CHAPTER – 4
METHODOLOGY
4. METHODOLOGY

Calcutta is one of the major mega city, located by the river Hugli (or Hoogly), along the deltaic region of the Ganges. It has metamorphosed from a region with sporadic hamlets and human habitations among forested areas, associated with marshlands, and ramified by tidal creek to the busiest and one of the most populous metropolises of India. During this period of metamorphosis of the area, there has been a considerable change in the natural habitat of the region, with a probable change in the animal life, too. Though there have been periodic studies on the animal life from time to time, mostly at the taxonomic level, little has been done to conduct any study at the community level, on the animal life along the whole gradient of urbanisation of Calcutta. This present study was however, aimed at the community level analyses of the vertebrate fauna in urban Calcutta. During the study 31 habitat fragments were selected, located in the different areas of Calcutta and its adjoining areas, where community level analyses of the vertebrate groups such as fish, Amphibia, reptiles, birds and mammalians were conducted.

The city of Calcutta is located at 22°82'N latitude and 88°20'E longitude. The city is at an average elevation of 9 meter from the sea level, and has an approximate area of 197.54 square kilometer (Anon., 2006). The riverine metropolis is demarcated by the river Hoogly on the west; extensive marshlands on the eastern side, which extends both north and south along the eastern fringe of the city; Baranagar Municipality in the north; and the south suburban areas and Garia marks the southern limit of the city. The metropolitan district of Calcutta, on the other hand, extends beyond the above mentioned limit, both on the east bank as well as on the western bank of Hoogly. The western limit of the metropolitan district extends up to Uluberia in the Howrah district; towards the north it extends till Bandel along the east bank and up to Kalyani, of Nadia district, on the west bank of the river; the marshlands forms almost a continuous boundary along the eastern fringe, which has been filled up at a number of places to establish human settlements; and towards south it extends till Joka on its southern edge, and Rajpur at the
south eastern edge, approximately. Both Joka and Rajpur have probably developed along the ancient marshlands that existed in the region and their remnants still exist in these localities. The population recorded during the 2001 census in the metropolitan district is 15.97 million. Within the Calcutta Municipal Corporation, however, the population is 4.85 million as per 2004 census with a density of 24760 per square kilometre during 2001 (Anon, 2006).

4.1. Geology

The city lies on a layer of clay floating on a reservoir of underground water. A thick pile of the alluvial sediments overlie the lower most clay layer. The upper 300 meter of this alluvial pile belongs to the quaternary age, and comprises of alternate layers of clay, silt, sand and coarser sediments and even pebbles. The entire sedimentary pile is capped by an extensive bed of clay about 30-60 meter or even more in thickness, thereby completing the sandwich. In addition, there are thin disjointed strips of silt, and peaty matter that lay exposed among the clay crust. The sandy layers that lies between the top and bottom clay varies in grain size fine to coarse with interspersed blocks of clay or zones of pebbles that vary in thickness from a few meter up to a depth of 130 meter in the Taratala area (Das Gupta, 1990).

4.2 Physical Environment

Kolkata has a subtropical climate with summer, monsoons (Anon, 2002). The annual mean temperature is 26.8°C, with the monthly temperatures ranging between 30°C to 35°C, occasionally reaching up to 40°C during the summer months (Chakraborti, 1990; Anon, 2006) during May and June. The winter lasts between mid November and early February. The temperature during this period ranges between 12°C-14°C. However, since the wind velocity is usually very low during this period, a thermal inversion results i.e., the ground is colder than the air above. This prevents the pollutants from escaping and hence keeping them restricted to the ground levels (Chakraborti, 1990).

The monsoon is one of the important climates of the region that spans from mid June to September. Maximum rainfall occurs during August (306mm approximately) and
the average annual total is 1582mm (Anon, 2002; Anon, 2006). The city atmosphere remains more or less clean during monsoon, with the rain keeping the atmospheric pollution in check. However, since the land surface in the locality is concave, polluting effluents cannot disperse easily causing surface pollution. The improper drainage system of the city compounds the problem of surface pollution (Chakrabarti, 1990).

4.3. Change in population trend of Kolkata

The gradual expansion of metropolis since the British set their foot on the banks of Hoogly at Kolikata in 1690 was associated with increase in the population. This increase was associated with increasing importance of Calcutta as the business and cultural hub with time. People from adjoining localities started coming to the city in search of shelter and job. Thus population increase was an inevitable event. First, rough census for Calcutta only, was conducted in 1706. The population was approximately 22,000. In the next 50 years it increased to 105,000, which are about 4.72 times of increase approximately. Between 1756 and 1850 there was 3.93 times increase in the population approximately in the municipal areas. Between 1850 and 1951 the population rose from approximately 413,000 to about 2.6 million at a rate of 3.05 times on average, and the population almost doubled between 1931 and 1941 from 1.22 million to 2.16 million approximately (Ghosh 1990, Chatterjee, 1990).

This increase in population also increased the need for space. As a result land acquisition and land conversion was increased leading to space crunch and there was a subsequent sprawl to the suburbs. This was associated with a further reduction in the native vegetation which often got replaced by exotic and ornamental forms. By 1984, there were 21 trees per square km instead of 100 per square km (Chakrabarti, 1990); and an open space area of about 20-21 square feet per capita instead of 290 sq. ft per person, which is the international standard (Chakrabarti, 1990; Ghosh, 1991). This leads to a highly demanding environmental condition for the biotic components of the city. The pressures were compounded by increasing pollution levels.
Thus these increasing levels of development and associated reduction in the qualities of natural environment does put a pressure in the faunal community. Though periodic studies have been conducted on the local fauna, little has been done to study how the faunal community shapes in accordance to the different degrees of urbanisation across the total gradient of the city from Calcutta’s perspective. Thus an attempt was made to understand the community structure of vertebrate fauna in the urbanised areas of Kolkata and its adjoining areas in the present work (Table 4.1).

