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Study Area

Bhadra Wildlife Sanctuary

Bhadra Wildlife Sanctuary is located in one of the biodiversity hotspots of Western Ghats geographically situated at 75° 15' to 75° 50' E and 13° 25' to 13° 50' N, and covers an area of 492 km². Vegetation types of the Sanctuary are unique to this biodiversity hotspot and include dry and moist deciduous forests, evergreen forests, Shola and grasslands and comprised of bamboo, a dominated species in evergreen and moist-deciduous forest (Karanth, 1982). The canopy of the forest is comprised of many timber yielding species such as Tectona grandis, Terminalia tomentosa, Terminalia paniculata, Lagerstromia lancelota, etc. Mid canopy consists of Kydia calycina, Dillenia pentagyna, Gmelina arborea, Randia sp. (Karanth, 1982). The under storey is found with the domination of bamboo and low lying valleys contain swampy grassland with villages and paddy fields-agriculture (Karanth, 1982; Karanth, 2003). The reserve provides habitat to more than 300 bird species and several threatened mammals like tigers (Panthera tigris), leopards (Panthera pardus) and elephants (Elephas maximus). During 1956–1966, a major irrigation reservoir was constructed. The reservoir limited accessibility and provision of basic amenities to some villages (Karanth, 1982; Sreekantaiah and Subramanya, 1992) and fauna of the reserve.

Background

Bhadra Wildlife Sanctuary was originally established as Jagara Valley Game Sanctuary (200 sq km, established in 1951). A local proverb says “The bamboo swings
to the voice of the wind. The tiger wonders for fun and if so, it must be “Jagara valley”. Jagara valley was named so by surveyors during the British rule on account of its nearness to the Jagara village, a small hamlet. The under storey is dominated by bamboos, especially *Bambusa arundineacea* and *Dendrocalamus strictus* (Karanth, 2003). This sanctuary, politically situated in Chikmagalur district of Karnataka was classified as a reserved forest between 1912 and 1930. This area was declared as “Jagara Valley Wildlife Sanctuary” by the Government of Mysore in the year 1951 with an area of 77.45 sq.miles (Karanth, 2006). After a systematic survey and census of the entire area including animals, birds and plants, it was decided to bring some more area under the Jagara valley sanctuary. The adjacent area which was rich in wild life was surveyed and the sanctuary was reconstituted in the year 1974 as Bhadra Wildlife Sanctuary vides G.O.No. AFD-25-FWL-74, dated 06.09.1974, covering an area of 492.46 sq.km. The sanctuary named after Bhadra river which flows perennially through this region. It was declared as the protected area under the project Tiger (25th Tiger reserve) in 19th November 1999.

**Study Sites**

The Western Ghats located in Karnataka is a unique biological entity and forests covers an area 30,755.73 sq km and are perhaps the most productive region, with large tracts of pristine forests, well wooded areas and unspoilt coastal line in the peninsula. In the heart of the Western Ghats of Karnataka lies, Bhadra Wildlife Sanctuary, divided into four forest ranges by the state forest department of Karnataka viz., Lakkavalli, Hebbe, Muthodi and Thanigebylu (Map 4.1).
Lakkavalli range

The study was carried out in Lakkavalli range of Bhadra Wildlife Sanctuary, comprising five state forests with an area of 223.17 sq. kms (13° 34' to 13° 46' N latitude and 75° 29' to 75° 45' E longitude) and runs across Bhadravathi taluk of Shimoga district and Tarikere taluk of Chikmagalur district in the Karnataka state of Southern India, which are characteristics around hills of lower elevation below 750 m. It receives an annual rainfall of 1600-2000 mm (Map 4.3).

a) Aldhara State Forest

This state forest is located in Bhadravathi taluk of Shimoga district. It is geographically situated between 13° 35' to 13° 38' N latitude and 75° 33' to 75° 37' E longitude and encompasses an area of 33.57 sq. km. It consists of dry deciduous type of forest.

b) Kakanahosudi State forest

This forest is situated in Lakkavalli range of the Sanctuary and is located between 13° 41' to 13° 44' N latitude and 75° 31' to 75° 34' E longitude and occupies an area of 2.02 sq. km and vegetation is of moist deciduous type.

c) Lakkavalli State Forest

This is the largest state forest region located in the Lakkavalli range of the sanctuary, which runs across Tarikere taluk of Chikmagalur district. This state forest is geographically located between 13° 34' to 13° to 39' N latitude and 75° 36' to 75° 39' E longitude and encompasses an area of 174.34 sq.km and comprises moist deciduous type of forest.
d) Singanamane State Forest

It is the smallest state forest situated besides the left bank of Bhadra reservoir. Geographically it is lies between 13° 35' to 13° 37' N latitude and 75° 35' to 75° 37' E longitude. It encompasses an area of 1.29 sq. km and comprises moist deciduous type of vegetation.

e) Thammadihalli State Forest

It is situated in Bhadravathi taluk of Shimoga district. It is a partial distributed area in the peripheral zone of the sanctuary. It is geographically located between 13° 35' to 13° 41' N latitude and 75° 37' to 75° 39' E longitude and covers an area of 11.95 sq.km, vegetation is of deciduous type.

