2.

Materials & Methods

CHAPTER II

2. MATERIALS AND METHODS

2.1 State of Gujarat- An Overview

Gujarat state is situated on the western coast of India located on the Tropic of Cancer,. Gujarat bears the country's longest coastline of more than 1600 kms. Gujarat is located at 20° 02' N- 24° 39' N latitude and 68° 10' E- 74° 37' E longitude. The state is bounded by the Arabian Sea in the west and surrounded by the states of Rajasthan, Madhya Pradesh and Maharashtra on the North, East and South directions respectively. Parts of mountain ranges extends in Gujarat namely- The Satpura and Vindhya hills occupy parts of the eastern belts, the southern tip of Aravali mountain range extends into Northern Gujarat and the Sahyadri range i.e. Western Ghats reaches over to the Dangs (Desai, 2011).

Climate

Gujarat observes sub-tropical climate with temperature range of 35- 45° C. This state experiences moderate rainfall. Based on climatic variations Gujarat is divided into different regions namely- Sub-humid; moderately humid; humid and sultry; dry and arid and semi-arid regions (Merh, 1995).

Seasons observed throughout the year in Gujarat are: Monsoon- Middle of June to middle of October; Winter- November to February, and Summer- March to June. Gujarat receives Southwest monsoon rainfall between June to September. The southernmost part of Gujarat receives an annual rainfall of 2000 mm. This gradually decreases northward and the extreme northwest observes an annual rainfall of as low as 300mm. Gujarat state experiences low relative humidity whereas the coastal areas it's moderately high. Moreover, intensity of the winds increases during late summer and monsoon seasons and

light to moderate in the rest. This State receives winds blowing from West to Southwest during monsoon months and Northeast to Northwest from October to April.

Water Resources

Water resources in Gujarat have been divided into 2 different sets- Rivers of North-western part of Gujarat and rivers of Central and Southern parts drain in Gulf of Khambhat and Arabian Sea. Arising from the Aravalli range, rivers like Rupen, Saraswati and Banas fall into Rann of Kutch. These rivers form the major portions of Northwestern part of Gujarat. Major rivers of Central and Southern part of Gujarat are Tapi, Narmada, Mahi and Sabarmati. Later, these major rivers flow in form of their tributaries that covers the remaining part of Gujarat in form of important water resources.

Soil Condition

Diverse Gujarat represents various types of soil. Sandy clay, loam or clay loam to clay soil forms characteristic type of soil of Saurashtra, North Gujarat and parts of Kachchh. Parts of Sabarkantha, Panchmahals, Ahmedabad, Mehsana, Banaskantha Central Gujarat and coastal plains have the presence of silty- loamy to clay soil. Whereas places like Bharuch, Surat and Valsad of South Gujarat, Mehsana and parts of Ahmedabad, Kheda and Vadodara districts and Bhal and Ghed parts of Saurashtra possess Regur soil also known as the Black Cotton Soil. Lastly, some parts of Kachchh, North Gujarat and Central Gujarat holds sandy to sandy loam with silty clay –loam with few patches of salty soil.

2.2 Study Area

The present research work was carried out for a period of 3 years i.e. 2011 -2014. Five different fragmented habitats were selected from different districts of Gujarat for the rhopaloceran study namely- Urban residential, Agricultural landscape, Industrial Vicinity, Botanical Garden and Hill Station. Major fragmented habitats along with the sub-habitats are depicted in form of flowchart in Figure 7

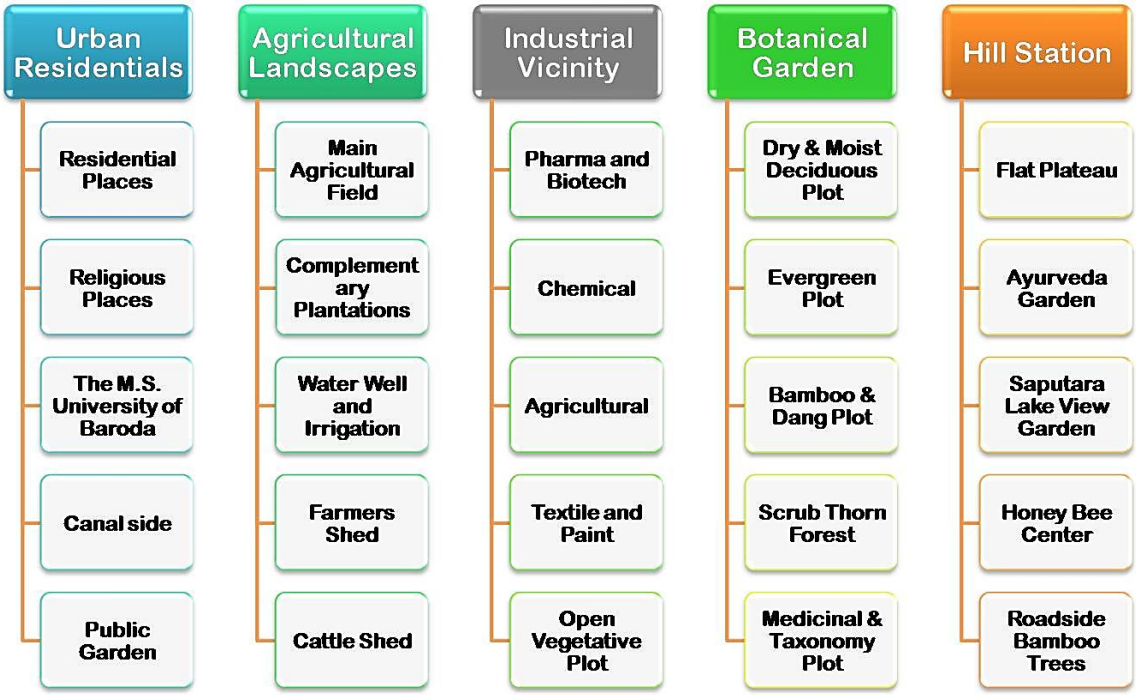

Figure 7: Categorization of selected fragmented habitats

The major fragmented habitats were selected based on the factors that affect the diversity of butterflies either positively or negatively:

