Chapter 2

General Materials and Methods

Nest building activity by *Camponotus* (species unidentified)

Study Area and its Climate

Vadodara District is in the eastern part of the State of Gujarat in Western India. It is located at 22°11' N latitude and 73°07' E longitude. Vadodara District covers an area of 7,794 sq km. and has a population of 36,41,802 as of 2001 census (www.worldgazetteer.com).

The district is bound by Panchmahal and Dahod districts to the north, Anand and Kheda districts to the west, Bharuch and Narmada districts to the south, and the state of Madhya Pradesh to the east. The tallest point in the region is Pavagadh hill. The Mahi River passes through the district. Vishwamitri River flows through the city of Vadodara.

The city of Vadodara is a centre for education, industry and commerce. A vision of Sir Sayajirao Gaekwad III (1875-1939), this city is known for its arches, domes, colourful gardens, fountains, supreme education and ever increasing industries. It is a peaceful, medium sized city - a delight for tourists and researchers alike.

Climate

The climate of Vadodara is semiarid type characterized by dry and increasingly hot summer from end of February to June, warm monsoon from July to September, and a dry and cold winter from October to early February.

The climatic factors of greater importance affecting the insect population in general are rainfall, temperature and relative humidity. Rainfall occurs when the monsoons arrive every year in the latter half of June and continue till September. There is heavy downpour in the months of July and August .(Table 1)

Great extremes of temperature characterize the semiarid climate of Vadodara. The heat during the summer (March- June) is intense with the temperature rising as high as 43.3 ^{0}C in May. June –September is warm monsoon, while winter sets in the month of November and continues till middle of February. December and January are cold months, when the temperature drops down reaching a mean average of and mean temperatures are 30 ^{0}C (maximum) and

13 ^{0}C (minimum). Relative humidity is minimum during winter month of December (31%) and maximum during monsoon, especially in the month of July (92%). (Table 5)

In recent years, Vadodara has suffered from increasing air, water and soil pollution from neighbouring industrial areas. This has also amounted into a constant and uncomfortable increase in average temperatures across all three seasons. Uncontrolled chemical dump from nearby industries has arguably turned the local river Vishwamitri into one big sewer.

Study Sites

Agricultural Ecosystems

The agricultural fields selected for this study are located within 25 kms radius of Vadodara district and were 5 hectares or more in size (Tables 1 and 3).

ASite1(Timbi): These agricultural fields with an approximate area of 3.5 hectares are located 15 kms from Vadodara city. The main crops that grow here are Paddy, Cotton, Pigeon pea, Millet. The soil is sandy loam .

ASite2 (Savli): This study area of approx. 2.5 hectares is located within 20 kms. from Vadodara city. Tobacco, castor and vegetable crops like Cauliflower and Cabbage are grown here. Yellow sandy loam soil is found here.

ASite3 (Waghodia): Located 20 kms. from Vadodara city and spread across 4.5 hectares, these fields grow Sugarcane, Paddy, Cauliflower, and Spinach on medium black soil.

ASite4 (Padra): These fields are spread in an area of 3.23 hectares and are located 15 kms. from Vadodara city. The main crops are Cotton, Pigeon pea, Cabbage, Spinach, Raddish and Brinjal. The soil is yellow sandy loam.

Urban Ecosystems

Urban ecosystem was categorized into Urban Residential Sites (URSites), Urban Community Garden Sites (USites) and Urban Fragmented Habitats (UFSites) (Table 2 and Tables 4a,4b and 4c)

Urban Residential Sites (URSites)

Samples have been collected from all regions of urban habitats like vegetable markets, roadsides, homes, offices, domestic gardens, pavements, construction sites etc.

The following sites were selected for this study:

URSite1 (Sama Road): This area is one of the most upcoming and happening place of Vadodara . Due to the presence of some prestigious schools in this location, residential complexes have burgeoned overnight. Expanding population and large scale construction and has made this place a crowded and chaotic area of the city.

URSite2 (Gotri Road): Located at the western end of the city this is another busy commercial and residential center. Gotri Road is gearing up to be the latest suburb of Vadodara. With a lot of development work underway, it holds an edge over upcoming residence zones around the city.

URSite3 (Manjalpur) : This busy area of the city has dense vegetation. Shopping complexes and malls can be seen mushrooming here like every other residential area of the city.

URSite4 (Subhanpura): This is a highly populated area with dusty traffic congested roads. This area has seen a lot of construction in the last few years and hence has sparse vegetation cover. Effects of urbanisation are most pronounced in this part of Vadodara city.