Topography

An imposing out spur of the Western Ghats called Bababudan mountain range rises abruptly from the Deccan plateau forming a rough crescent here. Inside the ‘crater’ formed by them, the terrain is gently undulating (670-760 m elevation) but the mountains reach an elevation of 1,200-1,500 m. One of these peaks called “Mullayyana Giri” is at 1,900 m, the highest in Karnataka. Inside the ‘crater’ another chain of hills called “Kagemane Giri” (Crow’s house mountain-in Kannada) further divides the valley. The wild life sanctuary essentially comprises of Muthodi area lying inside the crescent and Lakkavalli area spread on the northern outer slopes of Bababudans.

Geomorphology

The area consists of most undulating terrains with valley and steep hill locks. The altitude varies from 670 to 1,875 m. The main underlying rocks and the resulting soils of
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the track may be roughly classified as under 1) Granite and quartzite giving rise to sandy loam, 2) Horn blend trap and haematite, the characteristics rocks of the Bababudans producing soft ferruginous clay loam and, 3) Chlorite schist yielding a poor impervious soft of clay. The southern portions of Lakkavalli are abundant in horn blend, whilst chlorite schist is very conspicuous in the north and west.

Climate

Three seasons viz., rainy, summer and winter are clearly marked; rainy season from June to September, winter from October to January and summer from February to May. The temperature ranges from 10 to 32°C. The weather is hot and humid. The average rainfall varies from 1200 to 2600 mm (Sathisha, 2007). A distinct rainfall gradient result in a variation in vegetation type from moist deciduous forest and dry deciduous forest.

Vegetation pattern

The biotic factors and edaphic variations have played a dominant role in determining the forest growth in the sanctuary (Map 4.2). According to Champion and Seth (1968) classification, pattern of vegetation broadly falls in to two types.

The vegetation pattern of the sanctuary is as follows:

i. Dry-deciduous forest

These types of forests are characteristics of lower elevation generally below 750m, where the annual rainfall ranges from 1,400 to 1,800 mm. The characteristics tree species of this type are Terminalia paniculata, Xyilia xylocarpa, Casia fistula. Among shrub Lantana camara, Urena lobata and formulate the second canopy along with
majority dominance of introduced weed *Chromolena odorata*. Some of the common climbers are species of *Ziziphus, Argyreia, Ipomea* and *Carissa caranda*. Herb layer is composed of the species of *Sida, Barleria* and others. The bamboos are mainly of *Bambusa arundinacea* and *Dendrocalamus strictus*.

**ii. Moist-deciduous forest**

These type of forests are found where elevation ranges from 670-1000 m and rainfall from 1,800 to 2,600mm. They generally merge semi-evergreen type at the valleys and pockets, deciduous trees of lower elevations. The chunk of moist deciduous forests in the sanctuary are interspersed with the extreme of bamboo, teak plantation is common in moist deciduous forest. The characteristic tree species of this type are *Tectona grandis, Dalbergia latifolia*. Some important middle canopy includes shrubby species like *Antidesma diandrum, Gmelina arborea, Sterculia guttata, Helicteres isora* and others. The under growth consists of many species of Zingiberaceae and many orchids and ferns are seen on the tree trunks. Some of the climbing shrubs and twiners are *Asparagus racemosus, Hemidesmus indicus* etc. These forests in the sanctuary serve as main feeding area for the animals, because of the existence of many palatable fodder species in the floristic composition (Raju and Hegde, 1995).

**Fauna**

The fauna found is of typical south Indian type. Most of the carnivorous animals like tiger, leopards, jungle cats, wild dogs, hyena and herbivorous animals like elephant, sambar, gaur, spotted deer and barking deer are found in the sanctuary. The sanctuary has
some rare animals’ viz., the Giant Malbar Squirrel, Flying Squirrel, Pangolin besides rare birds like Malbar Grey Horn Bill, Great Black Wood Pecker, Green Pigeon etc. The study area supports the snake like Python, King Cobra, Vipers, Green Snakes and of these, the four species of large herbivorous mammals Sambar (*Cervus unicolor*), Spotted deer (*Axis axis*), Barking deer (*Muntiacus muntjak*) and Gaur (*Bos gaurus*) were selected for the present study.

