ECOLOGICAL STUDIES OF BIRD COMMUNITIES IN PROPOSED SUBMERGENCE AREA OF NARMADA SAGAR PROJECT, MADHYA PRADESH, INDIA

SUMMARY

Thesis submitted for the award of the Degree of Doctor of Philosophy in WILDLIFE SCIENCE

BY

PARIKSHIT GAUTAM

CENTRE OF WILDLIFE & ORNITHOLOGY ALIGARH MUSLIM UNIVERSITY ALIGARH (INDIA) 1995
Ecological studies of bird communities in proposed submergence area of Narmada Sagar Project, Madhya Pradesh, India

Summary

Development projects, both world wide and in India have created a need for biological monitoring of ecosystems. Monitoring is necessary not only to detect impacts of development but also the cumulative effects of numerous small impacts.

Birds are suitable communities to use for monitoring because they form ecologically diverse communities and use a wide variety of food and other resources. Thus they can reflect the condition of many aspects of an ecosystem. Also birds can be subdivided into trophic groups or guilds based on food preferences so that changes in the total community may be related to the changes of specific characteristics of an ecosystem. Most bird species have relatively short generation time, consequently they may show a quick response to environmental changes. Since some species are resident on a particular site, their population levels can be expected to reflect local condition. The abundance of migratory species may reflect condition on a particular site because the condition of the resources in the area may affect a bird’s decision to remain or migrate further. If bird communities are used as indicators, knowledge about the relationship with habitat is necessary.

The project like Narmada Sagar in which large area is going to be submerged due to the construction of a dam, bird community studies can provide valuable information about the condition of the ecosystem. For present study 'ornithological evaluation' approach was taken. Important attributes of evaluation were size (extent) of the area, diversity and species richness population size, rarity and fragmentation.

Following objectives were framed to design the study:

1. To use ornithological evaluation of the proposed submergence area to assess its potential as a habitat of the concerned species.
2. To evaluate the ecological value of the area for breeding as well as migratory populations.
To make species inventory for later comparison with other geographic areas
To investigate bird habitat relationships.
To identify the future impacts of impoundment on avifauna

The study was conducted in proposed submergence area of Narmada Sagar Project in Madhya Pradesh. The dam site is located at Punasa in district Khandwa. The total area which is to be submerged by the project is 91,348 ha including 40,332 ha of forest land. The forests coming under submergence mainly belong to subgroups, very dry teak, dry teak and dry mixed southern tropical dry deciduous forest. The project is expected to generate 1000 MW electricity and irrigate 1,23,000 ha land. The study was conducted in the forest coming under submergence and nearby impact areas outside the submergence zone. Eight sample sites, four in contiguous forest and four in different fragmented forest patches were selected for the study. Study was conducted from April 1990 to June 1993. Two winter and two summer periods were covered. The line transect census technique was used. Line transects were laid on each study site. Each transect was walked adequate number of time in each season. During the transect every sighting of bird species, numbers, time, horizontal distance from the transect and height were recorded. The Fourier Series Model was used to calculate the density of the birds. Bird species diversity was calculated as the Shannon Wiener index. Bird species richness was calculated from the rarefaction curves. A priori guild designations were used in categorizing guilds. Values of habitat variables for all sites were also calculated. Data on heterospecific formation and flock composition was obtained for all sites during winter and summer during the transects. Data on riverine birds was collected separately. Spearman’s rank correlation was used to test correlations of bird species diversity with all habitat variables. Prediction models were developed using stepwise multiple regression.

A total of 209 species representing 53 families were recorded in the study area. Out of which 156 residents, 26 winter visitors, 12 summer visitors and 15 were migratory species. One hundred twenty species of forest birds were recorded in the study area during the transects. Bird species diversity (BSD) and bird species richness (BSR) show the difference in bird community structure among all study sites. Significant
difference was found in BSD in both winter and summer seasons. BSD was higher in summer for all study sites. The bird density/ha varies from 4.6 to 12.7 for the study sites. Except one site, bird density was higher in contiguous forest than fragmented forests. The species were maximum in insectivore/foliage guilds for all study sites. Significant difference was observed between the sites in terms of representation of species in different guilds. Correlation analysis to test the relationship of BSD and BSR with area of the patch, distance from the nearest contiguous forest and distance from any nearest forest did not show any significant result. The result of the vegetation analysis were different in winter and summer. The BSD in winter was significantly correlated with number of tree species (TSP), tree species diversity (TSD), canopy cover (CCV), canopy height (CHT) and shrub cover (SCV). In summer BSD was correlated with number of shrub species (SSN), shrub species diversity (SSD), CCV and SCV. The result of the stepwise multiple regression of BSD with habitat variables showed that CCV and SCV explained most of the variation in BSD. No endemic species was recorded in the study area. However, species belonging to carnivore, Frugivore and Insectivore/Bark guilds which are sensitive to environmental changes were found in significant numbers. Highest number of heterospecific flocks were recorded on site 2 in contiguous forest. A total of 16 species were recorded in the flocks from all sites. White-browed fantail flycatcher was the most common species found in the flocks. Habitat model were developed for both winter and summer seasons using stepwise multiple regression. Canopy cover and shrub cover for winter and shrub cover for summer were found to be responsible for most of the variation in BSD.

The result of ornithological evaluation suggest the potential richness of the woodland habitat. The presence of 156 resident species reflects the potential of the area to support avifauna. The higher number of specialist forest bird species reflects on better diversity of the forest. The importance of habitat structure or physiognomy in bird habitat selection is apparent in the present study. Canopy cover was found responsible for more than 90% variability observed in bird species diversity. Strong linear correlations were also observed between BSD and floristic variables. It is postulated that in a given habitat if resources are present at optimum level, bird species diversity would reflect the structural diversity of the habitat.
Higher bird species diversity in summer is attributed higher number of summer visitors and also summer being the breeding season of most of the birds which become more conspicuous by their courtship displays. No relationship was found between BSD and foliage height diversity (FHD). It suggests that the famous BSD-FHD relationship was apparent only if both field and forest areas were taken together for evaluation, but not for the forested plots alone. Heterospecific flocking was inversely related to bird density. Since bird density is an indicator of food availability, flocking is inversely related to food availability and therefore reflects bleak resource conditions. Study suggests that the two hypotheses: increased foraging efficiency and predators avoidance, both together have the mutual role in heterospecific flocking which is a typical example of maximum utilization of resources with least efforts. The habitat models with predictive capability of over 90%, developed during the study can be used in making any prediction specially to evaluate the effect of management practices in forests, impacts of biotic pressures and development projects.

The submergence of area would be a direct and irreversible loss to the overall avian diversity of the area. Serious depletion in numbers, particularly of the more specialized species may occur as a result of the primary impact of submergence of the forest habitat, specially the riverine areas. In a river valley project, submergence of forest by a number of dams will break the contiguity of the forest. The total loss of the forest habitat will probably lead to the loss of a number of species confined to these habitats. At present it is undoubtedly the loss of habitat per se that is the most serious impacts of development on ecology in India. It is to be hoped that documentation of changes in bird species diversity may to some extent mirror the changes in species diversity of other groups.
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This is to certify that Mr. Parikshit Gautam was registered for M.Phil/Ph.D on November 11, 1997 under my supervision. Subsequent to the completion of M.Phil. work an submission of dissertation he worked as a Senior Research Fellow for the Ph.D. degree. The thesis on "Ecological Studies of Bird Communities in Proposed Submergence Area of Narmada Sagar Project, Madhya Pradesh, India" is based on his original work which was concluded in January 1994, just before he joined WWF-India as Senior Project Officer. In my opinion the thesis is suitable for submission for the Ph.D degree (Wildlife Science) of Aligarh Muslim University.

May 30, 1994

(A.H. Musavi)
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1. INTRODUCTION

River valley projects have an important role to play in the economy of developing countries. The positive aspects of dams are recognized in their capacity to provide irrigation, generate hydroelectric power and augment agricultural production, including raw materials for the agro-industries (Anon. 1994). However, over the years the realization has dawned that river valley projects also cause adverse environmental and social impacts (Goldsmith & Hildyard 1984). But irrespective of the undesirable ecological consequences, amelioration of people's plight and solutions of pressing problems are strong reasons which tilt the balance in favour of developmental projects. Dams will have to be accepted by ecologists as a necessary evil and it may not be possible to completely prevent the limited damage likely to be caused by dams.

During last two decades, increasing construction of dams have transformed the earth's landscape and economy of billions of people. The Aswan dam in Egypt, the Mahaweli project in Sri Lanka, the Itaipu dam on the Parana river between Paraguay and Brazil, Cabora Bassa dam in Mozambique, the Damodar Valley Project in India and the dams of Narmada Valley Project in Central India are some examples of this transformation. Most of the large dams have been constructed only in the last 30 years. There were 5,196 dams commissioned in the world till 1950. This figure increased to 35,000 in 1982, of which 34,798 dams were more than 15 meters high (Williams 1985). In India alone, 65 major and 626 medium river valley projects were completed from 1951 to 1985 (Anon. 1990).
The positive impacts of the dams such as the short term benefits of agricultural and industrial productivity have often been highlighted by those having vested interest in developmental projects. With growing concern and awareness for the environment world over, it has been realized that dams have numerous negative impacts also. Large dams flood the valleys upstream, and transform the nature and productivity of riparian, estuarine and coastal ecosystems. Water logging and salinity due to dams are the major threats to agricultural lands. Dams alter the social life of local people, affect traditional life styles and culture and accelerate the transition to a market economy centered in big towns (Anon. 1994).

A major conflict thus arises between development and biodiversity conservation when projects are located in the wilderness areas because such projects have adverse impacts upon prevailing pattern of allocation of land and resources to people and interfere with various forestry and wildlife conservation objectives (Anon. 1993). There are numerous example where forest and wildlife have been directly and indirectly damaged by irrigation and hydro-power projects. The submergence of forests by the hydel projects usually causes a great damage to biodiversity of the region as has been illustrated by Idukki and Periyar projects (Mohanty & Matthew 1987, Nair & Balasubramanyam 1985). The Silent Valley Project was abandoned on consideration of the damage it could have caused to the unique biodiversity of the region. The proposed Kutru and Bhopalpattnam dams on Indravati river in M.P. are likely to threaten the two protected areas- Bhairamgarh Sanctuary and Indravati Tiger Reserve, both being the last resorts of the highly endangered wild buffalo in Central India (Panwar et al. 1990). Fragmentation of wildlife habitat is another consequence of developmental projects. The Ramgnga reservoir and Chilla hydropower channel in
lower Himalayas and Siwaliks in Uttar Pradesh have fragmented the home range of the north-western elephant population.