1. Urban residential: Impact of urbanization of butterfly diversity

2. Agricultural Landscapes: Impact of pesticide application and positive involvement of complementary plantations on butterfly diversity

3. Industrial Vicinity: Impact of industrialization in the form of release from the oil fields and pharma companies on butterfly diversity

4. Botanical Garden: Positive approach of the green cover in form of medicinal plots and other mixed plots influencing the butterfly diversity

5. Hill Station: Influence of tourists activity along with the natural maintenance of flat plateau and other sub-habitats on butterfly diversity

2.2.1 Urban residential

Vadodara is located at 22.30°N 73.19°E in western India at an elevation of 39 metres (128 ft) on the banks of the Vishwamitri river, southeast of Ahmedabad. The railway line and NH 8 that connect Delhi and Mumbai pass through Vadodara. It is the 18th largest city in India with an area of 235 square kilometres and a population of 2.1 million according to the 2010–11 censuses. The Vishwamitri frequently dries up in the summer, leaving only a small stream of water. The city is situated on the fertile plain between the Mahi and Narmada Rivers. Vadodara is known as Banyan city owing to the presence of large number of Banyan trees *Ficus benghalensis*.

Vadodara features a tropical savanna climate under Köppen's Climate classification. There are three main seasons: Summer, Monsoon and Winter. Aside from the monsoon season, the climate is dry. The weather is hot through the months of March to July – the average summer maximum is 40 °C, and the average minimum is 23 °C. From November to February, the average maximum temperature is 30 °C, the average minimum is 15 °C, and the climate is extremely dry. Cold northerly winds are responsible for a mild chill in January. The southwest monsoon brings a humid climate from mid-June to mid-September. The average rainfall is 93 cm, but infrequent heavy torrential rains cause the river to flood.

Vadodara enjoys a special place in the state of Gujarat. Until the early 1960s Vadodara was considered to be a cultural and educational centre. It is divided by the Vishwamitri into two physically distinct eastern and western regions. The eastern bank of the river houses the old city, which includes the old fortified city of Vadodara. This part of Vadodara is characterised by packed bazaars and numerous places of worship. The colonial period saw the expansion of the city on the western side of Vishwamitri. This part of the city houses educational institutions such as The Maharaja Sayajirao University of Baroda (M.S.U.), the Vadodara Railway Station, modern buildings, well-planned residential areas, shopping malls, multiplexes and new business districts. A total of 77 public gardens were developed in different zones of Vadodara and since last decade, the city exhibited a remarkable augmentation of urban population and establishments of high-

tech residential schemes, express highways and fly-overs. Such heavy infrastructures hereby ruin the natural plant spread.

Table 3: List of plant resources utilized by butterflies in urban residential of Vadodara

Sr. No	Family	Botanical Name	Local Name
1	Annonaceae	*Annona squamosa* L.	Sugar Apple
2	Apocynaceae	*Alstonia scholaris* L. R. Br.	Indian Devil Tree
3	Apocynaceae	*Nerium oleander* L.	Oleander
4	Apocynaceae	*Vinca rosea* L.	Periwinkle
5	Apocynaceae	*Calotropis gigantea* L. R. Br.	Milkweed
6	Asteraceae	*Tridax procumbens* L.	Coat buttons
7	Euphorbiaceae	*Jatropha integerrima* Jacq.	Peregrina / Fire cracker
8	Fabaceae	*Cassia fistula* L.	Golden shower tree
9	Fabaceae	*Peltophorum pterocarpum* (DC.) K. Heyne.	Yellow Flame Tree
10	Fabaceae	*Albizia saman* F. Muell.	Rain Tree
11	Meliaceae	*Azadirachta indica* A. Juss.	Neem Tree
12	Moraceae	*Ficus bengalensis* L.	Banyan tree
13	Moraceae	*Ficus religiosa* L.	Peepal Tree
14	Nyctaginaceae	*Bougainvillea* Comm.	Paper Tree
15	Rutaceae	*Murraya koenigii* (L.) Sprengel	Curry Tree
16	Rutaceae	*Citrus limon* (L.) Burm.f.	Lemon
17	Rubiaceae	*Hamelia patens* Jacq.	Firebush
18	Rubiaceae	*Ixora coccinea* L.	Jungle Flame
19	Verbenaceae	*Lantana camara* L.	Wild Sage

2.2.2 Agricultural Landscape

The present study on butterflies and complementary plantations were carried out in the agricultural fields of Chhani. Chhani is situated 15 kms to the north in Vadodara city located in Gujarat state of India. The average temperature at the study site was 36 °C maximum and 19° C minimum with 55-65 % relative humidity.

The cultivated crops in the agricultural fields were observed during the study period. The outline fencing plantations were also noted during the same.

