other hand, in CZP it contributed to 31.36% of the total abundance of ants. *Monomorium gracillimum* Smith was found to have associated more with the *Acacia horida* tree, which was characteristic of the shrub thorny zone in CZP (Fig. 5.6). Its abundance near the termite colonies in *Acacia horida* tree seemed to have association with the termites also and it emphasised further investigation regarding their relationship with termites and *Acacia*. Being a generalised feeder and seed harvester (Musthak Ali, 1991) it feeds constantly on the inflorescence of *Acacia harida* and its abundance reached the peak during the month of February when the flowering of *Acacia horida* was high and uniform throughout the zone. The phenology of *Acacia horida* coupled with the termite association needs further investigation. In TNAU campus where *Acacia horida* was completely absent, the presence of *Monomorium gracillimum* Smith was very less (Total number of individuals 44). Hence a conclusion can be drawn that *Monomorium gracillimum* Smith was highly dependent on *Acacia horida* and hence as an indicator of the shrub thorny ecosystem.

In TNAU campus *Solenopsis geminata* Fabricius was the single most dominant and abundant species (Table 4.6 and 4.7) (Fig. 5.2, 5.5). *Solenopsis geminata* Fabricius was found abundant in the agricultural zone of TNAU campus (Total number of individuals 3149) and especially in crop fields with Bhendi (*Abelmoschus esculentus*), Groundnut (*Arachis hypogaea* L.). *Solenopsis geminata* Fabricius was considered as a foremost pest of agricultural crops especially for red gram and bhendi. Although it was a natural enemy for pests like aphids, coccids and mealy bugs its beneficiary role was

suppressed by its destructive role like crop raiding (Tiwari, 1999). Owing to their generalized feeding habit, seed harvesting and scavenging ability, it was a dominative ant species in agro-ecosystems (Musthak Ali, 1991). The monoculture system practiced in the agricultural ecosystems was responsible for the poor species richness of ants (Species number 9), which led to domination of *Solenopsis geminata* Fabricius in the agricultural zone and whole of TNAU campus, owing to their great numbers (Fig. 5.7). Hence, the domination of *Solenopsis geminata* Fabricius showed that the agro-ecosystem was frequently altered by agricultural activities and cropping system which led to domination of species that can tolerate disturbance to a greater extent. *Solenopsis geminata* Fabricius was one such weed species, which colonizes disturbed habitat by taking the advantage of the absence of other dominant ant species in the ecosystem. The disappearance of *Solenopsis geminata* Fabricius and recolonization by other ant species was used as an evidence for readjustment of the ant fauna, after disturbance (Greenslade and Greenslade, 1977). Dominant species such as *Solenopsis geminata* Fabricius tend towards monopoly of resources of vegetation and their populations were liable to fluctuate and communities were often unstable and diversity oscillates. As the diversity oscillates, the ecosystem becomes unstable and unsustainable (Greenslade and Greenslade, 1977). *Solenopsis geminata* Fabricius was one such species, which can be best studied, and its abundance and dominance in the ecosystem indicated whether the ecosystem was disturbed or undisturbed. Hence, *Solenopsis geminata* Fabricius can be used to indicate the level of disturbance in agro-ecosystem and thereby as a bioindicator of agro-ecosystem sustainability.

The study as a whole gave an idea of the ant fauna of CZP and TNAU Campus, where an inventory on ant fauna had never existed before. The study revealed that the evergreen zone in both sites was highly diverse owing to its plant species richness and

less human interference. In CZP, *Monomorium gracillimum* Smith was the dominant species and it was found associated with the tree *Acacia horida*, a characteristic of shrub thorny ecosystem and hence the dominance of *Monomorium gracillimum* Smith can be used an indicator of the shrub thorny ecosytem. In TNAU campus *Solenopsis geminata* Fabricius was the dominant species and it was found to indicate the disturbance due to agricultural activities in the agro-ecosystem of TNAU campus. However, further investigation was needed to prove the indicator quality of these two species.

Chapter VI

SUMMARY AND CONCLUSION

A study on the ant fauna of Coimbatore zoological park (CZP) and Tamil Nadu Agricultural University (TNAU) campus was carried out for six months from December to May, 2003 to assess the biodiversity of ant fauna of the two sites and to identify the indicator species for an ecosystem. Four sampling techniques were employed viz., pitfall trap, bait trap, winkler extraction and direct sampling so as to give a complete representation of the ant fauna in the study sites. The salient findings of the investigation carried out on the taxonomy and ant diversity in the CZP and TNAU campus are summarized here under.