Three houses at random were selected from each area. Baits were placed inside and outside these houses and hand collection was done according to the sampling schedule (described under Sampling methods for urban ecosystems)

Urban Community Garden Sites (USites)

Gardens in Vadodara have been set up for recreation and are open for general public. The gardens are lush green throughout the year. These gardens have several flowering plants. The flower shows during winter time are major attractions for locals and tourists. Hundreds of flower species are on display

during these shows. The garden has also large number of tree species including *Ficus bengalensis* which is found all over Vadodara (and the city is named after this tree).

The studies were carried out in the following gardens:

USite1 (Sayaji Baug): An extensive park spread in an area of 113 acres. It has a rich flora of more than 98 species of trees. Palm, Asopalav, Mango, Eucalyptus, Bamboo trees and such various avenues are all planned by horticulturists. This garden has a zoo, a museum, picture gallery and a small health centre. Soil type is deep black as well as yellow sandy loam.

USite2 (Sardar Baug): The Sardar Baug has well maintained lawns, play area, swimming pool and a much loved spot for children and evening-walkers.

USite3 (Lal Baug): This garden with its colorful plants, cool breeze and the adjoining play park is a popular picnic spot in the city. It is the second most popular garden of the city. The area covered is 9.31 acres .The soil type is of yellow sandy loam soil. It is the second most popular garden of the city. Lal Baug garden attracts large number of tourists as well as local people.

USite4 (Akota Garden): This garden possess beautiful lawns, flower beds growing with numerous imported and acclimatized annuals, hundreds of large and small trees, shrubs, ornamental plants etc. and is popular amongst evening-walkers.

Urban Fragmented Habitats (UFSites)

Fragmented habitats according to the classic view are large intact areas of a single vegetation type into smaller intact units (Lord and Norton,1990). Usually, the ecological effects are considered negative (Crist and Wiens,1994). However the purpose of including fragmented habitats in this study is to explore the possibility of them being able to support more species than the other urban areas like community gardens and residential areas. This is because of undisturbed patches of land with native vegetation are present among the concrete structures and human inhabited fragments. Two such fragmented habitats are:

UFSite1 (The M.S. University of Baroda Campus): This jewel in Vadodara's crown is conspicuous in being the only university in Gujarat with English as the medium of instruction. It has 13 faculties and 17 residential hostels, 4 of them for women students. The university caters to over 100,000 students, with various courses on offer, ranging from Medicine to Commerce. The university has been divided into several departments. The campus is full of huge gardens with innumerable varieties of flora and fauna. There is a cricket ground and an auditorium. The underbridge area (Bhookhi Nala) behind the Zoology Department Animal House has dense vegetation in an undisturbed setting. Large Banyan trees mark the area with their splendor.

UFSite2 (Laxmivilas Palace): Built in the Indo-Sarcemic style of architecture by Maharaja SayajiRao III in 1878 AD at a cost of about 6 million as his residence, Laxmivilas Palace is the most magnificent site. The Royal Family's residence is an extravagant building. This area is characterized by large manicured lawns around the palace building on one hand and undisturbed forest fragments on the other.

Figure 1. Map of Study Sites

Sampling Techniques

Ants are abundant, easy to collect but are variably and non-randomly distributed (Agosti, 2000). Study and sampling of ants is done considering them both as populations of individual foragers or as populations of colonies; because individual ants finally aggregate into colonies that are dispersed across the landscape.

Studies based on foragers often focus on the ecological or functional relationships to the environment (Andersen, 1991). On the other hand colony based studies emphasize on population structure (Herbers and Grieco, 1994). As this study is a combination of ecological relationships and population structure, it incorporates both - study of individual foragers as well as ant colonies.

Hence, in this study, choice of sampling methods and assessment techniques had to be decided keeping in mind the following facts:

1. There is variation between abundance of foragers and colonies between different species of ants.
2. The foragers of highly active ant species may cover large foraging distances and therefore are sampled more frequently than other sedentary species that forage near their colony.
3. The sampling probabilities will also depend upon diversity of behaviour and habitat selection between species for e.g. arboreal ants are seldom found in the leaf litter.
4. Different ants occupy different microhabitats, they may be litter-dwelling, ground dwelling or arboreal.

Since this piece of work has two major objectives- to compare ant communities and to prepare a species inventory (to record as many species as possible from a study site), a combination of sampling methods and assessment techniques has been used.

.Sampling methods can be broadly classified into two categories- Passive sampling and Active sampling .While Passive sampling includes pitfall trapping, baiting and quadrat sampling methods, Active sampling involves direct colony count, and intensive search to seek out ants over the study area (Agosti, 2000).

For fulfilling the first objective of this study, Passive sampling was done and for the second objective, Active sampling was resorted to.