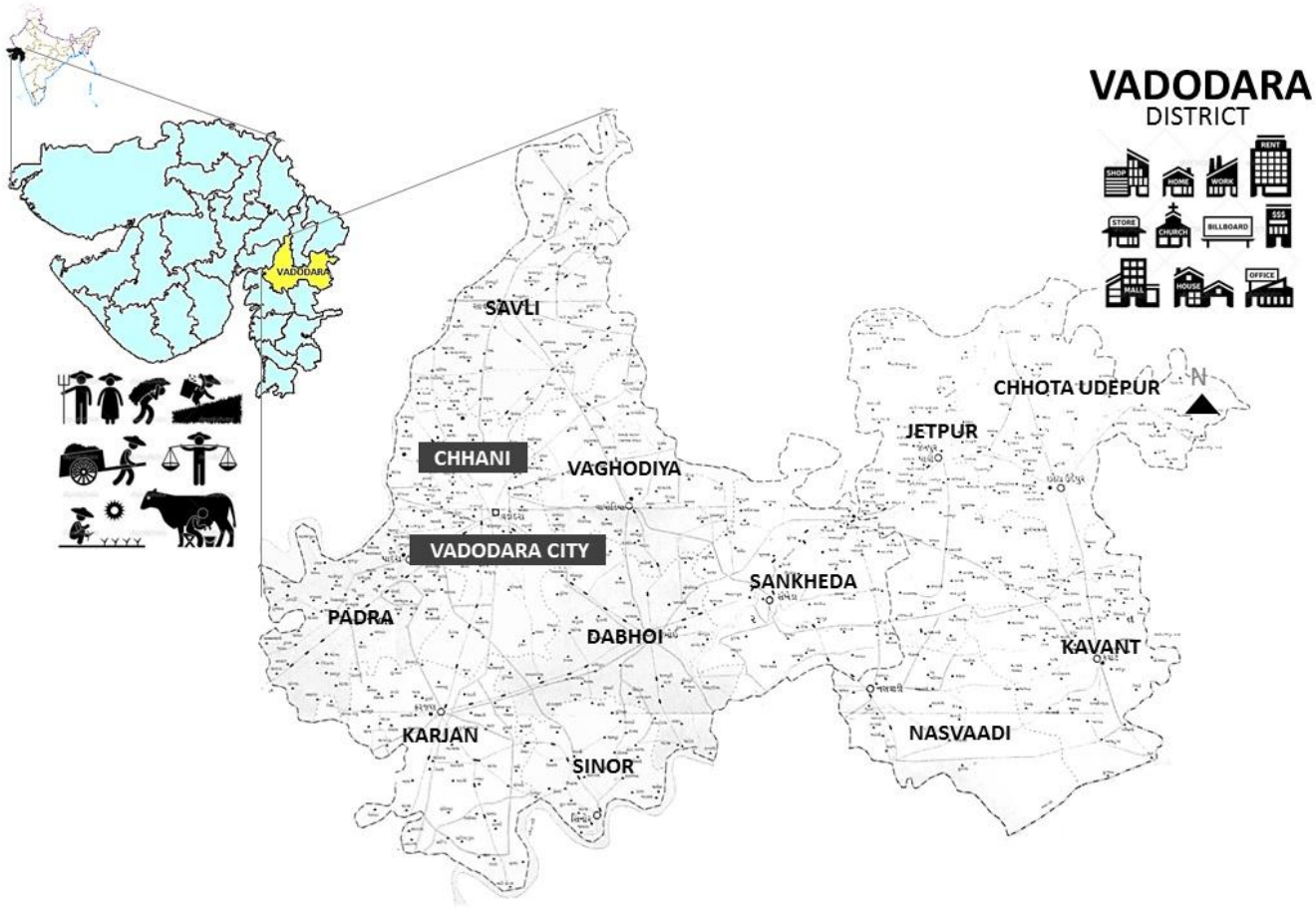

Figure 8: Study area representing urban residential (Vadodara city) and agricultural landscapes (Chhani) habitat

Habitat: Urban Residential

Figure 9: Garden plantation at urban areas of Vadodara

Figure 10: Open Residential plots in urban areas of Vadodara

Habitat: Agricultural Landscapes

Figure 11: Coriander cultivation in agricultural fields of Chhani

Figure 12: Papaya cultivation at Chhani agricultural fields of Vadodara

Table 4: List of agricultural and vegetable crops cultivated in agricultural landscapes of Chhani in Vadodara

Sr. No.	Family	Botanical Name	Common Name
1	Amaranthaceous	*Spinacia oleracea L.*	Spinach
2	Apiaceae	*Coriandrum sativum L.*	Coriander
3	Brassicaceae	*Brassica oleracea L. var. capitata L.*	Cabbage
4	Brassicaceae	*Brassica oleracea var. botrytis L.*	Cauliflower
5	Brassicaceae	*Raphanus sativus L.*	Radish
6	Caricaceae	*Carica papaya L.*	Papaya
7	Euphorbiaceae	*Ricinus communis L.*	Castor
8	Fabaceae	*Trigonella foenum-graecum L.*	Fenugreek
9	Malvaceae	*Abelmoschus esculentus (L.) Moench*	Okra
10	Malvaceae	*Gossypium hirsutum L.*	Cotton
11	Musaceae	*Musa paradisiaca L.*	Banana
12	Poaceae	*Triticum aestivum L.*	Wheat
13	Solanaceae	*Solanum tuberosum L.*	Potato

Table 5: List of complementary plantations around agricultural fields of Chhani in Vadodara