- Occurrences of the following 23 species of ants under five subfamilies were recorded in the CZP site.

I. Formicinae

- *Anaplolepis longipes* Jerdon
- *Camponotus compressus* Fabricius
- *Camponotus sericeus* Fabricius
- *Camponotus variegates* Smith
- *Camponotus* sp
- *Lepisiota simplex* Forel
- *Oecophylla smaragdina* Smith
- *Paratrechina longicornis* Latreille
- *Plagiolepis jerdoni* Forel
- *Polyrhachis exercita* Walker

II. Myrmicinae

- *Aphaenogaster* sp
- *Crematogaster rothneyi* Mayr
- *Crematogaster* sp
- *Meranoplus bicolor* Guerin
- *Monomorium gracillimum* Smith
- *Pheidole* sp
- *Solenopsis geminata* Fabricius

III. Ponerinae

- *Anochetus graeffei* Mayr
- *Diacamma rugosum* Le Guillou
- *Leptogenys chinensis* Walker
- *Pachycondyla tesserinoda* Emery

IV. Dolichoderinae

- *Tapinoma* sp

V. Pseudomyrmecinae

- *Tetraponera aitkeni* Forel

- Occurrences of the following 23 species of ants under five subfamilies were recorded in the TNAU campus.

I. Formicinae

- *Camponotus compressus* Fabricius
- *Camponotus sericeus* Fabricius
- *Camponotus rufoglaucus* Jerdon
- *Oecophylla smaragdina* Smith
- *Paratrechina longicornis* Latreille
- *Polyrhachis aculeate* Mayr

II. Myrmicinae

- *Crematogaster* sp
- *Meranoplus bicolor* Guerin
- *Monomorium gracillimum* Smith
- *Monomorium floricola* Jerdon
- *Monomorium pharaonis* Linnaeus
- *Monomorium scabriceps* Mayr
- *Pheidole sharpi* Forel
- *Pheidole spathifera* Forel
- *Solenopsis geminata* Fabricius
- *Tetramorium walshi* Forel

III. Ponerinae

- *Anochetus rudis* Emery
- *Pachycondyla rufipes* Jerdon
- *Pachycondyla* sp

IV. Dolichoderinae

- *Tapinoma melanocephalum* Fabricius

V. Pseudomyrmecinae

- *Tetraponera aitkeni* Forel
- *Tertraponera rufonigra* Jerdon
- *Tetraponera allaborans* Forel

- Nine Species of ants viz., *Camponotus compressus* Fabricius, *Monomorium gracillimum* Smith, *Oecophylla smaragdina* Smith, *Paratrechina longicornis* Latreille, *Camponotus sericeus* Fabricius, *Crematogaster* sp, *Meranoplus bicolor* Guerin, *Solenopsis geminata* Fabricius, *Tetraponera aitkeni* Forel were found to be common to both sites
- The subfamily **Myrmicinae** was dominant in both the sites

- The ant species *Monomorium gracillimum* Smith, *Aphaenogaster* sp., *Pheidole* sp., *Paratrechina longicornis* Latreille and *Meranoplus bicolor* Guerin were found to be predominant in CZP.
- The ant species *Solenopsis geminata* Fabricius, *Pheidole sharpi* Forel, *Camponotus compressus* Fabricius and *Tapinoma melanocephalum* Fabricius, were also found to be predominant in CZP.
- There was an association between *Monomorium gracillimum* Smith and *Acacia horida* in shrub thorny zone of CZP.
- The ant species *Solenopsis geminata* Fabricius was found to be an indicator of disturbance in agro ecosystem.
- The Shannon wiener index showed that evergreen zone was highly diverse (H (2.08)) in Coimbatore zoological park and deciduous zone was highly diverse in TNAU campus. The lowest diversity was obtained in shrub thorny zone of CZP (H (1.04)) and agricultural zone of TNAU Campus.
- The species richness of ants was found to be higher in CZP (Mean Jack knife Estimate (23.24)) than TNAU campus (Mean Jack knife Estimate (21.75)).
- In Coimbatore zoological park the moist deciduous zone and evergreen zone were found to be more similar (Jaccard's Index C_j (0.62)) and plantation zone and shrub thorny zone were less similar (C_j (0.18)).
- In TNAU campus evergreen and semi-evergreen zone were more similar (C_j (0.65)) and grassland zone and evergreen zone were less similar (C_j (0.25)).
- *Monomorium gracillimum* Smith and *Solenopsis geminata* Fabricius were identified as indicator of shrub thorny and agro-ecosystem of CZP and TNAU campus respectively.