Table 4.1. Table showing the changing population pattern since 1706

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Area (In Square Kilometer)</th>
<th>Population in CMC Area (In millions)</th>
<th>Population in CMD Area (in millions)</th>
<th>Growth Rate in CMC Area</th>
<th>Population Density in CMD Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1706</td>
<td>6.85</td>
<td>0.022</td>
<td></td>
<td></td>
<td>3212.37</td>
</tr>
<tr>
<td>1756</td>
<td>13.07</td>
<td>0.105</td>
<td>4.77</td>
<td>20509.72</td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td>20.22</td>
<td>0.413</td>
<td>3.93</td>
<td>34347.60</td>
<td></td>
</tr>
<tr>
<td>1901</td>
<td>80.76</td>
<td>0.848</td>
<td>2.05</td>
<td>15814.72</td>
<td></td>
</tr>
<tr>
<td>1951</td>
<td>78.59</td>
<td>2.698</td>
<td>5.08</td>
<td>15814.72</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>1380.00</td>
<td>4.573</td>
<td>15.97</td>
<td>24718.00</td>
<td></td>
</tr>
</tbody>
</table>

4.4 Study Site

During the study 31 sites were selected for the purpose of conducting regular surveys. The field surveys were undertaken from December 2002 to November 2006. During the first 13 months, i.e. from December 2002 to December 2003, field surveys were undertaken to inventorise the faunal life. From January 2004 to November 2006 regular field surveys were conducted at different locations to collect data for analytical studies. All these sites are located in the Calcutta Metropolitan Areas (CMA). Most of the sites are located within 10 km radius from Raj Bhawan which is the 0th km of Kolkata. Joka, Narendrapur, Shyamkhola, Kalyani University Campus and Kalyani Jheel are situated beyond this 10 km radius, with Kalyani University campus being the furthest situated site. During the present study we calculated the approximate area of the study sites and area covered by the water bodies within each site using the aerial data collected from Google Earth Software. The results obtained using the aerial study was validated at
the ground levels during field studies. Subsequently we chalked out the study plans using the aerial data and knowledge at the ground level. These sites have been classified into six major habitat classes on the basis of degree of urbanisation and the degree of habitat utilisation.

Initially the study was initiated at 21 habitats where surveys were conducted for first three years i.e., from December 2002 to 2005. These 21 sites are regarded as primary sites. During the final year, i.e., in 2006, ten more sites were added to the 21 primary sites. While the primary sites are distributed throughout the entire matrix of urbanisation, the additional sites are located exclusively within the core urban gradient. These 31 sites are broadly categorised under urban core, urban parks and gardens, open areas, protected areas, wetlands and heterogeneous habitats. On the other hand, the ten secondary sites can only be categorized as the core urban sites and protected areas. Among the 31 sites studied, 24 sites occur in and around the core city area, while 7 sites are situated in the Calcutta Metropolitan Area.

4.4.1 Habitat Class I - Urban Core

These sites include localities that occur within residential areas and areas of high human activities. These areas are marked by low vegetation – mostly ornamentals, dense residential buildings, markets and recreational areas. The human activities are very high in these localities. Ten sites are included in this class. These are –

(i) Tala Park

Tala Park is a matured residential area. This area is characterised by parks, a large open area accommodating CMC’s water supply tank, densely packed residential buildings and a market. The vegetation coverage is moderate.

(ii) Indian Statistical Institute (ISI), Kolkata

The Indian Statistical Institute is located c. 9.6 km from Raj Bhawan, which is 0th km of Kolkata. It comprises of closely packed buildings among gardens of ISI compound. This study site is situated along B.T.Road, near Dunlop crossing.
(iii) Esplanade (ESP)

Esplanade is one of the busiest transits of Kolkata. It comprises of bus terminus, tram terminus and an underground railway station, a single storied market complex, few isolated club tents and a park. The site lacks sufficient vegetation cover, which is mainly restricted around the club tents, the park at one end of the site, and the avenue plantations. These are primarily of ornamental types and a few are fruit yielding forms.

(iv) Ballygunj

Ballygunj is one of the matured residential and office areas of southern Kolkata. This area is characterised by multi-storeyed apartments, gardens of residential and official buildings and avenue plantation. During the present study, a portion of this extensive locality situated around Ballygunj Circular Road (presently known as Pramathes Barua Sarani) was studied for three seasons in 2006.

(v) Bagbazar

Bagbazar is represented by closely spaced old buildings and new apartments mostly 2-3 storeyed, markets, playgrounds, auditoriums occasional gardens and lawns and avenue plantation area. This is located near Shyambazar five point crossing and was studied during three successive seasons in 2006.

(vi) Burrabazar

The whole stretch of this urban transect is practically devoid of any vegetation and is represented by closely spaced multi-storeyed buildings for residential and business purposes. This area was studied in three seasons in 2006.

(vii) Boubazar (Ganesh Avenue)

The present study was conducted along the Ganesh Avenue which is bordered by Boubazar area at one side and Chandni Chowk on the other side along the southern fringe. Vegetation contains avenue plantation and plantation in the parks.
This locality is characterised by multi-storied office, business marts, recreational houses and residential buildings.