1.1 The Narmada Valley Project

The Narmada arising on the plateau of Amarkantak in Shahdol district of Madhya Pradesh is the largest west-word flowing river in the Indian peninsula. It flows through 1,312 km long course to the Arabian Sea and traverses the lush forested hills and rich agriculture lands. On its course to the sea, it drains an area of about 95,726 km$^2$ in the three States Madhya Pradesh, Gujarat and Maharashtra. The Narmada Valley Project is the single largest river valley project so far taken up in India. It involves the construction of 30 major dams along the course of river Narmada and its tributaries (Fig. 1.1). Out of these 5 are hydroelectric schemes, 6 multipurpose and 19 irrigation schemes. In addition, 135 medium and 3000 minor dams are also planned. The overall cost estimated will be over Rs 25,000 crores (Verma 1985) and the project is expected to irrigate 48 lakh hectares of land and generate 2,700 MW (installed capacity) of electricity. Over 10 lakh people will have to be displaced for the construction of dams in this Project. It is claimed that this project will check floods, generate big fisheries potential in the huge reservoirs, provide employment to thousands of people, supply water for domestic and industrial use, and promote tourism. The protagonists of this mega project also promise that it will bring an agricultural and industrial revolution in the region. Of the 30 major dams, Tawa, Barna and Bargi have already been commissioned in Madhya Pradesh. Sardar Sarovar in Gujarat is under construction.
Fig. 1.1 Location of Some Major River Valley Projects on Narmada River in Madhya Pradesh.
1.1.1 Narmada Sagar Project Setting

The Narmada Sagar Multipurpose Project is one of the 30 major dams planned on the river Narmada and its tributaries (Verma 1985). The Narmada Sagar Project is situated near Punasa village (Lat. 22°17’N and Long. 76°28’E) in Khandwa district of Madhya Pradesh, India (Fig. 1.2). The Narmada Sagar Project would submerge 91,348 ha of land and would also irrigate 1,23,758 ha in Khandwa and Khargone districts of Madhya Pradesh. The following are the other salient features of Narmada Sagar Project:

- Dam Height : 91.4 m
- Length of the dam : 574 m
- Full Reservoir Level (FRL) : 262.13 m
- Total area to be submerged : 91,348 ha
- Forest area to be submerged : 40,332 ha
- Cultivable area to be submerged : 44,363 ha
- Irrigation capacity : 1,23,758 ha
- Power generation (Installed capacity) : 1000 MW
- No. of villages to be affected : 254
- No. of people to be affected (1981 census) : 1,50,000

(Source: Paranjapaye 1989)

1.2 Background and Justification

Developmental projects, both world wide and in India have created a need for biological monitoring of ecosystems. Monitoring is necessary to be aware of the
Fig. 1.2  Map showing proposed submergence area under Narmada Sagar Project.
adverse impacts of development. The present study is a part of the comprehensive study to determine baseline status, evaluation and monitoring the impacts of Narmada Sagar Project on flora and fauna with attendant human aspects.

One common approach to monitoring on a specific plot of land is that of using "Indicator species" (Odum 1971). The rationale of indicator species approach is the fact that a few carefully selected species interact with various components of an ecosystem and thus get affected either positively or negatively by the presence or absence, abundance or scarcity of welfare factors. Indicator species therefore 'indicate' the state of the 'health' of the concerned ecosystem provided their indicatory responses are clearly understood. The indicator species approach suffers from a major limitation in that a large number of factors, unrelated to the health of the local ecosystem may influence populations of individual species (e.g. diseases, parasites, competition, predation, and condition in other areas). An absence of precise definitions and procedures, confounded criteria used to select species, and discordance with ecological literature severely weaken the effectiveness and credibility of using vertebrates species as ecological indicators (Landres et al. 1988). The alternative approach that of monitoring communities, integrates information from many ecosystem components and is less sensitive to unexplained population fluctuations of single species (Steel et al. 1984).

Birds are suitable as means for such monitoring, because they form ecologically diverse communities and each community uses a wide variety of food and other resources. Thus they can reflect the condition of many aspects of an ecosystem (Jarvinen and Vaisunen 1979). Birds can also be sub-divided into trophic groups or
guilds based on food preference so that changes in the total community may be related
to changes in specific characteristics of an ecosystem. Most bird species have
relatively short generation time, consequently they may show a quick response to
environmental changes. Since some bird species are permanent residents on a
particular site, variations in their population levels can be expected to indicate local
condition. Migrant birds are affected by condition in their wintering grounds and along
migratory pathways. The abundance of migrant bird species, however, may also reflect
conditions at a particular site because the condition of the resources in the area may
affect a bird's "decision" to remain or migrate further (Steel et al. 1984). If bird
communities are used as indicators, knowledge about their relationships with habitat is
necessary. Any changes in habitat would be reflected by changes in bird community, its
species richness and organization.

Bird community studies can provide valuable information about the condition of
the ecosystem and help in predicting the changes due to submergence of forest as a
consequence of the coming up of the Narmada Sagar Dam. In view of these facts the
present study was planned.

There were two major components of this study; ornithological evaluation of the
submergence area and prediction of the potential impacts on avifauna of submergence
area and adjoining forest.

Ornithological evaluation is being widely used as one component of wildlife
assessment, partly as a result of the wide interest in birds but also perhaps in
recognition that some sites with interesting bird populations are otherwise of limited
wildlife interest (Fuller & Langslow 1986). Because of their conspicuousness, ubiquity and ecological diversity birds have also been used as indicators of broad environmental quality in extensive land use planning (Graber & Graber 1976, Svenson 1977, Fuller 1980).

1.3 Objectives

The first step in undertaking any evaluation is to define the objectives. Following objectives were framed to design the study:

1. To use ornithological evaluation of the proposed submergence area to assess its potential as a hábitat of the concerned species.
2. To evaluate the ecological value of the area for breeding as well as migratory populations.
3. To make a species inventory for later comparison with other geographic areas.
4. To investigate bird habitat relationships.
5. To identify the future impacts of impoundment on avifauna.

At the core of an evaluation system are the attributes into which wildlife conservation can be classified (Fuller & Langslow 1986). The following attributes were used to fulfill the objectives:

Size (extent) : This is an important attribute for ornithological evaluation. The question is whether the site is large enough to meet the need of the species? A large area usually contains a larger population of each species. However, sometimes the
total area may be large but fragmented into small patches. Such a factor can adversely affect the population size and species diversity as pointed out by Black (1983a) and MacArthur & Wilson (1967).

**Diversity and species richness**: Measures of bird species diversity and of species richness are being used in evaluation systems. Comparable methods and sampling efforts are used to obtain a relative measure of species richness at sites of similar habitat. Birds are very mobile and isolated (in time), therefore breeding attempts or transient visits should also be recorded (Fuller 1982). Hence some requirements such as to the frequency of occurrence and abundance are also included.

**Population**: The greater the proportion of the total population present on one site, the greater is its potential for human interest and for biological importance (Fuller 1982). Population density has potential for comparing sites supporting bird communities. Although frequently used to compare different sites, the population size attribute can also be used to assess the relative significance of different parts of a single site.

**Rarity**: Rare birds have been given a high value and this attribute is found in virtually all evaluation schemes. Rare species can be defined into following different types (Drury 1974):

1. Species which occur at widely scattered localities within a large area of apparently suitable habitat but have few individuals.
2. Species which occur in large numbers but in a restricted number of localities.
3. Species which inhabit a changing or transitional environment.
4. Species which are highly endangered.
**Fragmentation**: A minimum area is required to support a breeding pair, and several such areas must be functionally connected so that a chance extinction in one area allows recolonization from another. This is an important attribute to consider for rare species and those found in scarce habitat.

**Habitat structure**: The long term conservation of bird species demands that all requirements of its life cycle are met from its habitat. These include breeding, migrating, wintering and roost sites. Most bird species apparently distinguish habitats on the basis of structural characteristics. A proper knowledge of habitat structure and diversity is required to forecast potential bird species richness and density.
2. STUDY AREA AND METHODS

2.1 Study Area

Study was conducted in proposed submergence area of Narmada Sagar Project (Lat. 22° 17' N and Long. 76° 28' E) in Khandwa district of Madhya Pradesh. According to Meher-Homji (1977b) and Puri et al. (1989) the area occurs within the limit of 700 mm to 2000 mm of the annual average precipitation with a dry season of eight months. The rainfall regime (season of occurrence of rains) is typically tropical; the rainy season begins in June and extends up to October. Winter period is from November to February. Summer starts in the month of March and extends up to the rainy season. The area lies in Satpura and Vindhyan hill ranges flanking the Narmada river. The entire area has good drainage system including Narmada and Chota Tawa as major rivers with number of secondary and tertiary tributaries.

2.1.1 Vegetation

The vegetation type in the study area is dry deciduous in nature. Teak (Tectona grandis) is the dominant tree species, generally associated with Diospyros melanoxylon, Anogeissus latifolia, Lagerstroemia parviflora, Terminalia tomentosa, Odina wodier, Hardwickia binata and Boswellia serrata.

Among shrubs, Helictres isora and Holarrhena antidysenterica are the most common species all over the area. Nyctanthes orbarnstis is also found in some areas.
Aristida spp., Eragrostis spp., Apluda mutica, Heteropogon contortus and Bracharia spp. are the common grass species found in the study area.

According to the revised classification of forest types in India by Champion and Seth (1968), the following 8 groups and sub groups of the forest types are likely to be represented in the entire study area:

1. Sub-Group 5A - Southern tropical dry deciduous forest
   (i) Climax type C1a - Very dry teak forest
   (ii) Climax type C1b - Dry teak forest
   (iii) Climax type C3 - Southern dry mixed deciduous forest

2. Sub-Group 5E - Edaphic climax types of dry deciduous forest
   (iv) E2 - Boswellia forest
   (v) E4 - Hardwickia forest
   (vi) E9 - Dry bamboo brakes

3. Sub-Group 5/1S - Primary serai types of dry deciduous forest
   (vii) 1S1 - dry tropical riverine forest

4. Sub-Group 3B - Southern Indian moist deciduous forest
   (viii) C1c - Slightly moist teak forest
2.1.2 Vegetation Association

A recent study conducted by the Wildlife Institute of India described the entire area to be quite similar in terms of vegetation composition. However, following species associations were found as a result of Two Way Indicator Species Analysis (TWINSPAN), a multivariate classification technique (Anon. 1994):

(1) Tectona - Zizyphus - Helicteres - Holarrhena type

This stand class has high abundance of Helicteres isora and Holarrhena antidysenterica with low abundance of Bauhinia malabarica and Zizyphus xylopyra. This association showed wide range of distribution in the entire area.