Pitfall trapping

Pitfall trapping is a frequently used method in studies of distribution of ground dwelling insects (Majer, 1983).

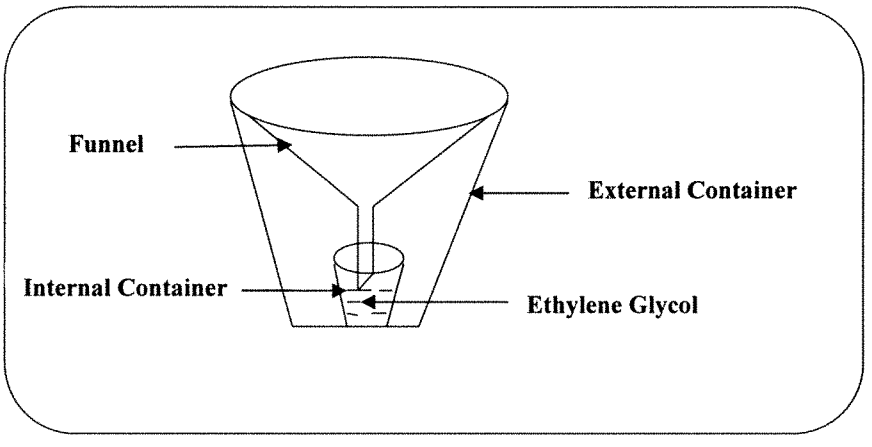
The pitfall trap used in this study consisted of a 250 ml polycarbonate sampling container with 48mm opening diameter. The opening was covered with a funnel, the stem of the funnel opened into a smaller container filled with 50 ml of 20% ethylene glycol or in some cases ethanol, with a few drops of glycerine added to it. Ethanol serves as a killing agent while glycerol retards evaporation. Traps with an opening diameter 42 mm or larger are more efficient at trapping samples of ant fauna (Abensperg-Traun and Steven, 1995) hence the diameter of the traps was 45mm. (Line Diagram 1)

Pitfall traps were sunk into the soil so that the container opening was level with the ground surface. The pitfall traps were placed such that they were spread evenly on the study area. Spreading the sampling effort is useful, as the same patch may reveal very different parts of the same ant fauna (Agosti, 2000).The pitfall traps were collected in a 24 hour period. The solution in the internal container was replaced and the pitfall left there for another round of sampling (Figure 2)

Pitfall traps have their limitations; they collect only surface ants they are believed not to provide an adequate sample of most leaf litter ants (Majer, 1996).Sometimes ant species show deliberate avoidance of pitfall traps (Marsh, 1984) and hence are not collected by this method.

The details of pitfall trapping employed with respect to the study sites and the species captured are described in Chapter 4: Ant Community Composition and Structure.

Line Diagram 1: Pitfall Trap Design



Baiting

Baiting uses food substances like peanut butter, honey, tuna fish, sugar syrup etc. to attract foraging ants where they may be observed or collected (Agosti, 2000). The abundance of ant foragers at baits helps to measure ecological and behavioural dominance and provides a general measurement of ant foraging efficiency (Greenslade and Greenslade, 1971).

The advantage of baiting is that baits can be set in different microhabitats and provide information on habitat use, biotic interactions and activity patterns on very fine scales (Bestelmeyer *et al., 2000*).

In this study peanut butter and sugar solution were used as baits. Baiting was done in two ways: Peanut sugar baits were placed in beverage straws 0.5 cm in diameter and 2 cm long or on paper platforms as the bait on the paper is likely to attract more dominant ant species and the oil around and under the paper attracts the smaller and less aggressive species.

Sugar solution and also peanut butter was used in the baits hung on trees and shrubs in the urban study sites (Figure 3).Peanut butter baits were especially effective in luring major workers of *Pheidole* spp. out of their nests in the ground. These baits were made of plastic cups with two holes in the rim through which a string is passed. This string was tied around the branches. The baits were collected after 90 minutes. The baits were then quickly placed in a plastic tub and then the ants removed with help of forceps from the tub. Petroleum jelly was pasted on the walls of the tub to prevent the fast moving ants from escaping. The ants were then transferred to ethanol filled vials.

Although baiting is a very simple and inexpensive technique employed for ant collection (Lattke, 2000), it has two major limitations. First, only generalist species are likely to visit baits as those species that have a particular food preference e.g. Specialist predators may not visit artificial baits. Second, as activity of different ant species varies with climate, time of the day and area, baits placed in specific time period and a specific area will attract same species and will hence result in repeated collections.

The details of Baiting method employed with respect to the study sites and the species captured are described in Chapter 4: Ant Community Composition and Structure (Materials and Methods).