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* Originals not seen

Table 4.8. Ant Individuals collected by different Sampling Methods in TNAU campus

Ant species	Agricultural zone			Semi evergreen zone			Evergreen zone			Grassland zone			Deciduous zone			Total
I. Formicinae	PF	B	DO	PF	B	DO	PF	B	DO	PF	B	DO	PF	B	DO	
<i>Camponotus compressus</i> Fabricius*	251	31	3	18	0	3	60	0	2	16	86	14	7	45	0	536
<i>Camponotus sericeus</i> Fabricius*	12	8	20	3	0	0	0	0	0	0	0	0	5	0	10	58
<i>Camponotus rufoglaucus</i> Jerdon	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	25
<i>Oecophylla smaragdina</i> Smith*	0	0	0	0	0	2	5	7	20	0	0	61	31	0	27	153
<i>Paratrechina longicornis</i> Latreille*	0	0	0	10	125	100	17	25	0	87	21	19	5	0	0	409
<i>Polyrhachis aculeata</i> Mayr	0	0	0	0	0	8	0	0	2	0	0	0	0	0	1	11
II. Myrmicinae																
<i>Crematogaster</i> sp*	12	0	0	0	0	0	15	0	10	0	0	0	0	0	5	42
<i>Meranoplus bicolor</i> Guerin*	333	7	2	28	2	10	2	0	18	0	0	2	0	0	0	404
<i>Monomorium gracillimum</i> Smith*	20	20	0	0	2	0	0	2	0	0	0	0	0	0	0	44
<i>Monomorium floricola</i> Jerdon	0	0	0	0	0	0	0	0	0	13	25	5	0	0	0	43
<i>Monomorium pharaonis</i> Linnaeus	0	20	0	0	205	1	0	25	0	0	0	0	0	40	4	295
<i>Monomorium scabriceps</i> Mayr	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	50
<i>Pheidole sharpi</i> Forel	68	77	0	243	127	15	29	78	5	59	0	0	20	45	5	771
<i>Pheidole spathifera</i> Forel	0	0	1	0	30	0	1	5	0	0	0	2	3	0	11	53
<i>Solenopsis geminata</i> Fabricius *	2500	434	215	23	0	2	170	475	110	12	50	0	125	0	0	4116
<i>Tetramorium walshi</i> Forel	0	0	0	0	0	10	0	0	0	0	0	25	0	0	0	35
III. Ponerinae																
<i>Anochetus rudis</i> Emery	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	4
<i>Pachycondyla rufipes</i> Jerdon	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
<i>Pachycondyla</i> sp	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	3
IV. Dolichoderinae																
<i>Tapinoma melanocephalum</i> Fabricius	500	27	3	0	0	0	0	0	0	0	0	0	0	0	0	530
V. Pseudomyrmecinae																
<i>Tetraponera aitkeni</i> Forel*	0	0	0	0	0	0	0	0	7	1	0	0	0	0	0	8
<i>Tertraponera rufonigra</i> Jerdon	0	0	0	5	0	43	5	8	38	0	0	10	2	0	2	113
<i>Tetraponera allaborans</i> Forel	0	0	0	3	0	0	10	10	0	0	0	0	0	0	0	23
Total No. of Individuals	3696	624	244	333	492	194	365	635	215	188	182	138	201	155	65	7727