(2) Tectona - Chloroxylon - Lantana - Vitex type

This stand class showed preference to Chloroxylon swietenia, Lantana camara and Vitex negundo. These species are found in relatively open canopy area with high biotic disturbance.

(3) Tectona - Anogeissus - Gymnosporia - Lantana type

This association was represented in wide range of areas and showed transitional nature between high and low elevated forests.

(4) Tectona - Holarrhena - Lagerstroemia - Cassia type

This stand class represented low elevated areas especially in the valleys with high abundance of Lagerstroemia parviflora. This association was distributed in most of the submergence zone.
(5) Tectona - Butea - Holarrhena - Acacia - Diospyros type

This association showed teak dominated areas with *Vitex negundo* in the riverine areas, and has very restricted distribution.

(6) Terminalia arjuna - Syzygium - Diospyros type

This association represented true riparian vegetation showing the abundance of *Syzygium cumuni* and *Terminalia arjuna*. This type was very restricted in distribution.

It is evident from the analysis that the area is mainly teak forest with different associations of trees and shrub species.

2.1.3 Fauna

With a large number of bird species, the area has a rich diversity of mammals, fish and reptiles also. Twenty nine species of mammals (Appendix 2.1), 30 species of fish (Appendix 2.2), and 24 species of reptiles (Appendix 2.3) were recorded in the study area. Although the mammalian species are present in low numbers, the area is represented by most of the species found in Central Indian forests. The Narmada river provides good habitat for aquatic mammals and reptiles.

2.1.4 Study sites

Eight sample sites were selected in the forest area of proposed submergence area. Sites were selected on the basis of fragmentation. Four sites were selected in different fragmented forest patches and 4 were in contiguous forest. Table 2.1 shows the area and category of the forest. The locations of the study sites have been shown in figure 2.1.
Fig. 2.1 Map showing transect locations for avifaunal study.
Table 2.1. Status and area of the study sites.

<table>
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<tr>
<th>Site of Transect</th>
<th>Status</th>
<th>Area km/sq.</th>
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<tr>
<td>1 (Punasa Reserve Forest)</td>
<td>Contiguous</td>
<td>&gt;300</td>
</tr>
<tr>
<td>2 (Punasa Reserve Forest)</td>
<td>Contiguous</td>
<td>&gt;300</td>
</tr>
<tr>
<td>3 (Satwas Reserve Forest)</td>
<td>Fragmented</td>
<td>8.6</td>
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<tr>
<td>4 (Chandgarh Reserve Forest)</td>
<td>Contiguous</td>
<td>&gt;200</td>
</tr>
<tr>
<td>5 (Punasa Reserve Forest)</td>
<td>Fragmented</td>
<td>8.5</td>
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<tr>
<td>8 (Punasa Reserve Forest)</td>
<td>Contiguous</td>
<td>&gt;200</td>
</tr>
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2.2 Methods

2.2.1 Study period

The methods used were based on methodologies prevalent in avian community structure studies. Some modifications were made to suit the local condition and limitations. Study was conducted from April 1990 to June 1993. April and May 1990 were spent familiarizing with the birds of the area. Data was collected on a seasonal basis. Two winter periods (1990-91 and 1991-1992) and two summer periods (1991 & 1992) were covered. Data collection was repeated for 2 years to record any annual variation, and also allow us to have more samples. Data from winters and summers was pooled separately.
2.2.2 Birds Community Structure

Line Transect method (Emlen 1971) was used to collect data. Permanent line transects each of 800 m. length were laid in 7 sites. At site 8 the transect length was 450 m. The line transect method was selected because of its robustness and efficiency in sampling (Burnham et al. 1980). Moreover, the line transect method is the most widely used and appreciated (Verner 1985).

The transect was walked only in the early hours of the morning since bird activity is highest at that time of the day (Robbins 1981). Transect was walked slowly ensuring that no bird was missed and recording only those birds that were seen in front so that there is no chance of double counting. Distances of the location of birds from the transect was visually estimated and since the observer remained the same for all the transects, the error if any in estimation would not affect the relative density figures.

Table 2.2. shows the number of times each transect was sampled. Transect 8 was sampled only for one winter and one summer season. Each transect was sampled at a few days interval in each season.
Table 2.2. Number of samples for each transect.

<table>
<thead>
<tr>
<th>Transects</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>2.</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>3.</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>4.</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>5.</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>6.</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>7.</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>8.</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

On encountering a bird on the transect following parameters were recorded:

a. the perpendicular distance from the transect to the bird or cluster of birds or the angular distance and sighting angle if perpendicular distance could not be measured.

b. the number of birds in the group, and species

c. the height or strata at which it was foraging

d. the species of foraging plant

e. other activity if any

Analysis: The Fourier series model in the computer program TRANSECT (Laake et al. 1981) was used to estimate densities of birds. This estimator was used in analysis because of its robustness. The densities of bird clusters were then multiplied by mean cluster size to get number of birds per hectare.
The bird species abundance were used to calculate the following indices and measures.

a) Birds species diversity (BSD) for each site was calculated as the Shannon-Wiener index $H'$ (MacArthur & MacArthur 1961)

$$H' = - \sum p_i \log p_i$$

Where $p_i$ is the proportion of species $i$, out of all species, $S$

b) Birds species richness (BSR) was calculated from the rarefaction curves. It would appear that an ambiguous and straightforward index of species richness would be $S$. However, since $S$ depends on the sample size (and the time spent searching), its use is limited as a comparative index (Yapp 1979). Rarefaction is a probabilistic distribution free method of sampling from a hierarchically classed universe. It is used to determine the expected number of species in a sample of individuals smaller than the original sample. By standardizing samples of different numbers of individuals from various communities, it permits comparison of species richness at a fixed number of individuals (Hurlbert 1971). Hurlbert's estimate for expected number of species $E(S_n)$ was calculated as:

$$E(S_n) = \sum_{i=1}^{s} \left\{ 1 - \left[ \frac{(N-n_i)}{N} \right] \right\}$$

Where $n_i$ is the number of individuals in species $i$ and $N$ the number of total individuals.
A Computer package 'Statistical Ecology' (Ludwig and Reynolds 1988) was used to calculate $E(S_n)$. The expected number of species for samples of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 individuals were generated and plotted to get rarefaction curves for each study sites. The $E(S_n)$ at 50 individuals was used as the species richness index.

### 2.2.3. Guild Structure

A priori guild designations using a small number of subjective criteria (Jaksic 1981) were used in categorizing guilds. Birds were allotted different guilds based on field observation and Ali & Ripley (1986).

### 2.2.4. Habitat Structure

#### 2.2.4.1 Introduction

In choosing suitable habitats, birds can use vegetation features as selection criteria (e.g. Hildy 1965), thereby "integrating" over a large number of biotic and abiotic factors without having to examine all of these separately. Information about vegetation structure and composition will implicitly contain information about a broad range of ecological factors and their interrelations (Erdelen 1984). Literature on habitat structure suggests many variables, but the aim of the present study has been the assessment and comparison of objectives and quantitative general indices for bird communities and for the vegetation structure of their habitats, as well as an investigation of their correlations. Following variables were chosen for the study:

a) Tree density (TDN)
b) Number of tree species (TSP)
c) Tree species diversity (TSD)
d) Shrubs diversity (SDN)
e) Number of shrub species (SSN)
f) Shrub species diversity (SSD)
g) Foliage height diversity (FHD)
h) Canopy cover (CCV)
i) Canopy height (CHT)
j) Shrub cover (SCV)

2.2.4.2. Field Methods: Each transect was divided into 50 m segments. In each segment a 10 m radius plot was laid. All the tree species were enumerated, their girth at breast height, and phenology were also recorded. For shrubs a 5 m radius plot was laid and all the shrub species and their numbers were recorded. In order to estimate foliage height diversity, canopy cover, canopy height and shrub cover data was collected at sample points at an interval of 7 m, thus giving 112 sample points in a 800 m long transect.

For canopy cover estimation a modified canopy cover estimation procedure was used to get a consistent result. A 20 cm x 20 cm mirror consisting of 20 squares was used. Canopy cover was estimated in percentage by placing the mirror horizontally and counting the number of squares in which foliage appeared. The mean of all sample points in a transect was used for further analysis. Shrub cover was visually estimated in percentage in 1 m radius circle at each sample point.

At each sample point within a radius of 0.5 m, the following height categories were chosen for recording the presence or absence of foliage: .25, .5, 1, 1.5, 2, 3, 4, 5, 7, 9, 12 and >12 m. These recordings were used to calculate foliage height
diversity. The canopy height was recorded at each sample point and the mean of all point was used.

2.2.4.3 Analysis: Tree species diversity and shrub species diversity were calculated by using Shannon-Wiener index ($H'$) as described before. Method described by Erdelen (1984) was followed in calculating foliage height diversity (FHD). The proportion of positive recording for a particular height category (for all points pooled) of the total positive recordings was calculated ($\alpha$) and the Shannon-Wiener index ($H'$) was used.

Spearman's rank correlation coefficient was used to test correlations of birds species diversity (BSD) and bird species richness (BSR) with all the habitat variables. Linear regression of BSD and BSR with all significantly correlated habitat variables was also done. To determine which variables are together the most important in explaining the trend in BSD and BSR, a stepwise multiple regression analysis was done using the computer package SPSS/PC. Prediction models were developed for BSD and BSR in both winter and summer seasons, using the equations developed by stepwise multiple regression analysis.

2.2.5 Heterospecific Flocking

Data on heterospecific formation and flock composition was obtained for all transects during winter and summer seasons. During the line transects sampling (as mentioned earlier), when a flock was encountered the following information were recorded:

a) The species composition
b) The height or strata at which each species was found foraging

c) The size of the flock

Observations on flock formation and anti-predatory behavior were also recorded.
3. RESULTS

3.1 General

A total of 209 species representing 53 families were recorded in the study area during the study period (Appendix 3.1). The breakup of total species according to the residential status is as follows:

- Resident -156
- Winter Visitor -26
- Summer Visitor -12
- Migratory -15

One hundred twenty species of forest birds were recorded in the study sites during the transects.