Hand Collection Method

Hand sampling involves searching for and collecting ants in different microhabitats within an area .This method fulfils the objective of recording the number of species inhabiting the area and also for creating a species inventory.

In this method foraging workers were picked up randomly as they were found. The ants collected thus were placed into vials of 75-95% ethanol. At least 20-30 individuals and all castes that are seen were collected in pre-filled vials of ethanol so that individuals keeping different colonies were kept.

The ants were placed into the vials with fingertips, forceps, a small-tipped paint brush, or other means. For large ants like those of genus *Camponotus*, the best way was to pick them up with forceps. For smaller species it was much easier to pick them up with the moistened tip of forceps or a brush (Figure 4)

Ants were searched in hollow twigs, grasses, galls, acorn, seedpods, or other cavities. This proved to be an effective way as minimum material with a lot of experience with ants was required. Galls and nuts were also collected in the field and opened later in the lab.

The details of Hand Collection method employed with respect to the study sites and the species captured are described in Chapter 4: Ant Community Composition and Structure (Materials and Methods).

Sweepnet method

Sweeping vegetation is an easy and effective way to collect some species of ants. In this method an insect net was swept back and forth once right to left and then left to right through the vegetation and the catch checked periodically. Ants were then collected from the net by hand. This was repeated after every half an hour. Sweepnet method was carried out specifically on garden hedges and the shrubs in the periphery of the agricultural fields. This method helped in collecting those ants which were actively exploiting plant food like Camponotus *compressus* tending homopterans, *Monomorium* sp.and *Camponotus sericeus* sucking nectar from extrafloral nectarines etc.

This method was only employed to collect ants for taxonomical purposes (Species inventory) and is hence not described anywhere later.

Soil Litter Sampling

Many ants are minute and would go unnoticed if litter samples were not collected. Typically, litter samples are made in forested areas where leaves may accumulate and decay layer by layer over a series of years.

Though soil and litter sampling is a more effective method in forest areas (Agosti, 2000), it can also be done in fallow agricultural fields or patches of unattended land. In this study, areas of thick accumulations of litter, such as the bases of large trees and rotting logs on the ground, yielded ants through soil litter sampling. In this method soil was spread out in a thin layer in a shallow pan and ants were visually sighted and pulled out with forceps or fingers.

This method was only employed to collect ants for taxonomical purposes (Species inventory) and is hence not described anywhere later.

Each of the sampling techniques used in this study was useful for fulfilment of specific research objective. Since all techniques have their limitations, a combination of all techniques was used in this study. This combination has ensured comparability of samples and a more or less complete representation of the ant fauna of Vadodara.

Specimen Processing

Ants collected from the fields need to be carefully preserved and prepared for identification in the laboratory.

The first step was removal of ant specimens from a mix of soil, debris, leaves and other organisms. For this salt water extraction method recommended by Lattke (2000) was used. A saturated salt solution was prepared by adding salt to hot water (not boiling) and adding salt till no more salt would dissolve. Then the vials with ants were emptied into a graduated cylinder and the alcohol drained off. Then saline water was added to the sample and the cylinder turned upside down a few times. The dirt and inorganic matter sunk while ants with other organic matter floated on the top. This was allowed to settle for 15 minutes and then decanted onto a metal strainer and then rinsed with alcohol. This process was repeated 2-3 times and then the material was placed on a petridish with alcohol. Then ant specimens were sorted from other organic material and were then placed in individual vials filled with alcohol.

Identification

Ants collected by various sampling methods were separated from other organisms. The alcohol ant samples were subsequently pre-sorted to genus level under a dissecting microscope and then mounted on cardboard pins, following the convention of Bolton (1994). Genus identification was checked again on the mounted specimen using the keys of Bolton (1994) and Bingham (1903). Finally morphospecies were designated based on external morphological characters of the worker class using stereomicroscope Leica MPS 60 ø 28/8x/MPS.

Photography

Photography has been taken by SONY DIGICAM DSC H2 version 6 megapixel resolution, 12x zoom. Mostly ants are photographed live as the pictures of live ants generate more interest, which, to some extent, fulfil one of the subtle objectives of this research.

Statistical Analysis

Statistical Analysis of data obtained over the four year study period is applicable only to Chapter 4- Ant Community Structure and Composition and is being described in detail in Materials and methods of that chapter.

Environmental Parameters

Temperature

Ants as well as other arthropods (spiders, crabs, lobsters, centipedes, etc.) are ectotherms. The body temperature of ants changes in response to the atmospheric temperature. In winter, their body temperature falls so greatly that their movements inevitably grow sluggish and eventually become dormant if the temperature gets low enough i.e. they hibernate restlessly in relatively warm places, such as the soil or under the bark of trees.