PF-Pitfall Trap; B- Bait Trap; DO – Direct Observation

* Ant species common to CZP and TNAU Campus

Table 4.1. Ant species in CZP and TNAU campus

	Subfamily	Ant species in CZP	Ant species in TNAU Campus
I.	Formicinae	<i>Anaplolepis longipes</i> Jerdon	<i>Camponotus compressus</i> Fabricius*
		<i>Camponotus compressus</i> Fabricius*	<i>Camponotus sericeus</i> Fabricius*
		<i>Camponotus sericeus</i> Fabricius*	<i>Camponotus rufoglaucus</i> Jerdon
		<i>Camponotus variegates</i> Smith	<i>Oecophylla smaragdina</i> Smith*
		<i>Camponotus</i> sp	<i>Paratrechina longicornis</i> Latreille*
		<i>Lepisiota simplex</i> Forel	<i>Polyrhachis aculeata</i> Mayr
		<i>Oecophylla smaragdina</i> Smith*	
		<i>Paratrechina longicornis</i> Latreille*	
		<i>Plagiolepis jerdoni</i> Forel	
		<i>Polyrhachis exercita</i> Walker	
II.	Myrmicinae	<i>Aphaenogaster</i> sp	<i>Crematogaster</i> sp*
		<i>Crematogaster rothneyi</i> Mayr	<i>Meranoplus bicolor</i> Guerin*
		<i>Crematogaster</i> sp*	<i>Monomorium gracillimum</i> Smith*
		<i>Meranoplus bicolor</i> Guerin*	<i>Monomorium floricola</i> Jerdon
		<i>Monomorium gracillimum</i> Smith*	<i>Monomorium pharaonis</i> Linnaeus
		<i>Pheidole</i> sp	<i>Monomorium scabriceps</i> Mayr
		<i>Solenopsis geminata</i> Fabricius*	<i>Pheidole sharpi</i> Forel
			<i>Pheidole spathifera</i> Forel
			<i>Solenopsis geminata</i> Fabricius*
			<i>Tetramorium walshi</i> Forel
III.	Ponerinae	<i>Anochetus graeffei</i> Mayr	<i>Anochetus rudis</i> Emery
		<i>Diacamma rugosum</i> Le Guillou	<i>Pachycondyla rufipes</i> Jerdon
		<i>Leptogenys chinensis</i> Walker	<i>Pachycondyla</i> sp
		<i>Pachycondyla tesserinoda</i> Emery	
IV.	Dolichoderinae	<i>Tapinoma</i> sp	<i>Tapinoma melanocephalum</i> Fabricius
V.	Pseudomyrmecinae	<i>Tetraponera aitkeni</i> Forel*	<i>Tetraponera aitkeni</i> Forel*
			<i>Tetraponera allaborans</i> Forel
			<i>Tetraponera rufonigra</i> Jerdon

* Ant species common to CZP and TNAU Campus

Table 4.2. The presence or absence of ant species in CZP and TNAU campus

[illegible]

Sub family	Species Name	Coimbatore Zoological Park (CZP)					Tamil Nadu Agricultural University Campus (TNAU)				
		PZ	MDZ	EZ	STZ	SGZ	AZ	SEZ	EZ	GZ	DZ
	<i>Pheidole sharpi</i> Forel						X	X	X	X	X
	<i>Pheidole</i> sp	X	X	X		X					
	<i>Pheidole spathifera</i> Forel							X	X	X	X
	<i>Solenopsis geminata</i> Fabricius*		X				X	X	X	X	X
	<i>Tetramorium walshi</i> (Forel)							X		X	
III. Ponerinae	<i>Anochetus graeffei</i> Mayr	X	X	X							
	<i>Anochetus rudis</i> Emery								X		X
	<i>Diacamma rugosum</i> Le Guillou			X	X	X					
	<i>Leptogenys chinensis</i> Walker			X							
	<i>Pachycondyla rufipes</i> Jerdon								X		
	<i>Pachycondyla</i> sp							X	X		
	<i>Pachycondyla tesserinoda</i> Emery				X	X					
IV. Dolichoderinae	<i>Tapinoma melanocephalum</i> Fabricius						X				
	<i>Tapinoma</i> sp		X								
V. Pseudomyrmecinae	<i>Tetraponera aitkeni</i> Forel*			X					X	X	
	<i>Tetraponera allaborans</i> Forel							X	X		
	<i>Tetraponera rufonigra</i> Jerdon							X	X	X	X

PZ - Plantation Zone, MDZ- Moist Deciduous Zone, EZ - Evergreen Zone, STZ-Shrub Thorny Zone, SGZ - Shola Grassland Zone, AZ -Agricultural Zone, SEZ - Semi-Evergreen Zone, GZ - Grasland Zone, DZ - Deciduous Zone.