3.2. Bird Community Structure

3.2.1 Bird species diversity

The use of indices such as bird species diversity (BSD) and bird species richness (BSR) show the differences in bird community structure among all 8 study sites (Table 3.1 & 3.2). Significant difference was found in bird species diversity in winter and summer seasons for all the 8 study sites using Willcoxon matched pairs signed rank test (T= 1, P<0.05) (Seigel 1956). Bird species diversity and Bird species richness were also calculated excluding 5 generalist species e.g. roseringed parakeet (RRP), blossomheaded parakeet (BHP), redvented bulbul (RWB), yellowthroated sparrow (YTS) and brahminy myna (BM). Since these species are generalists and are
common in study sites, there was no significant difference in BSR after excluding them and this does not affect the further analysis. The bird species diversity and bird species richness figures excluding these 5 species were used in further analysis.

Table 3.1 Bird species diversity/richness in Winter

<table>
<thead>
<tr>
<th>TRANSECT</th>
<th>Number of species</th>
<th>Birds species diversity (BSD)</th>
<th>Bird species richness (BSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Excluding RRP, BHP, RVB, YTS &amp; BM</td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>39</td>
<td>35</td>
<td>2.36</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>27</td>
<td>2.09</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>28</td>
<td>2.07</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>37</td>
<td>2.94</td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>38</td>
<td>2.78</td>
</tr>
<tr>
<td>6</td>
<td>36</td>
<td>32</td>
<td>2.70</td>
</tr>
<tr>
<td>7</td>
<td>35</td>
<td>31</td>
<td>2.28</td>
</tr>
<tr>
<td>8</td>
<td>32</td>
<td>28</td>
<td>2.49</td>
</tr>
</tbody>
</table>
Table 3.2 Bird species diversity/richness in Summer

<table>
<thead>
<tr>
<th>TRANSIENT</th>
<th>Number of species</th>
<th>Birds species diversity (BSD)</th>
<th>Bird species richness (BSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Excluding RRP,BHP,RVB,YTS &amp; BM</td>
<td>Total</td>
</tr>
<tr>
<td>1</td>
<td>41</td>
<td>36</td>
<td>2.73</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>41</td>
<td>2.56</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>26</td>
<td>2.25</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>31</td>
<td>2.11</td>
</tr>
<tr>
<td>5</td>
<td>47</td>
<td>43</td>
<td>2.57</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>45</td>
<td>2.78</td>
</tr>
<tr>
<td>7</td>
<td>43</td>
<td>38</td>
<td>2.47</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>21</td>
<td>2.35</td>
</tr>
</tbody>
</table>
It is evident that the expected number of species from a sample size of 50 individuals is a better index of bird species richness than direct count of total species. The rarefaction curves show a definite pattern in species richness between the study sites (Fig. 3.1 & 3.2). The steepness of curves indicate the degree of evenness. Since there is a strong correlation between BSR and BSD in both winter and summer seasons (Rs = 0.9929; p<0.001 and Rs = 0.9667; p<0.001), BSD was used in all further analysis.

3.2.2. Density

The results of the density estimation procedures are given in table 3.3. All the transects with exception of transects 2 and 4 show an increase in density from winter to summer. Except transect 2 all other transects in contiguous forest have higher densities than fragmented forests. The vegetation structure in transect 2 was different from other transects and was more open. This could be the reason for low density in transect 2.

Table 3.3 Densities of birds per hectare in different sites (Transects)

<table>
<thead>
<tr>
<th>Transect</th>
<th>Winter</th>
<th>Summer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.5</td>
<td>14.3</td>
<td>12.7</td>
</tr>
<tr>
<td>2</td>
<td>6.9</td>
<td>2.8</td>
<td>4.6</td>
</tr>
<tr>
<td>3</td>
<td>4.1</td>
<td>7.2</td>
<td>5.8</td>
</tr>
<tr>
<td>4</td>
<td>14.6</td>
<td>11.5</td>
<td>13.0</td>
</tr>
<tr>
<td>5</td>
<td>7.2</td>
<td>10.2</td>
<td>8.3</td>
</tr>
<tr>
<td>6</td>
<td>7.3</td>
<td>14.8</td>
<td>10.7</td>
</tr>
<tr>
<td>7</td>
<td>4.1</td>
<td>14.0</td>
<td>9.3</td>
</tr>
<tr>
<td>8</td>
<td>9.5</td>
<td>9.7</td>
<td>9.6</td>
</tr>
</tbody>
</table>
Expected Number of Species

Number of Individuals

Transect 1  Transect 2  Transect 3  Transect 4
Transect 5  Transect 6  Transect 7  Transect 8

Fig. 3.1 Rarefaction Curves of Bird Species for different Transects in Winter
Fig. 3.2 Rarefaction Curves of Bird Species for different Transects in Summer.
3.2.3. Guild structure

Table 3.4 shows the number of species in each guild for all the study sites. The species were maximum in insectivore/foliage guilds for all study sites. Friedman two way analysis of variance for the ten guilds showed significant difference between the sites in terms of representation of species in different guilds (Chi-Sq = 12.51, p < 0.05).

Table 3.4. Number of species in each guild for all study sites.
(Figures in parenthesis are percentage species of the total for the site)

<table>
<thead>
<tr>
<th>Guild</th>
<th>Tran. 1</th>
<th>Tran. 2</th>
<th>Tran. 3</th>
<th>Tran. 4</th>
<th>Tran. 5</th>
<th>Tran. 6</th>
<th>Tran. 7</th>
<th>Tran. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carnivore</td>
<td>3 (7.3)</td>
<td>3 (6.5)</td>
<td>1 (3.1)</td>
<td>3 (7.3)</td>
<td>4 (8.5)</td>
<td>2 (4)</td>
<td>1 (2.3)</td>
<td>2 (6.2)</td>
</tr>
<tr>
<td>Fruit/Seed</td>
<td>6 (14.7)</td>
<td>6 (13.5)</td>
<td>3 (9.4)</td>
<td>5 (12.2)</td>
<td>3 (6.3)</td>
<td>5 (10)</td>
<td>4 (9.3)</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>Fruit/Insect</td>
<td>1 (2.4)</td>
<td>2 (4.3)</td>
<td>2 (6.3)</td>
<td>1 (2.4)</td>
<td>2 (4.2)</td>
<td>2 (4)</td>
<td>2 (4.7)</td>
<td>2 (6.3)</td>
</tr>
<tr>
<td>Granivore</td>
<td>3 (7.3)</td>
<td>3 (6.5)</td>
<td>2 (6.3)</td>
<td>2 (4.9)</td>
<td>3 (6.4)</td>
<td>3 (6)</td>
<td>3 (7)</td>
<td>1 (3.1)</td>
</tr>
<tr>
<td>Insectivore/Terrestrial</td>
<td>4 (9.8)</td>
<td>5 (10.9)</td>
<td>4 (12.5)</td>
<td>5 (12.2)</td>
<td>7 (14.9)</td>
<td>7 (14)</td>
<td>6 (13.9)</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>Insectivore/Sally</td>
<td>7 (17.1)</td>
<td>6 (13)</td>
<td>6 (19.7)</td>
<td>5 (12.2)</td>
<td>8 (17)</td>
<td>8 (16)</td>
<td>7 (7)</td>
<td>4 (12.5)</td>
</tr>
<tr>
<td>Insectivore/Foliage</td>
<td>12 (29.2)</td>
<td>14 (30.4)</td>
<td>9 (28.1)</td>
<td>13 (31.7)</td>
<td>12 (25.5)</td>
<td>15 (30)</td>
<td>14 (32.5)</td>
<td>9 (28.1)</td>
</tr>
<tr>
<td>Insectivore/Bark</td>
<td>2 (4.9)</td>
<td>1 (2.2)</td>
<td>1 (3.1)</td>
<td>2 (4.9)</td>
<td>3 (6.4)</td>
<td>3 (6)</td>
<td>3 (7)</td>
<td>3 (9.4)</td>
</tr>
<tr>
<td>Omnivore</td>
<td>2 (4.9)</td>
<td>4 (8.7)</td>
<td>3 (9.4)</td>
<td>3 (7.3)</td>
<td>3 (6.4)</td>
<td>3 (6)</td>
<td>2 (4.7)</td>
<td>2 (6.3)</td>
</tr>
<tr>
<td>Nectarivore</td>
<td>1 (2.4)</td>
<td>2 (4.3)</td>
<td>1 (3.1)</td>
<td>2 (4.9)</td>
<td>2 (4.2)</td>
<td>2 (4)</td>
<td>1 (2.3)</td>
<td>1 (3.1)</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>46</td>
<td>32</td>
<td>41</td>
<td>47</td>
<td>50</td>
<td>43</td>
<td>32</td>
</tr>
</tbody>
</table>
3.2.4. Effect of fragmentation

The distribution of birds in a patchy environment is determined primarily by the presence of suitable habitat. The size of their habitat patches may also affect the presence of species, since population sizes are related to patch size and hence to extinction rate (Jones and Diamond 1976, Wright and Hubballs 1983). As described in Chapter 2, out of 8 study sites 4 were selected in fragmented forest of different areas. Correlation analysis was used to test the relationships BSD and BSR, with area of the patch, distance from the nearest contiguous forest and distance from any nearest forest. Correlation analysis did not show any significant result.

3.2.5. Bird - Habitat Variables relationship

The results of the vegetation analysis are different in winter and summer. The bird species diversity (BSD) in winter was significantly correlated with number of tree species (TSP), tree species diversity (TSD), canopy cover (CCV), canopy height (CHT) and shrub cover (SCV) (Table 3.5). But in summer BSD was correlated with number of shrub species (SSN), shrub species diversity (SSD), canopy cover (CCV) and shrub cover SCV (Table 3.6). Plots of correlated habitat variables with bird species diversity (BSD) using linear regression are presented in Fig. 3.3-3.4 for winter and Fig. 3.5-3.6 for summer. Canopy cover (CCV) and shrub cover (SCV) were correlated with BSD in both the seasons. The strategy of using linear regression to relate the variables can provide meaningful interpretations but the multiple regression is likely to be more informative, since ecological community data are multivariate in nature. The result of stepwise multiple regression of BSD with habitat variable showed that canopy cover (CCV) and shrub cover (SSV) explained most of the variation in BSD ($R^2=0.948$...
p<0.0002). It is evident from multiple regression that structural variables can explain the bird species diversity in forests.