(viii) Boubazar (Santosh Mitra Square)

This area unlike Ganesh Avenue region is predominated by the densely packed old residential quarters with shops and a park and a few playgrounds. Vegetation present at occasional stands along this urban transect. This area is located near Sealdah Railway Station which is one of the gateways to the city of Calcutta.

(ix) Free School Street

This is primarily a mixture of business area, official buildings, educational institutes and residential quarters. The area is comparatively devoid of vegetation. This is situated very close to Esplanade area.

(x) Park Street

Park Street is a mixture of matured residential and business hub of modern Kolkata. Our study is restricted to the portion of Park Street between Free School Street and southern Park Street Cemetery.

4.4.2 Habitat Class II - Urban Parks and Gardens

This is the second major habitat type that was covered during the study. This class comprises of the noted parks and gardens that were selected in order to conduct regular surveys. These sites include Agri-Horticultural Society of India (AHSI), Victoria Memorial Hall Compound, Raj Bhawan, Eden Gardens, Rabindra Sarovar and Subhas Sarovar. These sites vary considerably in size and their utilisation and are maintained regularly by the respective authorities. Brief resume of the individual sites are as follows-
residential areas on all sides and is used by residents from local slum for different purposes. This is maintained by CIT.

(vi) Subhas Sarovar

Like Rabindra Sarovar, Subhas Sarovar, too is built around a water body of considerable size. This site has a fair cover of plantation around the water body which is interrupted by open areas and occasional buildings. This site is primarily used for various purposes by the local people.

4.4.3. Habitat Class III - Open Area

This class includes sites with extensive open area with sporadic plantations and isolated human constructions such as buildings, monuments, stadiums and so on. The habitat class includes areas like Maidan and Kalyani University Campus area. However, Maidan is almost a closed system with the city proper surrounding it almost on the three sides, Kalyani University Campus is more or less an open system.

(i) Maidan

Surrounded by the city proper on three sides, Maidan is referred to as the “Lungs of the city”. This area is characterised by vast expanse of open fields crisscrossed by metalled roads. Vegetation include roadside plantation, plantations around innumerable club tents that exist here and the gardens associated with them. The plants are mostly ornamentals and exotics Maidan is often used by people for grazing their cattle, playing and other activities.

(ii) Kalyani University

Located c. 47.61 km from Kolkata, in Nadia district, Kalyani University Campus, like Maidan, is characterised by extensive open areas. The institution buildings and hostels form human made structures within the campus. The plantations are primarily associated around the buildings and occur as the avenue plantations dominated mainly by ornamentals and exotics, with occasional economically important forms.

4.4.4 Habitat Class IV – Protected Areas
The protected areas include localities which are under complete protection of mostly government authorities and private organisations. These areas are used sparingly or not at all by human beings. Sites under government jurisdiction are – Botanical Garden under Botanical Survey of India and Central Park and Chintamani Kar Wildlife Sanctuary, Narendrapur are under authority of Department of Forest, West Bengal Government.

(i) Botanical Garden, Shibpur

This site is located in the district of Howrah and is at a distance of 5.8 km from Kolkata along the border of river Hugli. This site has a fair cover of vegetation of various types – both residential and exotic forms. This place is used mainly by visitors for recreational purpose with little harm to the habitat.

(ii) Central park or Banabitan

Built around a water body, Banabitan is more of a garden with plantation in patches. It has a mixture of plantation open area, garden and a water body which is used for recreational fishing. The trees are primarily of economical importance and ornamentals. This site is opened to the visitors and is a popular site for walk and jog in the early hours of day.

(iii) Chintamani Kar Wildlife Sanctuary, Narendrapur

Situated at a distance of c. 15.84 km from the city, Chintamani Kar Wildlife Sanctuary is under the Rajpur Municipality. The park is built around an orchard in this area and is dominated by fruit yielding varieties of plants.
(iv) Tollygunj Golf Club (TGC)

This is located 7.6 km from the city centre. It is characterised by vast expanse of open area of golf course with moderate plantation that occur in between. Vegetation here is an important mixture of local and exotic forms.

(v) South Park Street Cemetery

This is situated at a distance of 2.08 km from the city centre and is situated at the crossing of lower circular road and Park Street. It is one of the oldest graveyards of Calcutta. One portion of this area is fairly wooded and the other half is comparatively open. This site was studied for three seasons in 2006.

(vi) Alipore Zoological Garden

This is located near National Library. This has a fair cover of vegetation. This site is characterised by the offices, food marts, and animal enclosures and a few water bodies. This site was studied for three seasons in 2006.

(vii) Baghmari Burial Ground

This is maintained by Kolkata Municipal Corporation and is adjacent to the ESI hospital, Manicktala. This ground contains fair cover of vegetation. This site was studied for three seasons in 2006.

4.4.5 Habitat Class V - Wetlands

These include important water bodies of substantial size, which form a suitable habitat for the fauna. Such wetlands include Nature Park, Nalban Bheri Areas, and Santragachi Railway Jheel. These sites vary considerably in size, character and utilization.
(i) Nature Park, Brace Bridge

Nature Park is located at a distance of 7.05 km from the city centre and is maintained by Mudiali Fisheries Cooperative Society. This area has undergone a marked change from marshland to a vast area of open water bodies divided by dikes over the past 20 years (Mookherjee, 2004). The dikes are lined by plantations which provide the area with a lush wooded cover along the dikes.