Temperature variations have been negligible in the four years of the study period (Table 5).

In 2005, the Average Maximum Temperature ranged from 40.2 ^{0}C to 27.4 ^{0}C in Phase I and 36.1 ^{0}C to 31.1 ^{0}C in Phase II of the Sampling Period. The Average Minimum Temperature ranged from 13.1 ^{0}C to 23.1 ^{0}C in Phase I and 29.2 ^{0}C to 30.4 ^{0}C in Phase II of the Sampling Period.

In 2006, the Average Maximum Temperature ranged from 38.9 ^{0}C to 30 ^{0}C in Phase I and 31 ^{0}C to 39.5 ^{0}C in Phase II of the Sampling Period. The Average Minimum Temperature ranged from 21 ^{0}C to 31.3 ^{0}C in Phase I and 23.5 ^{0}C to 35.7 ^{0}C in Phase II of the Sampling Period.

In 2007, the Average Maximum Temperature ranged from 40.4 0C to 29.4 ^{0}C in Phase I and 26.3 ^{0}C to 33 ^{0}C in Phase II of the Sampling Period. The Average Minimum Temperature ranged from 17.5 ^{0}C to 24.2 ^{0}C in Phase I and 18.1 ^{0}C to 23.9 ^{0}C in Phase II of the Sampling Period.

In 2008, the Average Maximum Temperature ranged from 38.4 ^{0}C to 28.2 ^{0}C in Phase I and 36.6 ^{0}C to 31.1 ^{0}C in Phase II of the Sampling Period. The Average Minimum Temperature ranged from 12.7 ^{0}C to 24.5 ^{0}C in Phase I and 18 ^{0}C to 23.5 ^{0}C in Phase II of the Sampling Period.

Studies report that high soil temperatures negatively influence the foraging behavior of a number of ant species (Ruano *et al.,* 2000). A study on invasive ant of Argentina *Linepithema humile* by Walters and Macay (2004), has shown that Argentine ants show lowered survival at heightened temperatures. This leads to bear upon their foraging success, forcing them to alter their foraging strategies so that they increase foraging activity during cooler seasons of the year or times of the day.

Under natural conditions, ants may alter their foraging behavior and nest structure in response to changes in temperature conditions, thus avoiding the negative effects associated with high temperature. In response to temperature

variations, many species change their foraging strategies from collective to individual (Crist and Macmahon, 1991). But it cannot be proved though, because many abiotic conditions interact, it is possible that the interaction between temperature and some other abiotic factor or factors are more limiting to the ants than temperature alone. Moreover, different populations of ants may display varying temperature tolerances and some populations experience plastic responses to changed temperature conditions.

As the temperature gives no clear indication of its effect on ant population barring the fact that fewer ants were seen during the study period of summer months, these hot summer months of May and June were excluded from the sampling period. The reason was that less ant species were encountered during these months and field visits were difficult to make during such hot summer.

Humidity

Materials besides soil which hold moisture provide more nesting incentives to ants. Ants of certain genera like *Lasius* and *Pheidole* have been reported to be found in nests occurring in moist areas of urban residential sites like around windows that sweat, gutters that leak, pin hole leaks in plumbing lines, leaky bathrooms shower enclosures, and even under roofing materials if moisture is consistently present.

The average relative humidity at 8.30 hrs. and 17.30 hrs. of the four year study period is given in Table 5.

Soil

Ants rely on the soil system for both food acquisition and development thus soils are considered one of, if not the most, important habitats for ants.

Soil texture plays an important role in the filtration of water, aeration and penetration capacity of plant roots. Texture also alters the workability of the soil and impacts the suitability of soils as habitat for a number of arthropod and vertebrate species. Soil texture is characterized by the quantities on sand, loam and clay present. The soil of Vadodara is primarily loam.

Table 1. Description of Agricultural Sites

Site Code	Site Name	Distance / Direction from Vadodara	Soil Type
ASite1	Timbi	11 Kms / Southeast	Yellow sandy loam
ASite2	Savli	25 Kms./ Northwest	Yellow sandy loam
ASite3	Waghodia	24 Kms / Northwest	Medium black
ASite4	Padra	15 Kms / Southeast	Yellow sandy loam