Table 3.5. Spearman's rank correlation coefficients between bird species diversity and bird species richness with habitat variables for Winter.

<table>
<thead>
<tr>
<th>Significance</th>
<th>* = 0.01</th>
<th>** = 0.001</th>
<th>n=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat variable</td>
<td>Bird species diversity</td>
<td>Bird species richness</td>
<td></td>
</tr>
<tr>
<td>BSD</td>
<td>BSR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDN</td>
<td>-0.2768</td>
<td>-0.2049</td>
<td></td>
</tr>
<tr>
<td>TSP</td>
<td>0.8355*</td>
<td>0.7722</td>
<td></td>
</tr>
<tr>
<td>TSD</td>
<td>0.8428*</td>
<td>0.7941*</td>
<td></td>
</tr>
<tr>
<td>SDN</td>
<td>0.5175</td>
<td>0.5515</td>
<td></td>
</tr>
<tr>
<td>SSN</td>
<td>0.3737</td>
<td>0.3739</td>
<td></td>
</tr>
<tr>
<td>SSD</td>
<td>-0.657</td>
<td>0.0204</td>
<td></td>
</tr>
<tr>
<td>FHD</td>
<td>0.5932</td>
<td>0.6084</td>
<td></td>
</tr>
<tr>
<td>CCV</td>
<td>0.9272**</td>
<td>0.9294**</td>
<td></td>
</tr>
<tr>
<td>CHT</td>
<td>0.7944*</td>
<td>0.7564</td>
<td></td>
</tr>
<tr>
<td>SCV</td>
<td>0.8183**</td>
<td>0.8240*</td>
<td></td>
</tr>
</tbody>
</table>

TDN = Tree density/ha, TSP = Number of tree species, TSD = Tree species diversity, SDN = Shrub density/ha, SSN = Number of shrub species, SSD = Shrub species diversity, FHD = Foliage height diversity, CCV = Canopy cover, CHT = Canopy height, SCV = Shrub cover.
Table 3.6. Spearman's rank correlation coefficients between bird species diversity and bird species richness with habitat variables for Summer.

<table>
<thead>
<tr>
<th>Habitat variable</th>
<th>Bird species diversity BSD</th>
<th>Bird species richness BSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDN</td>
<td>-0.6995</td>
<td>-0.6715</td>
</tr>
<tr>
<td>TSP</td>
<td>0.0375</td>
<td>0.0209</td>
</tr>
<tr>
<td>TSD</td>
<td>-0.1704</td>
<td>-0.2436</td>
</tr>
<tr>
<td>SDN</td>
<td>-0.3969</td>
<td>-0.4804</td>
</tr>
<tr>
<td>SSN</td>
<td>0.9148**</td>
<td>0.9383**</td>
</tr>
<tr>
<td>SSD</td>
<td>0.8346*</td>
<td>0.8281*</td>
</tr>
<tr>
<td>FHD</td>
<td>-0.5836</td>
<td>-0.5946</td>
</tr>
<tr>
<td>CCV</td>
<td>0.9557**</td>
<td>0.9823**</td>
</tr>
<tr>
<td>CHT</td>
<td>0.1301*</td>
<td>0.1801</td>
</tr>
<tr>
<td>SCV</td>
<td>0.9128**</td>
<td>0.9301**</td>
</tr>
</tbody>
</table>

TDN = Tree density/ha, TSP = Number of tree species, TSD = Tree species diversity, SDN = Shrub density/ha, SSN = Number of shrub species, SSD = Shrub species diversity, FHD = Foliage height diversity, CCV = Canopy cover, CHT = Canopy height, SCV = Shrub cover.
Fig. 3.3 Scatter Plots Showing Correlation of Bird Species Diversity with Different Vegetation Variables in Winter.
Fig. 3.4 Scatter Plots Showing Correlation of Bird Species Diversity with Bird Species Richness and Different Vegetational Variables in Winter.
Fig. 3.5 Scatter Plots Showing Correlation of Bird Species Diversity with Different Vegetation variables in Summer.
Fig. 3.6 Scatter Plots Showing Correlation of Bird Species Diversity with Bird Species Richness and Different Vegetation Variables in Summer.

BSD = BIRD SPECIES DIVERSITY
SSN = NUMBER OF SHRUB SPECIES
SSD = SHRUB SPECIES DIVERSITY
BSR = BIRD SPECIES RICHNESS
3.3. Rarity

No endemic species was recorded in the study area. As such no species was also recorded which could be considered as rare or endangered. However, it has been discussed in Chapter 2 that rare species can be differently categorized or defined in regard to their status. If we consider the different guilds, species belonging to Carnivore, Frugivore and Insectivore/bark guilds occur in widely scattered localities within a large area but are represented by only a few individuals and are sensitive to environmental changes. Significant number of species belonging to these guilds were recorded in the study area (Table 3.4)

3.4 Heterospecific Flocking

Table 3.7 shows the flock characteristics for all study transects. Highest number of flocks (21) were recorded from transect 2 which also has the highest number of species recorded in the flocks. It is apparent from the results that there is an inverse relationship of flocking tendency with the density of birds (Table 3.7). This trend is also evident from number of species encountered in the flocks on the transects. A total of 16 species were recorded in the flocks from all the transects. Whitebrowed fantail flycatcher was the most common species found in the flocks followed by greyheaded flycatcher. Small minivit was always recorded foraging on high canopy strata. Table 3.8 shows the percent frequency of occurrence in the flocks and preferred height category or strata for foraging.
Table 3.7  Flocks Characteristics for all Transects.

<table>
<thead>
<tr>
<th>Transect</th>
<th>No. of Flocks</th>
<th>No. of Species in Flocks</th>
<th>Bird Density per ha.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>12</td>
<td>12.7</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>16</td>
<td>4.6</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>14</td>
<td>5.8</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>15</td>
<td>8.3</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>8</td>
<td>10.7</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
<td>14</td>
<td>9.3</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>11</td>
<td>9.6</td>
</tr>
</tbody>
</table>

40
Table 3.8 Frequency of Occurrence of Species recorded in Mixed Foraging Flocks.

<table>
<thead>
<tr>
<th>Species</th>
<th>% Frequency of Occurrence</th>
<th>Foraging Height/Strata</th>
</tr>
</thead>
<tbody>
<tr>
<td>White browed faintail flycatcher</td>
<td>96</td>
<td>Shrubs and lower canopy</td>
</tr>
<tr>
<td>Greyheaded flycatcher</td>
<td>92</td>
<td>Shrubs and lower canopy</td>
</tr>
<tr>
<td>Grey tit</td>
<td>90</td>
<td>Lower and middle canopy</td>
</tr>
<tr>
<td>Yellow browed leaf warbler</td>
<td>90</td>
<td>Middle canopy</td>
</tr>
<tr>
<td>Black drongo</td>
<td>85</td>
<td>Lower and middle canopy</td>
</tr>
<tr>
<td>Small minivit</td>
<td>80</td>
<td>Upper canopy</td>
</tr>
<tr>
<td>White bellied drongo</td>
<td>80</td>
<td>Middle canopy</td>
</tr>
<tr>
<td>Large grey babbler</td>
<td>75</td>
<td>Ground and shrubs</td>
</tr>
<tr>
<td>Common iora</td>
<td>75</td>
<td>Lower and middle canopy</td>
</tr>
<tr>
<td>Chestnut bellied nuthatch</td>
<td>70</td>
<td>Middle canopy</td>
</tr>
<tr>
<td>Tickel's blue flycatcher</td>
<td>65</td>
<td>Shrubs</td>
</tr>
<tr>
<td>Pigmy woodpecker</td>
<td>60</td>
<td>Lower and middle canopy</td>
</tr>
<tr>
<td>Common wood shrike</td>
<td>40</td>
<td>Shrubs and lower canopy</td>
</tr>
<tr>
<td>Paradise flycatcher</td>
<td>30</td>
<td>Shrubs and lower canopy</td>
</tr>
<tr>
<td>Rufousbacked shrike</td>
<td>20</td>
<td>Shrubs and lower canopy</td>
</tr>
<tr>
<td>Redbreaseted flycatcher</td>
<td>20</td>
<td>Shrubs</td>
</tr>
</tbody>
</table>
3.5. Habitat Model

If a plot of the abundance of species against an environmental variable look linear, or can easily be transformed to linearity, then it is appropriate to fit a straight line by linear regression. Thus the fitted line can be used to predict the abundance of species in a site with a known value of the environmental variables.

Species experience the effect of more than one environmental variable simultaneously so more than one variable may be required to account for variation in species abundance. The joint effect of two or more environmental variables on a species or a community can be analyzed by multiple regression (Montgomery & Peck 1982). Stepwise multiple regression analysis using SPSS/PC (Norusis 1986) was done with BSD as the dependent variable and habitat variables such as TDN, TSP, TSD, SDN, SSN, SSD, FHD, CCV, CHT, and SCV as independent variables. For winter and summer following regression equations were obtained:

Model for Winter

\[
BSD = 0.01126 (+ 0.00217) \text{CCV} + 0.006 (+ 0.002) \text{SCV} + 1.916 (+ 0.097)
\]

\[
R^2 = 0.948 \quad \text{Adjusted } R^2 = 0.927 \quad p = 0.006
\]

Values in parenthesis are Standard Errors.

Model for Summer

\[
BSD = 0.327 (+ 0.00412) \text{CCV} + 1.64 (+ 0.173)
\]

\[
R^2 = 0.9133 \quad \text{Adjusted } R^2 = 0.899 \quad p = 0.002
\]

Values in parenthesis are Standard Errors

CCV = Canopy cover, SCV = Shrub cover
4. DISCUSSION

4.1 General

The number of forest species recorded suggests the potential richness of the woodland habitat. During the study 156 species were recorded as residents which itself reflects the potential of the area to support avifauna. Certain population differences characterize the avian communities. Preference for a habitat by a few very common species is indicative of disturbed habitat and greater equability of species often typifies the more complex and less disturbed habitat (Patrick 1963, Mac Arthur 1972). The higher number of specialist forest bird species reflects on better diversity of the forest. Since all specialists have their own individual niche, collectively they require a wider diversity of food and other resources from their habitat (Gautam et al., 1993).