Sr. No.	Family	Botanical name	Common name
1	Anacardiaceae	*Mangifera indica* L.	Mango
2	Annonaceae	*Annona squamosa* L.	Custard Apple
3	Apocynaceae	*Alstonia scholaris* L. R. Br.	Indian Devil tree
4	Asclepidiaceae	*Calotropis procera*	Milkweed Plant
5	Fabaceae	*Albizia saman* L.Muell	Rain tree
6	Fabaceae	*Tamarindus indicus* L.	Indian Date
7	Fabaceae	*Cassia fistula* L.	Golden shower
8	Meliaceae	*Azadirachta indica* A. Juss.	Indian Lilac
9	Moraceae	*Ficus benghalensis* L.	Indian Banyan
10	Moraceae	*Ficus religiosa* L.	Sacred Fig
11	Myrtaceae	*Psidium guajava* L.	Common Guava
12	Rutaceae	*Aegle marmelos* (L.) Correa	Stone apple
13	Rutaceae	*Murraya koenigii* (L.) Sprengel	Curry tree
14	Sapotaceae	*Manilkara zapota* (L.) P. Royan	Chikoo
15	Verbenaceae	*Lantana camara* L.	Wild sage

2.2.3 Industrial Vicinity

In ancient India, Bharuch was an important trading port with merchants from the Arabian Peninsula using this port for trading with the lucrative Indian market. In popular etymology, Broach is derived from Bar and Oach. Bar means "hill" and Oach means "located" – so, allegedly without any reference to historical etymology, Broach is taken to mean "located on a hill". According to this popular derivation, Broach was later transformed into Bharuch. Bharuch is located at 21.7°N 72.97°E. It has an average elevation of 15 metres (49 feet). Bharuch is a port city situated on the banks of the Narmada river. The Bharuch district is surrounded by Vadodara (North), Narmada (East) and Surat (South) districts. To the west is the Gulf of Khambhat.

Bharuch has a tropical savanna climate (under Köppen's Climate classification), moderated strongly by the Arabian Sea. The summer begins in early March and lasts until June. April and May are the hottest months, the average maximum temperature being 40 °C. Monsoon begins in late June and the Village receives about 800 millimetres (31 in) of rain by the end of September, with the average maximum being 32 °C during those months. October and November see the retreat of the monsoon and a return of high temperatures until late November. Winter starts in December and ends in late February, with average temperatures of around 23 °C. Very often heavy monsoon rain brings floods in the Narmada basin area.

Ankleshwar is a city in the Bharuch district of the state of Gujarat, India. The city is located ten kilometres from Bharuch. The town is known for its industrial township called GIDC (Gujarat Industrial Development Corporation). Gujarat Industrial Development Corporation (GIDC) was established under the Gujarat Industrial Development Act of 1962, with a goal of accelerating industrialization in the state of Gujarat, India. Main role of the GIDC is to identify locations suitable for industrial development and create industrial estates with infrastructure such as roads, drainage, electricity, water supply, street lights, and ready-to-occupy factory sheds. Ankleshwar has over 1500 chemical plants, producing products such as pesticides, pharmaceuticals, chemicals, textiles and paints.