* Ant species common to CZP and TNAU Campus

Table 4.3. Total number of ant individuals collected during the sampling period in CZP

Ant species	December	January	February	March	April	Total no. of individuals
I. Formicinae						
<i>Anaplolepis longipes</i> Jerdon	10	6	5	0	0	21
<i>Camponotus compressus</i> Fabricius*	89	91	4	58	0	242
<i>Camponotus sericeus</i> Fabricius*	7	14	27	118	109	275
<i>Camponotus variegates</i> Smith	2	2	0	0	0	4
<i>Camponotus</i> sp.	5	0	3	2	0	10
<i>Lepisiota simplex</i> Forel	0	0	0	40	37	77
<i>Oecophylla smaragdina</i> Smith*	230	20	1	1	0	252
<i>Paratrechina longicornis</i> Latreille*	100	250	223	58	50	681
<i>Plagiolepis jerdoni</i> Forel	28	22	4	245	0	299
<i>Polyrhachis exercita</i> Walker	2	2	0	33	0	37
II. Myrmicinae						
<i>Aphaenogaster</i> sp	0	0	310	1060	0	1370
<i>Crematogaster rothneyi</i> Mayr	70	72	84	10	0	236
<i>Crematogaster</i> sp*	0	0	12	43	155	210
<i>Meranoplus bicolor</i> Guerin*	124	66	5	131	102	428
<i>Monomorium gracillimum</i> Smith*	59	1171	692	21	623	2566
<i>Pheidole</i> sp	66	65	732	40	0	903
<i>Solenopsis geminata</i> Fabricius*	0	0	12	0	0	12
III. Ponerinae						
<i>Anochetus graeffei</i> Mayr	0	0	276	0	5	281
<i>Diacamma rugosum</i> Le Guillou	14	10	63	54	69	210
<i>Leptogenys chinensis</i> Walker	1	1	0	0	0	2
<i>Pachycondyla tesserinoda</i> Emery	0	0	15	0	31	46
IV. Dolichoderinae						
<i>Tapinoma</i> sp	0	0	6	10	0	16
V. Pseudomyrmecinae						
<i>Tetraponera aitkeni</i> Forel*	0	0	0	0	3	3
Total numbers of individuals	807	1792	2474	1924	1184	Grand Total = 8181

* Ant species common to CZP and TNAU Campus

Table 4.4. Total number of ant individuals collected in different zones of CZP

Ant species	Plantation zone	Moist deciduous zone	Evergreen zone	Shrub thorny zone	Shola grassland zone	Total no. of individuals
I. Formicinae						
<i>Anaplolepis longipes</i> Jerdon	0	12	0	0	9	21
<i>Camponotus compressus</i> Fabricius*	140	55	43	0	4	242
<i>Camponotus sericeus</i> Fabricius*	0	118	33	3	121	275
<i>Camponotus variegates</i> Smith	0	4	0	0	0	4
<i>Camponotus</i> sp	0	0	0	9	1	10
<i>Lepisiota simplex</i> Forel	0	0	2	5	70	77
<i>Oecophylla smaragdina</i> Smith*	40	0	2	0	210	252
<i>Paratrechina longicornis</i> Latreille*	0	30	78	573	0	681
<i>Plagiolepis jerdoni</i> Forel	10	22	178	89	0	299
<i>Polyrhachis exercita</i> Walker	0	30	5	2	0	37
II. Myrmicinae						
<i>Aphaenogaster</i> sp	0	815	37	13	505	1370
<i>Crematogaster rothneyi</i> Mayr	14	145	51	25	1	236
<i>Crematogaster</i> sp*	0	12	138	60	0	210
<i>Meranoplus bicolor</i> Guerin*	0	76	329	0	23	428
<i>Monomorium gracillimum</i> Smith*	4	28	24	2384	126	2566
<i>Pheidole</i> sp	233	147	24	0	499	903
<i>Solenopsis geminata</i> Fabricius *	0	12	0	0	0	12
III. Ponerinae						
<i>Anochetus graeffei</i> Mayr	275	1	5	0	0	281
<i>Diacamma rugosum</i> Le Guillou	0	14	32	139	25	210
<i>Leptogenys chinensis</i> Walker	0	0	2	0	0	2
<i>Pachycondyla tesserinoda</i> Emery	0	0	0	36	10	46
IV. Dolichoderinae						
<i>Tapinoma</i> sp	0	16	0	0	0	16
V. Pseudomyrmecinae						
<i>Tetraponera aitkeni</i> Forel*	0	0	3	0	0	3
Total no of Individuals	516	1537	875	3234	1106	Grand Total = 8181