4.2 Bird community and habitat structure

Studies on bird species diversity were frequently taken up after Robert Mac Arthur and associates (Mac Arthur & Mac Arthur 1961, Mac Arthur et al. 1962, 1966) suggested that information theory measures of bird species and of habitat structure are linearly related within a given region. These diversity studies (Mac Arthur et al. 1962, Mac Arthur 1966, Kar 1971, and Terborgh 1977) show that within broad limits, structural aspects of habitat can be used to predict diversity and there are correlations to features of the habitat that the birds themselves use. In general, the number of species that pack into a habitat, defined as alpha diversity, are directly related to structural diversity and in turn structural diversity is related to either resource diversity or the number of ways in which resources can be partitioned (Cody 1985). Thus birds
can be considered good indicators of resource availability or the health of the ecosystem.

The importance of habitat structure or physiognomy in bird habitat selection was apparent from Mac Arthur's work on species diversity and vegetation density against height, called foliage profiles. Kar (1971), Wilson (1974), and Terborgh (1977) also followed the similar approach. In the present study, multiple regression analysis showed that canopy cover (CCV) was strongly correlated with bird species diversity and was responsible for more than 90% variability observed in bird species diversity. James (1971), Whitmore (1975), Smith (1977) and Collins et al. (1982) measured up to two dozen or more habitat variables, among which vegetation height and percent canopy cover often recurred as most significantly related to bird distribution. Other structural variables such as shrub cover and canopy height were also linearly correlated in present study.

Habitat structure as we measure it, can clearly mean or translate into different resources for different species of birds; foraging sites, nesting sites and protection from predators are some obvious possibilities (Cody 1985).

Are structural variables the only ones which can affect a community? Strong linear correlations were observed between BSD and floristic variables such as TSP and TSD in winter and SSN and SSD in summer. Rai (1991) found TSP as a more reliable determinant of bird species richness although canopy cover was the variable responsible for variation in bird species richness. He postulated that after resources are available and above the threshold level, birds would respond to structural aspects
of the habitat. The present study also indicates the similar type of situation. It can be postulated that in a given habitat if resources are present at optimum level, bird species diversity would reflect the structural diversity of the habitat.

What contributes to the structural diversity? It was found that structural variables e.g. canopy cover, canopy height and shrub cover were linearly correlated with floristic variables such as tree species richness (TSP), tree species diversity (TSD) and shrub species number (SSN). Based on this it could be concluded that structural diversity in a given habitat would also reflect floristic diversity up to certain extent.

Even though structural features may correlate well with the density of a certain species, and in that sense we may be able to predict its occurrence and density, the correlation alone does not tell us what it is about the structural variable that bird responds to. Another problem with any community study is that it collectively deals with many species which are taken together in relation to habitat variables. As a result the importance of species from conservation point of view and their relationship with habitat is lost. Even a simple measure such as bird species richness obscures the quality of species. Finch (1985) suggested that techniques such as multivariate analysis combined with principal component analysis can identify groups of species (e.g. guilds) that responds to certain combination of habitat variables.

4.3 Seasonal changes

Significant changes were observed in bird species diversity and bird species richness with the change of seasons. In any community study it is essential to study the community dynamics on seasonal basis. Present study indicates that there is influx of
visitor species in respective seasons. A significantly high number of summer visitors come to the study area than do winter visitors. Bird species diversity as well as bird density was higher in summer. Another reason for higher density figures obtained in summer during this study may be the fact that summer is the breeding season of most of the birds which become more conspicuous by their courtship displays.

These changes may also correspond to the changes in vegetation structure. The observations data for winter and summer each taken together indicates that while BSD correlated with TSP and TSD during winter but BSD correlated with SSN and SSD in summer. The plausible explanation for this change is as follows: Though the dominant species of trees in the region start shedding their trees in November/December, sufficient foliage with associated insect fauna and other food is still available on trees. But with the onset of summer around late March, when most leaves have been shed particularly in the teak dominated parts, not much foraging material is left for the birds. However, the shrubs do not undergo any significant changes from winter to summer and therefore vegetative material and associated insect fauna remains there to attract birds. Most of the resident species which breed in the study area prefer lower strata of the habitat constituted by mainly shrubs and lower canopy trees. Therefore the nesting requirements of breeding birds in summer are also met by the shrubs and lower canopy trees.

4.4 BSD-FHD relationship

Much work has been done during the last two decades on bird communities and vegetation using a number of diversity indices. The results have usually been interpreted in terms of biological processes, often with far reaching conclusions.
referring to, for example, interspecific competition, the niche concept, and the mechanisms of evolution (Erdelen 1984). But the most popular is BSD-FHD relationship (MacArthur 1961). In the present study this relationship was neither found to exist in winter nor in summer. Erdelen (1984) had found a relationship between BSD and FHD for a number of different habitats, however, when a subsection of the habitat was taken into consideration no such relationship could be found. Willson (1974) had also found that the famous BSD-FHD relationship was apparent only if both field and forest areas were taken together for evaluation, but not for the forested plots alone. The present study was carried out in more or less similar habitats and no correlation between BSD and FHD was found to exist.

4.5 Heterospecific Flocking

Why does heterospecific flocking occur? Is there any relationship between flocking behaviour and food availability? These questions were attempted to be answered in the present study. Lack (1954) found that bird density is directly proportional to food abundance. Rai (1991) also found that flocking increases with decreasing food availability. Present study indicates that the number of flocks and the number of species found in the flocks are inversely related to bird density. Since bird density is an indicator of food availability, flocking is inversely related to food availability and therefore a response to bleak conditions (Rai 1991). Cody (1971) and Morse (1970) also found similar results for flocks in North America.

Birds do get advantage in foraging in flocks. Flocking birds 'beat' a patch as they move through it (Munn and Terborgh 1979, Diamond 1981). The insects which come out are then easily seen and captured by flock members. The air sallying birds
get more advantage by joining the flocks. Whitebrowed fantail flycatcher, a air sallying bird was the most common species in the flocks in the study area, followed by greyheaded flycatcher and drongos. Ali and Ripley (1983) observed that greyheaded flycatcher are found "acting as outriders, and catching any insect escaping from the main body".

From the above discussions it seems that only the sallying birds get advantage in joining the flocks. What benefits foliage gleaning birds derive from flocks? The probable explanation of occurrence of foliage gleaners and bark foragers in flocks is antipredatory advantages. Foliage gleaning birds are poor in detecting the predators, because of their foraging behaviour which involves searching for the food. The sally feeders are more efficient in detecting the predators while scanning for flying insects.

According to Powell (1985) the beater effect and predator avoidance by improved surveillance, are the only two attributes that are consistent with assumptions of hypotheses testing the adaptive significance of flocking.

Flocks are characterized by nuclear species and attendants. Species are categorized as nuclear or attendant more by gestalt than by a rigorous evaluation of their contribution to flocking (Powell 1985). In the study area the probable nuclear species were whitebrowed fantail flycatcher, greyheaded flycatcher and yellowbrowed leaf warbler. These species call continuously till they were joined by other members of the flocks. Terborgh (1979) reports similar flock formation in Amazonian birds: special calls by the nuclear species followed by the regular 'follow me' calls after formation.
Based on the above discussion it could be concluded that the two hypotheses: increased foraging efficiency and predators avoidance, both together have the mutual role in heterospecific flocking. Heterospecific flocking is a typical example of maximum utilization or resources with least efforts.

4.6 The Habitat Model

Habitat model approach has been tried by few workers (Rice et al. 1986, Dobkins & Wilcox 1986, Pai 1993). The results of multiple regression showed that canopy cover and shrub cover explained 94.8 % of the variability in bird species diversity in winter, while in summer canopy cover alone explained 91% of the variation in bird species diversity. Such habitat models can help biologists and managers in various ways. For example, just by putting the values of vegetation variables in the equation, bird species diversity can be calculated in a given area with certain degree of confidence.

The models are capable of making any prediction, because both the seasons were covered twice and sufficient data was collected to develop these models. Moreover the predictive capability of the models is over 90 % for both the seasons. According to Rice et al. (1986) a margin of error of about 30 % can be allowed. These models can be used to evaluate the effect of management practices in the forest, impact of biotic pressures and developmental project on the forest.
5. IMPACT IDENTIFICATION

The present study was a part of comprehensive study conducted by Wildlife Institute of India to identify impacts of Narmada Sagar Project on flora and fauna with attendant human aspects. The most important step in EIA is the impact identification. The process of EIA revolves around the identification of cause and effect, a cause being any action of the proposed project which has an effect upon the environment (Anon. 1994). These effects are environmental impacts of the project. Any effect on the biophysical and socio-economic environment that arises from a cause directly related to the project is termed as a ‘first order’ or ‘primary impacts’. ‘Secondary impacts’ are those effects on the biophysical and socio-economic environments which also arise from an action but which are not initiated directly by that action. Their occurrence is defined by the inter-dependencies which exist within and between the two systems (Shopley & Fuggle 1984). In this section an attempt has been made to mainly identify the primary impacts of Narmada Sagar Project on avifauna. The basis for impact identification is the baseline information on bird communities that has been collected from Narmada Sagar Project area.

Impacts of Narmada Sagar Project on Avifauna

The results of the ornithological evaluation of submergence area suggested the potential richness of woodland and riverine bird species. The submergence of this woodland habitat would in all likelihood be a direct and irreversible loss to the overall avian diversity of the area. No endemic species has so far been
recorded in the study area, but there will be a potential impact on highly specialized species such as carnivore, insectivore/bark, and frugivore species. In the event of their migration to the adjoining forest a resource competition with existing avifauna may occur. The size of a forest being strongly related to the habitat requirements of the concerned animal species which have large home ranges may find it difficult to adjust and co-exist with the indigenous avifauna of adjoining forests. Serious depletion in numbers, particularly of the more specialized species may occur as a result of the primary impact of submergence of the forest habitat, specially the riverine areas.

In a river valley project, submergence of forest by a number of dams will break the contiguity of the forest. The total loss of the forest habitat will probably lead to the loss of a number of species confined to these habitats. Reduction in size of the forest is expected to lead to the loss of some species as has been postulated by MacArthur & Wilson (1967) and Whitcomb et al. (1976). At present it is undoubtedly the loss of habitat per se that is the most serious impact of development on ecology in India. However, following impacts on specialized species of birds have been identified:

1. The inundation of small rivers and streams may cause decline in the variety of fishes and invertebrates which are important components of the food chains. This may affect the concerned bird species such as herons, egrets, bitterns, water hens and king fishers. Loss of feeding
ground such as shallow areas on the banks of rivers and streams would affect species like lapwings, plovers, sandpipers and shanks.

2. Loss of riverine trees and shrubs is likely to lead to the loss of perching and nesting sites of species such as flycatchers and owls.