**Wetlands**

The study site supports more than 16 wetlands and is of major conservation importance regardless of their relatively small size, they often shelter and support a diversity of species including plants, animals, plankton, many microorganisms and macro invertebrates and vertebrates which are endemic, rare and endangered species. Wetlands exhibit a self regulating hydrology, the flora and fauna are uniquely adopted species even depend on the hydrological changes of these wetlands for their reproduction after completion of their life cycle. In view of this we have selected and designated five wetlands in Lakkavalli range of Bhadra Wildlife Sanctuary for ecobiological studies, viz., Anegundi kere lies in (13° 35' 506" N and 75° 38' 620" E), Ramannana kere lies in (13° 36' 562" N and 75° 37' 943" E), Koramagudda kere lies in (13° 37' 173" N and 75° 39' 095" E), Pickup kere lies in (13° 36' 957" N and 75° 39' 307" E) and Mavinahalla kere (backwater) lies in (13° 38' 518" N and 75° 39' 271" E) and as a result can cope a status in great variety of environmental changes and protect these wetlands at alarming rate of loss and degradation (Map 4.5).
Wetlands in Lakkavalli range

1) Ramannana kere
2) Pickup kere
3) Koramagudda kere
4) Beerashetti kere
5) Kati road kere
6) Anegundi kere
7) Sukallatti road kere
8) Mavinahalla kere
9) Balegundi road kere
10) Nirallakere
11) Nirallamachan road kere
12) Kesukattekere
13) Mallakkana kere
14) Doctor kere
15) Aldhara kere
16) Chodikatte kere

Ecobiological assessment was made in selected five wetlands of Lakkavalli range of Bhadra wildlife sanctuary over a period of two years. The sampling is made at an interval of 30 days. In each of these localities based on preliminary survey, 10-10m quadrates were selected around the wetlands. The habitat characteristics of each quadrate viz., vegetation, and physical parameters like air, temperature and chemical parameters of soil and water were made concurrently with plankton sampling. The sampling in all these sites and animal census was made both in early and evening hours in the every month.
Map 4.1. Location of the study area
Map 4.2. Forest coverage of the study area
Map 4.3. Forest coverage of state forest
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Map 4.4. Transects of the study area

Note:
Walking transect 1: Annegundi kere (1km)
Walking transect 2: Ramannana kere (1km)
Walking transect 3: Koramagudda kere (1km)
Walking transect 4: Pickup kere (1km)
Walking transect 5: Mavinahalla kere (1km)

Vehicle transect 1: Dry deciduous forests
Vehicle transect 2: Moist deciduous forests
Vehicle transect 3: Grass coverage
Vehicle transect 4: Teak plantation

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Map 4.5. Satellite imagery of the selected wetlands in the study area
Physico-chemical parameters of water

Collection of water sample

The surface water was collected randomly from a minimum of three places in the site in inert polythene containers. Using this water samples, some of the physico-chemical parameters were estimated on spot. The sample was transported to laboratory for other water quality parameter analysis.

Table 4.1. Showing standard prescribed method followed for the physico-chemical analysis of the water samples

<table>
<thead>
<tr>
<th>SL. No.</th>
<th>Parameters</th>
<th>Method</th>
<th>Instrument used</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temperature</td>
<td>Direct</td>
<td>Mercury thermometer</td>
<td>°C</td>
</tr>
<tr>
<td>2</td>
<td>pH</td>
<td>Electrometric</td>
<td>pH meter</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EC</td>
<td>Electrometric</td>
<td>Water analyzer 371 (Systronics)</td>
<td>µMhos/cm</td>
</tr>
<tr>
<td>4</td>
<td>TDS</td>
<td>Conductometric method</td>
<td>Water analyzer 371 (Systronics)</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>5</td>
<td>Turbidity</td>
<td>Photometric</td>
<td>Digital Nephelo turbidity unit model 132 Systronics</td>
<td>NTU</td>
</tr>
<tr>
<td>6</td>
<td>DO</td>
<td>Winkler’s</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>7</td>
<td>BOD</td>
<td>Winkler’s modified</td>
<td>BOD incubator (Cintex)</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>8</td>
<td>COD</td>
<td>Potassium dichromate</td>
<td>COD Reflex condenser</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>9</td>
<td>Free CO₂</td>
<td>Titrimetric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>10</td>
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<td>Argentometric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>11</td>
<td>TH</td>
<td>EDTA titrimetric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
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<td>EDTA Titrmetric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>13</td>
<td>Magnesium</td>
<td>EDTA Titrmetric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
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<td>T.Alk</td>
<td>Titrimetric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
<tr>
<td>15</td>
<td>T.Aci</td>
<td>Titrimetric</td>
<td>Titration</td>
<td>mg/L⁻¹</td>
</tr>
</tbody>
</table>