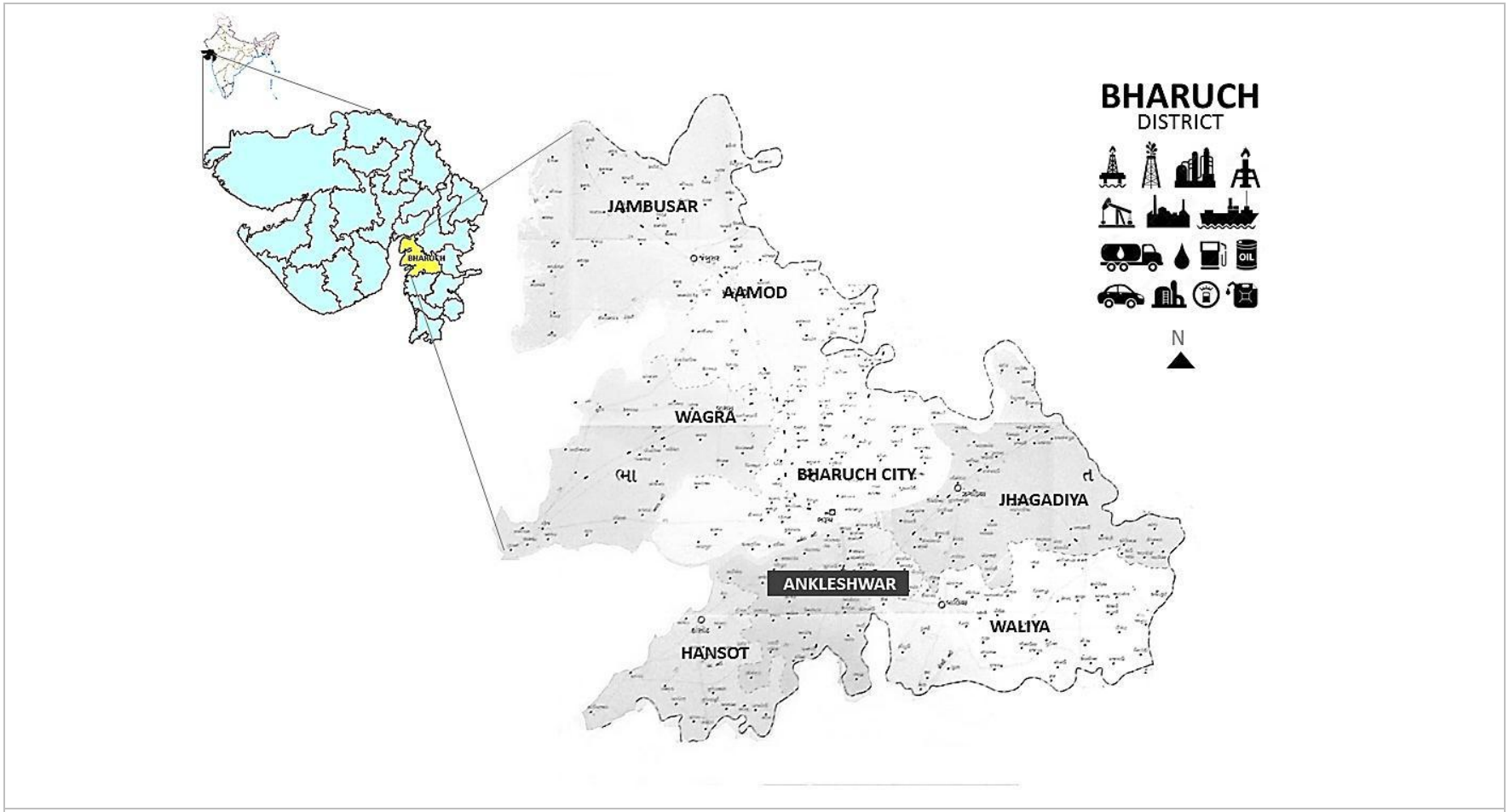

Figure 13: Study area representing industrial habitat (Ankleshwar-Bharuch)

Habitat: Industrial Vicinity

Figure 14: Plantations outside the main ONGC headquarters of Ankleshwar

Figure 15: Open Vegetative plots around industrial plots in Ankleshwar

2.2.4 Botanical Garden

Waghai is about 32 km north from the district headquarters of Ahwa, and about 52 km south of the hill station of Saputara in the Dangs district. Also known as the Cherrapunji of the state, average rainfall of 2000 mm, which is spread over 90 days makes Dang a paradise. With lush green forest, bamboo breaks and waterfall, the entire hilly terrain of Dangs harbour an amazing variety of plants, butterflies and birds. Temperature varies from minimum of 10°C in January to maximum of 36 °C in June. The Dangs forest tract falls between the parallels of latitude 20.33'53″ and 21.3'52″ and the meridians of longitude 73.27'58″ and 73.56'36″. The Dangs forest tract starts from the rugged mountain chains of Sahyadri in the east and descends on the western side extending to the edge of plains of Gujarat. The hills are mostly low and flat topped, except in the south and the East Dangs where hills are rugged and higher going up to 1100 m.

Botanical Garden is a large (24-hectare) garden with 1,400 varieties of plants from all over India. The amateur nature lover can marvel at different varieties of bamboo like the Chinese Bamboo, Golden Bamboo, Beer Bottle Bamboo, etc. and enjoy strolling along the beautiful walkways each lined with different species of tree.

2.2.5 Hill Station

Saputara is a hill station municipality in the Dang district of Gujarat state in India. This hill station is on a plateau in the Dang forest area of Western Ghats (Sahyadri) range at an altitude of about 1,000 metres. Saputara means the 'Abode of Serpents' and a snake image on the banks of the river Sarpagana is worshiped by the Adivasis on Holi.

Saputara has been developed as a planned hill resort with amenities like hotels, parks, swimming pools, boat club, theatres, ropeways and a museum. It is 172 kilometres (km) from Surat and 250 km from Mumbai. The Maharashtra state border is 4 km from Saputara. Excursions from Saputara can be made to the wild life sanctuary in the Mahal Bardipara forest, 60 km. and to Gira Waterfalls 52 km away. Saputara, situated in a densely forested plateau in the Sahyadri range, holds the distinction of being the only hill station in the Dang district of South Gujarat State.