* Ant species common to CZP and TNAU Campus

Table 4.5. Ant Individuals collected by different sampling methods in CZP

Ant species	Plantation zone			Moist deciduous zone			Evergreen zone			Shrub thorny zone			Shola grassland zone			Total
	PF	B	DO	PF	B	DO	PF	B	DO	PF	B	DO	PF	B	DO	
I. Formicinae																
<i>Anaplolepis longipes</i> Jerdon	0	0	0	10	0	2	0	0	0	0	0	0	5	0	4	21
<i>Camponotus compressus</i> Fabricius*	120	10	10	40	0	15	25	14	4	0	0	0	0	0	4	242
<i>Camponotus sericeus</i> Fabricius*	0	0	0	8	3	107	12	19	2	3	0	0	7	14	100	275
<i>Camponotus variegates</i> Smith	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4
<i>Camponotus</i> sp.	0	0	0	0	0	0	0	0	0	7	0	2	1	0	0	10
<i>Lepisiota simplex</i> Forel	0	0	0	0	0	0	2	0	0	0	0	5	0	5	65	77
<i>Oecophylla smaragdina</i> Smith*	20	10	10	0	0	0	2	0	0	0	0	0	100	0	110	252
<i>Paratrechina longicornis</i> Latreille*	0	0	0	0	30	0	78	0	0	123	125	325	0	0	0	681
<i>Plagiolepis jerdoni</i> Forel	10	0	0	1	10	11	7	163	8	4	85	0	0	0	0	299
<i>Polyrhachis exercita</i> Walker	0	0	0	0	0	30	3	0	2	2	0	0	0	0	0	37
II. Myrmicinae																
<i>Aphaenogaster</i> sp	0	0	0	460	235	120	34	3	0	13	0	0	310	145	50	1370
<i>Crematogaster rothneyi</i> Mayr	12	0	2	13	49	83	0	0	51	0	10	15	0	0	1	236
<i>Crematogaster</i> sp*	0	0	0	0	0	12	3	105	30	10	10	40	0	0	0	210
<i>Meranoplus bicolor</i> Guerin*	0	0	0	10	43	23	73	214	42	0	0	0	5	10	8	428
<i>Monomorium gracillimum</i> Smith*	2	2	0	6	8	14	8	11	5	7	2227	150	68	46	12	2566
<i>Pheidole</i> sp	133	100	0	27	27	93	11	12	1	0	0	0	458	40	1	903
<i>Solenopsis geminata</i> Fabricius*	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	12
III. Ponerinae																
<i>Anochetus graeffei</i> Mayr	275	0	0	0	0	1	5	0	0	0	0	0	0	0	0	281
<i>Diacamma rugosum</i> Le Guillou	0	0	0	9	0	5	10	3	19	38	25	76	25	0	0	210
<i>Leptogenys chinensis</i> Walker	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
<i>Pachycondyla tessarinoda</i> Emery	0	0	0	0	0	0	0	0	0	0	1	35	10	0	0	46
IV. Dolichoderinae																
<i>Tapinoma</i> sp	0	0	0	12	0	4	0	0	0	0	0	0	0	0	0	16
V. Pseudomyrmecinae																
<i>Tetraponera aitkeni</i> Forel*	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
Total numbers of individuals	572	122	22	600	417	520	275	544	167	207	2483	648	989	260	355	8181

PF-Pitfall Trap; B- Bait Trap; DO – Direct Observation

* Ant species common to CZP and TNAU Campus

Table 4.6. Total number of ant individuals collected during the sampling period in TNAU campus