Table 2. Description of Urban Sites

Site Code	Site Name	Distance / Direction from Vadodara	Soil Type
URSite 1	Sama Road	4.2 km / Northwest	Yellow sandy loam
URSite 2	Gotri Road	5 km./ East	Yellow sandy loam
URSite 3	Manjalpur	4.9 km / Southeast	Deep black
URSite 4	Subhanpura	4.2 km / Northwest	Yellow sandy loam
USite1	Sayaji Baug	2.5 km / Northwest	Deep black , yellow sandy loam
USite2	Sardar Baug	3 km / Northwest	Yellow sandy loam
USite3	Lal Baug	5.1 km / Southeast	Yellow sandy loam
USite4	Akota Garden	3.1 km / Northwest	Yellow sandy loam
UFSite1	The M.S.University of Baroda	0.5 km / Southeast	Yellow sandy loam
UFSite2	Laxmivilas Palace compound	3.2 km / Southeast	Deep black

Source : Municipal Corporation Of Vadodara, Park and Garden Department,Sayajibaug.

Table 3. Flora of Agricultural Sites

Site Code	Site Name	Flora
ASite1	Timbi	Crop plants: Paddy (*Oryza sativa*), Cotton (*Gossypium Sp.*) ,Castor(*Ricinus communis*), pigeon pea(Cajanus cajan).
ASite2	Savli	Crop plants: Castor (*Ricinus communis*), Cotton (*Gossypium sp.*).
ASite3	Waghodia	Crop plants : Cabbage(*Brassica olerasea var.campestris*) , Castor (*Ricinus communis*), Spinach(*Spinacia olerecea*), Raddish(*Raphanus sativus)*,Paddy (*Oryza sativa*),Pigeon pea(*Cajanus cajan*).
ASite4	Padra	Crop plants : Cabbage (*Brassica olerasea var.campestris*), Castor (*Ricinus communis*). Spinach(*Spinacia olerecea*), Raddish(*Raphanus sativus*),Paddy (*Oryza sativa*),Pigeon pea(*Cajanus cajan*).
Common in all fields		Big trees: *Azadirachta indica, Mangifera indica ,Glycine abrus, Tamarindus indicus, Moringa oleifera* Hedges: *Euphorbia neriifolia, E.tirucalli, Capparis decidua, C.zeylacnica, Lawsonia inermis, Annona squamosa, Clerodendrum inermis, Zizyphus mauritiana, Z.oenoplia, Caeselpenia crista, Calotropis procera, Capparis cepiaria, Salvadora persica, Opuntia elatior, Ipomea obscura, Coccinea cordifolia,Tinospora cordifolia.* Weeds: *Melochia corchorifolia, Ammania baccifera, Jussiaea perennis, Eclipta prostrate, Oryza rufipogon, Portulaca oleracea, Sida alba, Solanum nigrum, Boerhavia diffusa, Amaranthus spinosus, Chenopodium album, Cuscuta chinensis, Setaria tomentosa, Euphorbia geniculata.*

Source: Sabnis S.B (1967) and Dave Mona (2002)

Table 4a. Flora of Urban Residential Habitats

Site Code	Site Name	Flora
URSite1	Sama Road	Trees: *Mangifera indica ,Polyalthia longifolia , Livistona chinensis, Murrya koengii , Azadirechta indica, Moringa oleifera ,Pithecellobium dulce, Terminalia catappa , Cocos nucifera , Achras zapota , Ficus glomerata, Tecoma stan, Ficus bengalensis.* Herbs,Shrubs,Creepers :*Rosa chinensis,Lawsonia inermis, Ixora coccinea ,I.arborea, Vinca rosea , Nerium oleander , Calotropis procera, Ocimum sanctum, Caeselpinia crista, Bryophyllum calycinum , Datura fastuosa , Bignonia stans, Nyctanthes arbortristis, Chrysanthemum sp. ,Clerodendrum splendens , Mirabilis jalapa,Jasminum sambac, etc.*
URSite2	Gotri Road	Trees:, *Polyalthia longifolia , Ficus religiosa,* Azadirachta *indica,* Herbs, Shrubs, Creepers: *Rosa chinensis, I.arborea. Euphorbia neriifolia, Ocimum sanctum ,Vinca rosea, Nerium oleander, Jasminum sambac , Datura fastuosa , Bignonia stans, Calotropis procera, ,Euphorbia neriifolia, Aloe vera , Andropogon annulatus ,A.martinii ,Thevetia peruviana , Caeselpinia crista etc*
URSite3	Manjalpur	Trees: *Mangifera indica ,Polyalthia longifolia , Azadirechta indica,etc. ,Pithecellobium dulce, Cocos nucifera , Achras zapota , Ficus glomerata, Tecoma stans, Ficus benghalensis.* Herbs,Shrubs,Creepers :*Rosa chinensis,Lawsonia inermis, ,I.arborea, Vinca rosea , Nerium oleander , Calotropis procera, Ocimum sanctum , Quisqualis indica , Caeselpinia crista, , etc.*
URSite4	Subhanpura	Trees:, *Polyalthia longifolia , Azadirachta indica,* Herbs, Shrubs, Creepers : *Ixora,. Euphorbia neriifolia, Ocimum sanctum ,Vinca rosea, Zizyphus jujube, Nerium oleander, Jasminum sambac , Andropogon annulatus ,A.martinii ,Thevetia peruviana, Quisqualis indica, Pyrostegia, Caeselpinia crista, Achyranthes aspera var porphyristachya,etc*