3. Loss of bushes and dense herbaceous vegetation, which are important for feeding and nesting, may affect species such as warblers, babblers, munias and weaver birds.

4. Forest clearing in proposed submergence area is apprehended to adversely affect the ground dwelling birds such as partridges, quails, peafowls and spurfowls. These birds nest on ground and any change like forest clearing on a large scale would severely disturb the breeding ecology of these species resulting in their population decline.

5. Species such as buzzards, hawks, eagles and owls which are highly territorial and require large areas as home ranges, would be adversely affected by the loss of the forest due to submergence. The movement of these species to the adjoining forest may create resource competition with the population of the same species there.

6. Species such as woodpeckers, nuthatches, barbets, tits and hornbills, which are bark gleaners and are dependent on old trees for feeding and
nests, may suffer due to the loss of old mature trees, and may face resource competition from existing avifauna of the forest adjoining the submergence area.

7. The presence of more than 30 species of riverine birds shows the suitability of the Narmada river and its tributaries as a habitat for riverine bird communities (Appendix 3.1). These communities will be adversely impacted by the proposed submergence. Considering the ecological similarities of Tawa Reservoir (M.P.) with Narmada Sagar Project area, a comparative study was conducted in Tawa Reservoir. Tawa Dam was completed some 15 years ago and large forest area was submerged for construction of dam and reservoir. It can be expected that the effects of the developmental changes that took place there will also take place in Narmada Sagar Project area. Based on the observations in Tawa area, the likely chain of ecological events in the study area is as follows: Changing a lotic riverine ecosystem to lentic reservoir system would adversely modify the existing habitat conditions and its impact on most of the riverine birds may be undesirable. Migrant birds are affected by the conditions prevailing in their wintering grounds and along their migratory pathways. The abundance of migrant bird species, therefore reflects the suitability of a particular site as a habitat because the condition of the resources in the area may affect a bird's "decision" to remain or migrate further (Steel et al. 1984). In the study area some of the migrant species were recorded in good numbers. Most of these migratory species are aquatic and dependent on the river system for feeding
and breeding requirements. Inundation of sand and rocky banks and islands would affect the ecology of these species. The fish fauna will be changed when the reservoir is formed. The present fish diversity will be lost and commercially important fish species like carps will dominate the new aquatic system. The piscivorous bird species such as cormorants, darters, egrets, herons, storks, ibis and spoonbill would be affected by this change of aquatic system and fish fauna. The proposed reservoir will be very deep and the composition of aquatic vegetation would be very different than what it is at present. It has been observed that aquatic weeds take over the deep reservoirs (Moss 1980). If it happens here too, birds such as pintail, gadwall, spotbill duck and shovellers which feed on vegetation growing in shallow water will be deprived of their natural food and may disappear from NSP area.

Birds do have special advantages over other groups, because of their consciousness, ubiquity and ecological diversity which make them worth studying. It is to be hoped that documentation of changes in bird species diversity may to some extent, mirror the changes in species diversity of other groups.
6. REFERENCES


Panwar, H.S., Rajvanshi, A; Gautam, P; Murlidharan V.V.; and Rastogi, A. (1990). A Study of Impacts of Bodhghat Hydel Project upon Wildlife and Related Human Aspects with Special Reference to Wild Buffalo Conservation in Bastar. Wildlife Institute of India, Dehra Dun, India.


Appendix 2.1 Checklist of mammals of Narmada Sagar Project area.

1. Indian wild boar - *Sus scrofa*
2. Sambhar - *Cervus unicolor*
3. Chital - *Cervus axis*
4. Barking deer - *Munticus muntjak*
5. Chowsingha - *Tetracerus quadricornis*
6. Nilgai - *Boselaphus tragocamelus*
7. Chinkara - *Gazella gazella*
8. Blacknaped hare - *Lepus nigricollis*
9. Porcupine - *Hystrix indica*
10. Sloth bear - *Melurs ursinus*
11. Jackal - *Canis aureus*
12. Indian fox - *Vulpus bengalensis*
13. Indian wolf - *Canis lupus*
14. Hyaena - *Hyaena hyaena*
15. Leopard - *Panthera pardus*
16. Tiger - *Panthera tigris*
17. Jungle cat - *Fellis chaus*
18. Rhesus macaque - *Macaca mulatta*
19. Common langur - *Presbytis entellus*
20. Palm civet - *Paradoxurus hermaphroditus*
21. Small Indian civet - *Viverricula indica*
22. Ratel - *Mellivora capensis*
23. Common mongoose - *Herpestes edwardsi*

24. Ruddy mongoose - *Herpestes smithi*

25. Smooth Indian otter - *Lutra perpicilata*

26. Common giant flying squirrel - *Petaurista petaurista*

27. Five striped palm squirrel - *Funambulus pennati*

28. Flying fox - *Pteropus giganteus*

29. Fulvous fruit bat - *Rousettus leschenaultii*
Appendix 2.2 - Checklist of Fish of Narmada Sagar Project Area.

1. *Notopterus chitala*
2. *Notopterus nototerus*
3. *Channa marulius*
4. *Channa stiatus*
5. *Heteropneustes fossilis*
6. *Clarius batrachus*
7. *Labeo rohita*
8. *Labeo bata*
9. *Labeo calbasu*
10. *Cirrhina mirgala*
11. *Cirrhina reba*
12. *Mastacembelus armatus*
13. *Ambassia ranga*
14. *Ambassia nanna*
15. *Oxygaster spp.*
16. *Puntius sophore*
17. *Puntius tetrarupagus*
18. *Puntius chrysopterus*
19. *Botia birdi*
20. *Wallago attu*
21. *Mystus aor*
22. *Mystus vittatus*
23. *Mystus seenghala*
24. Rita rita
25. Catla catla
26. Colisa fasciatus
27. Barbus spp.
28. Cyprinus carpio
29. Anguilla anguilla
30. Hilsa ilisha
Appendix 2.3 - Checklist of Reptiles of Narmada Sagar Project area.

Snakes
1. Indian Rock Python - *Python molurus*
2. Common Sand Boa - *Eryx conicus*
3. Red Sand Boa - *Eryx johnii*
4. Banded Kukri - *Oligodon arnensis*
5. Striped Keelback - *Amphiesma stolata*
6. Checkered Keelback Watersnake - *Xenochropis piscator*
7. Rat Snake - *Ptyas mucosus*
8. Common Krait - *Bungarus caeruleus*
9. Banded Krait - *Bungarus fasciatus*
10. Indian Cobra - *Naja naja*
11. Russells Viper - *Vipera russelli*

Lizards
12. House Gecko - *Hemidactylus flaviviridis*
13. Rock Gecko - *Cyrtodactylus dekkaniensis*
14. Common Garden Lizard - *Calotes versicolor*
15. Forest Calotes - *Calotes rouxi*
16. Fan-throated Lizard - *Sitana ponticeriana*
17. Common Skink - *Mabuya carinata*
18. Snake Skink - *Riopa punctata*
19. Indian Monitor Lizard - *Varanus bengalensis*
Turtles

20. *Trionyx gangeticus*
21. *Lissemys punctata*
23. *Kachuga tecta*
24. *Kachuga tentoria*
25. *Chitra indica*
Appendix 3.1 - Checklist of birds of Narmada Sagar Project area.

Status:  
R - Resident  
M - Migratory (Extralimital)  
W - Winter Visitor  
S - Summer Visitor

PHALACROCORACIDAE

Cormorant - Phalacracorax carbo - R  
Little Cormorant - Phalacracorax niger - R  
Darter - Anhinga rufa - R

ARDEIDAE

Purple Heron - Ardea purpurea - R  
Little Green Heron - Ardeola striatus - R  
Pond Heron - Ardeola grayii - R  
Cattle Egret - Bubulcus ibis - R  
Median Egret - Egretta intermedia - R  
Little Egret - Egretta garzetta - R  
Night Heron - Nycticorax nycticorax - R  
Grey Heron - Ardea cinerea - R  
Chestnut Bittern - Ixobrychus cinnamomeus - R
CICONIIDAE
Blacknecked Stork - *Ephippiorhynchus asiaticus* - R
Whitenecked Stork - *Ciconia episcopus* - R
Openbill Stork - *Anastomus oscitans* - R

HRESKIORNITHIDAE
White Ibis - *Tureskiornis aethiopica* - R
Black Ibis - *Pseudibis papillosa* - R
Glossy Ibis - *Plegadis falcinellus* - R
Spoonbill - *Platalea leucornodia* - M

ANATIDAE
Lesser Whistling Teal - *Dendrocygna javanica* - W
Ruddy Shelduck - *Tadorna ferruginea* - M
Spotbill Duck - *Anas poecilorhynca* - R
Pintail - *Anas acuta* - M
Gadwall - *Anas strepera* - M
Wigeon - *Anas penelope* - M
Shoveller - *Anas clypeata* - M

ACcipitridae
Blackwinged Kite - *Elanus caeruleus* - R
Honey Buzzard - *Pernis ptilorhyncus* - R
Pariah Kite - *Milvus migrans govinda* - R
Shikra - *Accipiter badius* - R
Sparrow Hawk - *Accipiter nisus* - R
Indian Longbilled Vulture - *Gyps indicus* - R
Indian Whitebacked Vulture - *Gyps bengalensis* - R
Egyptian Vulture - *Neophron percnopterus* - R
Marsh Harrier - *Circus aeruginosus* - R
Creasted Hawk Eagle - *Spizaetus cirratus* - R
Creasted Serpent Eagle - *Spilornis cheela* - R
Booted Hawk Eagle - *Hieraetus pennatus* - R
Greyheaded Fishing Eagle - *Ichthyophaga ichthyaetus* - R

**FALCONIDAE**

Kestrel - *Falco tinnunculus* - R

**PHASIANIDAE**

Black Partridge - *Francolinus francolinus* - R
Grey Partridge - *Francolinus pondicerianus* - R
Painted Partridge - *Francolinus pictus* - R
Jungle Bush Quail - *Perdicula asiatica* - R
Painted Bush Quail - *Perdicula erthrorhyncha* - R
Common Peafowl - *Pavo cristatus* - R
Red Spurfowl - *Gallopardix spadicea* - R
TURNICIDAE
Little Bustard Quail - *Turnix sylvatica* - R
Common Bustard Quail - *Turnix suscitator* - R

GRUIDAE
Sarus Crane - *Grus antigone* - R

RALLIDAE
Indian Moorhen - *Gallinula chloropus* - R
Whitebreasted Waterhen - *Amaurornis phoenicurus* - R