Contd...
Physico-chemical parameters of soil

Collection of soil samples

Soil samples from top six inches from an area of 30-30 cm was collected from each site. These samples were preserved in inert polythene bags, were labeled and transported to laboratory.

Processing of Soil for analysis

In laboratory, the soil samples were shade dried, finely powdered using pestle and mortar. Later samples were sieved through the 10 mesh (2mm) sized sieve. The processed soil samples were stored in labeled inert polythene container for analysis and taken to the soil testing centre of Krushi Vignanya Kendra. (KVK) in Shimoga. After processing the soil samples, the analysis was made for the following parameters.
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**pH**

Soil pH was determined in 1:2.5 soil-water / KCl / CaCl₂ suspension using Systronic digital pH meter (Baruah and Barthakur, 1998).

**Electrical conductivity (dsm⁻¹)**

The electrical conductivity of the soil was determined in 1:2.5 soil-water extract using Systronic conductivity bridge (Baruah and Barthakur, 1998).

**Organic Carbon (%)**

The organic carbon was determined by the Walkley and Black's Wet Oxidation method by oxidizing organic matter with chromic acid making use of the heat of dilution of sulphuric acid for the reaction as described by Tan (1995).

**Available Nitrogen (kg ha⁻¹)**

Available Nitrogen is estimated by the method of Subbaiah and Asija (1956).

**Available Phosphorus (kg ha⁻¹)**

For determining plant available P in soils, two methods are commonly used. The Olsen's method (Olsen, 1954) is used for neutral-alkaline soils while the Bray and Kurtz P₁ method (Bray and Kurtz, 1945) is used for acids soils.

**Available Potassium (kg ha⁻¹)**

Available potassium was extracted from the soil with neutral normal ammonium acetate solution and estimated flame photometrically (Jackson, 1973).
Exchangeable Cations \([\text{Ca}^{2+}, \text{Mg}^{2+}]\) (c.mol (P') kg\(^{-1}\))

The exchangeable cations \(\text{Ca}^{2+}\) and \(\text{Mg}^{2+}\) were determined in the ammonium acetate extract as described by Black (1965). Exchangeable \(\text{Ca}^{2+}\) and \(\text{Mg}^{2+}\) were estimated by Versenate titration method (Jackson, 1973).

DTPA extractable iron, copper, manganese and zinc (mg kg\(^{-1}\))

DTPA-extractant (0.005 M diethylene triamine penta acetic acid, 0.01 M \(\text{CaCl}_2\) + 0.1N triethanol amine pH 7.3) was used for extracting iron, copper, manganese and zinc and the concentration of micronutrients in the extract was determined by using atomic absorption spectrophotometer (AAS) as outlined by Lindsay and Norvell (1978).

Plankton sampling

Collection of Plankton samples

For qualitative and quantitative analysis of phytoplankton one liter of composite water samples at surface level were collected at interval of 30 days one liter of sample was fixed with 20 ml of percent Lugol's iodine solution and kept 24 hours for sedimentation. 100 ml of sample is subjected to centrifugation at 1500 rpm for 20 minutes and used for further investigation. Identification of plankton up to species level was done by referring standard manual Smith (1950), Patrick and Reimer (1966), Prescott (1962), Hegde and Bharathi (1985), Needham and Needham (1962) and APHA (2005). Quantitative estimation of phytoplankton was done using by a Sedgewick Rafter counting cell.
Zooplankton were calculated by Lackey's drop count method identification of zooplankton were carried out by using (Tonapi, 1980 and APHA, 1998).

**Floral diversity**

The best method to estimate the plant diversity in the surrounding of wetlands is belt transect method. Transects of the size 1000m x 5m, was laid in the adjacent forest cover of each wetlands. All plant species including trees, herbs and climbers which are present in transects were identified to the species level and their number was counted and systematic enumeration was made with the available monographs relevant literatures and taxonomic revisions (Cambel, 1918; Rath, 1999 and Dharamendra Singh, 1999).