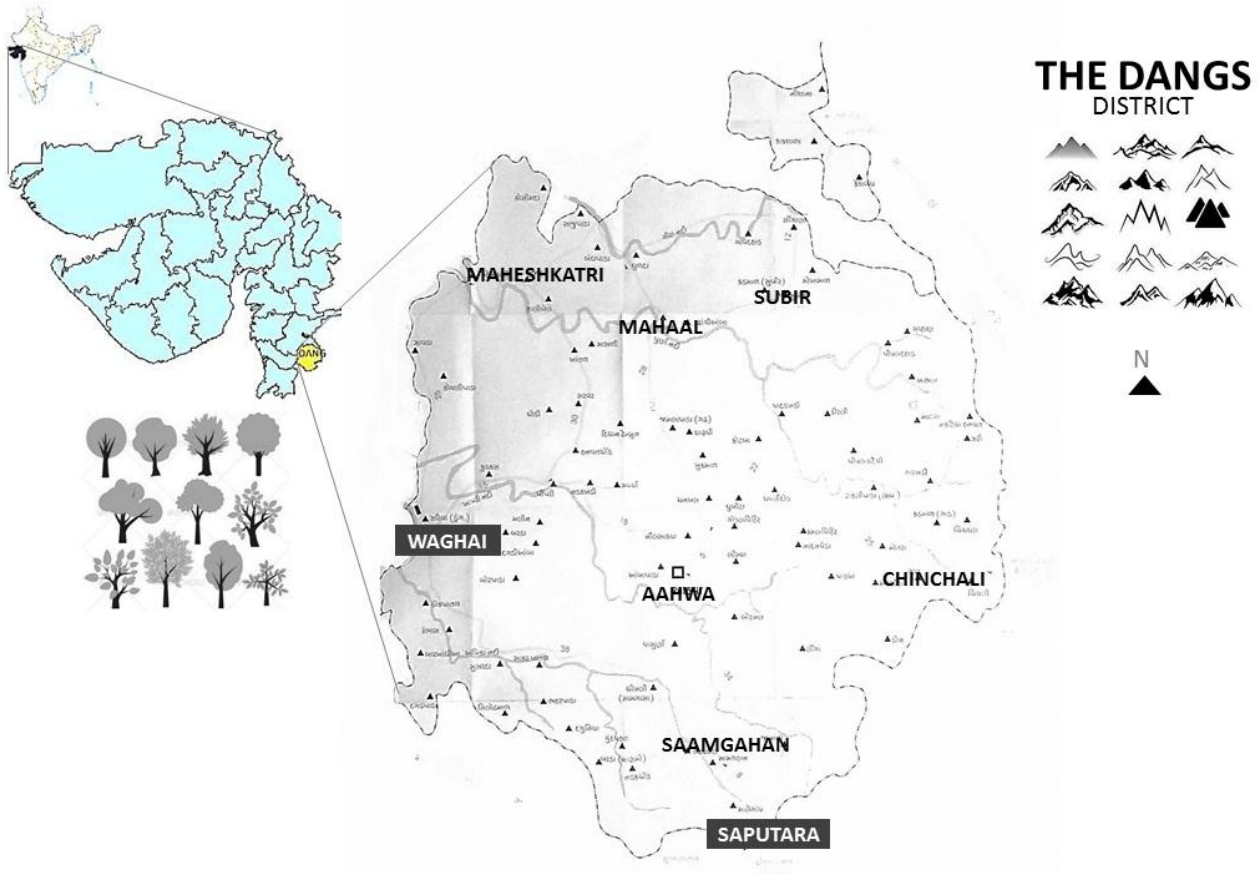

Figure 16: Study area representing botanical garden (Waghai-The Dangs) and hill station (Saputara-The Dangs)

Habitat: Botanical Garden (Waghai)

Figure 17: Insight Plot Map of Waghai Botanical Garden

Figure 18: Evergreen plot at Waghai Botanical Garden

Habitat: Hill Station

Figure 19: Pre monsoon greenery at Saputara in month of June

Figure 20: Dry vegetation at Saputara in winter month of January

2.3 Sampling Protocol

2.3.1 Pollard- Walk Method

Systematic approach was followed to monitor the rhopalocerans. During the entire study of three years, Pollard Walk method was utilized to document the butterflies though with modification. Pollard Walk method states that each fixed path is walked along a fixed duration time. In the present study, selected path visits were made during the morning time i.e. 900-1200 hours and later at 1500-1800 hours.

Each path is walked upon for a period of 2-3 hours and the visibility of 10 meters was kept at both the sides of the path. Visual encounters were made during the entire study period. Rhopaloceran collection was made whenever butterflies were unidentified on field sessions. Butterflies were observed along the pedal paths which separate two agricultural fields and were observed on both the sides of the paths.

2.4 Collection of Data

Studies on rhopaloceran diversity was conducted from July 2011 to October 2014, i.e. for a period of three years. Every selected habitat type from Gujarat was visited once a month for all the consecutive years of observation. Utilizing the Pollard Walk Method, required observations were made in the morning peak hours. Majority of the rhopalocerans were identified on field.

On- field essentials were carried during all the field visits. This includes well-featured camera, butterfly net, storage vials and identification keys (picture guides). Visual observations and butterfly net method was used to monitor and identify butterflies. Butterflies were identified on the field site itself and if not identified were collected using butterfly net. Adult butterflies were usually collected with the help of butterfly net (Kunte, 2000). It's easier to catch adult butterflies while basking, resting or sometimes while feeding from nectar resources. Depending on the number of sightings, abundance of butterfly species were categorised into Very Common (>25 sightings during the entire study period), Common (10-25 sightings) and Rare (1-5 sightings).

2.4.1 Rendering Habitat Preferences

Urban Residential

Table 6: Sub- habitats of Urban Residential in Vadodara city

Sr No	Fragmented Habitats	Description of Zone
1	**Residential Places**	Typically a house, apartments, tenements and other housing types provided with personal gardens
2	**Religious Places**	Places relating to or believing in a religion. Kirti Mandir, Swaminarayan Temple, Dakshinamurty
3	**The M.S. University of Baroda**	Within university campus, related studies were undertaken from The Maharaja Sayajirao University of Baroda
4	**Canal side**	The land or property alongside Narmada Canal in the city
5	**Public Garden**	Sayaji Baug/Kamati Baug the largest garden in Western India, on the river Vishwamitri

Vadodara city area of Gujarat state was selected to study the abundance of butterfly species in urban residential habitat. For carrying out organized study, Vadodara city habitat was fragmented into five sub habitats as mentioned in Table 6 .i.e. **(i)** Residential places, **(ii)** Religious places, **(iii)** The M.S. University, **(iv)** Canal side & **(v)** Public Garden. Residential places comprising of house garden, tenements and apartments. Karta Mandir, Swaminarayan Temple, Dakshinamurty temples were selected as religious places within residential. India's internationally renowned The Maharaja Sayajirao University of Baroda is one of the oldest centres of learning in western India. The land alongside Narmada canal in the city also acts as nectar resource. Sayaji Baug was selected as the largest garden in western India to study the public garden habitat on the river Vishwamitri. Intra-individual comparative abundance study for observed butterfly species within fragmented habitats of Vadodara city was carried out graphically to study the butterfly's preference for the fragmented habitats of urban residential zone.