Ant species	January	February	March	April	May	Total no. of individuals
I. Formicinae						
<i>Camponotus compressus</i> Fabricius*	216	63	4	0	253	536
<i>Camponotus sericeus</i> Fabricius*	0	0	47	0	11	58
<i>Camponotus rufoglaucus</i> Jerdon	25	0	0	0	0	25
<i>Oecophylla smaragdina</i> Smith*	33	62	58	0	0	153
<i>Paratrechina longicornis</i> Latreille*	0	409	0	0	0	409
<i>Polyrhachis aculeata</i> Mayr	0	5	6	0	0	11
II. Myrmicinae						
<i>Crematogaster</i> sp*	15	0	15	0	12	42
<i>Meranoplus bicolor</i> Guerin*	29	35	17	0	323	404
<i>Monomorium gracillimum</i> Smith*	0	0	4	20	20	44
<i>Monomorium floricola</i> Jerdon	0	43	0	0	0	43
<i>Monomorium pharaonis</i> Linnaeus	2	233	60	0	0	295
<i>Monomorium scabriceps</i> Mayr	0	50	0	0	0	50
<i>Pheidole sharpi</i> Forel	239	0	404	36	92	771
<i>Pheidole spathifera</i> Forel	23	30	0	0	0	53
<i>Solenopsis geminata</i> Fabricius *	153	150	913	974	1926	4116
<i>Tetramorium walshi</i> Forel	10	25	0	0	0	35
III. Ponerinae						
<i>Anochetus rudis</i> Emery	4	0	0	0	0	4
<i>Pachycondyla rufipes</i> Jerdon	0	1	0	0	0	1
<i>Pachycondyla</i> sp	3	0	0	0	0	3
IV. Dolichoderinae						
<i>Tapinoma melanocephalum</i> Fabricius	0	0	0	30	500	530
V. Pseudomyrmicinae						
<i>Tetraponera aitkeni</i> Forel*	3	0	5	0	0	8
<i>Tertraponera rufonigra</i> Jerdon	0	99	14	0	0	113
<i>Tetraponera allaborans</i> Forel	0	23	0	0	0	23
Total no. of individuals	755	1228	1547	1060	3137	Grand Total = 7727

* Ant species common to CZP and TNAU Campus

Table 4.7. Total number of ant individuals collected in different zones of TNAU campus

Ant species	Agricultural zone	Semi evergreen zone	Evergreen zone	Grassland zone	Deciduous zone	Total no. of individuals
I. Formicinae						
<i>Camponotus compressus</i> Fabricius*	285	21	62	116	52	536
<i>Camponotus sericeus</i> Fabricius*	40	3	0	0	15	58
<i>Camponotus rufoglaucus</i> Jerdon	0	0	0	0	25	25
<i>Oecophylla smaragdina</i> Smith*	0	2	32	61	58	153
<i>Paratrechina longicornis</i> Latreille*	0	235	42	127	5	409
<i>Polyrhachis aculeata</i> Mayr	0	8	2	0	1	11
II. Myrmicinae						
<i>Crematogaster</i> sp*	12	0	25	0	5	42
<i>Meranoplus bicolor</i> Guerin*	342	40	20	2	0	404
<i>Monomorium gracillimum</i> Smith*	40	1	1	0	0	44
<i>Monomorium floricola</i> Jerdon	0	0	0	43	0	43
<i>Monomorium pharaonis</i> Linnaeus	20	206	25	0	44	295
<i>Monomorium scabriceps</i> Mayr	0	0	50	0	0	50
<i>Pheidole sharpi</i> Forel	145	385	112	59	70	771
<i>Pheidole spathifera</i> Forel	1	30	6	2	14	53
<i>Solenopsis geminata</i> Fabricius *	3149	25	755	62	125	4116
<i>Tetramorium walshi</i> Forel	0	10	0	25	0	35
III. Ponerinae						
<i>Anochetus rudis</i> Emery	0	0	1	0	3	4
<i>Pachycondyla rufipes</i> Jerdon	0	0	1	0	0	1
<i>Pachycondyla</i> sp	0	1	2	0	0	3
IV. Dolichoderinae						
<i>Tapinoma melanocephalum</i> Fabricius	530	0	0	0	0	530
V. Pseudomyrmecinae						
<i>Tetraponera aitkeni</i> Forel*	0	0	7	1	0	8
<i>Tertraponera rufonigra</i> Jerdon	0	48	51	10	4	113
<i>Tetraponera allaborans</i> Forel	0	3	20	0	0	23
Total no. of individuals	4564	1018	1214	508	423	Grand Total = 7727

* Ant species common to CZP and TNAU Campus

Table 4.10. The various diversity estimates of ant species during the survey period in CZP and TNAU campus

Coimbatore Zoological Park (CZP)				Tamil Nadu Agricultural University (TNAU) Campus			
Month of Survey	Shannon – Wiener Index H	Species number	Margalef D	Month of survey	Shannon – Wiener Index H	Species number	Margalef D
December	2.13	16	2.24	January	1.75	13	1.81
January	1.30	15	1.87	February	2.07	14	1.83
February	1.90	17	2.04	March	1.22	12	1.50
March	1.69	16	1.98	April	0.37	4	0.43
April	1.79	12	1.53	May	1.21	8	0.87