**Faunal diversity**

**Encounter rate estimation method**

Based on vegetation types, the area was stratified into different habitat zones such as dry deciduous forests, moist deciduous forests, teak plantations and grass coverage forests (Champion and Seth, 1968) and transects were laid on selected wetlands (Map 4.4). Standard line transect methodology (Buckland *et al.*, 2001, 2004; Jathanna *et al.*, 2003 and Karanth *et al.*, 2002) was used to estimate the animals. In each site, permanent transects were first measured and marked and the checklist of faunal distribution, census was made regularly in early and evening hours in the first week of every month.

**a. Vehicle based counts**

During our census several game roads were traversed using a vehicle at a near constant speed of 20 km per hour. Four routes were identified so as to cover all the
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habitat types in rough proportion to their areas in morning (7.00 AM to 9.30AM) each month. Total distance covered by vehicle transect was 372 kms during the study period. The good network of roads inside the sanctuary made it possible to cover these regularly by vehicle.

b. Walking transect

Five permanent transect lines of 1 km were laid in different wetlands and walked on a regular basis during 2007-09. The total distance walked was 60 kms per year. Each transect was covered once in morning (7.00 AM to 9.30AM) each month. The transects were covered from opposite ends in order to minimize any bias arising from variation in animal activity with time. For each sighting the location of the animal group was noted in the prescribed encounter rate data sheet.

Faunal distribution

Although the present study is concerned with only few mega animals of the Lakkavalli range of the sanctuary, efforts were made to collect information on most of the macroscopic animals found in the study area, to assess the biodiversity and status of their existence. Data on the population status of various wild animals were obtained by means of sightings and other supplementary evidences like tracks, calls, droppings etc. Additional information was obtained from forest department staff and other reliable local sources.

Statistical analysis

The data generated in the above work were fed in to MS-EXCEL spread sheets and later using SPSS programme (Ver. 10.0) was used for statistical analysis.
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Calculation of Encounter rate

**Encounter rate**

Variance of the mean encounter rate was estimated as a composite of the variances of sample size, mean, standard deviation per km.

\[
\text{Encounter rate} = \frac{\text{Number of sightings}}{\text{Total kilometers of distance travelled}}
\]

**Diversity indices**

1. **Species richness (S):** Total number of species in the study area.

2. **Simpson’s diversity index (D):** This index represents the abundance ratio of individual species to that of total abundance values. It was calculated using the following formula

\[
D = \frac{1}{\sum p_i^2}
\]

where ‘\( p_i \)’ is the proportion of the \( i^{th} \) species to total abundance value.

3. **Simpson’s equitability index (E):** The chance of occurrence of individual species in one sample can be understood using this index, calculated using the formula

\[
E = \frac{D}{S}
\]

where ‘\( D \)’ is the Simpson’s diversity index and ‘\( S \)’ is the species richness.

4. **Shannon-Wiener’s diversity index (H’):** This index value was calculated by using the formula

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

where \( p_i \) is the proportion of the \( i^{th} \) species to total abundance value.

5. **Shannon-Wiener’s equitability index (J):** It was calculated using the formula

\[
J = \frac{H'}{\ln S}
\]

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Abundance ranking (Pi)

Pi was calculated as the proportion of density of each species to the total density of all species in a site. Then based on Pi values each species was given ranking in the ascending order.

Abundance - species richness relationship (PI)

It was calculated using the formula-

\[ \Pi = \frac{Ab}{S} \]

where \( S \) is the species richness and \( Ab \) is the abundance.

ANOVA

One way ANOVA test was calculated for various physico-chemical parameters of the study sites to understand the mean variances. ‘F’ value and ‘P’ values were represented in the respective tables.

Correlation coefficient

Correlation coefficient (r) was calculated to detect the relationship between the physico-chemical parameters of the wetlands and also with the abundance of the plankton.
Fig. 4.1. Main gate of Lakkavalli Range of Bhadra Wildlife Sanctuary

Fig. 4.2. A View of Anegundi kere
Fig. 4.5. A view of Picup kere

Fig. 4.6. A view of Mavinahalla kere (Backwater)
Fig. 4.7. Anegundi kere walking transect -1

Fig. 4.8. Ramannana kere walking transect -2
Fig. 4.9. Koramagudda kere walking transect -3

Fig. 4.10. Pickup kere walking transect -4
Fig. 4.11. Mavinahalla kere walking transect -5

Fig. 4.12. A view of watch tower
Fig. 4.15. Vehicle transect- 3

Fig. 4.16. Vehicle transect- 4
Fig. 4.17. Photographs showing sample collection