JACANIDAE
Pheasant-tailed Jacana - *Hudrophasianus chirurgus* - R

ROSTRATULIDAE
Painted Snipe - *Rostratula benghalensis* - R

BURHINIDAE
Great Stone Plover - *Esacus magnirostris* - R

RECURVIROSTRIDAE
Blackwinged Stilt - *Himantopus himantopus* - R
GLAREOLIDAE

Indian Courser - *Cursorius caromandelicius* - R
Small Indian Pratincole - *Glareola lactea* - W

CHARADRIIDAE

Redwattled Lapwing - *Vanellus indicus* - R
Spurwinged Lapwing - *Vanellus spinosus* - R
Yellow-wattled Lapwing - *Vanellus malabaricus* - R
Little Ringed Plover - *Charadrius dubius* - M
Kentish Plover - *Charadrius alexandrius* - M
Lesser Sand Plover - *Charadrius mongalus* - M
Grey Plover - *Pluvialis squatrola* - M
Greenshank - *Tringa nebularia* - M
Redshank - *Tringa totanus* - M
Common Sandpiper - *Tringa hypoleucos* - M
Green Sandpiper - *Tringa ochropus* - M
Little Stint - *Calidris minuta* - M

LARIDAE

Indian River Tern - *Sterna aurantia* - R
Blackbellied Tern - *Sterna acuticauda* - R

PTEROCLIDIDAE

Indian Sandgrouse - *Pterocles exustus* - R
COLUMBIDAE

Yellowlegged Green Pigeon - *Treron phoenicoptera* - R
Blue Rock Pigeon - *Columba livia* - R
Indian Ring Dove - *Streptopelia decaocto* - R
Red Turtle Dove - *Streptopelia tranquebarica* - R
Spotted Dove - *Streptopelia chinensis* - R
Little Brown Dove - *Streptopelia senegalensis* - R
Rufous Turtle Dove - *Streptopelia orientalis* - R
Emerald Dove - *Cnalcophaps indica* - R

PSITTACIDAE

Roseringed Parakeet - *Psittacula krameri* - R
Blossomheaded Parakeet - *Psittacula cyanocephala* - R
Alexandrine parakeet - *Psittacula eupatria* - R

CUCULIDAE

Sirkeer Cuckoo - *Taccocua lescenhaultii* - R
Crow Pheasant - *Centropus sinensis* - R
Pied Crested Cuckoo - *Clamator jacobinus* - S
Common Hawk-Cuckoo or Brainfever - *Cuculus varius* - S
Indian Plaintive Cuckoo - *Cacomantis passerinus* - S
Koel - *Eudynamus scolopacea* - S
The Cuckoo - *Cuculus canorus* - S
STRIGIDAE

Great Horned Owl - *Bubo bubo* - R
Longeared Owl - *Asio otus* - R
Spotted Owlet - *Athene brama* - R
Barn Owl - *Tyto alba* - R
Brown Fish Owl - *Bubo zeylonensis* - R

CAPRIMULGIDAE

Indian Jungle Nightjar - *Caprimulgus indicus* - R
Common Indian Nightjar - *Caprimulgus asiaticus* - R
Franklin's Nightjar - *Caprimulgus affinis* - R

APODIDAE

House Swift - *Apus affinis* - R

ALCEDINIDAE

Lesser Pied Kingfisher - *Ceryle rudis* - R
Small Blue Kingfisher - *Alcedo atthis* - R
Whitebreasted Kingfisher - *Halcyon smyrnensis* - R
Storkbilled Kingfisher - *Pelargopsis capensis* - R

MEROPIDAE

Green Bee-eater - *Merops orientalis* - R
Bluetailed Bee-eater - *Merops philippinus* - S
CORACIIDAE
Indian Roller - *Coracias benghalensis* - R

UPUPIDAE
Hoopoe - *Upupa epops* - R

BUCEROTIDAE
Common Grey Hornbill - *Tockus birostris* - R

CAPITONIDAE
Crimsonbreasted Barbet - *Megalaima haemacephala* - R
Large Green Barbet - *Megalaima zeylonica* - R
Small Green Barbet - *Megalaima viridis* - R

PICIDAE
Lesser Golidenbacked Woodpecker - *Dinopium benghalensis* - R
Yellofronted Pied Woodpecker - *Picoides mahrattensis* - R
Greycrowned Pigmy Woodpecker - *Picoides canicapillus* - R
Blackbacked Woodpecker - *Chrysocoloptes festivus* - R

PITTIDAE
Indian Pitta - *Pitta brachyura* - S

ALAUPIDAE
Redwinged Bush Lark - *Mirafra erythroptera* - R
Ashycrowned Finch-Lark - *Eremopterix grisea* - R
Short-toed Lark - *Calandrella cinerea* - R
Crested Lark - *Galerida cristata* - R
Rufoustailed Finch-Lark - *Alaemon alaudipes* - R
Sykes's Crested Lark - *Galerida deva* - R

**HIRUNDINIDAE**

Swallow - *Hirundo rustica* - R
House Swallow - *Hirundo tahitica* - R
Wiretailed Swallow - *Hirundo fluvicola* - R

**LANIIDAE**

Grey Shrike - *Lanius excubitor* - R
Baybacked Shrike - *Lanius vittaus* - R
Rufousbacked Shrike - *Lanius schach* - R
Brown Shrike - *Lanius critatus* - R

**ORIOLIDAE**

Blackheaded Oriole - *Oriolus xanthornus* - R
Golden Oriole - *Oriolus oriolus* - R

**DICRURIDAE**

Black Drongo - *Dicrurus adsimillis* - R
Whitebellied Drongo - *Dicrurus caerulescens* - R
Greater Racket-tailed Drongo - *Dicrurus paradiseus* - R

**STURNIDAE**

Brahminy Myna - *Sturnus pagodarum* - R

Pied Myna - *Sturnus contra* - R

Common Myna - *Acridotheres tristis* - R

Bank Myna - *Acridotheres ginginiunus* - R

Starling - *Sturnus vulgaris* - W

**CORVIDAE**

Indian Tree Pie - *Dendrocitta vagabunda* - R

House Crow - *Corvus splendens* - R

Jungle Crow - *Corvus macrorhynchos* - R

**CAMPEPHAGIDAE**

Common Wood Shrike - *Tephrodornis pondicerianus* - R

Small Minivet - *Pericrocotus cinnamomeus* - R

Whitebellied Minivet - *Pericrocotus erhropygius* - R

Blackheaded Cuckoo-Shrike - *Coracina malanoptera* - S

Smaller Grey Cuckoo-Shrike - *Coracina melaschistos* - S

**IRENIDAE**

Common Iora - *Aegithina tiphia* - R

Goldenmantled Chloropsis - *Chloropsis chochinchinensis* - R
PYCNONOTIDAE

Redvented Bulbul - *Pycnonotus cafer* - R
Redwhiskered Bulbul - *Pycnonotus jocosus* - R

MUSCICAPIDAE

Common Babbler - *Turdoides caudatus* - R
Large Grey Babbler - *Turdoides malcolmi* - R
Jungle Babbler - *Turdoides striatus* - R
Rufusbellies Babbler - *Dumetia hypertytha* - R
Redbreasted Flycatcher - *Muscicapa parva* - W
Whitebrowed Fantail Flycatcher - *Rhipidura aureola* - R
Greyheaded Flycatcher - *Cuclicicopa ceylonensis* - W
Whitebrowed Blue Flycatcher - *Muscicapa supercillia* - W
Paradise Flycatcher - *Terpsiphone paradisi* - S
Franklin's Wren Warbler - *Prinia hodgsonii* - W
Plain Wren Warbler - *Prinia subjlava* - W
Ashy Wren Warbler - *Prinia socialis* - R
Indian Great Reed Warbler - *Acrocephalus stentoreus* - W
Tailor Bird - *Orthotomus sutorius* - R
Lesser Whitethroat - *Sylvia curruca blythi* - W
Bluethroat - *Erithcus svecicus* - W
Yellowbrowed Leaf Warbler - *Phylloscopus inornatus* - W
Tickell's Leaf Warbler - *Phylloscopus affins* - W
Magpie Robin - *Copsychus saularis* - R
Brown Flycatcher - *Muscicapa latirostris* - W
Blacknaped Flycatcher - *Hypothymis azurea* - W
Verditer Flycatcher - *Muscicapa thalassina* - W
Black Redstart - *Phoenicurus ochruros* - R
Stone Chat - *Saxicola torquata* - W
Brown Rock Chat - *Cercometa fusca* - R
Pied Bush Chat - *Saxicola caprata* - W
Pied Chat - *Oenanthe picata* - W
Indian Robin - *Saxicoloides fulicata* - R
Blue Rock Thrush - *Monticola solitarius* - W
Tickell's Thrush - *Turdus unicolor* - W
Wheatear - *Oenanthe oenanthe* - W

**PARIDAE**

Grey Tit - *Parus major* - R

**SITTIDAE**

Chestnutbellied Nuthatch - *Sitta castanea* - R
Spotted Grey Creeper - *Salpornis spilonotos* - R

**MOTACILLIDAE**

Tree Pipit - *Anthus trivialis* - R
Paddyfield Pipit - *Anthus novaeseelandiae* - R
Brown Rock Pipit - *Anthus similis* - R
Yellowheaded Wagtail - *Motacilla citreola* - W
Grey Wagtail - *Motacilla cinerea* - W
Pied Wagtail - *Motacilla alba* - W
Large Pied Wagtail - *Motacilla maderaspatensis* - R

**DICAEDAE**

Tickell's Flowerpecker - *Dicaeum erythrarhynchos* - R

**NECTARINIIDAE**

Purple Sunbird - *Nectarinia asiatica* - R
Purplerumped Sunbird - *Nectarinia zeylonica* - R

**ZOSTEROPIDAE**

White Eye - *Zosterops palpebrosa* - R

**PLOCEIDAE**

House Sparrow - *Passer domesticus* - R
Yellowthroated Sparrow - *Petronia xanthocollis* - R
Baya - *Ploceus philippinus* - R
Whitethroated Munia - *Lonchura malabarica* - R
Blackheaded Munia - *Lonchura malacca* - R
Spotted Munia - *Lonchura punctulata* - R
Red Munia - *Estrilda amandava* - R
RINGILLIDAE

Common Rose Finch - *Carpodacus erythrinus* - W

EMBERIZIDAE

Crested Bunting - *Melophus lathami* - R