Agricultural Landscapes

Table 7: Sub- habitats of Agricultural Landscapes in Chhani area in Vadodara

Sr No.	Fragmented Habitats	Description of Zone
1	**Main Agricultural Field**	Field where farming including the rearing of crops and animals
2	**Complementary Plantations**	Combined plants in such a way as to enhance or emphasize the qualities of each other or another.
3	**Water Well and Irrigation**	An excavation created in the ground by digging, driving, boring to access groundwater
4	**Farmers Shed**	A simple roofed structure used for resting farmers with one or more sides open
5	**Cattle Shed**	A simple roofed structure used for resting cattle and to shelter animals with one or more sides open

Agricultural field of Chhani area was selected to study the abundance of butterfly species in agricultural landscapes. For carrying out systematic study, farms were fragmented into five zones as mentioned in Table 7 .i.e. **(i)** Main Agricultural Field, **(ii)** Complementary plantations, **(iii)** Water well & irrigation system, **(iv)** Farmer's shed & **(v)** Cattle's shed. In main agricultural field, farming activities including the rearing of crops along with the regular pesticide application are carried out. Complementary plants are combined in such a way as to enhance or emphasize the qualities of each other or another and also in turn provide shade to farmers during the peak hours of hot summers and also provide nectar resource and host plant requirements for butterflies. By means of Water Well excavation created in the ground by digging, driving, boring, groundwater is accessed. Farmers Shed provides simple roofed structure for resting farmers & to shelter animals with one or more sides open. While cattle shed provides a simple roofed structure for resting cattle and to shelter animals with one or more sides open.Intra-individual comparative abundance study for observed butterfly species within fragmented habitats of Chhani agricultural fields was carried out graphically to study the butterfly's preference for the fragmented habitats of agricultural landscapes.

Industrial Vicinity

Table 8: Sub-habitats of industrial vicinity in Ankleshwar in Bharuch district

Sr No	Fragmented Habitats	Description of Zone
1	**Pharma and Biotech**	Sun Pharma, Sanofi, Cadila, Glenmark, Torrent Pharma RPG, Ipka, Lupin
2	**Chemical**	BASF, JB Chemicals, Navdeep Chemicals, Jayshree Aromatics
3	**Agricultural**	Bayer, United Phosphorous, Shree Suphurics, Gujarat insecticide
4	**Textile and Paint**	Asian Paint, Dystar paints, Heubach Colors
5	**Open Vegetative Plots**	Plots having unwanted and essential plants collectively especially those in a particular area

Ankleshwar GIDC region of Bharuch district was selected as a model fragmented habitat to study the abundance of butterfly species in industrial vicinity. For carrying out organized study, industries were fragmented into five zones as mentioned in Table 8 .i.e. **(i)** Pharma & Biotech industries, **(ii)** Chemical industries, **(iii)** Agricultural industries, **(iv)** Textile & Paint industries & **(v)** Open vegetative plots in the surrounding areas. Sun Pharma, Sanofi, Cadila, Glenmark, Torrent Pharma RPG, Ipka, Lupin are the major Pharmaceutical and Biotechnological industries in the Ankleshwar GIDC area; while BASF, JB Chemicals, Navdeep Chemicals & Jayshree Aromatics are other chemical synthetic companies. Bayer, United Phosphorous, Shree Suphurics, Gujarat insecticide shares major agricultural industry in Ankleshwar, while Asian Paint, Dystar paints, Heubach Colors forms dyes & paint industry. Open Vegetative Plots covers unwanted and non-essential weeds collectively surrounding those in a particular area.

Intra-individual comparative abundance study for observed butterfly species within fragmented habitats of Ankleshwar industrial area was carried out graphically to study the butterfly's preference for the fragmented habitats of industrial vicinity.

Botanical Garden

Table 9: Sub- habitats of Waghai Botanical Garden in The Dangs

Sr No	Fragmented Habitat	Description of Zone
1	**Dry & Moist Deciduous Plot**	Dry & Moist tree or shrub species shedding its leaves annually
2	**Evergreen Plot**	Plants retaining green leaves through out the year
3	**Bamboo & Dang Plot**	A plot having giant woody grass which is grown chiefly in the tropics.
4	**Scrub Thorn Forest**	Consists primarily of small, tall, thorny trees that shed their leaves seasonally
5	**Medicinal& Taxonomy Plot**	General & Specific systemic arrangement of trees and plants

Waghai botanical garden of the Dangs was selected as a model fragmented habitat to study the abundance of butterfly species in botanical garden. For carrying out organized study, Waghai Botanical Garden was fragmented into five sub habitats as mentioned in Table 9 .i.e. **(i)** Dry & Moist Deciduous plot, **(ii)** Evergreen plot, **(iii)** Bamboo plot & Dang plot, **(iv)** Scrub Thorn Forest & **(v)** Medicinal & Taxonomy plot. Dry tree or shrub shedding its leaves annually forms Dry Deciduous Plot& Moist tree or shrub shedding its leaves annually forms Moist Deciduous Plot; while plants retaining green leaves throughout the year forms the evergreen plot. Bamboo & Dang plot covers giant woody grass which is grown chiefly in the tropics. Scrub Thorn Forest consists primarily of small, tall, thorny trees that shed their leaves seasonally. Medicinal & Taxonomy Plot comprises of general & specific systemic arrangement of trees and plants which are medically important.