(ii) Bheri Areas, Salt Lake (Nalban)

Nalban Bheri Areas comprise of a string of water bodies separated by dikes. This area is situated at c. 8.27 km from the city centre. These water bodies are used for fishing purposes. These bheries are owned by both the Government and private owners.

(iii) Santragachi Railway Jheel

Located in Howrah district, Santragachi Railway Jheel is located c. 6.81 km from the heart of the city, Kolkata. This water body unlike Nature Park or Bheri Areas is not used for fishing purposes and is noted for the aggregation of winter migrants. It is surrounded by the human habitations except for the side that is covered by the railway yard. The main lake is surrounded by the plantation of ornamentals, economically important trees and exotic plants. Waste water drains from adjoining human habitations into the main water body.

(iv) Kalyani Jheel Complex

Located in Nadia district, c. 46.23 km from the city and maintained by Kalyani Municipality. The lake is occasionally used for boating, but at present, the condition of water body has deteriorated to a great extent.
4.4.6 Habitat Class VI - Heterogeneous Habitats

This class includes the localities characterised by presence of human habitation and natural environment. The vegetations are mixtures of natural and exotic forms. These areas are subjected to periodic low scale disruptions from time to time and are maintained in this moderately depauperated conditions by the people living here.

(i) Shyamkhola (SHK)

Located in the Rajpur Municipality, about 16.31 km from the heart of the city, Shyamkhola is characterised by mosaic human habitation among a semi natural environment, with fair cover of vegetation and with denser patches among human habitations. Plants found here are mixtures of local ornamentals fruit yielding and exotic varieties. There are innumerable ditches and ponds and a large water body that occurs here.

(ii) Joka

Joka is located 14.07 km from the city proper and encompasses areas of Indian Institute of Management, Kolkata campus and adjoining localities. This locality develops on a low lying marshland and is characterised by mosaic of human habitation among a mixture of natural and planted vegetation. A large part of low lying grassland, that occur in the area fill up during monsoon increasing the water body area.

4.5. Parameters used

Information regarding the faunal diversity collected during the field surveys were analysed using different parameters. The data were used to assess the daily diversity index, cumulative species richness and species abundance for the different vertebrate groups. The results obtained from these studies were subjected to different statistical analyses to test the significance between the results of the diversity studies and the
landscape parameters of the urban environment. The equation used for the respective diversity studies and the statistical analyses are -

4.5.1 Cumulative species richness

Cumulative species richness is calculated as the total number of different species those were recorded during the survey. Greater number of species recorded per day per site, higher is the richness. Cumulative species richness was calculated for fishes, amphibians, reptiles, birds and mammals.

4.5.2 Shannon Diversity Index (H)

Shannon Diversity Index (Magurran, 2004) formulated to express the diversity in telecommunication system, is also used to show the degree of diversity in the animal world. According to this theory, higher the diversity index value, the greater is the diversity (Odum and Barrette, 2005). The equation is depicted as –

\[ H = - \sum p_i \ln p_i \]

Where, \( H \) is the diversity index; \( p_i \) is the species apportionment which is depicted as \( n_i / N \); \( n_i \) = number of individuals of a given across the sample. Diversity indices only calculated for the avian species only.

4.5.3 Species Abundance

Species abundance was estimated for the trees and larger shrubs, fishes, amphibians, reptiles, birds and mammals.

1. To analyse the vegetation abundance 10 meter × 10 meter quadrates were chosen at random within a given habitat. The trees and large \( \geq 30 \) cm in girth at the breast height, which existed within these quadrates, were recorded. The abundance was
represented as the number of individuals of the species per sampling unit of occurrence (Verma and Agarwal, 2000).

\[
\text{Abundance} = \frac{\text{Total number of individuals of the species in all the sampling units}}{\text{Number of sampling units in which the species has occurred}}
\]

2. For fishes and amphibians we collected the data using 10 mtr x 10 mtr quadrates. Thus for these groups abundance was calculated as,

\[
\text{Abundance (A)} = \frac{\text{Total number of individuals of each species in all sampling units}}{\text{Total number of quadrates of occurrence}}
\]

3. For the reptiles, birds and mammals data were collected using the fixed radius point count method. Thus, here, abundance was calculated as,

\[
A = \frac{\text{Total number of individuals of the species in all the sampling units}}{\text{Total number of point count stations in which the individuals occur}}
\]

The data obtained in the field were subsequently used to analyse the species abundance as the number of individuals of the species per sampling unit of occurrence.

4.5.4. Habitat Fragmentation

During the present study the fragmentation of land mass was assessed by estimating the isolation of the survey habitats. Three different parameters were chosen to estimate habitat isolation. Firstly, habitat isolation between the patches having at least one species more than the nearest habitat was estimated. Secondly, isolation between the
similar habitats studied was measured. Finally, isolation of each habitat from nearest probable primordial habitats was estimated. These measurements were obtained by calculating the linear distances between the sites using land use maps (Anon, 1997, 1998) and using aerial photographs provided by Google Earth Software (Anon, 2005).

4.6. Vegetation Density and Cover

4.6.1. Vegetation Density

To analyse the vegetation density 10 mtr by 10 mtr quadrates were chosen at random within a given habitat. The trees and larger shrubs ≥ 30 cm in girth at the breast height, which existed within these quadrates, were recorded. The tree density represents the numerical strength of the species in the community (Verma and Agarwal, 2000)

\[
\text{Density} = \frac{\text{Total number of individuals of the species in all the sampling units}}{\text{Total number of sampling units studied}}
\]

The mean species abundance calculated for all the sites was 22.05 (Range = 7.00-40.00, S.D =9.84); on the other hand mean density calculated is 4.22 (Range = 0.70-9.43, S.D=2.18). The list of plants recorded during the present study is provided in Table 4.2.