Source: Sabnis S.B (1967) and Dave Mona (2002)

Table 4b. Flora of Urban Fragmented Habitats

Site Code	Site Name	Flora
UFSite1	The M.S.University of Baroda	Trees: *Pithecellobium dulce, Ficus benghalensis, Santalum album,Couroupita guianensis, Polyalthia longifolia, Saraca indica ,Plumeria kubra, Caryota urens,Cassia fistula,Delonix regia* Herbs,Shrubs,Creepers:*Canna indica,Nerium odorum, Tecoma stans, Papavera somniferum, Calendula officinalis, Dianthus, Cosmos, Gaillardia aristata, Caryophyllus, Gerbera, Phlox paniculata, P drumondi, Hibiscus populineus, H.syriacus, Michelia champaca., Annona uncinat.,A. sqamosa, A.reticulata,Reseda odorata, portulaca oleracea, Canna species, Viola odorata,Tamarix gallica, cynodon dactylon,Nicotiana plumbaginifolia ,Calotropis gigantia, C.procera, Crotalaria juncea, C.medicagenea, Argemone mexicana,etc.* Aquatic plants : *Nymphea stellata,Trapa species,Utricularia stellaris,Hydrilla verticillata,Typha augustata,Vallisnaria spiralis.*
UFSite2	LaxmiVilas Palace Compound	Trees: *Casuarinas, Tamarindus indicus,* Azadirachta *indica ,Aegle mermelos ,Feronia Lemonia ,Zizyphus jujube.,Butea monosperma,Pongamia pinnata , Pithecelobium dulce ,.Borasus flabellifer,Delonix regia , Morus alba etc* Herbs,Shrubs,Creepers *Tridax procumbens, Commelina nudiflora, Sida acuta, Agave, ,Cassia species, Abutilon indicum, Cymbopogon martini, Urena lobata, Brassica nigra ,Cassia siamea , Acacia nilotica ,Hyphaena indica, Cuscuta species, Sesbania aculeata*,etc

Source : Sabnis S.B (1967) and Dave Mona (2002)

Table 4c. Flora of Urban Community Gardens

Site Code	Site Name	Flora
USite1	Sayaji Baug	Trees: *Ficus bengalensis, Azadirachta indica, Terminalia catappa, Feronia limonia , Aegle marmelos , Butea monosperma , Casuarina equisetifolia, Tamarindus indicus, Dalbergia latifolia ,Mangifera indica, Syzygium cumin., Tabebuia spectabilis* Herbs,Shrubs,Creepers*: Caeselpenia pulcherrima, Commelina nudiflora, Tephrosia purpurea, Hibiscus lobatus, Abutilon indicum, Bougainvillea spectabilis, Ixora, Coccinea ,Tephrosia strigosa, Andropogon annulatus (common grass) ,Zomia gibbosa,Vinca rosea , Rosa chinensis, Lantana camara, Canna indica, Nerium odorum, Oxalis corniculata, Giaillardia pinnatifida,G.aristata,etc.*
USite2	Sardar Baug	Herbs,Shrubs,Creepers: *Canna indica, ,Tecoma stans, Ixora , Hibiscus , Cymbopogon martini , Cynodon dactylon, Helianthus annus, Rosa chinensis, Lantana camara*
USite3	Lal Baug	Trees: *Butea monosperma.* Herbs,Shrubs,Creepers: *Canna indica, Nerium odorum, Tecoma stans, Ixora rubiacea, Hibiscus syriacus ,Ipomea palmate, Cymbopogon martini,Cynodon dactylon, Helianthus annus, Rosa chinensis.* Aquatic plants :*Hydrilla verticillata, Typha augustata, Vallisnaria spiralis.*
USite4	Akota Garden	Trees: *Casuarina equisetifolia , Butea monosperma ,* Herbs,Shrubs,Creepers:*Canna indica, Nerium odorum, Tecoma stans, , Hibiscus , Oxalis corniculata, Cynodon dactylon, Helianthus annus, Lantana camara Vinca rosea Giaillardia pinnatifida, G.aristata,etc.*
Common in all gardens		Trees: *Polyalthia longifolia, Saraca indica, ,Oreodoxa regia, Cassia tora*