Intra-individual comparative abundance study for observed butterfly species within fragmented plots of Waghai botanical garden was carried out graphically to study the butterfly's preference for the fragmented habitats of botanical garden.

Hill station

Table 10: Sub- habitats of Saputara Hill Station in The Dangs

Sr No	Fragmented Habitat	Description of Zone
1	**Flat Plateau**	High plain or tableland area of highland, usually consisting of relatively flat terrain.
2	**Ayurvedic Garden**	The garden contains various ayurvedic medicinal plants, shrubs and trees lies en route Governor hill
3	**Saputara LakeView Garden**	Lake Garden is situated along the banks of Saputara Lake and comprising various kinds of plants and trees
4	**Honey Bee Center**	Apiary is place where honeybees are reared and pure honey is extracted and sold.
5	**Roadside Bamboo Trees**	Bamboo trees grown along the sideways of serpent shaped roads of Saputara

Saputara hill station of the Dangs was selected as a model to study the abundance of butterfly species in hill station. For carrying out organized study, Saputara hill was fragmented into five sub habitats as mentioned in Table 10 .i.e. **(i)** Flat plateau, **(ii)** Ayurvedic garden, **(iii)** Saputara lake, **(iv)** Rose garden & **(v)** Roadside bamboo trees. High plain or tableland area of highland, usually consisting of relatively flat terrain forms a major tableland flat plateau region. Ayurvedic Garden having various ayurvedic medicinal plants, shrubs and trees lays en route Governor hill. Saputara Lake View Garden is well maintained garden situated along the banks of Saputara Lake and comprising various kinds of plants and trees providing shade to the visiting tourists. Honeybee center is an apiary where honeybees are reared and pure honey is extracted and sold. Moreover, Bamboo trees grown along the sideways of 'serpent' shaped roads of Saputara from which name of Saputara basically originated.

Intra-individual comparative abundance study for observed butterfly species within fragmented plots of Saputara Hill Station was carried out graphically to study the butterfly's preference for the fragmented habitats of hill station.

2.4.2 Rendering Seasonal Variations

Table 11: Climatological Seasons of India with respect to Months

Sr No	Climatological Season	Months
1	**Winter**	December, January, February, March
2	**Pre Monsoon (Summer)**	April, May, June
3	**Monsoon (Rainy)**	July, August, September
4	**Post Monsoon (Autumn)**	October, November

To study the effect of different seasons on the diversity of butterflies, seasonal monthly visits were made to the selected fragmented habitats like the urban residential, agricultural landscapes, industrial vicinity, botanical garden and hill station. The months were quarterly divided into pre-monsoon, monsoon and post monsoon season. February, March, April and May are considered as the pre-monsoon months. Whereas June, July, August and September months form the monsoon season. October, November, December and January form the post monsoon season.

During the visit to the selected fragmented habitats, the maximum temperature and rainfall data was obtained. Hence, the average maximum temperature and average monthly rainfall details of three years i.e. from 2011 -2014 were utilized for monthly comparative study with respect to the observed number of butterfly species.

2.4.3 Photographing Butterflies

One of the most pleasant aspects of studying butterflies is capturing them digitally garnishing with some patience. Rhopaloceran photography was done using Sony Cybershot DSC- W220 with 12.1 megapixels and 4X optical zoom.

Along with that, Lumix Panasonic DMC-FZ 60 with 16.1 megapixels and 24X Optical Zoom was also utilized for photographing small sized butterflies. Required editing of photographs was done using essential softwares.

2.5 Taxonomical Identification of Rhopalocerans

Taxonomic identification of the rhopalocerans using the multiple pictorial field guides as on-field identification manuals and standard reference books for their systematic identification. Pictorial guides of (Kunte, 2000), (Kehimkar, 2008) and (Parasharya & Jani, 2007) were helpful during field visits. Standard works of (Evans, 1932) and (Wynter Blyth, 1957) were utilized to confirm the on field identification. Expert advice was taken as and when required for the confirm identification of species.

Concerned identification of host plants or nectar resources was done by the faculty members of Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara.

2.6 Statistical Analysis of Species Diversity

Alpha diversity indices were utilized to analyse the butterfly diversity using the statistical software PAST version 2.17c:

Shannon Weiner Diversity Index: This typical diversity index states the number of species within site with the relative abundance of each species.

It is defined as:

$H' = \Sigma\ pi \ln pi$ (where pi = proportion of the i^{th} species in the total sample)

Pielou's Evenness Index: This index states the distribution of the relative abundance of species in a site.

It is defined as:

$J = H' / \ln S$ (where S = number of species present in the site)

The value of J ranges from 0 to 1. Less is the variation in communities between the species, the higher the value of J.

Beta diversity was analysed between the various fragmented habitats:

Sorensen's Similarity Index: It is a simple measure of beta diversity which ranges from a value of 0 to 1.

It is defined as:

$B = 2c / (S_1 + S_2)$

(where S_1 = the total number of species recorded in the first community, S_2 = the total number of species recorded in the second community and c = the number of species common to both communities)

If the value is 0, then there is no species overlap between the communities whereas value is 1 then, exactly same species are found in both the communities.

Species richness in various sub-habitats of the selected fragmented habitats was graphically compared so as to signify the rhopalocerans habitat preference.

Seasonal distribution of rhopalocerans amongst all the selected fragmented habitats were graphically represented combining all the 3 major components namely the temperature, rainfall and documented species of the fragmented habitat.