4.6.2 Vegetation cover

The vegetation cover was estimated at each site using the Braun-Blanquete categorical scale (Waite, 2000). We calculated the percentage vegetation cover (trees and...
Table 4.2.
List of trees and larger shrubs recorded during the present study

<table>
<thead>
<tr>
<th>SI no.</th>
<th>Common name</th>
<th>Scientific Name</th>
<th>Local name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mango tree</td>
<td>Mangifera indica</td>
<td>Aam Gachh</td>
</tr>
<tr>
<td>2</td>
<td>Arjun</td>
<td>Terminalia arjuna</td>
<td>Arjun</td>
</tr>
<tr>
<td>3</td>
<td>Mast tree</td>
<td>Polyalthia longifolia</td>
<td>Debdaru</td>
</tr>
<tr>
<td>4</td>
<td>Elephant Apple</td>
<td>Dillenia indica</td>
<td>Chalta</td>
</tr>
<tr>
<td>5</td>
<td>Monkey Jack</td>
<td>Artocarpus lakucha</td>
<td>Deo/deua</td>
</tr>
<tr>
<td>6</td>
<td>Indian Coral tree</td>
<td>Erythrina variegata</td>
<td>Ter palte/ Palte madar</td>
</tr>
<tr>
<td>7</td>
<td>Flame Tree</td>
<td>Delonix regia</td>
<td>Gulpohor/Krishnachura</td>
</tr>
<tr>
<td>8</td>
<td>Banana</td>
<td>Musa paradisiacal</td>
<td>Kala</td>
</tr>
<tr>
<td>9</td>
<td>Fig Tree</td>
<td>Ficus hispida</td>
<td>Kak Dumur</td>
</tr>
<tr>
<td>10</td>
<td>Jack Fruit</td>
<td>Artocarpus heterophyllus</td>
<td>Kanthal</td>
</tr>
<tr>
<td>11</td>
<td>Indian medlar</td>
<td>Mimusops elengi</td>
<td>Bokul</td>
</tr>
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<td>Coconut palm</td>
<td>Cocos nucifera</td>
<td>Narkel Gachh</td>
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<tr>
<td>13</td>
<td>Betelnut</td>
<td>Areca catechu</td>
<td>Supuri/ Supari</td>
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<tr>
<td>14</td>
<td>Champaka</td>
<td>Michelia champaka</td>
<td>Champa</td>
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<tr>
<td>15</td>
<td>Nona</td>
<td>Annona reticulate</td>
<td>Nona</td>
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<tr>
<td>16</td>
<td>Crepe Jasmine</td>
<td>Tabernaemontana coronaria</td>
<td>Tagar</td>
</tr>
<tr>
<td>17</td>
<td>Siuli</td>
<td>Nyctanthes arbortritis</td>
<td>Siuli</td>
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<td>Mangosa</td>
<td>Azadirachta indica</td>
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<td>Papyra</td>
<td>Carica papaya</td>
<td>Penpe</td>
</tr>
<tr>
<td>20</td>
<td>Trema</td>
<td>Trema orientalis</td>
<td>Ban Siuli / Chikan</td>
</tr>
<tr>
<td>21</td>
<td>-</td>
<td>Lagerstroemia thorelli</td>
<td>Srabani</td>
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<td>Bakful</td>
<td>Sesanalia grandiflora</td>
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<td>23</td>
<td>Queen’s crape</td>
<td>Lagerstroemia speciosa</td>
<td>Jarul</td>
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<td>24</td>
<td>Copperpod</td>
<td>Peltophorum pterocarpum</td>
<td>Radhachura</td>
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<td>25</td>
<td>Siamese cassia</td>
<td>Cassia siamea</td>
<td>Kasod / Minjiri</td>
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<td>Earpod Wattle</td>
<td>Acacia auriculiformis</td>
<td>Akashmani / Sonajhuri</td>
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<td>27</td>
<td>Silk cotton</td>
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<td>Simul</td>
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<td>Banyan tree</td>
<td>Ficus benghalensis</td>
<td>Bot</td>
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<tr>
<td>29</td>
<td>Manila tamarind</td>
<td>Pithecellobium dulce</td>
<td>Jilipi Fal</td>
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<tr>
<td>30</td>
<td>Wild nut</td>
<td>Sterculia foetida</td>
<td>Kouto badam</td>
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<td>31</td>
<td>Black plum</td>
<td>Syzgium cumini</td>
<td>Kalo jam</td>
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<td>32</td>
<td>Tulip Tree</td>
<td>Spathodea campanulata</td>
<td>Rudra palash</td>
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<td>33</td>
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<td>Tectona grandis</td>
<td>Segun</td>
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<td>Indian rosewood</td>
<td>Dalbergia sisso</td>
<td>Sisu</td>
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<td>35</td>
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<td>Anthocephalus kadamba</td>
<td>Kadam</td>
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<td>Scientific Name</td>
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<td>36.</td>
<td>White popinac</td>
<td><em>Leucaena leucocephala</em></td>
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<td><em>Tamarindus indica</em></td>
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<td>38.</td>
<td>Golden apple</td>
<td><em>Aegle marmelos</em></td>
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<td>39.</td>
<td>Sacred fig</td>
<td><em>Ficus religiosa</em></td>
<td>Aswattha</td>
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<td>40.</td>
<td>Devil’s Tree</td>
<td><em>Alstonia scholaris</em></td>
<td>Chhatim</td>
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<td>41.</td>
<td>Indian Trumpet flower</td>
<td><em>Oroxylum indicum</em></td>
<td>Kasmalla</td>
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<td>42.</td>
<td>Fish fruit</td>
<td><em>Euphoria longan</em></td>