Table 4.11. The various diversity estimates of ant species in different zones of Coimbatore Zoological Park (CZP) and Tamil Nadu Agricultural University (TNAU) Campus

Coimbatore Zoological Park (CZP)				Tamil Nadu Agricultural University Campus			
Study zones	Shannon – Wiener Index H	Species number	Margalef D	Study zones	Shannon – Wiener Index H	Species number	Margalef D
Plantation zone	1.38	7	0.912	Agricultural zone	1.10	9	0.950
Moist Deciduous zone	1.76	17	2.18	Semi evergreen zone	1.70	15	2.02
Evergreen zone	2.08	17	2.32	Evergreen zone	1.54	18	2.39
Shrub Thorny zone	1.04	13	1.48	Grassland zone	1.93	11	1.60
Shola Grassland zone	1.73	13	1.63	Deciduous zone	2.00	11	1.65

Table 4.9. Class/ Order of invertebrates found in CZP and TNAU Campus

Coimbatore Zoological Park	Tamil Nadu Agricultural University Campus
I Class: Insecta	I Class : Insecta
Orthoptera :	Orthoptera :
- Acrididae	- Acrididae
- Gryllidae	- Gryllidae
Hemiptera :	Hemiptera :
- Cicadellidae	- Cicadellidae
- Pentatomidae	- Pentatomidae
- Reduviidae	- Reduviidae
Diptera :	Diptera :
- Muscidae	- Muscidae
Lepidoptera :	Lepidoptera :
- Lymantridae	- Noctuidae
Coleoptera :	Coleoptera :
- Coccinellidae	- Coccinellidae
- Buprestidae	
- Melolonthidae	
Hymenoptera :	Hymenoptera
- Vespidae	- Vespidae
Dictyoptera :	Dictyoptera :
- Blattidae	- Blattidae
Isoptera :	Isoptera :
- Termitidae	- Termitidae
Homoptera :	Homoptera :
- Coccidae	- Coccidae
II Class : Arachnida	Dermaptera :
Araneae	-Anisopidae
Scorpionida	Neuroptera :
III Class : Diplopoda	- Mantispidae
IV Class : Chilopoda	Thysanura
	II Class : Gastropoda (Molluscans)
	III Class : Arachnida
	Araneae

Table 4.14. Jaccard's index (C_j) of similarity matrix for different zones in CZP

Study zones	Plantation zone	Moist deciduous zone	Evergreen zone	Shrub thorny zone	Shola grassland zone
Plantation zone					
Moist deciduous zone	0.33				
Evergreen zone	0.41	0.62			
Shrub thorny zone	0.18	0.43	0.50		
Shola grassland zone	0.33	0.36	0.50	0.44	
Mean	0.31	0.47	0.50	0.44	0.41

Table 4.15. Jaccard's index (C_j) of similarity matrix for different zones in TNAU campus

Study zones	Agricultural zone	Semi evergreen zone	Evergreen zone	Grassland zone	Deciduous zone
Agricultural zone					
Semi evergreen zone	0.41				
Evergreen zone	0.35	0.65			
Grassland zone	0.25	0.53	0.45		
Deciduous zone	0.43	0.53	0.53	0.47	
Mean	0.36	0.57	0.49	0.47	0.49

Table 4.12. The ant species accumulation in CZP and TNAU Campus observed during the study period

Coimbatore Zoological Park		Tamil Nadu Agricultural University	
Month of Survey	Species Accumulation	Month of Survey	Species Accumulation
December	16	January	13
January	16	February	20
February	21	March	22
March	22	April	23
April	24	May	23

Table 4.13. The Jack knife estimator of ant species richness in different zones of CZP and TNAU Campus

Coimbatore Zoological Park			Tamil Nadu Agricultural University Campus		
Sample	Jack knife estimator		Sample	Jack knife estimator	
	Estimate	SD		Estimate	SD
Using 1 sample	7	0	Using 1 sample	9	0
Using 2 samples	24	5	Using 2 samples	22	3
Using 3 samples	25.67	2.40	Using 3 samples	25	2
Using 4 samples	30.75	2.56	Using 4 samples	25.75	1.89
Using 5 samples	28.8	2.33	Using 5 samples	27	1.26
Mean	23.24		Mean	21.75	