Source: Sabnis S.B (1967) and Dave Mona (2002)

Table 5. Meteorological Data for the Sampling Periods

Year 2005	Phase 1 (Jan-Apr)	Average Maximum Temp.^{0}C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average Rainfall mm	Phase 2 (Sept-Dec)	Average Maximum Temp.^{0}C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average. Rainfall mm
				at 8.30 hrs	at 17.30 hrs					at 8.30 hrs	at 17.30 hrs	
Sampling Period 1	1 Jan - 31 Jan	27.4	13.1	59	35	0	1 Sept - 30 Sept	31.1	29.2	39.6	45.3	29.4
Sampling Period 2	1 Feb - 28 Feb	30.1	15.8	59.6	45.3	0	1 Oct - 31 Oct	35.9	28.8	37.2	36.5	0
Sampling Period 3	1 Mar - 31 Mar	36	21	55	29.3	0	1 Nov - 30 Nov.	36.1	33.2	33.9	33.5	0
Sampling Period 4	1 Apr - 30 Apr	40.2	23.1	47.3	36.3	0	1 Dec - 31 Dec	33	30.4	31.6	31.8	0

Year 2006	Phase 1 (Jan-Apr)	Average Maximum Temp.^{0}C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average Rainfall mm	Phase 2 (Sept-Dec)	Average Maximum Temp.^{0}C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average. Rainfall mm
				at 8.30 hrs	at 17.30 hrs					at 8.30 hrs	at 17.30 hrs	
Sampling Period 1	1 Jan - 31 Jan	30	21	27.9	29.2	0	1 Sept - 30 Sept	49.6	35.7	53.5	55.2	54.3
Sampling Period 2	1 Feb - 28 Feb	30.7	28.4	29.4	29.1	0	1 Oct - 31 Oct	35.9	29.6	40.1	41.6	0
Sampling Period 3	1 Mar - 31 Mar	35.9	27.4	29.3	28.5	0	1 Nov - 30 Nov.	39.5	35.1	37.1	37.3	0
Sampling Period 4	1 Apr - 30 Apr	38.9	31.3	33.8	31.5	0	1 Dec - 31 Dec	31	23.5	32.4	35.5	0

Year 2007	Phase 1 (Jan-Apr)	Average Maximum Temp.^{0}C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average Rainfall mm	Phase 2 (Sept-Dec)	Average Maximum Temp.^{0}C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average. Rainfall mm
				at 8.30 hrs	at 17.30 hrs					at 8.30 hrs	at 17.30 hrs	
Sampling Period 1	1 Jan - 31 Jan	29.4	21.3	28.9	31	0	1 Sept - 30 Sept	33	25.1	75.8	70.3	25.4
Sampling Period 2	1 Feb - 28 Feb	33.1	17.5	45.1	34.2	0	1 Oct - 31 Oct	34.6	21.8	49	36	0
Sampling Period 3	1 Mar - 31 Mar	36.1	19.1	36.1	25.7	0	1 Nov - 30 Nov.	33.1	18.1	45.3	35.2	0
Sampling Period 4	1 Apr - 30 Apr	40.4	24.2	36	31	0	1 Dec - 31 Dec	26.3	23.9	43.4	39.5	0

Year 2008	Phase 1 (Jan-Apr)	Average Maximum Temp.0C	Average Minimum Temp.0C	Average Relative Humidity %		Average Rainfall mm	Phase 2 (Sept-Dec)	Average Maximum Temp.0C	Average Minimum Temp.^{0}C	Average Relative Humidity %		Average. Rainfall mm
				at 8.30 hrs	at 17.30 hrs					at 8.30 hrs	at 17.30 hrs	
Sampling Period 1	1 Jan - 31 Jan	28.2	13.5	42.6	36.5	0	1 Sept - 30 Sept	31.6	25.3	76	68	24.16
Sampling Period 2	1 Feb - 28 Feb	30	12.7	37.3	29.8	0	1 Oct - 31 Oct	36.6	23.6	52.6	41.8	2
Sampling Period 3	1 Mar - 31 Mar	36.5	20	36.3	28.6	0	1 Nov - 30 Nov.	32.4	18.6	40.1	35.6	
Sampling Period 4	1 Apr - 30 Apr	38.4	24.5	36.9	28.8	0	1 Dec - 31 Dec	31.1	18	35	32	

Source: Department of Physics, The M.S.University Of Baroda, Vadodara, GUJARAT

Figure 2. Pitfall Trap

Figure 3. Bait

Figure 4. Hand Collection