<td>Anshfal</td>
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<td>43.</td>
<td>Bayur</td>
<td><em>Pterospermum acerifolium</em></td>
<td>Muchhkunda champc.</td>
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<td>44.</td>
<td>White teak</td>
<td><em>Gmelina arborea</em></td>
<td>Gamar / Gamari</td>
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<td>45.</td>
<td>Water Rose Apple</td>
<td><em>Syzygium malaccense</em></td>
<td>Jamrul</td>
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<td>46.</td>
<td>Rose apple</td>
<td><em>Syzygium jambos</em></td>
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<td>Whistling pine</td>
<td><em>Casuarina equisetifolia</em></td>
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<td><em>Bauhinia purpurea</em></td>
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<td>Weeping Bottlebrush</td>
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<td>Botolburush</td>
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<td>Egyptian mimosa</td>
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<td>Babla</td>
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<td>-</td>
<td><em>Holarrhena antidysenterica</em></td>
<td>Kurchi</td>
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<td>55.</td>
<td>Sausage tree</td>
<td><em>Kigelia pinnata</em></td>
<td>raktathunti</td>
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<td>56.</td>
<td>-</td>
<td><em>Ficus rumphii</em></td>
<td>Pakur</td>
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<td>57.</td>
<td>Wild olive</td>
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<td>Putranjeev</td>
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<td>Cork tree</td>
<td><em>Millingtonia hortensis</em></td>
<td>Akashnim</td>
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<td>Weeping fig</td>
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<td>White silk cotton</td>
<td><em>Ceiba pentandra</em></td>
<td>Sada Simul</td>
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<td>61.</td>
<td>Pink trumpet tree</td>
<td><em>Tabebula impetiginosa</em></td>
<td>Nil parul</td>
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<td>62.</td>
<td>Bay Caedar</td>
<td><em>Guazuma ulmifolia</em></td>
<td>Kath Fal</td>
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<td>Spanish Mahogany</td>
<td><em>Swietenia mahagoni</em></td>
<td>Chhoto Mehagini</td>
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<td>Mountain Rose</td>
<td><em>Brownea coccinea</em></td>
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<td>65.</td>
<td>Wild Almond</td>
<td><em>Terminalia catappa</em></td>
<td>Kath badam</td>
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<td>Sal</td>
<td><em>Shorea robusta</em></td>
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<td>67.</td>
<td>Large leaved Mahogany</td>
<td><em>Swietenia macrophylla</em></td>
<td>Baro Mehagini</td>
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<td>Gaub persimmon</td>
<td><em>Diospyros peregrina</em></td>
<td>Gab</td>
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<td>Indian beech</td>
<td><em>Derris indica</em></td>
<td>Karanja</td>
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<td>70.</td>
<td>Cannon Ball</td>
<td><em>Couropita guianensis</em></td>
<td>Naglingam</td>
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<td>71.</td>
<td>Sandpaper tree</td>
<td><em>Streblus asper</em></td>
<td>Shaora</td>
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<td>72.</td>
<td>Cashew nut</td>
<td><em>Anacardium occidentale</em></td>
<td>Kaju badam</td>
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<td>73.</td>
<td>Royal Palm</td>
<td><em>Roystonea regia</em></td>
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<tr>
<td>SI no.</td>
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<td>Scientific Name</td>
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<td>74.</td>
<td>Eucalyptus</td>
<td><em>Eucalyptus tereticornis</em></td>
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<td>75.</td>
<td>Koko</td>
<td><em>Albizia lebbeck</em></td>
<td>Siris</td>
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<td>Tree antigenon</td>
<td><em>Kleinhovia hospita</em></td>
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<td>Olive Tree</td>
<td><em>Olea europaea</em></td>
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<td>78.</td>
<td>Chir Pine</td>
<td><em>Pinus roxburghii</em></td>
<td>Pain gachh</td>
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<td>Frangipani</td>
<td><em>Plumeria rubra</em></td>
<td>Kathchampa / Gulancha</td>
</tr>
<tr>
<td>80.</td>
<td>Drumstick Tree</td>
<td><em>Moringa olifera</em></td>
<td>Sajne</td>
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<tr>
<td>81.</td>
<td>Badminton Ball Tree</td>
<td><em>Parkia biglandulsa</em></td>
<td>-</td>
</tr>
<tr>
<td>82.</td>
<td>Golden Shower</td>
<td><em>Cassia fistula</em></td>
<td>Bandar Lathi / Amaltash</td>
</tr>
</tbody>
</table>

large shrubs only) within a 20 meter radius around the point count stations (Crooks, 2004) and assigned value according to the scale on the basis of the percentage cover. The cover scale chosen in our study was 0 (<1% cover), 1 (1-5% cover), 2 (6-25% cover), 3 (26-50%), 4 (51-75% cover) and (76-100% cover) (Waite, 2000; Crooks, 2004).

4.7 Collection of data to estimate air pollution

The details, regarding the air pollution was availed from the website of West Bengal State Pollution Control Board for each day of every month during 2004, 2005 and 2006 respectively. From the obtained data the mean monthly values of the air pollutants – SPM, RPM, NOx, SOx were estimated. At the same time we also availed the pollution data of some of the locations close to some of the survey sites chosen for the present study to understand whether pollution had some effect on the vertebrate fauna or not at specific microhabitats too.

4.8 Data collection to estimate climatic condition

Information regarding daily ambient temperature and daily relative humidity was recorded from the temperature information presented in the newspaper during 2004 to 2006 and also during field surveys using digital thermometer (model no – ST9269). The daily ambient temperature and relative humidity were meant to calculate the mean
monthly temperatures and relative humidity during the study period to understand the climatic conditions during this phase.

4.9 Estimation of built up area and area of water body

The built up area of each site and the area of the water bodies present were estimated using the aerial images availed using Google Earth Software. The data obtained were subsequently validated at the ground level from past records and at the site during the survey too.

4.10 Statistical analysis of data

The results of diversity study were subjected to statistical analyses to test their significance when paired against landscape data like - built-up area, tree cover, the area of the site surveyed during the study and isolation of the sites.

4.10.1 Linear multiple correlation (R)

Multiple correlation is a measure of the relation between one variable (the criterion) and the weighted sum of two or more other variables (called the predictors) (Das and Das, 2000). The multiple correlation coefficient ($R_{1,23}$) may be computed between a criterion variable ($X_1$) and weighted sum of the predictor variables ($X_2$ and $X_3$), using the beta ($\beta$) coefficients, $\beta_2$ and $\beta_3$. $\beta_2$ and $\beta_3$ are those proportions of the total variance of the criterion $X_1$ as are associated with the variances of $X_2$ and $X_3$ respectively, the predictor variables, where $r_{1,2}$, $r_{1,3}$ and $r_{2,3}$ are the product moment of $r$ values between $X_1$ and $X_2$, $X_1$ and $X_3$ and $X_2$ and $X_3$ respectively.

Thus the multiple correlations with three variables were computed with one criterion and two predictors using their $\beta$ coefficient.
\[ \beta_2 = \frac{r_{23}}{1 - r^2_{23}} \]
\[ \beta_3 = \frac{r_{13} - r_{12}r_{23}}{1 - r^2_{23}} \]
\[ R_{1.23} = \sqrt{(\beta_2 r_{12} + \beta_3 r_{13})} \]

The \( r \) is converted to \( t \) which is compared to critical \( t \) scores for interpretation.

\[ \frac{1}{S_R} = \frac{R}{t}; \quad \frac{t}{S_R} = \frac{R}{1/\sqrt{n-3}} \]

**4.10.2. Multiple Regression Analyses**

Multiple regression predicts the most likely value of a dependent variable from the value of two or more other variables. It can be computed only if the variables possess significant correlations with each other.

The multiple regression predicts the most likely value of \( X \) of the criterion \( X_1 \) from the given values of two predictors \( X_2 \) and \( X_3 \). The general regression equation for the straight line, showing \( X_1 \) as the linear function of \( X_2 \) and \( X_3 \), is as follows;

\[ X_1 = a_{1.23} + b_{12.3}X_2 + b_{13.2}X_3 \]

Where, \( b_{12.3} \) and \( b_{13.2} \) are the partial regression coefficients, and \( a_{1.23} \) is the \( y \) intercept of the line. \( b_{12.3} \) and \( b_{13.2} \) are calculated as,

\[ b_{12.3} = \beta_2 \times \frac{S_1}{S_2}; \quad b_{13.2} = \beta_3 \times \frac{S_1}{S_3} \]

where \( S_1, S_2 \) and \( S_3 \) are the standard deviations of the respective variables; and \( \beta_2 \) and \( \beta_3 \) and the \( \beta \)-coefficients.
The SE of is worked out as follows, using the coefficient of multiple determination.

\[ S_{23} = S_1 \sqrt{(1 - R^2_{1.23})} \]

4.11 Intensive animal survey methods

Different survey methods were adopted for collection of data during field survey for individual groups, both plants and animals. Data collection was conducted during the early parts of the day from 6.30 am in the morning to 12.30 in the noon and then in the later half of the day from 5.30 pm in the evening to 7.30 pm in the evening. The evening surveys were conducted once in every season while day surveys were conducted twice in every season for the first three years of the study, and for once in every season during the final year. During the present study, 567 field surveys were conducted during which exhaustive amount of data were collected. The different survey methods that were adopted for data collection were modified to certain extent to suit the study.

4.11.1 Sampling methods for fishes

During the present study, to obtain data regarding the fishes, the types of catch by the local fishermen used to have in a given fragment were used. These fishermen used different sort of devices to procure their catch and their catch was used to establish the data regarding the fishes which were recorded at each site. In addition, the visual observation was used to identify the known species at some of the localities. For collection and observation random spots were chosen at every fragment where data recording were done. Due to permission problems regarding collection and sampling, no recording could be done at Maidan, Esplanade and Tollygunj. The study on fishes was conducted in the 21 primary sites only. The devices used by the fishermen and the techniques to use them are produced in brief here.

4.11.1.1 Dip Nets

A dip net comprises of a net attached to a circular rim or frame. This rim is fitted with a handle of variable length. The person using this stands on the ground and uses the
net to catch small fishes from pools and water channels. These nets are helpful for catching fishes that swim along the surface.

4.11.1.2 Drag Nets

These nets can be of varying sizes and can also be used to trap fishes from considerable depths. The corners of the nets can be tied to ropes and the net is dragged along the bottom of the aquatic habitats and thereby trapping the fishes. Depending on the size and the nature of the habitat large fishes can also be caught without any damage.

4.11.1.3 Cast Nets

These nets can be used to catch fishes of variable size from deep and open water. The only difficulty with this net is that the fishes get entangled and are suffocated easily (Daniels, 2002).

4.11.2 Broad quadrate sampling

Broad quadrate sampling was used to collect data for analyses in courses of trees and amphibians. During data collection 10 meter by 10 meter square areas were established at regular distances along the predefined paths selected within the study area. The species observed within the given area of the quadrate. The availed data were then subjected to diversity analyses (Taylor et al., 1997).

4.11.3 Fixed Radius point count

In a fixed radius point count method, data collection is initiated at a chosen point and a compass direction is selected at random. The individual doing recording follows the direction chosen and data collection is conducted at points selected at regular intervals along the path, the recording proceeds. The points are located at such a distance so that the detection from the different points remain statistically different (Hutto et al. 1986). The radius around the points chosen for observation can vary in size. However when a study is conducted within a given habitat fragment, the radius of all the survey points has to be of same dimension.
During the present study, because of the variable dimensions of the study sites and the visibility along the chosen path of the study, certain changes were made to the general rules of the fixed radius point count to suite the present work. In connection to that, specific predefined paths were selected for the study instead of choosing a path at random, in all study areas. Then study points were established at specific distances along the predefined path. The radius within which the observation was done was selected in such a way that the area of one observation never overlapped the observations of other adjoined observation point. Species occurring only with the specified radius of a given point were taken into account. If a species occurred outside the radius before recording started at a given point, but moved into the area covered by the radius after observation had also recorded. The birds that existed within the radius of a given point was recorded as “inside” detections, while travelling one point to the other, whether the observations were within the predefined radius was determined before leaving the point where the observation will be done next. The observations that were made outside the radius, was recorded as “present” and was marked with ‘+’ sign. These species were not included for later analyses.

For the purpose of study we chose either 100 meter or 50 meter radii points were chosen depending on the nature of the different habitat fragments. The choice of the point radius depends on the dimension of the site and visibility within the fragment surveyed. The 50 meter radius point count stations were established at Victoria, Chintamani Kar Wildlife Sanctuary (Narendrapur), Raj Bhawan, Esplanade, ISI Baranagar, Eden Gardens and AHSI. Care was taken so that the 100 meter radius points were situated at a distance...
of 250 meters apart while the 50 meter points were spaced by 150 meter space between them. This was to ensure that no overlapping of observations occurred at each point. Fixed Radius point count was used to record reptiles, birds and mammals.

4.12 Behaviour Studies

4.12.1 Feeding Behaviour

The feeding behaviour of each species was studied during the exhaustive field surveys conducted at each habitat. During the study the feeding height, food type and feeding substrate were observed. The feeding height was estimated by two basic processes. In the first process, the height up to 10 feet was calculated using spring measuring tape. On the other hand the height of activity of the animals occurring at a height beyond the 10 feet level was estimated using a simple clinometers made from a protractor, that has a small hole drilled in the centre through which a piece of fishing line was passed with a weight on the end (Wheater, 1999).

To measure the height the observer had to stand at the same level as the tree and at a distance of about 10 meter (distance measured using a 15 meter measuring tape). With the flat side of the protractor uppermost and allowing the weight to hang freely, the position of the substrate that the animal occupied was sighted along the protractor. The angle along which the weighted line hangs was measured. The angle along which the animal occurred was calculated as 90° minus the angle along which the weighted line hangs. The distance from the eye level of the observer to the ground was also calculated. Taking into account that all the above points have been calculated properly, the height of the occurrence of the animal was calculated using the formula (Wheater, 1999):

\[ \text{Height of the tree} = (\text{The distance from the tree} \times \text{the tangent of the angle}) + \text{eye height of the observer} \]

The food type was recorded through direct observations and the feeding habit of the vertebrate species were finally assigned on the basis of the type of food taken by each
species in maximum number of occasions (Probably in more than 65 percent of cases). The substrate occupied by each species was recorded through direct observations. Feeding behaviour was studied for reptiles, birds and mammals.

4.12.2 Breeding Behaviour

4.12.2.1 Study on individual species

Based on the abundance data some species that were present in majority of the sites along the urban gradient were chosen for nesting behaviour of the individual species. Some of the species were more abundant along the urban end of the gradient, while others were more abundant in the peripheral area. A few species that prospered along the peripheral areas of the urban gradient were also studied to test the effect of increasing disturbance in these areas.

4.12.2.2 Nest location and fate

The nests were located through extensive field surveys during 2005 – 2006 and 2006 breeding seasons in all the 31 study sites. The behaviour of the animal species was used to localize these nests during the breeding periods. The nests were discovered during the building, egg laying, or early incubation stages. We monitored nests periodically during the incubation to determine the hatch dates and after hatching to determine fledging success. For each nest, number of eggs laid, hatched, and fledged and as well as predation events or other instances of loss of eggs or nestlings were recorded.

4.12.2.3 Breeding community

Based on the abundance data the nesting guilds of the resident species were also classified as:

i) Breeding strategy (single, double or multiple broods per season)

ii) Nesting height in meters (ground; low= 0-3 ; mid height =3-6 ; and high height ≥6).

iii) Nest location (tree, shrubs, ground or buildings etc.).

iv) Nest type (open, cavity, cup shaped and others).